City of Flint, Michigan Water Department

FLINT WTP

Operations & Maintenance Manual

With SOPs

Using the Cross-Reference Feature (Control-Click)

This manual was produced using Microsoft Word 2016. It contains interactive capability which allows the user to easily navigate through the document employing Word's "REFERENCES" feature. The Table of Contents, the Equipment List, and Appendices A and B are the chief areas where the user can make use of this powerful tool.

1. To return to the beginning of the document, hit "Control-Home" keys. To go to the end of the document, hit the "Control-End" keys.

2. In the Table of Contents, run your cursor over the table, and you will see it change background color. Click on the table and move the mouse, and you will see the "Update Table" feature appear. This can be used to update the table when new material is added to it. Also, while the Table is highlighted, hold down the "Control" key and click on any line to jump to that section in the document.

3. In the Equipment List, look for colored table cells – these are linked cells that use the "Control-Click" method. When you have used this method to jump to a section, you can return to that point in the Equipment List by "Control-Clicking" the phrase that contains the words "*Return Point*".

4. In Appendix A there are pictures placed into a table that has three columns. The first column holds each picture. The second column has language relating to the picture, and in many cases there is also a cross-reference link which can be invoked by using the "Control-Click" method as above. The third column is left blank, and is intended for future notes as they come available.

5. Appendix B contains website links than can be accessed if the user has an internet connection. These links are activated using the "Control – Click" method also.

6. There are various places in the text colored dark red that will bring you back to the beginning of the Table of Contents if you use the "Control-Click" method.

7. The graph depicting backwash rate versus temperature should be updated when the staff has accumulated sufficient data and experience. Simply click on the graph to highlight, and then right click. A menu will appear with an option for "edit data". Choose that option, and type new data points into the spreadsheet as may be appropriate.

This is the return point to the beginning of the Table of Contents.

Table of Contents

Chapter 1 – Introduction

1.1 Purpose of Manual

The purpose of this manual is to inform and instruct the plant personnel in the proper procedures for operating and maintaining this Water Treatment Plant (WTP). The document is also written to satisfy the USEPA requirement for submission of SOPs as part of an overall plan which is due March 1st, 2017. The submission deadline comes before some decisions were made for final plans by the City to determine its future source of supply, and so there is an attempt being made by the author to cover several possible scenarios. When final decisions are made, this document can be amended to more closely describe the actual operation. It is important to understand that this Manual will grow in content as we know more details.

The job of an operator is to remove undesirable contamination from the source water, and provide sufficient quantities of the cleansed and purified water to the general public. The operator must also meet all federal regulatory requirements in the SDWA and those that are required by Michigan DEQ.

There are or will be, within the structures of this plant, all of the tools for the operator to do this job on a continual basis. This manual describes the tools at the operator's disposal, and describes how best to use them. There is no one set unchanging way to treat the Karegnondi (KWA) source water – rather, there are many subtle ways to meet the standards that are set for drinking water. The changing quality of the source water and the changing seasons will require the operators to make choices on their shift. This manual serves as a guide for the operator to choose the best procedures for changing circumstances. Process descriptions and SOPs found in the manual also serve as the basis for the production of classroom instruction which is ongoing for plant personnel and for DEQ staff.

1.2 Scope of Manual and SOP Discussion

All aspects of the treatment processes contained in the WTP are or will be covered in this manual. The dimensions and locations of process equipment are given. Where appropriate, operators are shown how to operate the equipment, and when possible, alternatives are shown because there is (sometimes) more than one way to achieve the goals set by supervision. The Safe Drinking Water Act (SDWA) and the Michigan DEQ dictate the quality goals – called Maximum Contaminant Levels (MCLs) and Treatment Techniques – that must be met. Additionally, the United States Environmental Protection Agency (USEPA) has issued an Emergency Administrative Order with amendments which require that the Flint water system develop a 'New Source Treatment Plan" (NSTP) that addresses the City's technical, managerial, and financial capacity to operate its PWS in compliance with the SDWA and the NPDWRs, including requirements for optimal corrosion control treatment and water quality parameter monitoring. In part, the NSTP requires the finalizing of necessary standard operating procedures (SOPs) for each aspect of the water treatment process for the Flint WTP. These quality goals and the methods that operators use to achieve them are two separate and distinct issues. Therefore, the scope of this manual will strive to make it clear when things MUST be done, when things SHOULD be done, and when things are SUGGESTED to be done. The latter fall under the category of time tested experiences that other operators have found to be reasonable and helpful. Where applicable, plant process descriptions are introduced with **a descriptor bar** informing the reader of existence of SOPs, Regulations, and City goals. It is being written at a time when the plant is undergoing upgrades and expansion.

