Results of the
Comprehensive Performance Evaluation
for the
Havre Water Treatment Plant
Havre, Montana

May 20 – 24, 2024

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Date of Site Visit:
May 20 – 24, 2024

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INTRODUCTION

The Composite Correction Program (CCP)[1] is an approach developed by the U.S. Environmental Protection Agency (USEPA) and Process Applications, Inc. (PAI) to improve surface water treatment plant performance and to achieve compliance with the Surface Water Treatment Rule (SWTR). Its development was initiated by PAI and the State of Montana[2], which identified the need for a program to manage performance problems at its surface water treatment plants.

A Comprehensive Performance Evaluation (CPE) is a thorough evaluation of an existing treatment plant, resulting in a comprehensive assessment of the unit process capabilities and the impact of the operation, maintenance, and administrative practices on performance of the plant. The results of the evaluation establish the plant capability to meet regulatory requirements and optimization goals and list a set of prioritized factors limiting performance. Follow-up technical assistance can be used to improve performance of an existing plant by systematically addressing the factors limiting performance identified during the CPE.

The federal Surface Water Treatment Rule (SWTR), Interim Enhanced Surface Water Treatment Rule, and Long-Term 1 Surface Water Treatment Rules require conventional and direct filtration plants to achieve less than 0.3 NTU (nephelometric turbidity units) in 95% of the monthly combined filter effluent (CFE) samples and to continuously monitor individual filter performance. The enhanced SWTR requirements have been in effect for all surface water treatment plants since 2005. Research results and field experience have shown that just meeting the requirements of the rules does not guarantee adequate protection against some pathogenic microorganisms, as evidenced by some waterborne disease outbreaks.

For a conventional or direct filtration system, producing a finished water with a turbidity of less than or equal to 0.10 NTU provides much greater protection against pathogens like *Cryptosporidium*. This microorganism passed through the treatment plant and was responsible for a large outbreak of *Cryptosporidiosis* in Milwaukee, Wisconsin in April 1993, when 400,000 people became ill and nearly 100 died. *Cryptosporidium* cysts are extremely resistant to chlorine disinfection, necessitating optimization of physical removal of particles.

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[1] Hegg, B.A., L.D. DeMers, J.H. Bender, E.M. Bissonette, and R.J. Lieberman, Handbook - Optimizing Water Treatment Plant Performance Using the Composite Correction Program, EPA 625/6-91/027, USEPA, Washington, D.C. (August 1998).

[2] Renner, R.C., B.A. Hegg, and D.F. Fraser, Demonstration of the Comprehensive Performance Evaluation Technique to Assess Montana Surface Water Treatment Plants, Association of State Drinking Water Administration Conference, Tucson, AZ (February 1989).

This CPE was conducted at the request of the Montana Department of Environmental Quality. The basis for this request was the failure of the Havre Water Treatment Plant to meet the treatment technique requirements for turbidity removal and disinfection in February and March of 2024 and documentation of at least three cases of giardiasis by the CDC. These events triggered a regulatory requirement to conduct the CPE. Administrators and staff at the Havre Water Treatment Plant (WTP) participated in preparatory site visit calls with the CPE team, provided historical performance data, were forthcoming in interviews, and were receptive to the CPE. The CPE team would like to thank the plant staff for taking the time to assist them in completing the evaluation at the Havre WTP. During the evaluation, plant staff members acted in a professional manner and demonstrated an interest in learning about methods to improve plant performance. Their willingness to participate in the process represents a solid basis for an improvement in plant performance, a return to compliance, and future optimization activities. This report documents the findings of the CPE conducted at the Havre WTP from May 21 – May 24, 2024.

DESCRIPTION OF WATER TREATMENT PLANT

Overview

The City of Havre, population approximately 9,200, is located in north central Montana and is surrounded by agricultural land, grasslands, and shrub land. The City owns and operates a 6 MGD water treatment plant that primarily services the City's residences, businesses, and industry. The location of the plant is shown in Figure 1 on the following page. The intake for the treatment plant is located on the Milk River, approximately 12 miles downstream from Fresno Reservoir and above a small dam. There are two additional creeks contributing above the Havre raw water intake – Beaver Creek and Big Sandy Creek. Big Sandy Creek watershed covers about 1,850 square miles with several smaller reservoirs and agricultural uses. Beaver Creek watershed covers about 120 square miles which include agricultural land and local airports. Potential sources of microbial contamination in the watershed include grazing cattle (Beaver Creek), other agricultural runoff, wildlife, and septic systems.

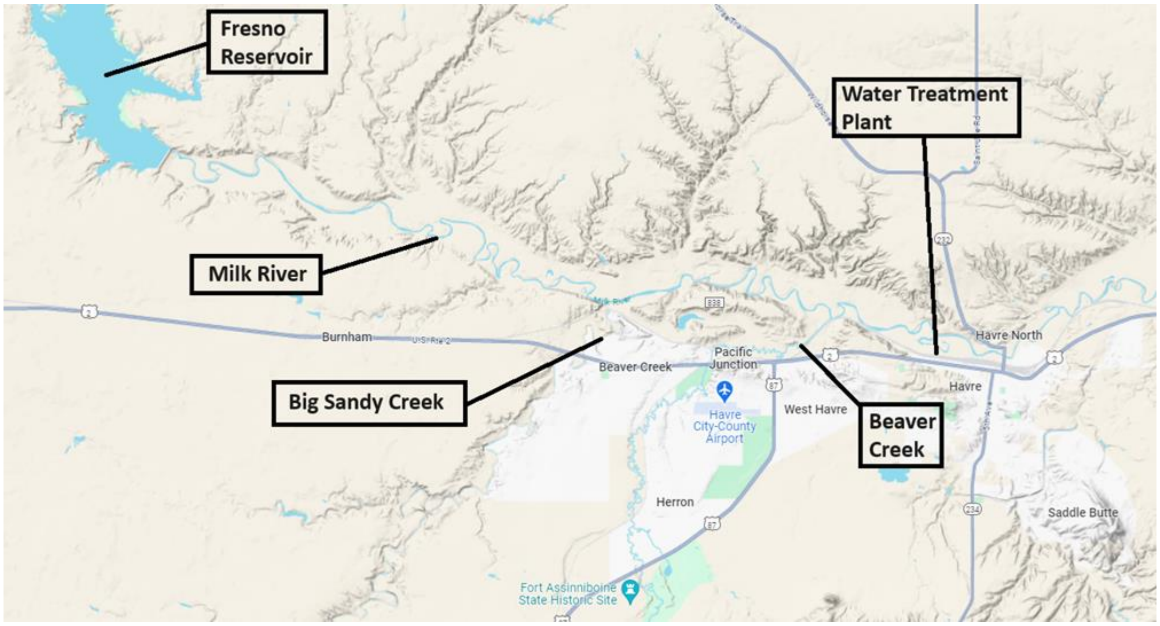


FIGURE 1. City of Havre source water area and WTP location.

Water Treatment Processes

An aerial view of the river intake and pre-sedimentation pond is shown in Figure 2 on the following page, and a process flow schematic for the treatment plant, developed by the CPE team, is shown in Figure 3 on the following page. The plant was initially built in 1949 and was expanded in 2002. The expansion included two additional filters along with media replacement in the original two filters. Water from Havre's side-stream intake on the Milk River flows by gravity to a 3.6 MG pre-sedimentation basin, which is an unlined, impounded oxbow of the Milk River. This pre-sedimentation basin is approximately 8-feet deep and was recently dredged. The pre-sedimentation basin influent from the intake structure is treated seasonally with copper sulfate to control algae (twice per month, June to mid-August). Raw water then flows by gravity to the water treatment plant's raw water chamber, to which powdered activated carbon (PAC) can be added. PAC is added for tastes and odors due to compounds such as geosmin and MIB from about March through November. Water is pumped from this chamber using two constant-speed pumps (#1, #2) rated at 2,100 gpm each and two variable-speed pumps (#3, #4) each with a maximum capacity of 1,050 gpm. Water is then pumped from the raw water chamber through an in-line hydraulic *"pumped diffusion"* mixer. This mixer functions by using a side-stream of the raw water flow and pumping it against the main flow direction to induce turbulence for mixing. Ferric sulphate is fed as the primary coagulant prior to the rapid mixer, and a cationic polymer (T Floc 1417) is fed after the rapid mixer.

FIGURE 2. Milk River intake, pre-sedimentation pond, and WTP locations.

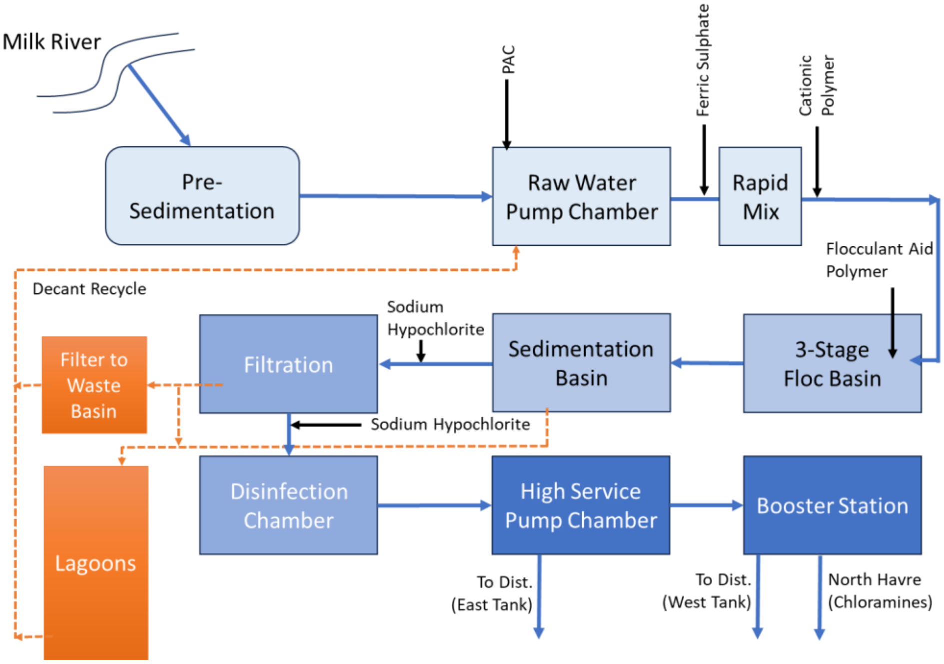


FIGURE 3. Process flow schematic of the Havre WTP.

From the in-line mixer, water is pumped to two parallel, three-stage flocculation basins. A flocculant aid (Superfloc A-100) is fed at the beginning of the basins during runoff season. These parallel floc basins are equipped with Philadelphia Mixers with variable frequency drives (VFDs), set at incrementally decreasing rotational speeds for each of the three floc stages (40 rpm, 30 rpm, and 20 Hz). The two parallel trains then continue to two sedimentation basins equipped with tube settlers and mechanical sludge collection. A filter aid injection point is available at the end of the sedimentation basin, but this is currently not in use.

From the sedimentation basins, water then passes to four filters equipped with dual-media sand and anthracite. Filter Nos. 3 and 4 are in proximity to the sedimentation basins while Filter Nos. 1 and 2 are in an adjacent room. The bottoms of Filter Nos. 3 and 4 sit two feet lower than the bottoms of Filter Nos. 1 and 2 and hold two additional feet of water. Sodium hypochlorite is added to the filter influent. The filter media design specifies a total of 36 inches of media, consisting of 24 inches of anthracite and 12 inches of sand, underlaid by 2 inches of torpedo sand and block-style underdrains. Filters are designed to operate at a constant rate. The design filtration rate is 3.5 gpm/sf with all four filters in operation and 4.6 gpm/sf with three filters in operation.

The filters are backwashed based on headloss or time in service, typically about 65 hours of service, and the backwash procedure includes a surface wash step. There are two 60 hp backwash pumps with maximum flow of 6,000 gpm; however, one has been out of service for over a year. Backwash water and filter-to-waste water are either wasted to a collection basin and recycled directly from this basin to the head of the plant or pumped from this basin to lagoons, where the decant is then recycled to the head of the plant at the raw water collection chamber. Filter-to-waste is controlled manually, and only one filter can filter-to-waste at a time.

After filtration, water flows to a 190,000-gallon capacity clearwell with baffles. Sodium hypochlorite for disinfection and caustic soda for pH adjustment are added to the clearwell influent. Caustic soda is dosed based on a daily Langlier Saturation Index (LSI) calculation. Design drawings show a baffling factor of 0.55 assigned to the clearwell at the design capacity flow of 6 MGD.

Sodium hypochlorite is generated onsite by a ChlorTec CT DN200, and softened process water is used for makeup water. Plant residuals are monitored in the clearwell effluent with a CL-17sc and SC4500 controller. The high-service pumps include one variable-speed pump (#1) with a flow range of 150 to 1,350 gpm and two constant-speed pumps (#2 at 960 – 1,100 gpm, #3 at 1,650 – 1,825 gpm, capacities dependent on static level of distribution storage tanks).

PERFORMANCE ASSESSMENT

Historical Performance Assessment

To maintain compliance and achieve optimized performance, a water treatment plant must demonstrate that it can take a raw water source of variable quality and produce consistent, high quality finished water. Further, the performance of each treatment process must demonstrate its capability to act as a barrier to the passage of particles at all times. This capability is particularly important at the Havre WTP, based on discussions with operators and administrators regarding seasonal changes that affect the raw water quality.

Performance of each barrier in the Havre WTP was evaluated against optimization performance goals. If a barrier can meet the optimization goal consistently, the plant staff can have confidence that it is intact and that the regulatory requirements will be met as well. The optimization goals are described in Table 1 on the following page.

During this CPE, turbidity data was collected from continuous-reading turbidimeters to assess the effectiveness of the multiple flocculation/sedimentation and filtration barriers. The inactivation ratio was also calculated using continuous flow, chlorine, and pH data to assess the performance of the disinfection barrier. The turbidity and disinfection data used in the performance evaluation were collected over approximately nine months starting on July 25, 2023 and ending on May 16, 2024. See Table 2 on page 13 for a discussion of the data sources used in the CPE performance analysis.

TABLE 1. Optimization goals by barrier.

Barrier	Optimized Performance Goal	Barrier Monitoring
Sedimentation/Clarification	For raw water turbidity consistently ≤ 10 NTU, settled (clarified) water turbidity ≤ 1.0 NTU. For raw water turbidity consistently > 10 NTU, settled (clarified) water turbidity ≤ 2.0 NTU.	Continuous turbidity monitoring or grab samples from the effluent of each sedimentation basin at least once every 4 hours, more often if raw water turbidity is changing.
Filtration	Individual filter effluent (IFE) turbidity ≤ 0.10 NTU while filter is in service.	Continuous turbidity monitoring on each filter.
	Combined filter effluent (CFE) turbidity ≤ 0.10 NTU.	Continuous turbidity monitoring on combined filter effluent or CFE grab samples at least once every 4 hours.
	If filter-to-waste capability is available after backwash (as is the case at Havre), return to service after the filtered water turbidity is ≤ 0.10 NTU.	Monitor filter return-to-service turbidity after every backwash. Document filter-to-waste time.
Disinfection	Meet the regulatory requirement for inactivation of *Giardia*/viruses at the first customer with a safety factor. A safety factor of 10% was applied to develop an inactivation ratio goal of ≥ 1.1.	Regulatory monitoring for first customer inactivation ratio; continuous disinfectant residual, continuous monitoring for water temperature and pH. Also track peak hourly flow that determines the detention time to the first customer.

TABLE 2. CPE performance analysis data acquisition description.

Performance Parameter	Data Used in the CPE Performance Analysis
Raw water turbidity	The raw water sample point is located in a wet well where powdered activated carbon is added and a recycle stream from the filter backwash and filter-to-waste holding tank enters the plant and mixes with the raw water. The 15-minute turbidity records were obtained from Ross Hanson (Advanced Engineering and Environmental Services [AE2S]). He downloaded the data from the plant SCADA system and provided the data to the team. During the evaluation, additional data was provided by the Plant Superintendent. Data screening was performed to ensure that it was included only when raw water flow was detected, i.e., data was only utilized if the plant was producing water. The highest daily value was used for the analysis.
Settled water turbidity	Settled water turbidity represents combined effluent from the sedimentation trains; the sample is collected from the inlet channel to the filters and analyzed with a continuous turbidimeter. The 15-minute turbidity data provided by Ross Hanson (AE2S) and the Plant Superintendent were screened to ensure that data were included only when raw water flow was greater than zero, i.e., data were only considered when the plant was producing water. The highest daily value from the combined settled water was used for the analysis, though the instrument was capped at 4 NTU for all but the last two weeks of the data evaluation period.
IFE turbidity	The 15-minute IFE turbidity records were provided by Ross Hanson (AE2S) and the Plant Superintendent. Turbidity values were excluded from the data set when the filter effluent valve was closed (filter was idle, being backwashed, or filtering to waste). The data were analyzed to identify the highest daily value for each filter, though the instrument was capped at 1.00 NTU for all but the last two weeks of the data evaluation period and may not have been representative during periods of elevated turbidity. Additionally, a *"Hold Outputs"* button on the SCADA system was utilized until May 4th during startup and some other periods, including times when the backwash pumps were used to recycle finished water out of the clearwell to the head of the plant while filters were still producing water. Consequently, prior data may not have been representative of actual conditions.
Filter recovery turbidity	The continuous turbidimeters used for IFE monitoring also captured data during filter-to-waste conditions. The 15-minute turbidity data were analyzed to determine when a filter was backwashed, i.e., a filter had zero flow while the other filters had flow. Following backwash, turbidity data were reviewed during periods when flow through the filter-to-waste line was greater than 100 gpm to determine the peak turbidity value during filter-to-waste and time of filter-to-waste. The 100-gpm threshold was used to screen out erroneous low flow readings on the filter-to-waste flow meter. Time of filter-to-waste was likely conservative given that this analysis was performed with 15-minute data, e.g., filter-to-waste could have occurred for 15 or 45 minutes when two consecutive 15-minute readings indicated filter-to-waste was occurring. The return-to-service turbidity was estimated by using the last filter-to-waste value that was recorded prior to return-to-service, since spot-checking indicated the two values were usually comparable. This might have provided a conservative estimate of return-to-service turbidity due to the use of 15-minute readings.

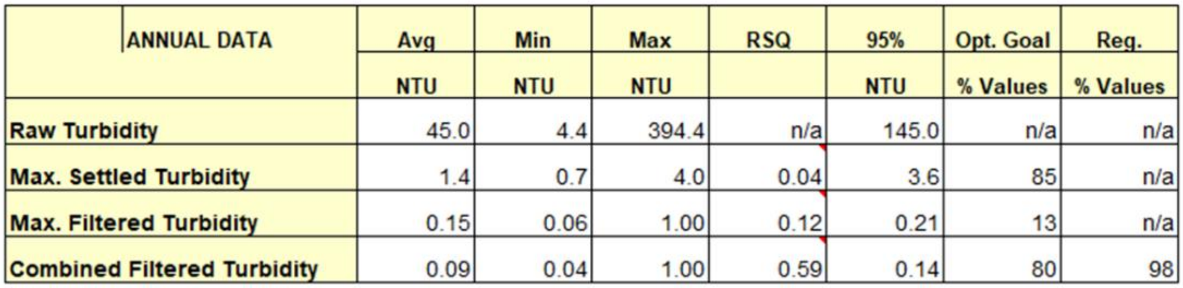
Performance Parameter	Data Used in the CPE Performance Analysis
CFE turbidity	The continuous CFE monitoring point is located on the inlet line to the clearwell. The 15-minute CFE turbidity data were provided by Ross Hanson (AE2S) and the Plant Superintendent. Turbidity values were excluded from the data set when there was no individual filter flow, i.e., no water was flowing to the clearwell. The data set was analyzed to identify the highest daily value, but the instrument was capped at 1.00 NTU for all but the last two weeks of the data evaluation period. Additionally, a *"Hold Outputs"* button on the SCADA system was utilized until May 4th during startup and some other periods, including times when the backwash pumps were used to recycle finished water out of the clearwell to the head of the plant while the filters were still producing water. Consequently, prior data may not have been representative of actual conditions.
Disinfection	Chlorine residual is monitored continuously on the clearwell effluent. The pH and temperature of the final effluent are monitored with a continuous meter. Disinfection data were obtained from the 15-minute plant data provided by Ross Hanson (AE2S) and the Plant Superintendent. The peak daily flow was identified, and data for chlorine residual, pH, temperature, and clearwell depth associated with the time of peak flow were used to calculate the CT and the plant inactivation ratio. Flows may have been conservative, as the peak instantaneous values recorded at 15-minute intervals were used in lieu of peak hourly flows.

Maximum daily turbidity data for raw water, combined settled water, IFE, and CFE were entered into an Optimization Assessment Spreadsheet (OAS) and analyzed through the spreadsheet calculations and charts. Table 3 on the following page shows the OAS summary statistics for the plant.

Turbidity Removal Performance

The statistics in Table 3 were generated using the maximum daily values for raw, combined settled, IFE, and CFE turbidity during the period with available 15-minute data (July 25, 2023 – May 16, 2024), along with a comparison to optimization goals. For optimization purposes, the maximum daily turbidity readings are used to show the daily worst case performance by each of the barriers. If the plant can perform within the optimization goals at the time of its worst daily performance, then the plant staff can be assured that it is also meeting the goals during the rest of the day and providing maximum public health protection. Table 3 shows that the average daily maximum raw water turbidity during the period with available data for the Havre WTP was 45.0 NTU. For raw water conditions such as this, where the annual average daily raw water turbidity is consistently greater than 10 NTU, the optimization goal for settled water turbidity is 2.0 NTU in 95% of daily readings.

TABLE 3. OAS summary statistics for settled and filtered water barriers at the Havre WTP.



ANNUAL DATA	Avg	Min	Max	RSQ	95%	Opt. Goal	Reg.
	NTU	NTU	NTU		NTU	% Values	% Values
Raw Turbidity	45.0	4.4	394.4	n/a	145.0	n/a	n/a
Max. Settled Turbidity	1.4	0.7	4.0	0.04	3.6	85	n/a
Max. Filtered Turbidity	0.15	0.06	1.00	0.12	0.21	13	n/a
Combined Filtered Turbidity	0.09	0.04	1.00	0.59	0.14	80	98

It is worth noting that the Havre WTP routinely recycles backwash water directly from the filter washwater basin to the head of the plant. There are backwash ponds with associated decant pumps where water from the filter washwater basin can be sent for settling prior to recycling; however, these ponds are reported to be used minimally during the winter months. The filter washwater basin recycle pumps draw water from near the bottom of this basin. As discussed above, the raw water turbidimeter pulls a sample from a location that is impacted by recycle flows as well as by the addition of powdered activated carbon (PAC) which is introduced directly into the same chamber. Significant spikes in raw turbidity (from about 5 NTU up to 30 NTU or greater) that persist for 1.5 hours or longer were observed when water was recycled directly from the filter washwater basin. One example turbidity spike is illustrated in Figure 4 below. Although it is important to know the turbidity of the water entering the treatment process (including the recycle stream), it would also be helpful to have a true raw water sample from the source to understand the impact of the recycle stream, since spent filter backwash water contains concentrated particles and microorganisms. It is recommended that the impact of allowing the filter washwater basin to settle prior to decanting on the raw water turbidity be investigated going forward.

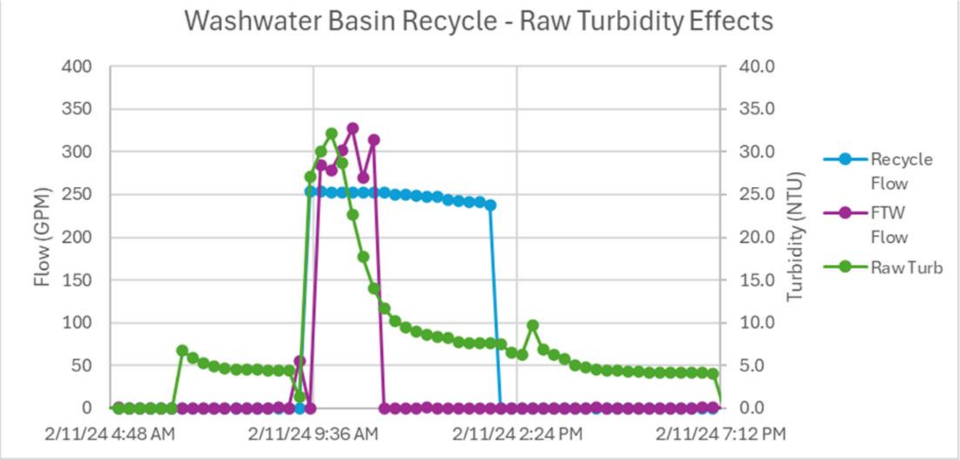


FIGURE 4. Filter washwater basin recycle impact on raw turbidity.

During the period reviewed, the 95th percentile of the combined settled water turbidity for the Havre WTP was 3.6 NTU, and the plant performance met the optimization goal in the combined settled water effluent on 85% of the days during the evaluation period. However, the signal span on the settled water turbidimeter was set at 0 – 4.0 NTU, so readings above 4.0 NTU were not recorded in the settled water database forwarded by AE2S. Note, the settled water turbidity of the combined treatment trains was used in the OAS spreadsheet and in Table 3 for the historical performance analysis of the plant. However, each sedimentation train should be able to perform well enough to meet the optimization goal individually.

Table 3 also shows that the highest daily turbidity from the four individual filters met the optimization goal of 0.10 NTU on only 13% of the days, with the 95th percentile of the daily maximum values being 0.21 NTU. The signal span on the IFE turbidimeters was set at 0 – 1.0 NTU, so readings above 1.0 NTU were not recorded in the IFE database forwarded by AE2S. Use of the "*Hold Outputs"* button in the SCADA screen discussed previously also affected these values. Therefore, even though the IFE 95th percentile is above the optimization goal, the 95th percentile was likely higher than indicated by the data.

The annual trends for the raw, settled (taken from the combined settled water effluent channel), IFE turbidity, and CFE turbidity are shown in Figure 5.

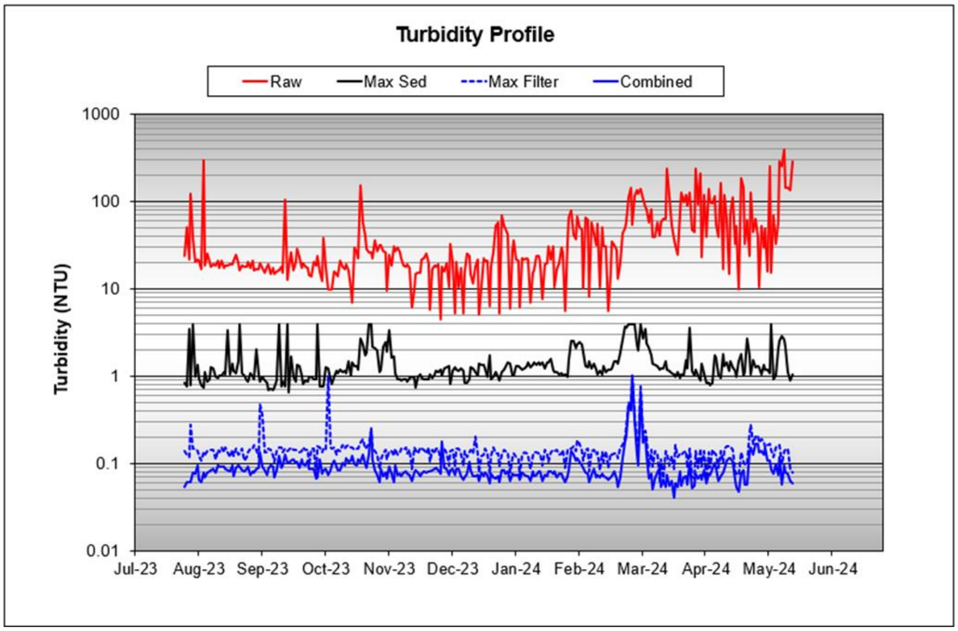


FIGURE 5. Raw, combined settled, IFE, and CFE maximum daily turbidity trend lines.

Figure 5 provides a visual representation of the variation in the IFE (dashed blue line) maximum daily turbidity values, ranging from 0.06 NTU to 1.0 NTU during the evaluation period, with a significant and prolonged increase showing in the trend line during late February to early March. The significance of the late February to early March turbidity event on the max. daily IFE turbidity is also illustrated for one individual filter (Filter No. 1) in Figure 6 below. The *"Hold Outputs"* SCADA function was used for several multi-hour time blocks during the late February to early March timeframe, which reduced the reported daily maximum turbidity displayed in this chart.

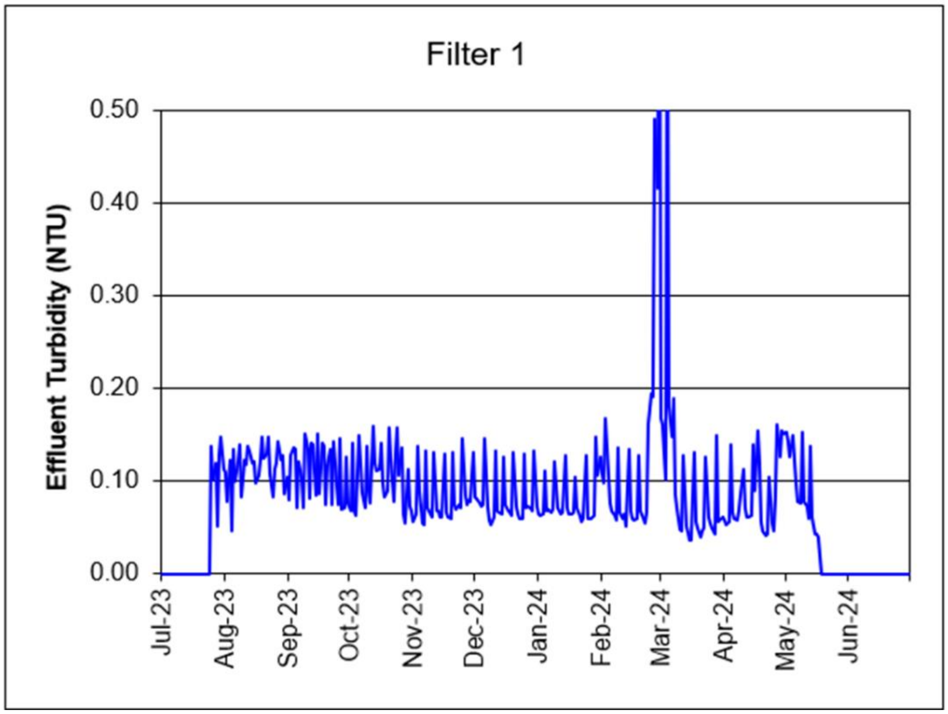
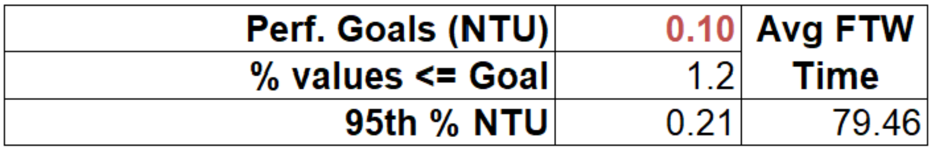


FIGURE 6. Example of IFE turbidity profile (Filter No. 1 data shown are representative of what occurred in the other three filters.)