Does SOP Exist?		**Pertinent Regulation?**		**Does Flint Goal Exist?**	

Example of Descriptor bar

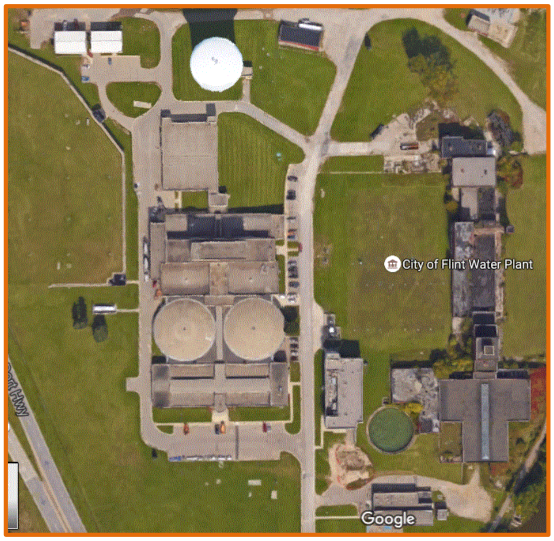
This descriptor bar, found mostly at the beginning of each chapter, alerts the reader to the existence of SOPs within the text, and tells him or her if a Regulation is addressed here and/or if there is an Operational Goal that has been set by the plant management team. A simple “yes” or “no”, or a checkmark, tells the reader if more material can be found that helps them make decisions. If the answer is a “yes”, the reader is given help as to where or how to find that information, which more than likely can be found with the built-in cross-reference feature. In some cases, a “yes” descriptor may direct the operator to seek information from plant management.

If a class on the subject material has been taught, and the operator was in attendance for that class, he or she will be reminded that they have a handout of the material covered, and perhaps a book or a guidance document was provided to them in that class. Those materials are made available in the OC.

Plant management is being given this document in a PDF format which can readily be uploaded to the computer(s) in the operators control room, and as such it will be available to them along with the access features built in to the document. Management can also make the PDF available to operators for installation on their personal cell-phone so that it can be carried around with them as they make rounds. Some discussion on privacy and protection against “hacking” might be in order before this decision is made.

Chapter 2 – General Features and Equipment List

2.1 Facilities



Flint WTP Plant Facilities

The City of Flint Water Treatment Plant (WTP) is a drinking water treatment facility that is under the regulatory jurisdiction of the Michigan Department of Environmental Quality (MDEQ). The WTP has distinct capacities based on its working components. These components are listed in the material presented here, which is an overall Operations and Maintenance (O&M) Manual containing unit process Standard Operating Procedures (SOPs). The WTP has the processes of Ozone addition, hypochlorite addition, rapid mixing with coagulant addition, flocculation, sedimentation with plate settlers, granular media filtration, and post chlorination. It is anticipated that the WTP will be treating a supply of Lake Huron Source Water which it will receive from the Karegnondi Water Authority (KWA). The supply line that conducts that source water to the plant is scheduled to be completed in 2017. These processes are discussed in detail in this manual:

1. Ozone addition with destruct.
2. Hypochlorite addition.
3. Rapid mixing and coagulant addition.
4. Flocculation.
5. Sedimentation with plate settlers.
6. Granular media filtration.
7. Post Chlorination.
8. Other treatment Chemicals.
9. Various pumping capabilities.