Available data were also analyzed to assess the historical performance of backwash durations and filter recovery following a backwash. The process used to generate the data used in this analysis is explained in Table 2 above. The post-backwash filter performance is summarized in Table 4 on the following page. Filters met the return-to-service turbidity goal of ≤ 0.10 NTU in 1.2% of backwashes assessed, and the 95th percentile for return-to-service turbidity was 0.21 NTU. The average filter-to-waste time was 79.46 minutes, which is a relatively long period of time to send water to waste.

TABLE 4. OAS summary statistics for post-backwash performance.



Perf. Goals (NTU)	0.10	**Avg FTW Time**
% values <= Goal	1.2	
95th % NTU	0.21	79.46

Post-backwash trends are summarized graphically in Figure 7. As shown, the filter-to-waste time (blue shaded area) frequently exceeds 100 minutes. This figure also shows that events in early February as well as late February to early March caused an increase in filter particle loading, as evidenced by a peak in the red line which indicates the max. turbidity following a backwash during the filter-to-waste period. An increase in filter-to-waste time and the return-to-service turbidity (green line) also occurred in late February to early March.

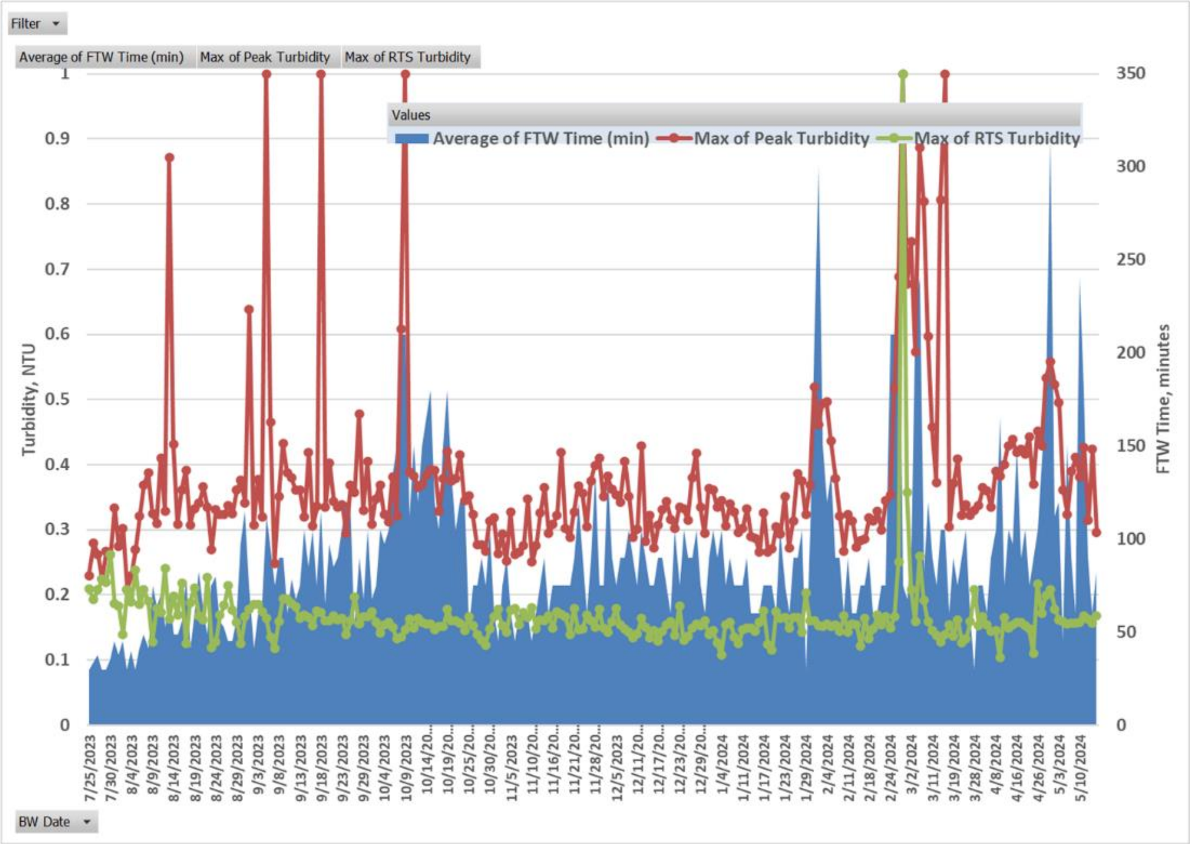


FIGURE 7. Historical backwash recovery turbidity profile.

One example of a filter backwash and associated filter-to-waste/filter recovery period that demonstrates the long filter-to-waste time often required following a backwash is shown for Filter No. 3 in Figure 8 below. Overall, the analysis indicated that the Havre WTP did not meet the post-backwash optimization goals during the evaluation period.

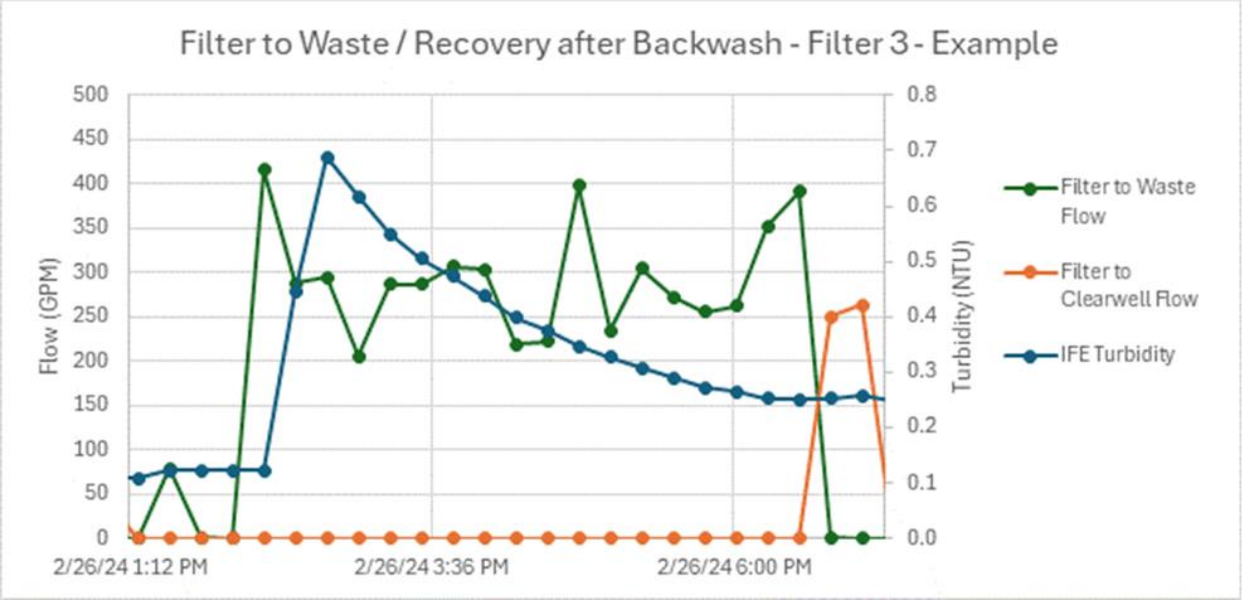


FIGURE 8. Example of filter-to-waste cycle following a backwash demonstrating long filter recovery times (Filter No. 3 data are representative of other filters).

Review of the historical data also revealed highly variable individual filtration rates. There were long periods where one filter experienced more than twice the filtration rate of other filters, with rates sometimes changing very suddenly. These changes were often caused by filters coming into or out of service for backwash. During the period when Filter No. 4 was out-of-service for media changeout (February 27 – May 15), filtration rate changes appeared to be more significant. Significant changes in the filtration rate are a potential concern because they can result in hydraulic disturbances that may dislodge particles, including microorganisms captured by the media. In addition, the increased flow rates sometimes approached the design loading rate for the individual filter. An example of these variable filtration rates is illustrated in Figure 9 on the following page.

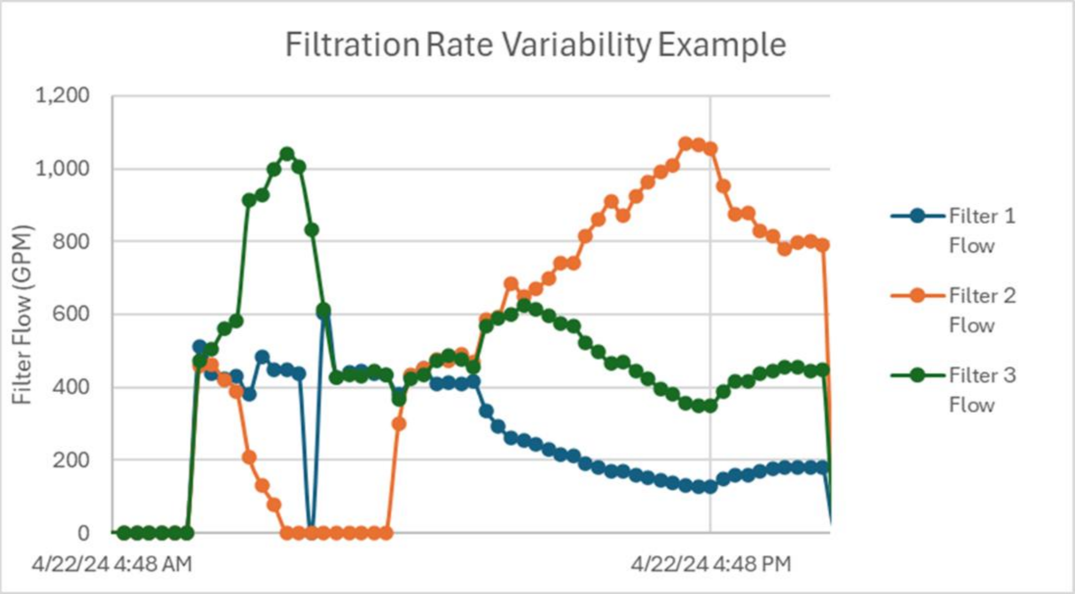


FIGURE 9. Example of filtration rate variability.

A monthly analysis of the individual filtered water effluent data is shown in Table 5 on the following page. The filter with the highest 95th percentile maximum daily turbidity is shown in red. Keeping in mind that the *"Hold Outputs"* button on the SCADA system was being used during periods of filter startup and recycling and may have impacted the data set by screening out high turbidities that may have occurred, Table 5 does not show any significant difference in performance among the individual filters. The maximum daily turbidities for each filter typically occur when a filter is first brought online. The spike in turbidity when a filter is returned to service after filtering to waste also impacts the CFE turbidity. This is reflected in the relatively high RSQ value (0.59) shown for Combined Filtered Turbidity in Table 3. An RSQ value above 0.25 indicates a relative correlation between the Max. Filtered Turbidity (IFE) and Combined Filtered Turbidity maximum values; ideally there would be little to no correlation between these values. These effects are illustrated in Figure 10 on the following page. The filters did appear to have better overall performance during the colder months (November – April). This could be due to less frequent backwashing and associated return-to-service spikes than during the warmer months but could be investigated with a Special Study.

TABLE 5. Individual filter effluent performance summary.

Max Daily Filtered Water Turbidity Monthly 95th Percentile Values (NTU)					
	Filter 1	**Filter 2**	**Filter 3**	**Filter 4**	**% of Values Meeting 0.1 NTU Goal All Filters**
Jul-23	0.14	**0.23**	0.14	0.14	25.0
Aug-23	0.15	0.15	**0.15**	0.15	16.1
Sep-23	0.15	**0.15**	0.14	0.15	35.8
Oct-23	0.16	0.16	**0.20**	0.15	42.3
Nov-23	0.14	0.15	**0.15**	0.15	72.5
Dec-23	0.13	**0.15**	0.14	0.14	75.8
Jan-24	0.13	0.14	**0.14**	0.14	69.4
Feb-24	0.46	0.42	**0.47**	0.16	56.1
Mar-24	0.18	**0.29**	0.29	NA	60.2
Apr-24	0.15	**0.22**	0.17	NA	57.8
May-24	0.15	**0.18**	0.16	NA	43.1
Yr. 95%	0.16	0.19	0.17	0.15	
Yr. Goal	58.4%	50.2%	47.3%	54.6%	

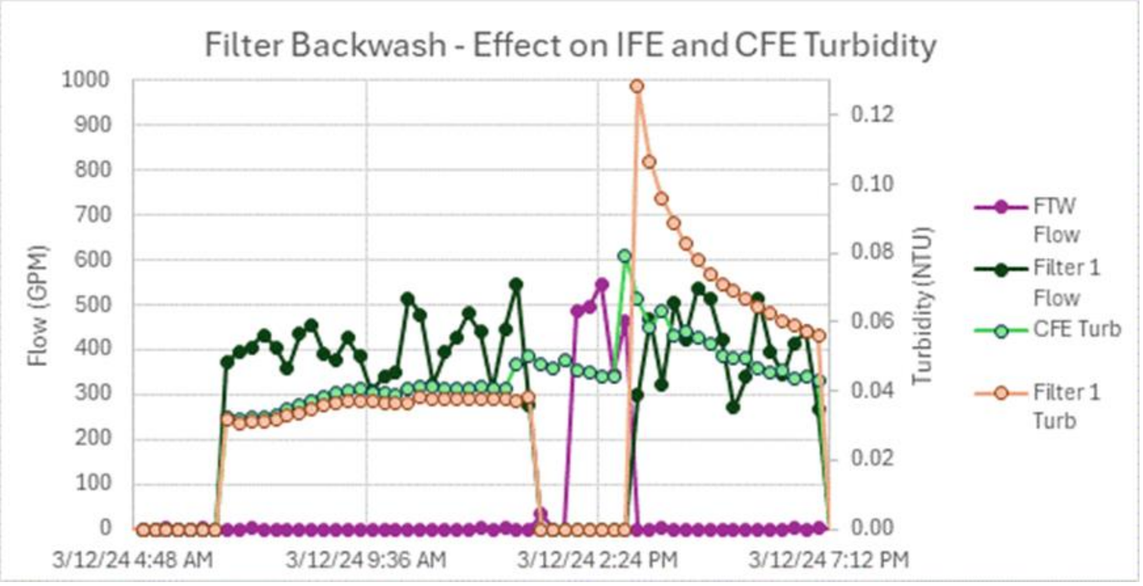


FIGURE 10. Effect of filter return-to-service on IFE and CFE turbidity.

Disinfection Performance

Disinfection performance at the Havre WTP was evaluated over approximately nine months (July 25, 2023 to May 16, 2024). Data inputs were generated using the process described in Table 2 on page 13. The evaluation of the disinfection process uses *Giardia* inactivation as the critical parameter due to the higher required inactivation as compared to viruses when using free chlorine. If the optimization goal for *Giardia* inactivation can be achieved with free chlorine, then the inactivation requirement for viruses will also have been achieved. The Havre WTP is not required to meet additional inactivation targets or goals for *Cryptosporidium*. Of the 298 days included in the evaluation period, the optimization goal for the *Giardia* inactivation ratio (IR) of 1.1 at the first customer was met on 294 days (98.7% of days). The inactivation ratio trend lines for the months evaluated are compiled in Figure 11 below.

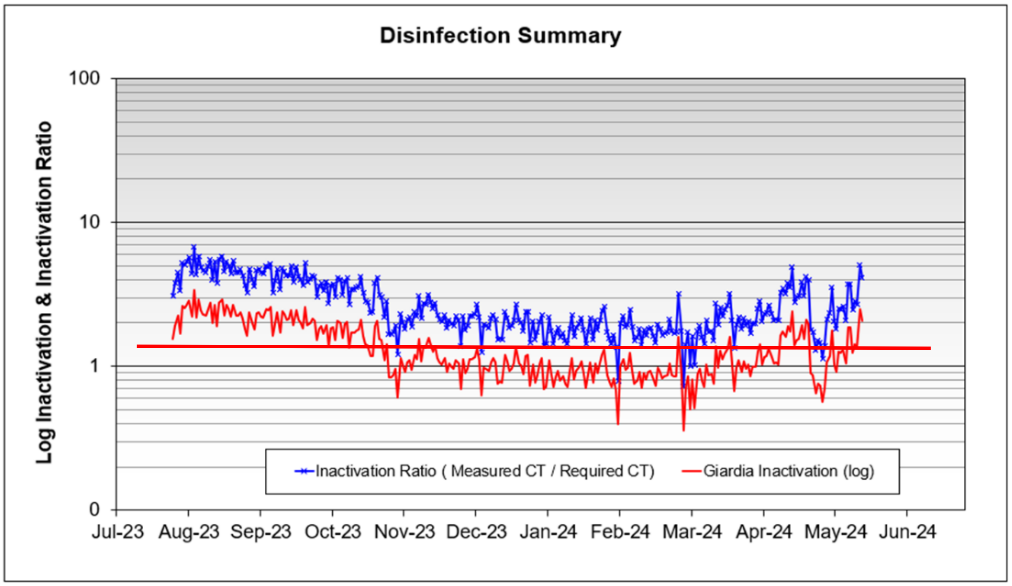


FIGURE 11. *Giardia* inactivation ratio trend July 2023 – May 2024.

An analysis was also performed to evaluate performance against a the regulatory requirement for *Giardia* inactivation ratio (1.0 at the first customer). While this calculation was performed conservatively using the time of peak instantaneous flow as opposed to peak hourly flow, as required by the regulation, it indicated that the disinfection requirement was not met at least twice during the evaluation period (failure to meet this requirement is a violation of the treatment technique for disinfection of surface water). The Havre WTP's failure to meet *Giardia* inactivation requirements on specific days appeared to be associated with finished water pH excursions to >9.0.

The inactivation tables in the federal Surface Water Treatment Rules do not assign credit for *Giardia* inactivation at pH levels >9.0. The Havre WTP began to have significant variability in finished water pH around the time that Filter 4 was taken out of service for media replacement (February 27th). This is demonstrated in Figure 12.

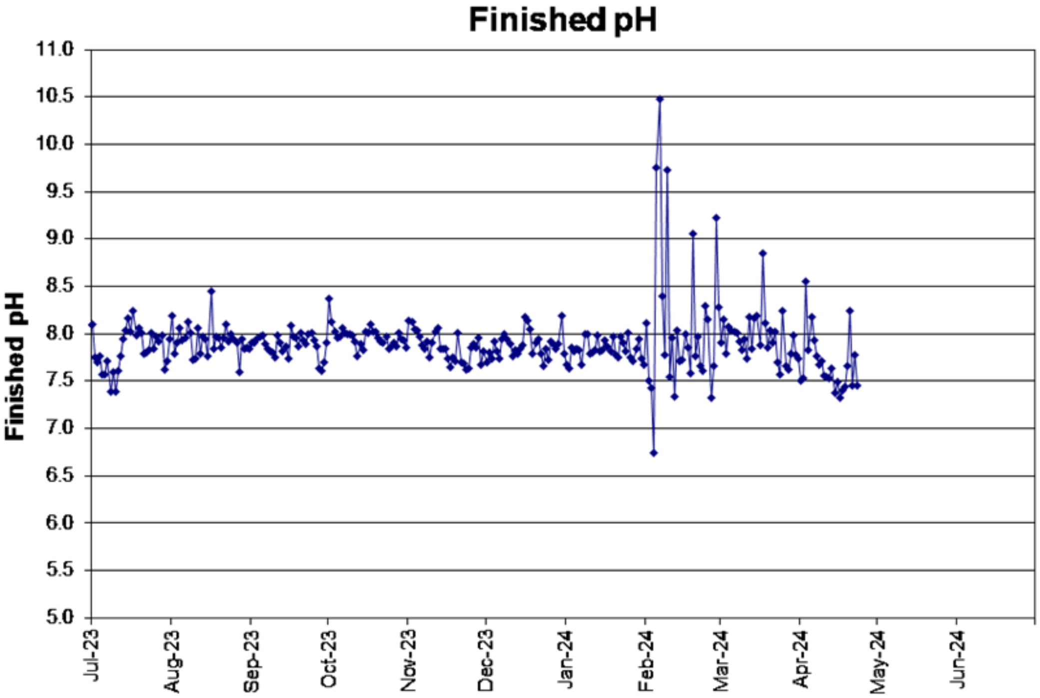


FIGURE 12. Finished water pH at peak daily high-service pump flow.

In the historical data, it appears that the finished water caustic soda feed is flow paced on the raw water flow rate. When a filter is taken out of service for backwashing and followed by a filter-to-waste period, the caustic soda feed is not automatically reduced by the control system (it requires a manual adjustment by the operator). When the filter-to-waste period lasts for more than two hours, the resulting overdose of caustic soda can result in a significant increase in finished water pH, as illustrated in Figure 13 on the following page.

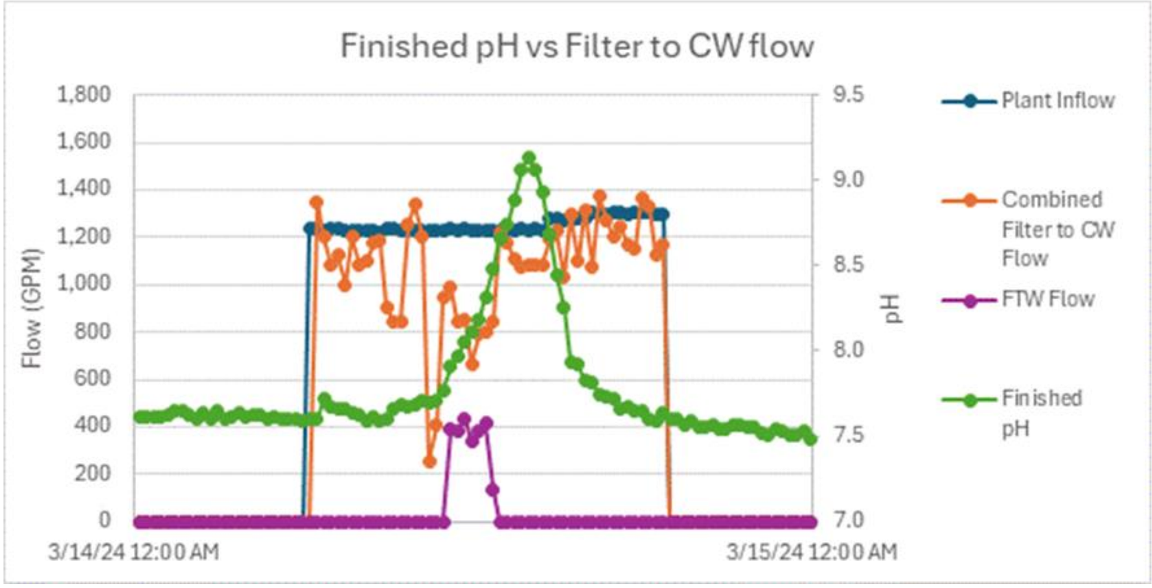


FIGURE 13. Impact of filter-to-waste on finished pH.

Performance Summary

The performance observations described above are summarized in Table 6 on the following page.

TABLE 6. Havre WTP performance summary.

Barrier	Optimization Goal	Performance
Sedimentation	Settled water turbidity 1.0 NTU or less 95% of days, based on daily maximum values. Combined settled water is being used to assess this goal at the Havre WTP.	The settled water goal was achieved on 85% of the days, with an annual 95th percentile value of 3.6 NTU. *NOTE: This value was likely higher than shown since recording was capped at 4.0 NTU.*
Filtration	IFE And CFE Turbidities 0.10 NTU or less 95% of days, based on daily maximum values.	Based on 15-minute data, the IFE performance met the optimization goal on about 13% of the days, with an annual 95th percentile of 0.21 NTU. *NOTE: These values were likely higher than shown since values were excluded via the use of "Hold Outputs" function in SCADA prior to May 4, and recording was capped at 1.0 NTU.* Based on 15-minute data, the CFE turbidity met the optimization goal on about 80% of the days, with an annual 95th percentile of 0.14 NTU. *NOTE: These values were likely higher than shown since values were excluded via the use of "Hold Outputs" function in SCADA prior to May 4, and recording was capped at 1.0 NTU.*
	For filters with filter-to-waste, filter placed back in service with turbidity less than 0.10 NTU and minimize filter-to-waste time.	Data is not routinely collected to assess this performance goal, but is based on 15-minute SCADA data. The post-backwash return-to-service turbidity goal was met on 1.2% of days with a 95th percentile of 0.21 NTU. Average filter-to-waste time was just over 79 minutes.
Disinfection	Inactivation ratio above 1.1 every day (100% of days) that the plant is in operation.	The disinfection process was evaluated for approximately nine months (July 25, 2023 – May 12, 2024), and it met the *Giardia* inactivation ratio goal on 98.7% of the days evaluated. The regulatory requirement for a daily *Giardia* inactivation ratio of at least 1.0 was not met at least twice during the evaluation period.

Special Studies

During the CPE, several Special Studies were conducted for use in assessing plant performance and process control. These studies included: 1) a filter assessment consisting of filter media depth probing and surface media examination, 2) a filter cleaning assessment using spent backwash water turbidity readings and media expansion during backwash, 3) a post-backwash turbidity recovery evaluation, 4) jar testing to determine coagulant dose, 5) chemical feed dose verification, 6) documenting the impact of washwater basin recycle flow on pH, and 6) extended terminal subfluidization wash (ETSW) demonstration.

Special Study 1: Filter No. 1 Media Assessment

Filter 1 was selected for the media assessment Special Study because it was ready for backwash. The filter run was approximately 62 hours prior to the study. The four filters in the Havre WTP are dual-media filters with 18 inches of anthracite on top of 14 total inches of sand. The filter design shows the bottom two inches of the 14 inches of sand as torpedo sand (see Figure 14 below). The media is supported by a gravel-less block underdrain system. The filter media and underdrain systems were reportedly changed for Filter Nos. 1 and 2 during the plant expansion in 2003 that added Filter Nos. 4 and 5.

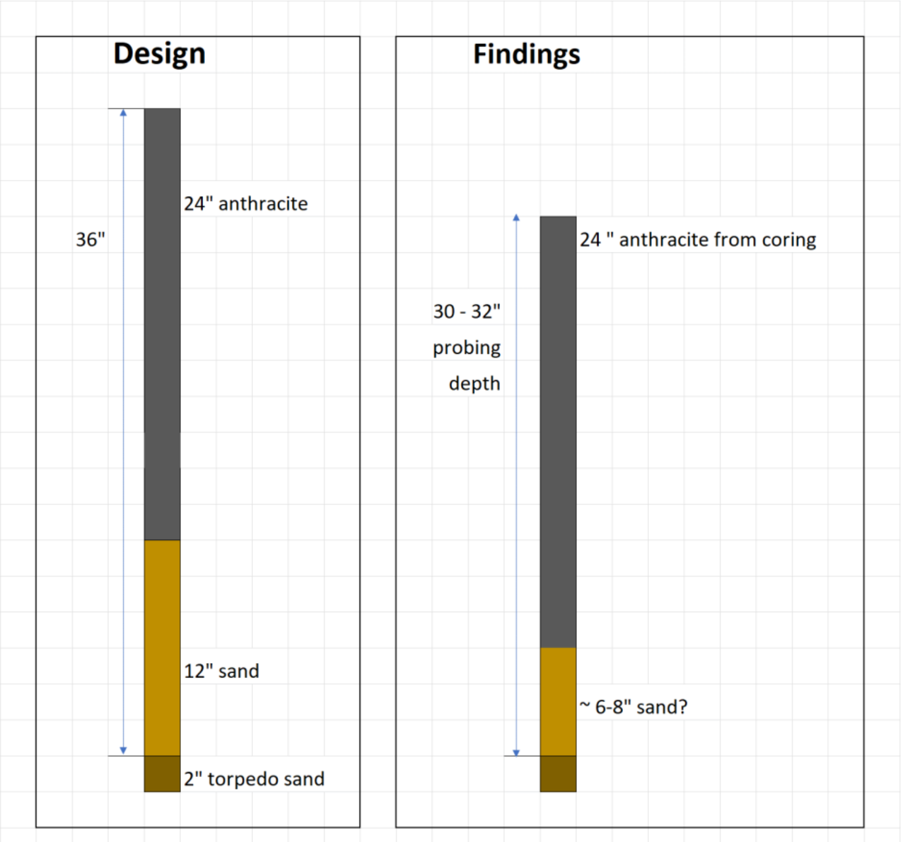


FIGURE 14. Media depth assessment.

The filter was drained prior to backwashing at the request of the CPE team. Two members of the evaluation team probed and inspected the filter media for variations in total depth at several places across the length and width of the filter (see Figure 15). Results of the filter probing are shown in Figure 16 on the following page. The probing showed filter media depths ranging from 29 inches to 32.5 inches. The expected total depth of the filter media was 38 inches based on the design information that was provided. There were no signs of mudballs on the media surface and the surface was relatively level; however, there was a cratered area on the media surface at the southwest corner of the filter (see Figures 16 and 17 on the following page).