2.2 Process Description

The Flint Water Treatment Plant (WTP) is a 24 mgd conventional treatment plant employing Ozone addition, coagulant addition and chemical mixing, flocculation, sedimentation, filtration, disinfection, pH adjustment, and corrosion control to produce drinking water that meets Federal Safe Drinking Water Act (SDWA) and MDEQ requirements. It was originally configured to soften water by the precipitative softening process, and so contains components for that purpose. Those components will not be used to treat KWA water.

The plant will obtain its source water through a 36 inch dedicated raw water main which is part of the KWA system and which should be made available in 2017. It is proposed that the raw water will enter the plant property and be directed into a newly constructed raw water reservoir which should be able to provide 2 or 3 days of storage for the WTP. The average day demand is projected to be 14 mgd. Raw water can be sampled and analyzed prior to entering the plant, and thus will provide some advanced notice of quality changes that the operators will react to quickly. As part of the training, the operators are taking a Jar Testing class and will be given an SOP for developing the protocol each time they need to perform Jar Testing. The SOP will be site-specific for Flint and its components, and so should be a good tool for them to use as needed. Staff needs to perform periodic jar tests to develop a proficiency early on so that when times are difficult, they won't be under any more stress than is necessary. The Jar test SOP is located in the rapid mix section.

Water will leave the reservoir and be directed to the Ozone contact chamber which is baffled to provide sufficient contact time for the reactions to take place. The unit is equipped with a Sodium Thiosulfate feed system and a destruct unit. The likely dose for Ozone, if used, will be 1 to 2 mg/L used as a pre-oxidant.

Water flows from the Ozone contactor through a metering system and into one or both of the rapid mixers. It receives a dose of coagulant (likely to be Alum) which will have been determined by the operators as optimal through jar testing. The operators can choose to operate one or both of the units based on pant flow rate and water quality conditions. The mixers are labeled as “east” and “west” and are tied to the flocculation trains which follow. Therefore, an east or west mixer operating alone will dictate the need to operate the corresponding flocculator trains. Maintenance activities involving the mixers will need to be planned in advance so that the needed flocculators are available.

Water flows from mixing into the east and west flocculator trains, which will undergo a retrofit soon. CDM-Smith is planning to install FRP structural baffle walls which will make the units act as true and discreet flocculator units, which allows operators to place them in or out of service based on plant flow rates so that proper detention time can be had. Flocculation at the Flint

WTP will consist of two modules – one east and one west – which will each have two trains. Each train will have three compartments that are baffled and each compartment has a dedicated mixer and propeller assembly that can provide the proper energy input to allow for tapered flocculation. Therefore, there are two modules, each with two trains, with each train baffled into three compartments, for a total of 4 flocculators. Operators have been given classroom training in the theory of compartmentalized flocculation basins, and will be trained in their use once KWA water is available.

Water leaves the flocculators and heads over to the sedimentation units which are equipped with plate settlers for high rate clarification. CDM-Smith is planning to convert one of the three units into a sludge holding tank. The two remaining units will be operated as high rate clarifiers, and be retrofitted with a new MRI sludge removal system. The basins are designed to produce clear effluent for filtration, and have an overflow rating of 0.35 gpm/square foot at a 14 mgd flow rate. The basins are equipped with 560 linear feet of effluent launders, for a weir overflow rate of 17.4 gpm/ft at a flow rate of 14 mgd.

Clarified water leaves the basins and is directed to the filtration system, which consists of 12 granular media units with a surface area of 694 ft^2 each. At present, the filters are comprised of 18 inches of 1 mm ES GAC over 12 inches of 0.5 mm ES sand. CDM-Smith is investigating the reconfiguration of the units, which they believe can have a deeper bed arrangement utilizing the existing boxes. They have suggested a configuration of 36 inches of 1.1 mm ES anthracite over 0.5 mm ES sand will provide longer filters runs and low turbidity effluent because of the L/De ratio of approximately 1,400. Spent Filter Backwash Water will be recycled.

After filtration, the finished water proceeds to the clearwell through an intermediate chamber and receives a post-chlorine dose there. It is sent to the finished water storage (Dort Reservoir) on the plant grounds, and is pumped to the customers after being dosed with more chlorine, phosphates for corrosion control (and if needed, pH adjustment) and fluoride. The reservoir is baffling factor is not known. Plans are being made to retrofit the Dort Reservoir with baffling to improve contact time for disinfection, and those changes will provide more than sufficient CT value when water levels kept above a predetermined minimum depth, regardless of the cold water it will hold in winter.