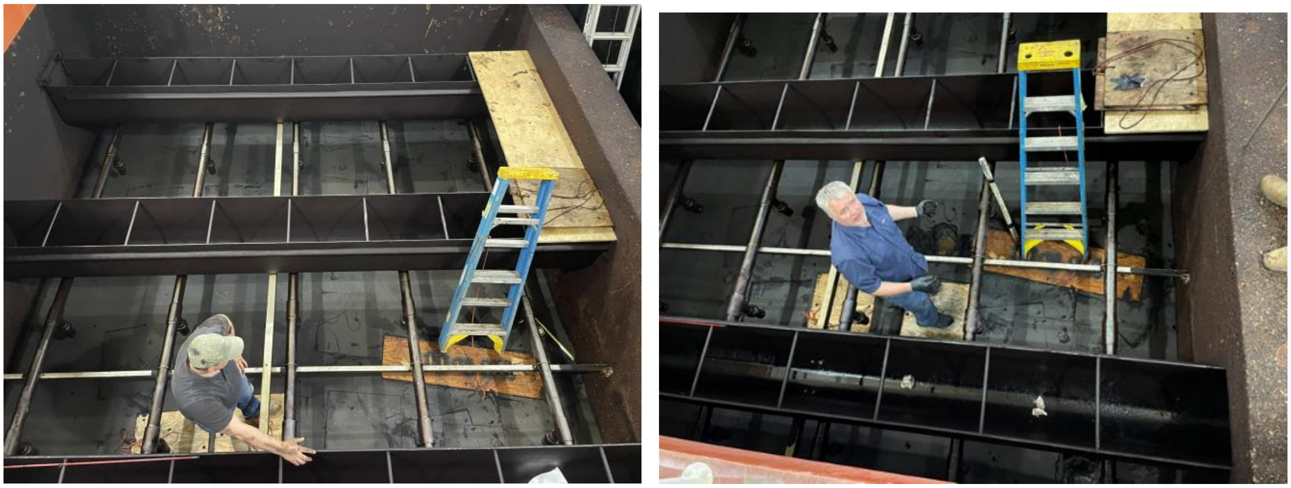
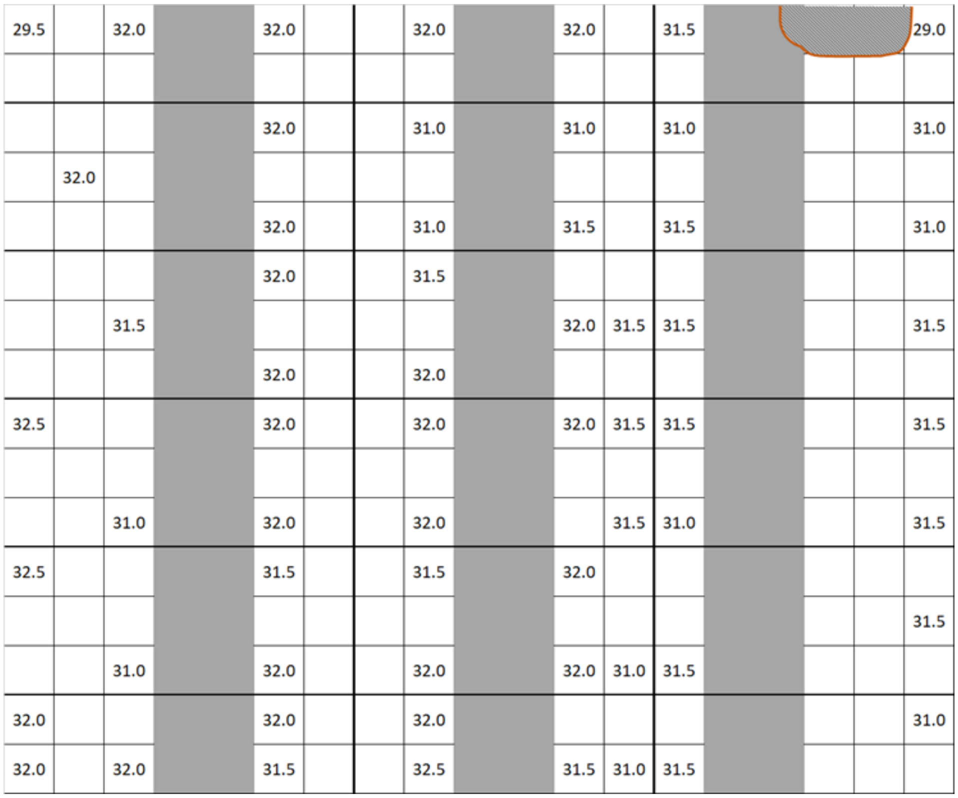


FIGURE 15. Filter No. 1 media depth probing.



29.5		32.0		32.0			32.0		32.0		31.5				29.0
				32.0			31.0		31.0		31.0				31.0
	32.0														
				32.0			31.0		31.5		31.5				31.0
				32.0			31.5								
		31.5							32.0	31.5	31.5				31.5
				32.0			32.0								
32.5				32.0			32.0		32.0	31.5	31.5				31.5
		31.0		32.0			32.0			31.5	31.0				31.5
32.5				31.5			31.5		32.0						
															31.5
		31.0		32.0			32.0		32.0	31.0	31.5				
32.0				32.0			32.0								31.0
32.0		32.0		31.5			32.5		31.5	31.0	31.5				

FIGURE 16. Filter No. 1 depth measurement results (cratered area redlined).

FIGURE 17. Cratered area in Filter No. 1.

The CPE team attempted to excavate at least two areas in Filter No. 1 to perform a media core analysis; however, the plant operators were unable to completely drain the filter down to the underdrain. The filter only drained to around eight inches below the surface of the media, which made excavation of the media impossible and prevented complete coring analysis. Visual inspection of the media in the top eight inches did not reveal evidence of any accumulation of debris or fines that would lead to mud balls. Excavation of the media would have allowed the team to observe media stratification and compaction and determine if mudballs were present. Additionally, excavation at the area of the surface crater would have allowed the team to determine if there was a problem with the underdrain system in that area that may have caused the crater.

Coring the filter would have shown the media interfaces and layering. The coring would also give the relative depth of each filter medium and the extent of the media interface. Various coring techniques were tried in different locations on the filter, but the inability to completely drain the filter prevented full-depth media from remaining in the coring tools. A coring tool borrowed from the City of Havre was able to document approximately 24 inches of anthracite media. If the filter does have 24 inches of anthracite, it would indicate that 5.5 to 9 inches of sand media is missing. Without the ability to excavate the filter, determining why there is a difference between the design filter media depth and the probing results is not possible. Routine inspection of filter media by plant staff is considered a good practice to ensure that this component of the filters performs at its optimum level. When the filter media is replaced in Filter No. 1, the underdrain system in the crater area should be carefully inspected to determine if there is a failure in this area.

Special Study 2: Filter No. 1 Backwash Duration Assessment and Media Expansion

During the Filter No. 1 backwash, turbidity grab samples were collected from the backwash effluent laundering trough, and they were analyzed with a Hach 2100Q portable turbidimeter. Grab samples were collected as wash began overtopping the laundering trough and then at 1-minute intervals for the duration of eight minutes when the backwash was terminated (see Figure 18 on the following page). The results of the grab samples and analyses are shown in the turbidity profile bar graph in Figure 19 also on the following page. The bar graph shows that turbidity in initial samples was approximately 550 NTU, decreased to 420 NTU after one minute of backwash, and decreased substantially in the sample taken after only four minutes of backwash to 22.7 NTU. Anthracite media was present in the backwash waste sample at one minute, indicating some media was being lost in backwashing. This Special Study was conducted to evaluate the filter backwash procedure. The backwashes were being implemented by operators at varying durations, with some much longer in length than others. The backwash rates also may benefit from further analysis/adjustments as discussed below.

FIGURE 18. Filter No. 1 backwash waste turbidity samples.

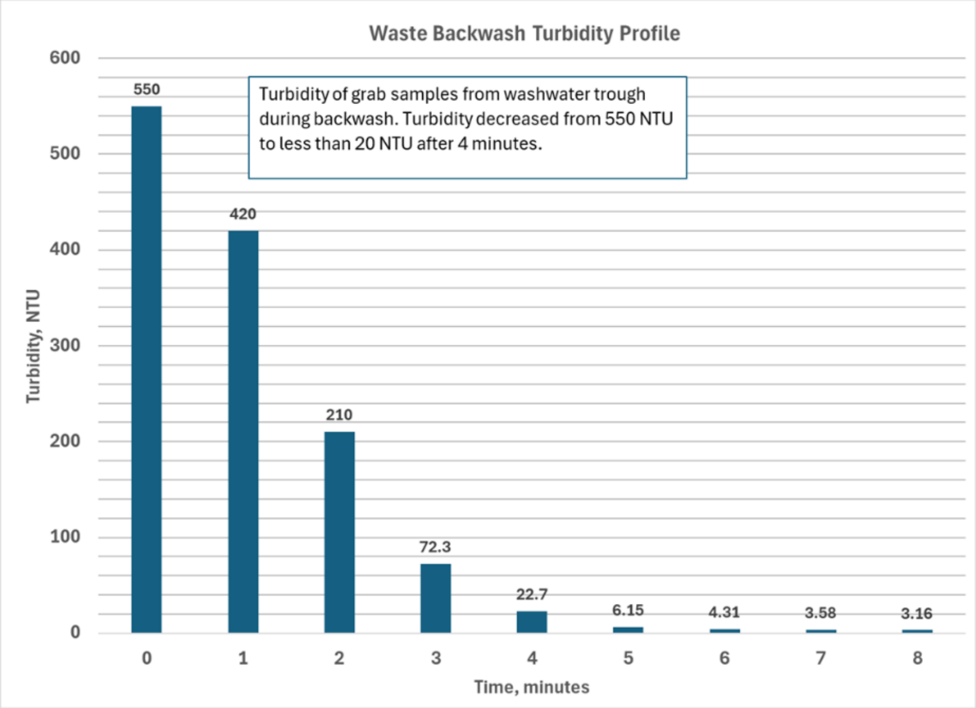


FIGURE 19. Filter No. 1 waste turbidity during backwash.

At the end of the filter backwash, a filter media expansion check was conducted. Prior to the filter backwash, a Secchi disk was used to determine the distance from the media surface to a reference point on the handrail. Toward the end of the backwash, the Secchi disk was lowered to a location where the disk disappeared below the expanded anthracite media (Figure 20). The distance between the expanded media surface and the reference point was measured, and the difference between the two measured was determined. The expanded media height was seven inches, and when compared to the measured media depth of 30 inches, a media expansion of 23% was calculated and deemed sufficient.

FIGURE 20. Filter No. 1 media expansion determination.

For the Havre plant filter configuration, a media expansion of at least 20% is considered sufficient to support effective media cleaning during backwash. Plant staff should measure filter media expansion in all filters on a routine basis. Seasonal changes in water temperature can impact filter bed expansion, with colder water resulting in increased bed expansion and the potential loss of filter media during backwash if not monitored closely.

Special Study 3: Filter No. 1 Post Backwash Recovery Study

The post-backwash recovery of Filter No. 1 was assessed by measuring the turbidity during filter-to-waste and after return-to-service. The treatment plant utilizes Hach TU5300 turbidimeters to monitor IFE and CFE turbidity continuously. The IFE turbidimeters monitor filter effluent prior to it being diverted to the clearwell or to waste. The CFE turbidimeter monitors the CFE prior to the water entering the clearwell. The turbidimeters appeared to be calibrated and maintained as required. The controller for these instruments was set to log data at 15-minute intervals. The data utilized for the graph below was taken from the turbidimeter instrument controller data logs and observation of the controller. Turbidity data was collected from controllers every minute for ten minutes, starting at the time the filter effluent was directed to the clearwell after filter-to-waste. The post-backwash recovery curve for Filter No. 1 is shown in Figure 21. The filter was placed into filter-to-waste mode at approximately 12:00 p.m., 15 minutes after the filter backwash ended. The maximum turbidity observed during filter-to-waste was 0.35 NTU. After about 90 minutes of filter-to-waste, the filter was returned to service at a turbidity of 0.12 NTU, which was slightly above the optimization goal of 0.10 NTU. At the time that Filter No. 1 was returned to service, the CFE turbidity experienced a short spike from 0.04 NTU to 0.13 NTU. Additional studies around backwash should be conducted to reduce return-to-service turbidity to less than 0.10 NTU.

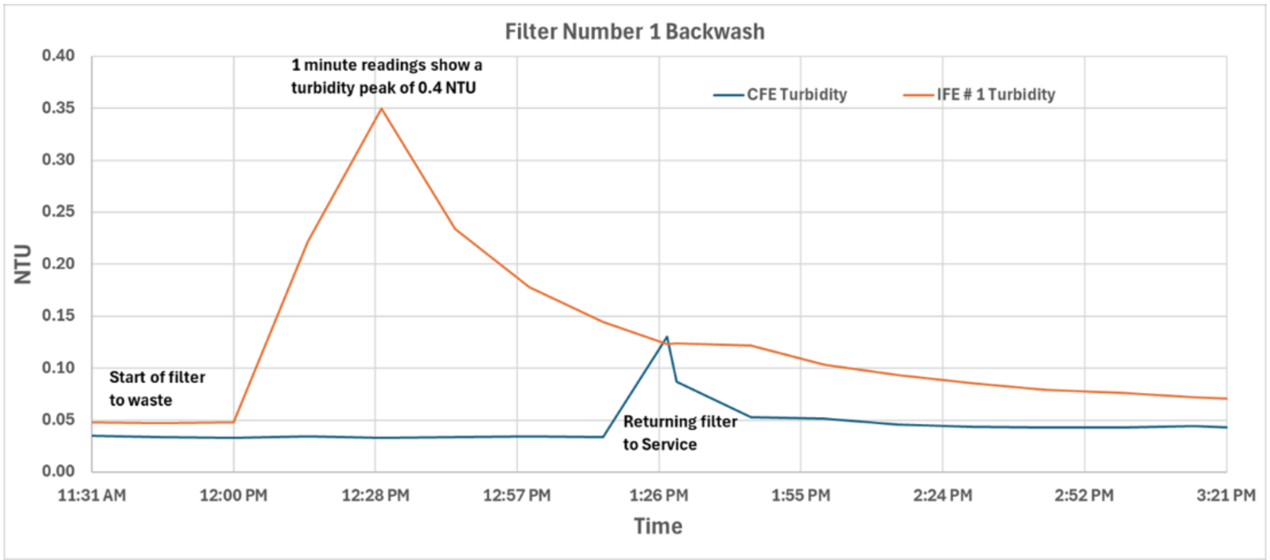
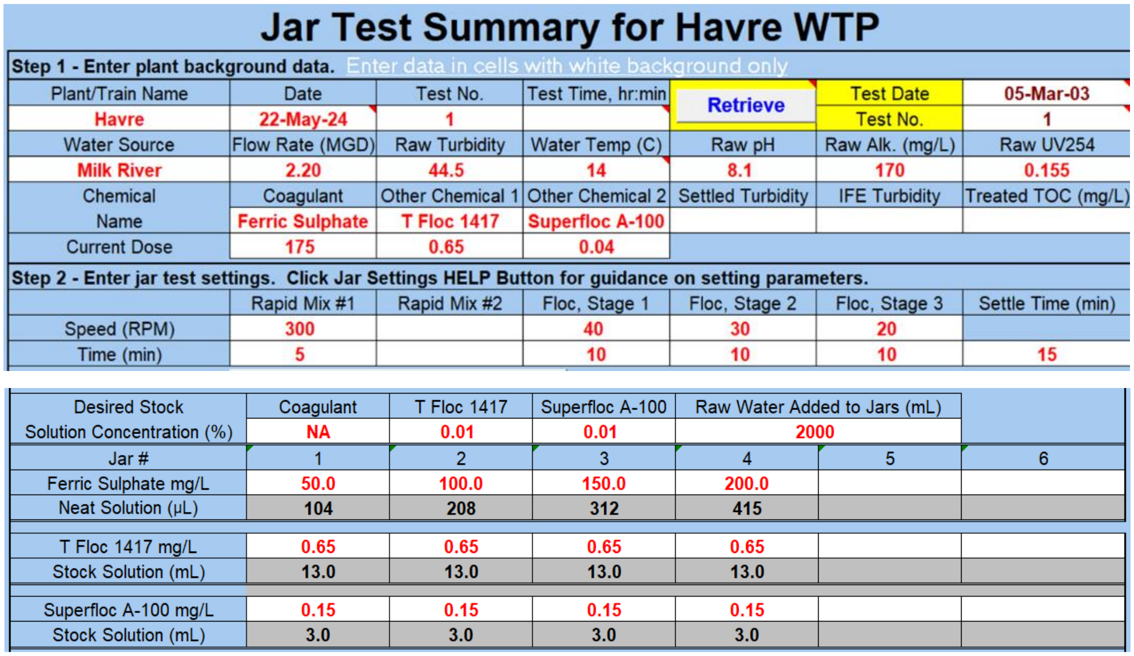


FIGURE 21. Filter No. 1 filtered water turbidity after backwash.