A more detailed unit process description follows for each of the components, as well as the chemical feeds. Where applicable, these descriptions will contain SOPs.

2.3 High Service Area and Pumping

The plant serves the City of Flint in the State of Michigan.

CDM-Smith is recommending that a new finished water pump station be designed and built to serve the system needs. They also state that a new filtered water transfer pump station would be needed to convey water from the gravity filters over to the Dort Reservoir. When that information is available, we will include it in this document.

The improvements would include five pumps for the new transfer station (3 @ 14 mgd, and 2 @ 5 mgd). The improvements would also include a new high service and backwash pump station with H.S. Pumps (2 @ 14 mgd and 2 @ 5mgd) along with two new backwash pumps at 22 mgd.

The existing system is serving Flint by taking in finished water from GLWA through a 36" piping system that comes in at the North end of the site and flows under the temporary chemical feed building. This allows the WTP operators to inject the needed chemicals into the pipe before it heads out into the distribution system.

When the WTP is treating water, the filtered water makes its way into that same pipe and also the Dort Reservoir on site, and then into the Reservoir #4 at the south end of the site. Reservoir #4 serves as suction head to the existing High Service Pumps located in the adjacent building. When operating, these four pumps push water into the system and into other system storage units situated at the east and the west side of the City. The four existing pumps are:

- 2 @ 20 mgd
- 1 @ 6 mgd
- 1 (new) VFD with pumping range of 5 – 15 mgd

There is an elevated storage tank on site which serves as a supply of backwash water and also acts as a surge suppressor.

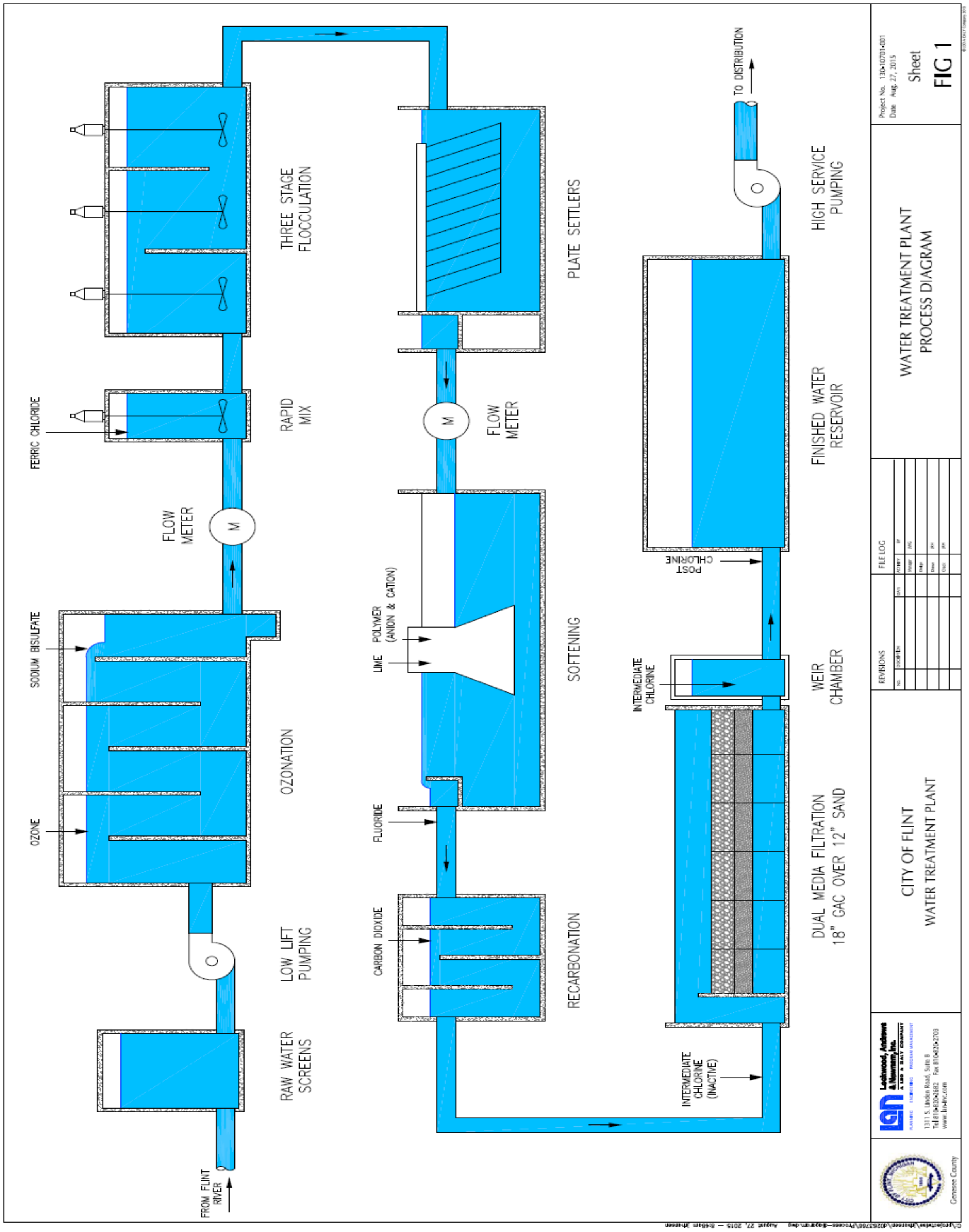
System Reservoirs

There are two below ground reservoirs (BGR) in the City. They are:

- West Side Reservoir
- Cedar Street Reservoir

Associated with them is the need to increase chlorine residual, and so there is an SOP written for those procedures in the hypochlorite feed section.

2.4 Schematic of Flint WTP



2.5 Equipment List

The Flint WTP equipment is tabulated here, and components specifics are shown

	Equipment	Descriptions, Dimensions, etc.	
	Source Water Structures		*Raw Water Return Point*
	Incoming Flint line (when complete and if used)	ductile iron pipe	
	Size	Various lengths of 66" and 60"	
	Facilities	Pump Stations and Impoundments	
	Pump Station Capacity	85 mgd	
	Approximate Volume if Discharge Piping	22.5 MG	
	Estimated Water Age from Lake Huron to Flint WTP	6 to 18 days	
	Raw Water Line from GCDC to Flint WTP	Genesee County Drain Commission	
	Size	36"	
	Length	17.3 miles	
	Volume	645,345 ft^3 (4.8 MG)	
	Velocity at 14 mgd (21.66 cfs)	3.06 fps	
	Pump Station Units Dedicated to Flint	4 pumps at 6 mgd ea.	
	Firm Capacity	18 mgd	
	Influent Flow Control	GCDC will maintain a HGL of 835'	
	Flint WTP Raw Water Pumping	3.1 Raw Water from KWA	
	3 pumps	14 mgd each	
	2 pumps	5 mgd each	
	Raw Storage Calculations	(As suggested by CDM-Smith)	
	Total Volume	42 million gallons	
	2 tanks	Open topped, pre-stressed design	
	2 each	21 MG	
	Detention time at 14 mgd	3 days	
	Flint WTP Historic Capacities	Assumes all treatment units in service	
	Flow rate	36 mgd	
	Components		
		2 rapid mixers, DT of 17.5 seconds, G value range = 350 to 537 sec^{-1}	