Special Study 4: Jar Testing to Determine Coagulant Dose

Jar testing is an important process control tool that can be used to determine optimum coagulant dosing for particle and organics removal, both treatment objectives of the Havre plant. To achieve these objectives, ferric sulfate, a cationic polymer (T Floc 1417), and a flocculant aid (Superfloc A-100) are fed at the plant. The dosing of ferric sulfate during changing water quality conditions was identified as a possible contributing factor to the spring high-turbidity event; consequently, the operations teams decided to conduct a jar test during the CPE. One of the plant operators routinely conducts jar tests to assess the plant coagulant dose. A standard jar test procedure, developed by one of the City’s consultants, is used to run the jar tests. The plant conditions and settings for the jar test run by the operations teams are summarized in Figure 22 (Steps 1 and 2). On the day of the test, the raw water turbidity and UV254 were 44 NTU and 0.155 per cm, respectively. The current ferric sulfate dose was 175 mg/L, and the polymer dosages were within typical ranges for these products.



Jar Test Summary for Havre WTP

Step 1 - Enter plant background data. Enter data in cells with white background only

Plant/Train Name	Date	Test No.	Test Time, hr:min	Retrieve	Test Date	05-Mar-03
Havre	22-May-24	1			Test No.	1
Water Source	Flow Rate (MGD)	Raw Turbidity	Water Temp (C)	Raw pH	Raw Alk. (mg/L)	Raw UV254
Milk River	2.20	44.5	14	8.1	170	0.155
Chemical Name	Coagulant	Other Chemical 1	Other Chemical 2	Settled Turbidity	IFE Turbidity	Treated TOC (mg/L)
	Ferric Sulphate	T Floc 1417	Superfloc A-100			
Current Dose	175	0.65	0.04			

Step 2 - Enter jar test settings. Click Jar Settings HELP Button for guidance on setting parameters.

	Rapid Mix #1	Rapid Mix #2	Floc, Stage 1	Floc, Stage 2	Floc, Stage 3	Settle Time (min)
Speed (RPM)	300		40	30	20	
Time (min)	5		10	10	10	15

Desired Stock Solution Concentration (%)	Coagulant	T Floc 1417	Superfloc A-100	Raw Water Added to Jars (mL)		
	NA	0.01	0.01	2000		
Jar #	1	2	3	4	5	6
Ferric Sulphate mg/L	50.0	100.0	150.0	200.0		
Neat Solution (µL)	104	208	312	415		
T Floc 1417 mg/L	0.65	0.65	0.65	0.65		
Stock Solution (mL)	13.0	13.0	13.0	13.0		
Superfloc A-100 mg/L	0.15	0.15	0.15	0.15		
Stock Solution (mL)	3.0	3.0	3.0	3.0		

FIGURE 22. Jar test study conditions and settings.

The jar test settings used for the test were similar to the plant settings, with two exceptions. The flocculation time was increased from two minutes per stage to ten minutes per stage. This change provided a total flocculation time of thirty minutes, which was still less than the plant flocculation time. Sufficient flocculation time is needed during the jar test to develop floc particles that have similar characteristics to those in the plant flocculation process. This outcome typically produces similar settled water turbidity results between the jar test and the plant settled water. The second change with the jar test settings was to increase the jar settling time from ten minutes to fifteen minutes. Given the use of tube settlers in the plant sedimentation basins, this extended jar settling time was thought to provide more comparable settled water turbidity results between the jars and the plant settled water.

Similar to the plant operator's procedure, a micropipette was used to dose ferric sulfate to the jars, and stock solutions were made for the two polymers. The chemical doses and associated volumes transferred to the jars during the jar test are shown in Figure 22 (bottom portion of figure). The ferric sulfate micropipette volume was determined using the following formula:

$$Micropipette\ Volume, \mu L = Dose, \frac{mg}{L} x \frac{1}{Specific\ Gravity} x \frac{1}{\%\ Strength, as\ decimal}\ x\ 2, L\ per\ jar$$

$$Example\ Micropipette\ Volume, \mu L = 50\ Dose, \frac{mg}{L} x \frac{1}{1.568} x \frac{1}{0.61}\ x\ 2, L\ per\ jar = 104$$

Using the plant's four-station jar tester, a ferric sulfate dose range of 50 to 200 mg/L was tested. All jars received the same cationic polymer dose at 0.65 mg/L. All jars also received the same flocculant aid polymer dose at 0.15 mg/L. The flocculant aid polymer dose was increased from the plant dose of 0.04 mg/L since this was thought to provide more significant results, i.e., increased floc weight and strength. A picture of the jars during the flocculation jar test step is shown in Figure 23.

FIGURE 23. Jars during flocculation step showing increasing ferric sulfate dose, left to right.

After completion of the settling step, samples were collected from the jars using the sample ports. Use of the sample ports allows for more representative sampling from the jars, i.e., the sample time and distance of the tap from the top of the jar can be equated to the settling velocity in the sedimentation basin tube settlers. Samples were tested for turbidity, and an additional sample from each jar was filtered through 20 – 25 micron filter paper to provide an indication of expected filtered water turbidity results. A tighter paper (~ 8 micron) would have provided a better representation of filtration performance, but it was not available during the jar jest. Both sets of results are shown in Figure 24.

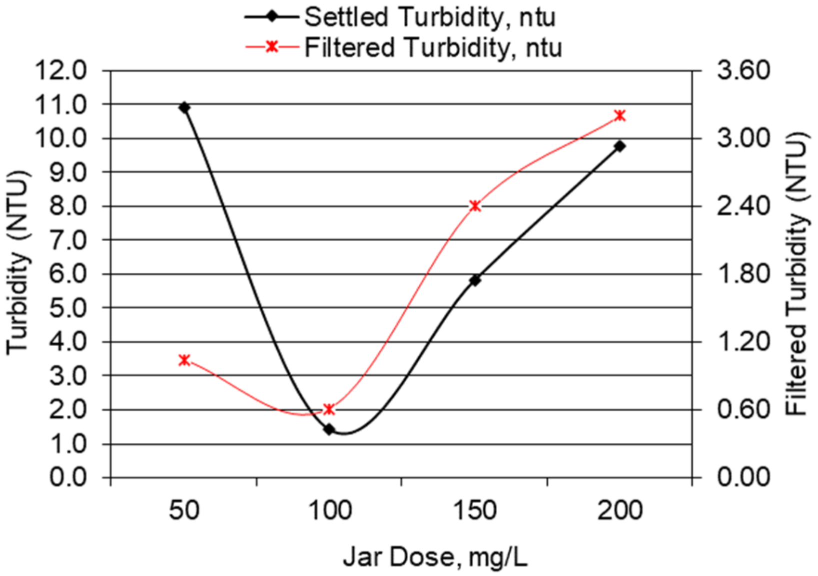


FIGURE 24. Jar test settled and filtered turbidity results.

For both the settled water and filtered water turbidity results, the 100 mg/L ferric sulfate dose was optimum for this jar test. These results suggested that, based on raw water conditions and turbidity performance only, the current ferric sulfate dose of 175 mg/L could be reduced. Settled water pH readings were also tested from each jar, and these results are shown in Figure 25 on the following page. As would be expected, the pH was suppressed with the addition of ferric sulfate and the relationship was linear and downward sloping with increasing doses.

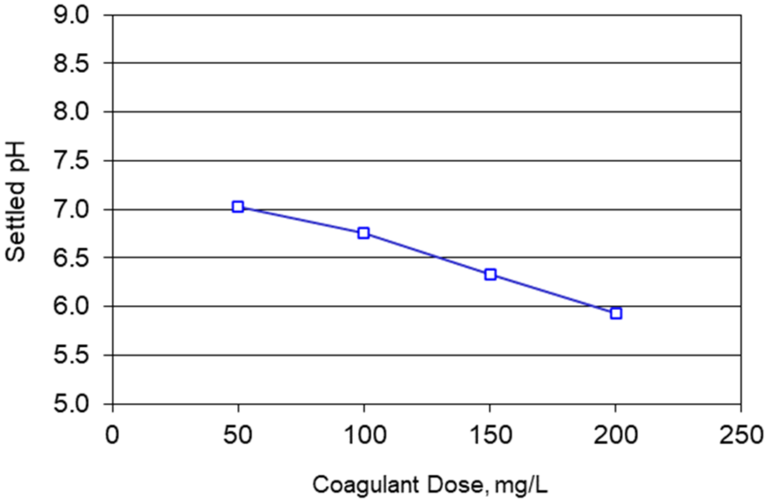


FIGURE 25. Jar test coagulated pH results.

Samples were also collected from each jar and tested for UV254, a surrogate indicator for organics. Prior to testing, each sample was filtered through 0.45-micron filter paper. Results of this testing are shown in Figure 26 below, and they show increasing removing of UV254 for each additional increase in ferric sulfate dose. Testing of organics (DOC) would provide additional insights into the significance of organics removal with increasing coagulant dose.

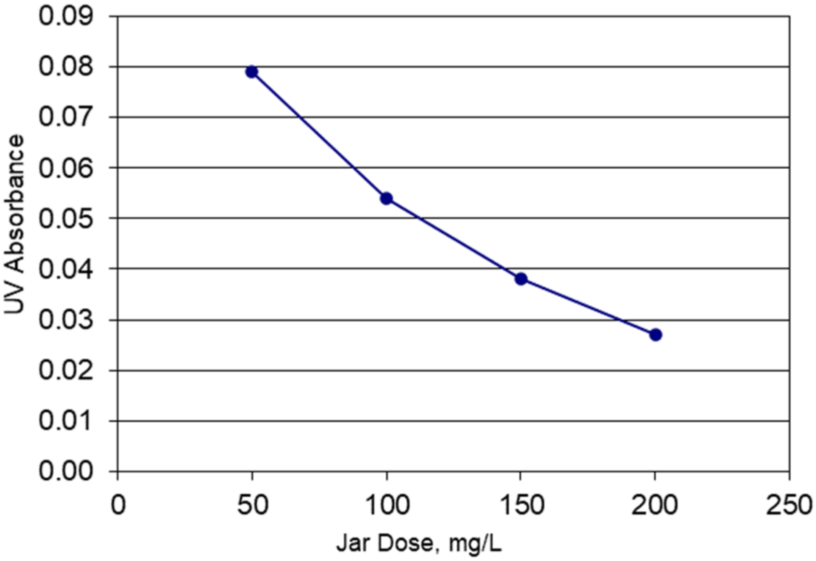


FIGURE 26. Jar test coagulated UV254 results.

The jar test study conducted during the CPE provided useful information on assessing the plant jar testing procedure and comparing predicted optimum coagulant and polymer doses with the plant doses. Additional jar testing would be needed to confirm the results and refine the procedure, e.g., use of the filter paper. While the jar tests indicate that a lower coagulant dose could be trialed full-scale for turbidity removal, additional dosing may be needed to achieve the level of organics removal needed for optimal DBP control.

Special Study 5: Chemical Feed and Dose Verification

A Special Study was conducted to determine the feed rates and doses of chemicals used at the plant. A summary of the study findings is included in Table 7. Powdered activated carbon is fed with a screw-type auger into a side stream that enters the raw water wet well prior to chemical addition. The dosing for powdered activated carbon (PAC) was determined by collecting a sample of carbon from the feeder for one minute and determining its weight. Through calculations, the dose was calculated at 3 mg/L. The plant reported their carbon dose as 8 ft^3/hr, as noted in Figure 27 on the next page. The reporting of the carbon dose in ft^3/hr made it difficult to compare the reported dose with the measured dose in mg/L. It is recommended that the carbon dose be reported in mg/L, similar to the other chemicals fed in the plant.

TABLE 7. Results of chemical feed dosing verification.

Chemical	Drawdown, mL/min	% Strength/SG	Calculated Dose, mg/L	Reported Dose, mg/L
Carbon	17.2 g/min	100% purity	3	8 ft^3/hr
Ferric Sulfate	1,185	61.4 / 1.568	197	175
Polymer (T Floc 1417)	3.4	100 / 1.05	0.62	0.65
Floc Aid Polymer	1,300	0.024% (90 g poly added to 100 gal water) / 1	0.05	0.04
Caustic	440	50 / 1.52	58	55
Chlorine	5,800	0.8%?	8?	?

For liquid chemicals the following formulas were used:

$$Product\ Strength, \frac{lb}{gal}$$

$$= Product\ \%\ Concentration\ (as\ decimal)\ x\ Product\ Specific\ Gravity\ x\ 8.34\frac{lb}{gal}$$

$$Feed\ Rate, \frac{lb}{day} = Feed\ Rate\ \left(\frac{mL}{min}\right) x\ \left(\frac{gal}{3{,}785\ mL}\right)\left(1{,}440\frac{min}{day}\right) x\ Product\ Strength\frac{lb}{gal}$$

$$Dose, \frac{mg}{L} = Feed\ Rate\frac{lb}{day}\, x\frac{day}{Flow\ (MG)}\ x\frac{gal}{8.34\ lb}$$

For powdered activated carbon the following formulas were used:

$$Feed\ Rate, \frac{lb}{day} = Feed\ Rate\ \left(\frac{g}{min}\right) x\ \left(\frac{0.0022\ lb}{g}\right)\left(1{,}440\frac{min}{day}\right) x\ Product\ Purity\ \%$$

$$+Dose, \frac{mg}{L} = Feed\ Rate\frac{lb}{day} + x\frac{day}{Flow\ (MG)}\ x\frac{gal}{8.34\ lb}$$

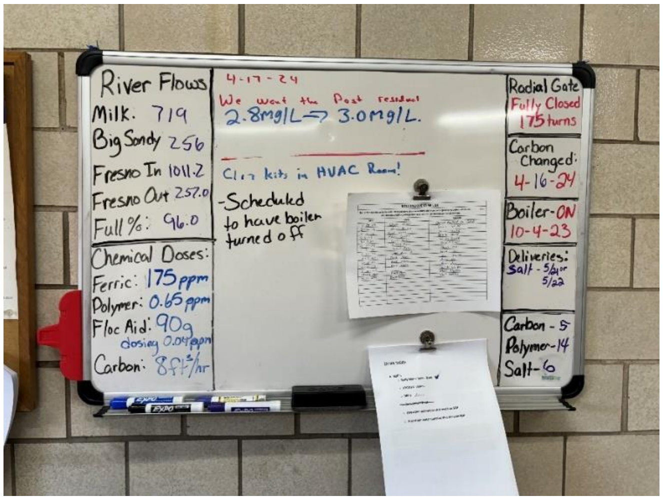


FIGURE 27. Plant white board showing chemical feed information.

Three peristaltic feed pumps (SCADA labeled tags 836, 835 and 834) are used to feed coagulant (ferric sulfate) prior to rapid mix. Each peristaltic pump was set at 350 mL/min. The CPE team could not use drawdown tubes supplied for chemical calibration verification due to a valving failure needed for the isolation of the drawdown cylinder. Chemical feed was verified using a graduated cylinder and a stopwatch, with combined results determining a feed rate of 1,185 mL/min. The corresponding dose was 197 mg/L. This dose exceeded the expected dose of 175 mg/L by about 13%.

The CPE team used a graduated cylinder and a stopwatch to conduct a drawdown test for the T Floc 1417 cationic polymer. The test indicated a feed rate of 3.4 mL/min and a dose of 0.62 mg/L. This dose compared well with the plant expected dose of 0.65 mg/L.