		2 flocculator modules with 10 trains – 3 stages ea. DT of 150 minutes, G values ranges 25 to 85 sec^{-1}
		3 sedimentation basins with IPS, DT of 78 minutes, plates at 104,620 ft^2
		12 dual-media filters, 700 ft^2 ea., 18 in. of activated carbon over 12 in. of sand, approved filtration rate of 3 gpm/ft^2
	Anticipated WTP details	
	Flint WTP Capacity Flows	(As suggested by CDM-Smith)
	Max	24 mgd
	Avg	14 mgd
	Min	4 mgd
	Chemical Building and Process	Calculations based on average day of 14 mgd, and low flow minimum of 4 mgd
	Flow rate of 14 mgd	9,722 gpm, 21.7 cfs
	Flow rate of 4 mgd	2,777 gpm, 6.2 cfs
	Ozone System	3.2 Ozone
	Transfer Eff. At 14 mgd	92%
	Number of Contact Basins	3
	Basins in service at 14 mgd	1
	Design applied dose at 14 mgd	1 mg/L
	Existing Rapid Mixers	3.3 Rapid Mixers / *Rapid Mix Return Point*
	Number of units	2
	Dimensions	5.5' X 5.5' X 14.25' water depth (each)
	Volume	431 ft^3; 3,224 gallons (each)
	Detention time at 14 MGD	39 sec (both in service)
	Detention time at 4 MGD	69.5 sec (one in service)
	Agitator	Lightnin Model NDLG-200, 2 HP 1150 rpm
	G Value cold water	300 sec^{-1}
	G Value warm water	500 sec^{-1}
	Flocculators	3.4 Flocculators / *Flocculator Return Point*
	Number of units	4, tapered flocculation
	Dimensions	water depth
	Volume	63,617 gallons (each)
	Stages (compartments)	3
	G Values	Approx. 20 – 100 sec^{-1}

	Detention time at 14 mgd	10.3 min each stage – 30 mins total (all in service)	
	Detention time at 4 mgd	36 min each stage – 108 mins total (all in service)	
	Diameter of paddle travel	5.75 feet	
	Distance to make 1 rev	3.14 X 5.75' = 18.06'	
	Time to make 1 rev at 1 fps	18.06 seconds	
	Sedimentation Basins	This is the return point to the beginning of the Table of Contents. 3.5 Sedimentation Basins	*Basin Return Point*
	Number of Units	3	
	Complete with plate settlers	2 units will remain; third unit will hold sludge per CDM-Smith (not decided)	
	Plate settler values		
	Chemical Storage and Feeders	Chemical Feeds	
	Alum (if used)	Coagulant Dosage Calculation	
	Tanks	3	
	Volume	12,000	
	Day Tanks	1	
	Volume	400	
	Material Characteristics	Liquid alum is 48.8% dry-basis alum – 642mg/mL	
	Feeders	3 LMI	
	Feed Point	Into each of the two rapid mix units	
	Sodium Hypochlorite	3.7 Disinfection Requirements - Hypochlorite	
	12.% Hypochlorite	CDM-Smith intends dilution to 8%	
	Feed points	Rapid mixers, inlet to Dort reservoir, outlet of Dort reservoir	
	Design dose averages	1 mg/L rapid mix, 2 mg/L influent to Dort, 0.5 effluent of Dort	
	Day Tank volume at Mixers – 12.5%	125 gals	
	Day Tank volume at Mixers – 8%	200 gals	
	Storage Tank volume at Dort Inf – 12.5%	6,000 gals	

	Storage Tank volume at Dort Inf – 8%	9,000 gals
	Day Tank volume at Dort Eff – 12.5%	250 gals
	Day Tank volume at Dort Eff – 8%	400 gals
	Feeders	Peristaltic
	Capacity	
	Fluoride	Will be needed when the WTP begins operations 3.9 Fluoridation – Hydrofluosilicic Acid
	Storage Tanks	1
	Volume	6,000
	Day Tanks	1
	Volume	50
	Feeders	2
	Make	Peristaltic type
	Feed Point	Influent to Dort Reservoir
	Caustic (NaOH)	3.10 Adjustment of pH – Sodium Hydroxide
	Storage Tanks	1
	Volume	6,000
	Day Tanks	1
	Volume	175
	Feed pump	Current system is too small, but is in process of being replaced with a new pump which will be capable of handling system needs
	Supply	1 tote
	Powdered Activated Carbon	Not determined as yet
	Phosphoric acid	3.8 Corrosion Control - Orthophosphate
	Storage	221 gallon Tote Tank
	Feeder	2 LMI Feed Pumps – one lead, one lag
	Calibration column	1,000 mLs
	Day Tank Capacity	N/A
	Filters	3.6 Filters
	Filters	
	Number of units	12
	Approved Filtration Rate	3 gpm/ft^2
	Surface area per filter	694 ft^2