Two peristaltic feed pumps (SCADA labeled tags 843 and 844) are used to feed the flocculant aid polymer. The CPE team used a graduated cylinder and a stopwatch to conduct a drawdown test for each peristaltic feed pump. The combined results indicated a combined feed rate of 1,300 mL/min. This resulted in a dose of 0.05 mg/L that compared closely to the expected dose of 0.04 mg/L.

Caustic feed was verified using a graduated cylinder and a stopwatch, with combined results indicating a feed rate of 440 mL/min with a calculated dose of 58 mg/L. This dose was slightly higher than the plant reported dose.

Three peristaltic feed pumps (SCADA labeled tags 854, 855, and 856) are used to feed sodium hypochlorite solution prior to filtration and into the clearwell influent for final disinfection. The CPE team used a graduated cylinder and a stopwatch to conduct a drawdown test for each peristaltic sodium hypochlorite feed pump. The results concluded in feed rates of 1.8 L/min, 1.8 L/min, and 2.2 L/min. Sodium hypochlorite is generated onsite. The 0.8% ClorTec onsite hypochlorite generation uses softened water, salt, and electricity to produce chlorine-based disinfectants when a solution of sodium chloride passes through an electrolytic cell. Due to time constraints, the percentage of strength could not be verified; however, an estimated concentration of 0.8% was used to calculate a chlorine dose. This resulted in a chlorine dose of 8 mg/L. Confirming these calculations could provide useful information for the plant operators, i.e., better understanding of chlorine demand of the finished water.

Special Study 6: Impact of Washwater Basin Recycle Flow on pH

The practice of recycling flow directly from the filter washwater basin directly to the head of the plant was noted to have an effect on the raw water pH (see Figure 28 on the following page). It is possible that other parameters, like alkalinity, are impacted as well. These water quality changes may necessitate adjustments in coagulant and caustic dosing depending on the source of the water being recycled, but it does not appear that adjustments are being made to account for these changes. Special Studies to determine how to adjust coagulant and caustic doses to maintain stable settled water turbidity during filter washwater basin recycle should be prioritized by the plant operators.

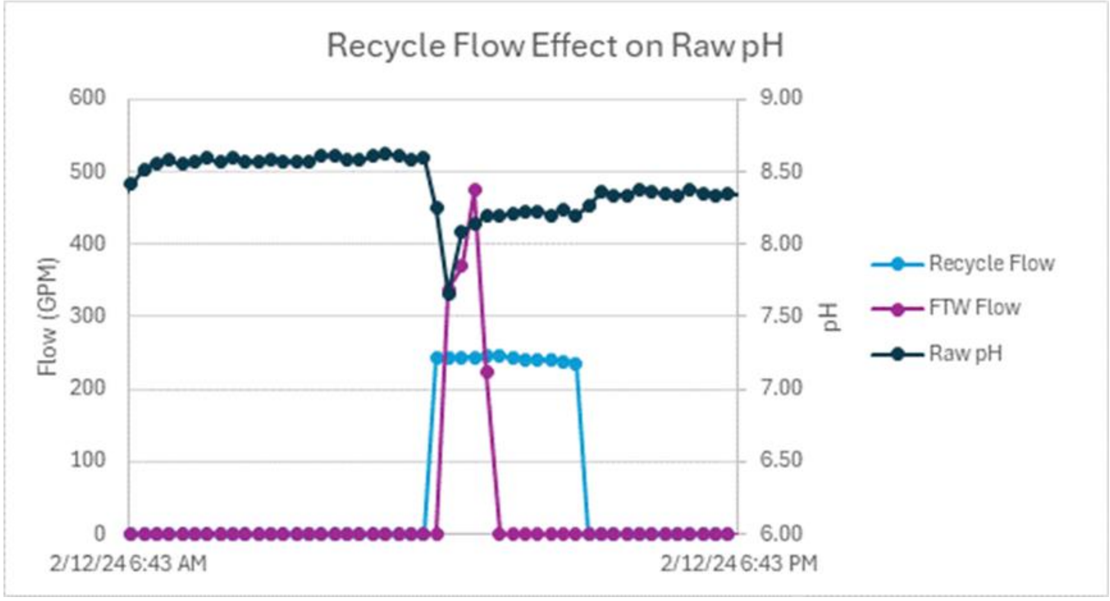


FIGURE 28. Example of recycle effects on raw pH.

Special Study 7: Extended Terminal Subfluidization Wash (ETSW) Demonstration

Some studies suggest that 90% of particles that pass through a well-operated filter do so during the filter ripening period after backwashing (Amburgey et al., 2003). The Area-Wide Optimization goal for filter backwash return-to-service is 0.10 NTU for plants such as Havre’s that have filter-to-waste capability.

A review of historical 15-minute backwash recovery turbidity data spanning from July 2023 to May 2024 indicated that the optimization goal was met on 1.2% of days evaluated with a 95th percentile of 0.21 NTU; the optimization goal was not met for any filter. The average filter-to-waste time during the period evaluated was 79 minutes. The long filter-to-waste times and post-backwash turbidity spikes suggest room for improvement in the backwash procedure.

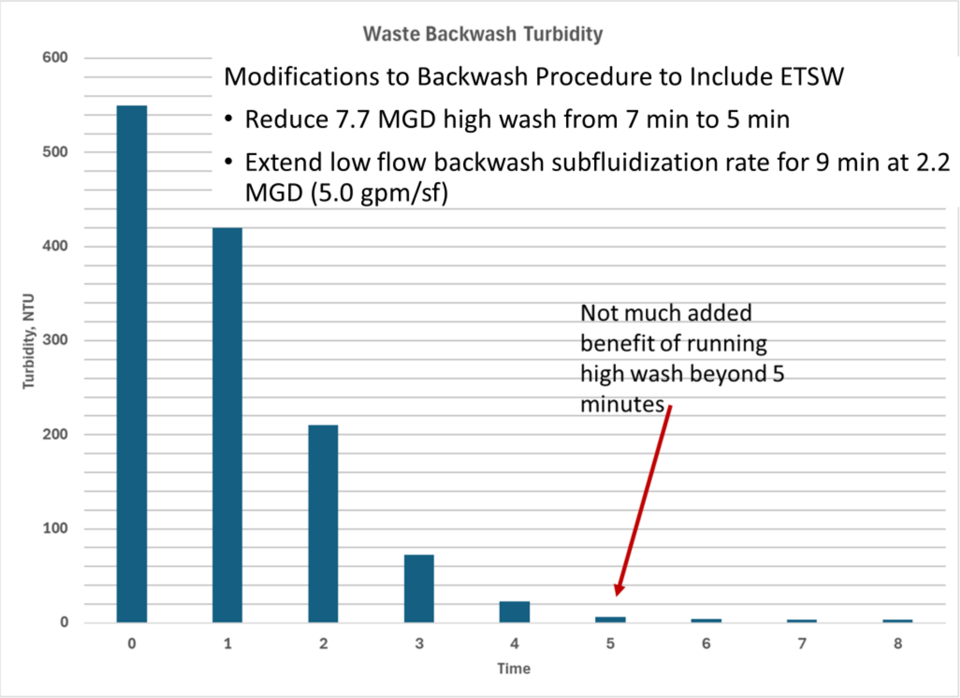
The CPE team introduced a filter backwash technique known as *“extended terminal subfluidization wash”* or ETSW. ETSW is a procedure that extends the normal backwash duration at a backwash rate such that the filter media is no longer fluidized, and at a duration long enough to flush one filter bed volume of water through the filter. This added step is intended to remove dislodged remnant particles that are usually left behind following backwashing and discontinue shearing off additional particles from the media while allowing the media to restratify. Several benefits have been demonstrated, not only in scientific literature, but also in several case studies from other states that participate in AWOP, such as Maryland, Connecticut, and Alabama. These include:

- Reducing or eliminating return-to-service turbidity spikes,
- Shortening necessary filter-to-waste times to reach the optimization goal of 0.10 NTU before return-to-service,
- Reduced production water wasted during filter-to-waste.

The CPE team demonstrated the ETSW procedure on Filter No. 2 at Havre’s WTP. The typical filter backwash sequence ends with a seven-minute high rate wash at 7.7 MGD. The team determined that flushing one filter bed volume, from the top of the underdrains to the top of the backwash trough, would take nine minutes at a low wash rate of 2.2 MGD, which is in the range of the recommended ETSW loading rates. Therefore a nine-minute ETSW step was added to the backwash procedure for Filter No. 2 at 2.2 MGD. Additionally, the team observed backwash wastewater turbidity during Special Study No. 3 (discussed above) for Filter No. 1, and they observed that the backwash wastewater turbidity was reduced from approximately 550 NTU at the start of the trough flow down to less than 10 NTU by four minutes. The additional three minutes of high-rate wash did not proportionally remove much additional turbidity; therefore, the CPE team concluded that the high-rate wash could potentially be reduced to about four minutes. See Figure 29 on the following page.

Therefore, by making these two modifications to the backwash procedure, namely: 1) reducing the high wash duration from seven minutes to four minutes and 2) reducing the backwash flow rate down from 7.7 MGD to the subfluidization rate of 2.2 MGD and running at the ETSW rate for an additional nine minutes.

Results of this study, shown in Figure 30 on the following page, depict filter-to-waste turbidity recorded from the Filter No. 2 IFE turbidimeter controller and compared with the same filter-to-waste profile for Filter No. 1 generated in Special Study No. 3.



Modifications to Backwash Procedure to Include ETSW

- Reduce 7.7 MGD high wash from 7 min to 5 min
- Extend low flow backwash subfluidization rate for 9 min at 2.2 MGD (5.0 gpm/sf)

Not much added benefit of running high wash beyond 5 minutes

Figure 29. ETSW filter-to-waste profile comparison.

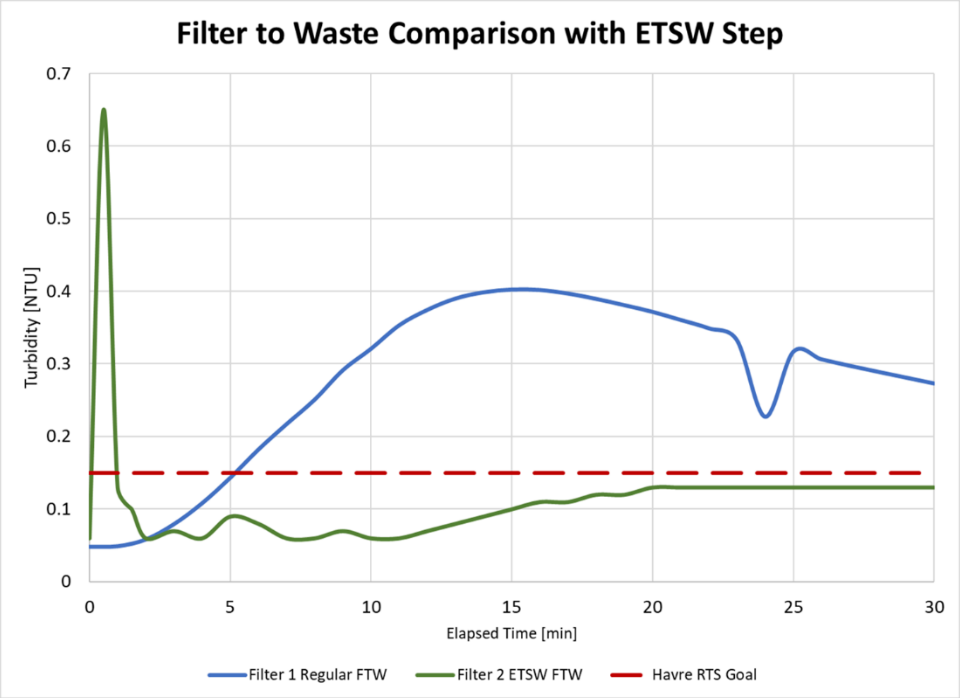


Figure 30. ETSW filter-to-waste profile comparison.

Results from this study indicate that ETSW may be a beneficial technique for Havre to explore further. Compared with the filter-to-waste turbidity profile observed after the backwash of Filter No.1, the filter-to-waste turbidity profile for Filter No. 2, on which ETSW was performed after the normal backwash procedure, (recall: with slight reduction to the high wash time) depicts a much quicker decrease in turbidity to below Havre's return-to-service goal. Filter No. 2 exhibited a quick turbidity spike, and thereafter turbidity was reduced to less than 0.15 NTU within about two minutes and remained below this value for the remainder of the filter-to-waste. In contrast, Filter No. 1 was filtered-to-waste for over thirty minutes and still had not reached Havre's goal of 0.15 NTU. Although these studies were conducted on two different filters, Filter Nos. 1 and 2 are adjacent and of similar design. Further investigation is needed to better understand the potential benefits of ETSW at Havre's plant, but this preliminary study suggests that ETSW could benefit the filter backwash and return-to-service process.

MAJOR UNIT PROCESS EVALUATION

Major unit processes were assessed with respect to their capability to meet the optimized settled and filtered water goals as well as the disinfection goals based on CT (residual concentration multiplied by contact time prior to the first customer). The capability of each individual unit process was also assessed to verify its ability to provide consistent optimized performance. This level of plant performance is considered necessary to help ensure removal or inactivation of pathogens. Calculation of plant disinfection capability was based on chlorine CT values outlined in the USEPA Guidance Manual[3] for meeting both filtration and disinfection requirements.

Since the treatment processes of the plant must always provide multiple effective barriers, a peak instantaneous operating flow was determined. The peak instantaneous operating flow represents conditions when the treatment processes are the most vulnerable to the passage of parasitic cysts and microorganisms. If the treatment processes are adequate at the peak instantaneous flow, then the major unit processes should be capable of providing the necessary effective barriers at lower flow rates. The peak instantaneous flow for the flocculation through filtration processes in the Havre WTP was determined to be 3.4 MGD (maximum day flow in summer 2023) based on the raw water flow records and plant staff feedback. More recently, the maximum production from the

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[3] Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources, USEPA, Office of Drinking Water, Washington, D.C. (1989), revised 1991.

plant has been reduced to about 2.8 MGD. Staff are investigating possible hydraulic and instrumentation issues that could be causing this flow reduction. For the disinfection process, the contact time available for chlorine disinfection is controlled by the maximum operating flow rate of the high-service pumps. Due to the dramatically different water temperature experienced between summer and winter, two peak instantaneous flow rates were determined. For summer operating conditions, the maximum daily flow was 4.5 MGD (3,153 gpm); for winter operating conditions, the maximum daily flow was 3.2 MGD (2,207 gpm).

Unit process capability was assessed using a performance potential graph, where the projected treatment capability of each major unit process was compared against the peak instantaneous operating flow rate. The Major Unit Process Evaluation graph developed for the Havre WTP is shown in Figure 31 on the following page.

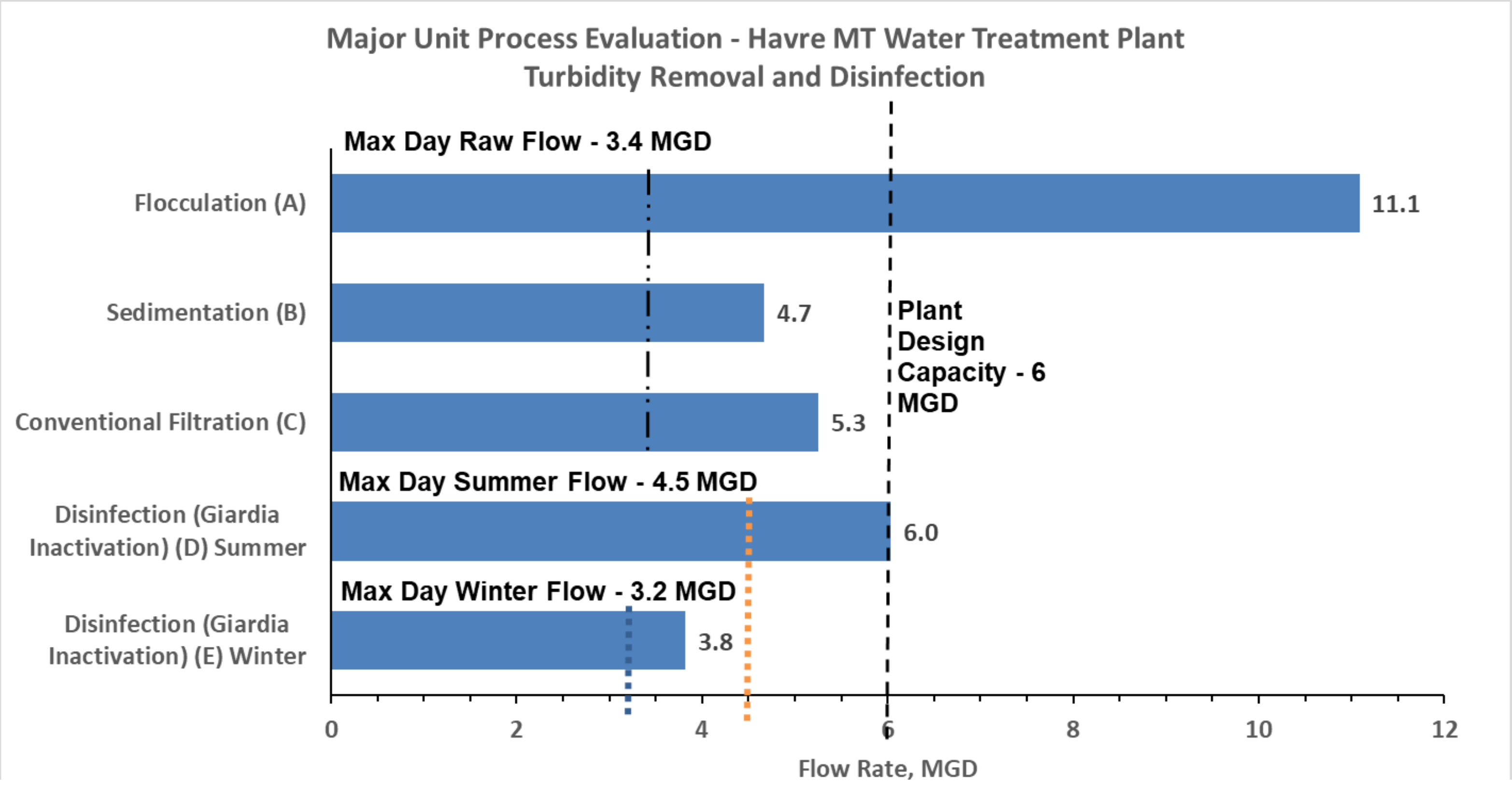
The unit processes evaluated during the CPE are shown along the vertical axis. The horizontal bars on the graph represent the projected peak capability of each unit process that would support achievement of optimized process performance. These capabilities were projected based on several factors, including: the combination of treatment processes at the plant, the CPE team's experience with other similar processes, raw water quality, industry guidelines, the Havre WTP design, and regulatory standards.

Each unit process can fall into one of three categories:

Type 1: Where the bar for the unit process exceeds the peak instantaneous flow (>100% of peak flow), the plant should be expected to achieve the performance goals.

Type 2: If the bar for the unit process falls short but close to the peak instantaneous flow (80 to 100% of peak flow), then operational adjustments may still allow the plant to achieve the performance goals.

Type 3: If the bar for a particular unit process falls far short of the peak instantaneous flow (<80% of peak flow), then it may not be possible to achieve the performance goals with the existing unit process.



(A) Flocculation: Calculation based on 2°C water temperature, multiple stage, tapered flocculation, and assigned 20 min. detention time.

(B) Sedimentation: Calculated based on loading rate of 1.5 gpm/ft^2 of tube settler area; total of 2,160 ft^2.

(C) Conventional Filtration: Calculated based on three of four filters in service, each with a surface area of 304 ft^2. Assigned loading rate of 4 gpm/ft^2.

(D) Disinfection (*Giardia*): Calculation based one segment (clearwell): Surface area = 2,500 ft^2, minimum operating depth = 7 ft, T10/T ratio = 0.6. A minimum free chlorine residual of 1.5 mg/L, maximum pH of 8.7, and a minimum temperature of 14.2 °C was used. These were min/max for May through September 2023, as reported in plant records. Maximum daily flow is based on high-service pumping rate.

(E) Disinfection (*Giardia*): Calculation based one segment (clearwell): Surface area = 2,500 ft^2, minimum operating depth = 7 ft, T10/T ratio = 0.6. A minimum free chlorine residual of 2 mg/L, maximum pH of 8.2, and a minimum temperature of 1.53 °C was used. These were min/max for November 2023 through March 2024, as reported in plant records. Maximum day flow is based on high-service pumping rate.

FIGURE 31. Major unit process evaluation graph.

The shortest bar represents the most limiting unit process relative to achieving optimized plant performance. The major unit processes evaluated included flocculation, sedimentation, filtration, and disinfection.

Flocculation is achieved through three-stage flocculation basins. Each stage includes two vertical paddle mixers, and the mixer frequencies were set at 40 Hz – first stage, 30 Hz – second stage, and 20 Hz – third stage during the CPE. Based upon the CCP Handbook criteria, a hydraulic detention time (HDT) of 20 minutes was selected to rate the process. The approximate flocculation basin volume of 154,058 gallons and HDT of 20 minutes resulted in a flocculation capability rating of 11.1 MGD. The flocculation unit process evaluation resulted in a flocculation capacity that exceeds the current instantaneous operating flow rate of 2 MGD. This qualifies the flocculation process as a Type 1 process.

The sedimentation basins following the flocculation process contain tube settlers for enhanced sedimentation. A surface loading rate of 1.5 gpm/ft^2 of the surface area covered by tube settlers was assigned based on turbidity removal and a basin depth exceeding 12 feet. While particle settling does occur prior to the tube settlers, sedimentation loading rates are typically based on only the area covered by the tubes. Using the area of the tube settlers (two trains x 27 ft x 40 ft), the effective settling area is 2,160 ft^2. Using the 1.5 gpm/ft^2 criterion and the tube settling area of 2,160 ft^2, the sedimentation unit process is rated at 4.7 MGD, exceeding the peak instantaneous flow of 2 MGD and qualifying the sedimentation process as Type 1.

Gravity filtration is performed using four dual-media filters. Each filter has a surface area of 304 ft^2 (19 ft x 16 ft). Assuming typical operation with one filter out of service for backwashing, the total surface area of 912 ft^2 is available for filtration. A filter loading rate of 4.0 gpm/ft^2 was selected to evaluate the filtration unit process based on dual-media filters with surface wash and no indication of air binding. The resulting rating of the gravity filtration process is 5.3 MGD. The filtration process rating is above the peak instantaneous operating flow, and the filters are therefore rated a Type 1 process.

The USEPA SWTR requires the inactivation/removal of 3 log (99.9%) of *Giardia* cysts and 4 log (99.99%) of viruses. The Havre WTP is classified as conventional filtration and is credited for 2.5-log (99.7%) removal of *Giardia* cysts and 2-log (99%) virus removal through the plant's physical treatment processes. The remaining 0.5 log of *Giardia* and 2-log virus inactivation must be achieved through disinfection. For disinfection with free chlorine, the *Giardia* inactivation requirement is more stringent than the virus disinfection requirement. As such, *Giardia* inactivation was used as the basis for the free chlorine disinfection evaluation. The residual disinfectant concentration (C), in mg/L, multiplied by the time the water is in contact with the disinfectant (T), in minutes, comprises CT. The only segment in the Havre WTP used for disinfection is the disinfection chamber (clearwell).

As described previously in this section, the disinfection process for the Havre plant was assessed based on summer and winter conditions. For 0.5-log inactivation of *Giardia* during summer conditions, a required CT value of 28.1 mg/L-min was obtained from the USEPA Guidance Manual[3]. The corresponding CT value for winter conditions was 59.3 mg/L-min. The required CT was selected using the highest reasonable free chlorine residual, highest pH, and the lowest temperature values that the plant experienced during those periods, as indicated in Table 8 on the following page. The baffling factor used for disinfection chamber is 0.6 based on the EPA guidance manual for a well-baffled contact tank (same value approved by Montana DEP). A review of plant operating records indicated that the lowest operating depth of the disinfection chamber is seven feet. Based on the disinfection tank dimensions (50 ft x 50 ft surface area), assuming a seven-foot depth and using the 0.6 baffling factor, the effective volume of the disinfection chamber was calculated to be 78,540 gallons.

For summer operating conditions, a chlorine residual of 1.5 mg/L, a minimum water temperature of 14.2 °C, and a maximum pH of 8.7 were used to determine the disinfection process capability. Based on these conditions, the required CT for 0.5-Log *Giardia* inactivation, and the calculated effective volume, the chlorine disinfection capability is 6 MGD, which is higher than the peak instantaneous operating flow of 4.5 MGD through the high-service pumps. This qualifies chlorine disinfection as a Type 1 process during summer operating conditions.

TABLE 8. Summary of performance-limiting factors.

Rank	Rating	Performance-Limiting Factor (Category)
1	A	Policies (Administration)
2	A	Supervision (Administration)
3	A	Application of Concepts and Testing to Process Control (Operations)
4	A	Process Controllability/Instrumentation (Design)
5	B	Sludge/Backwash Water Treatment Disposal (Design)
6	B	Microbial Contamination (Design)
7	B	Coverage (Administration)
8	B	Standby Units (Design)
9	B	Testing (Operations)
10	C	Training Program (Operations)
11	C	Disinfection (Design)

For winter operating conditions, a chlorine residual of 2 mg/L, a minimum water temperature of 1.53 C, and a maximum pH of 8.18 were used to determine the disinfection process capability. Based on these conditions, the required CT for 0.5-Log *Giardia* inactivation, and the calculated effective volume, the chlorine disinfection capability is 3.8 MGD, which is higher than the peak instantaneous operating flow of 3.2 MGD through the high-service pumps. This qualifies chlorine disinfection as a Type 1 process during winter operating conditions.

All the major unit process capabilities are shown in Figure 31 on page 45. The graph shows that all particle removal and disinfection processes are capable of treating the assigned peak instantaneous operating flow rates and are considered Type 1 processes. It should be noted that other design constraints may exist within the plant that could impact plant performance (refer to design-related Performance-Limiting Factors in the next section).

PERFORMANCE-LIMITING FACTORS

The areas of design, operation, maintenance, and 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 CPE team. Each of the factors was assessed for a possible classification as A, B, or C according to the following guidelines:

A	Major effect on a long-term repetitive basis
B	Moderate effect on a routine basis, or major effect on a periodic basis
C	Minor effect

The performance-limiting factors identified were prioritized as to their relative impact on performance, and they are summarized in Table 8 on the previous page. While developing the list of factors limiting performance, over 50 potential factors were reviewed, and their impact on the performance of the Havre WTP was assessed. Each of the factors, along with specific examples of why the factor was identified, are described in this section.

Policies – Administration (A)

Existing policies do not encourage staff members to make required operation, maintenance, and management decisions for optimized plant performance. Examples of policies limiting performance include the following:

- The Havre WTP administration has not adopted written water quality goals (regulatory or optimization) for microbial water quality.

- Policies have not been established to hold operators accountable to meet water quality goals or to optimize operations.

Supervision – Administration (A)

Management styles and communication practices do not currently support optimized plant performance. Staff need clear direction from plant supervisors to promote consistent operational practices.

Application of Concepts and Testing to Process Control – Operation (A)

Staff are not routinely applying process control skills in their day-to-day operation of the Havre WTP.

- The filter backwash return-to-service turbidity setpoint was increased from 0.10 NTU to 0.15 NTU due to long filter-to-waste times; this results in an increase in the number of particles passing through the filters during a critical phase of filter operation, the filter ripening period.
- Operators do not follow consistent filter backwashing procedures.
- Process control is often based on historical experience and visual observations versus data-based decision making.
- Jar testing capability primarily resides with one operator.
- Filter backwash water is often directed to the front of the plant versus sending it to the lagoons.
- Plant personnel have relied on outside technical assistance provider and vendor advice that has contributed to inconsistent operations.

Process Controllability/Instrumentation – Design (A)

Process controls and instrumentation are limiting plant controllability, chemical feed control, and turbidity data capture.

- Lack of flow control between the filters results in hydraulic surging (valve pulse control modulation issue).
- Caustic and chlorine feed are paced with the raw water flow instead of the finished water flow which has at times increased the pH to a level that resulted in disinfection non-compliance.
- The backwash routine is often interrupted due to communication issues between the old and new programmable logic controllers (PLCs) that are in used in the plant.

- The SCADA system storage appears to be limited to about nine months of IFE/CFE turbidity data; regulations require storage of at least five years of data.

- CFE SCADA trend only includes 15-minute data points; continuous, real-time turbidity trending is not available to the operators.

Sludge/Backwash Water Treatment Disposal – Design (B)

Waste backwash handling facilities are impacting plant performance.

- There is a lack of flexibility for handling backwash water and no ability at the current time to discharge decant from the lagoons.

Microbial Contamination – Design (B)

The potential presence of microbial pathogens in proximity to the water treatment plant intake may impact the plant's ability to provide an adequate treatment barrier.

- Recent evidence of microbial contamination (*Giardia, Cryptosporidium, E.* coli) was detected in the source water, and there are likely contamination sources (cattle, septic system discharges, agriculture activities, etc.) in upstream tributaries.

Coverage – Administration (B)

The lack of plant alarms may adversely impact operations.

- The plant is unstaffed at night during the summer (while it is producing water) and is not equipped with fully functional alarms or auto shutdown capability.

Standby Units – Design (B)

The ability to repair high-service and backwash pumps is impacted by available access to the pump room.

- One backwash pump has been out of service for over a year due to challenges with installation.

Testing – Operation (B)

Monitoring and process control testing results do not accurately represent plant performance.

- Individual sedimentation basin turbidity is not monitored, which does not allow for individual basin performance monitoring or troubleshooting.

- The jar testing procedure may not be representative of plant performance, e.g., operators are currently using a two-minute flocculation time and a ten-minute settling time to run the jar test more quickly, samples are collected from the jars with a pipette instead of using the sample taps, and micropipette use may not be correct for ferric dosing (corrections for specific gravity and percent concentration are not being made).

- The raw water sample location is in a wet well that includes carbon feed and recycled backwash and filter-to-waste flow; this would not provide a true indicator of raw water quality to assist with making process control decisions.

Training – Operation (C)

A formal training program does not exist for operators at the Havre WTP.

- The need for additional training on process control, e.g., application of different coagulation chemicals, determining dose changes based on water quality changes, jar testing techniques and testing) was expressed by the operations staff.

Disinfection – Design (C)

Disinfection efficiency may be reduced due to degraded clearwell baffles.

- The baffle walls in the clearwell have not been inspected recently; a 2016 investigation by a diver indicated possible degradation that should be investigated.

EVALUATION FOLLOW-UP

The Havre CPE was conducted as the result of treatment plant performance issues that occurred in February and March of 2024 and subsequent documentation of at least three cases of *Giardia* by the CDC. The findings of this CPE, specifically the identified Performance-Limiting Factors, provide direction for the City to improve and sustain the performance of the plant.