	Filter capacity (each)	2,082 gpm
	Capacity with one filter O.O.S.	22,902 gpm, or 33 mgd
	Media Configuration	Dual-media, GAC over sand
	Proposed configuration	Dual-media, Anthracite over sand
	Anthracite layer	36' of 1.15 ES anthracite, UC of 1.35
	Sand layer	12' of 0.5 mm ES sand, UC of 1.65
	L/De ratio	Anthracite = (36*25.4) ÷ 1.15 = 795 Sand = (12*25.4) ÷ 0.5 = 610 Total ratio = 1,405
	Current Filter Backwash system	*Filter Backwash Return Point*
	Backwash	Air scour, wash water, surface wash
	Typical amount water used	110,000 gals
	Current Filter Backwash Solids Handling	
	Current use	A backwash event generates about 110,000 gallons of used Spent Filter Backwash Water (SFBW)
	Storage of SFBW	2 tanks at 82,000 gals total
	SFBW transfer	Recirculation tank = 482,000 gals This tank serves as a wet well for water fed to the Ozone system
	Proposed Filter Backwash System Solids Handling	
	New EQ Tank Volume	219,000 gals
	Transfer pumps	3 @ 500 gpm each
	Clarification	Use Sedimentation Basin #3
	Recycle pumps	3 @ 500 gpm each
	New Transfer Pump Station	Will provide pumping to Dort Reservoir
	Dort Reservoir	
	Volume	20 mg (two wells at 10 mg each)
	Layout	2 chambers with total surface area of 134,000 ft^2
	Working depth	Maximum depth of 20 feet
	Primary Disinfection with Cl_2 (sodium hypochlorite)	Design includes 50% extra C x T than is required for compliance
	Purpose	Twofold: storage with primary disinfection, and storage for backwash water

	Compartment #1 and #2	Both compartments to have baffling installed
	Baffling factors of compartments	Tracer study needed to determine T10
	Baffling factor needs	Estimated to be 0.3 after retrofit of baffles
	Elevated Storage Tank	
	Current use	Backwash Supply
	Future use	Secondary backwash supply as redundancy for the system
	High Service and Backwash Pump Station	
	High Service Pumps	Pressure districts
	2 each	14 mgd
	2 each	5 mgd
	Wash Water Supply Pump	
	2	22 mgd each
	Sludge Handling Facilities	Undetermined for now

Chapter 3 – Raw Water Source and Treatment Unit Processes

3.1 Raw Water from KWA

The Flint WTP will receive source water from the KWA system which is in process of being constructed. When it arrives, we will treat it for a period of not less than 90 days, during which we will stress each unit process component to determine the effectiveness of the scheme.

Expected raw water quality parameters for Lake Huron (KWA) water

	Maximum	Minimum	Average
pH	8.4	7.0	7.7
Alkalinity	85	70	80
TOC	3	1.5	2.2
Hardness	110	90	100
Turbidity	100	2	6

Turbidity removal should be readily accomplished because there is more than sufficient alkalinity available for the Alum coagulant, and the ranges of turbidity are manageable. Good coagulation and settling, coupled with well-designed and operated filters have shown to be very effective for this type of Great Lakes water at many other WTPs. Removing TOC will be a more challenging effort because it will be a low molecular weight NOM that cannot be removed in higher quantities. Flint will need to remove 25% of the incoming TOC, or meet one of the six avoidance criteria that the SWDA provides to Utilities. This concept is more thoroughly discussed in the next section under Coagulation Theory.

In that section, operators are shown the SOP for meeting these requirements, along with the method for determining the "enhanced coagulation endpoint" that the DBP Rule specifies.

3.2 Ozone

CDM-Smith is proposing the use of Ozone in the pre-treatment scheme to act as a pre-oxidation/coagulation aid. They estimate that an average dose of about 2 mg/L will be effective, and allow for a reduced amount of alum to be used. The existing feed system was purchased from Ozonia Corporation and installed in the year 2004. Its original use was to assist in the prevention of excess TTHMs by conditioning the water and relying on the ability of the GAC filtration system to act as biologically active filters. They do not think that the production of

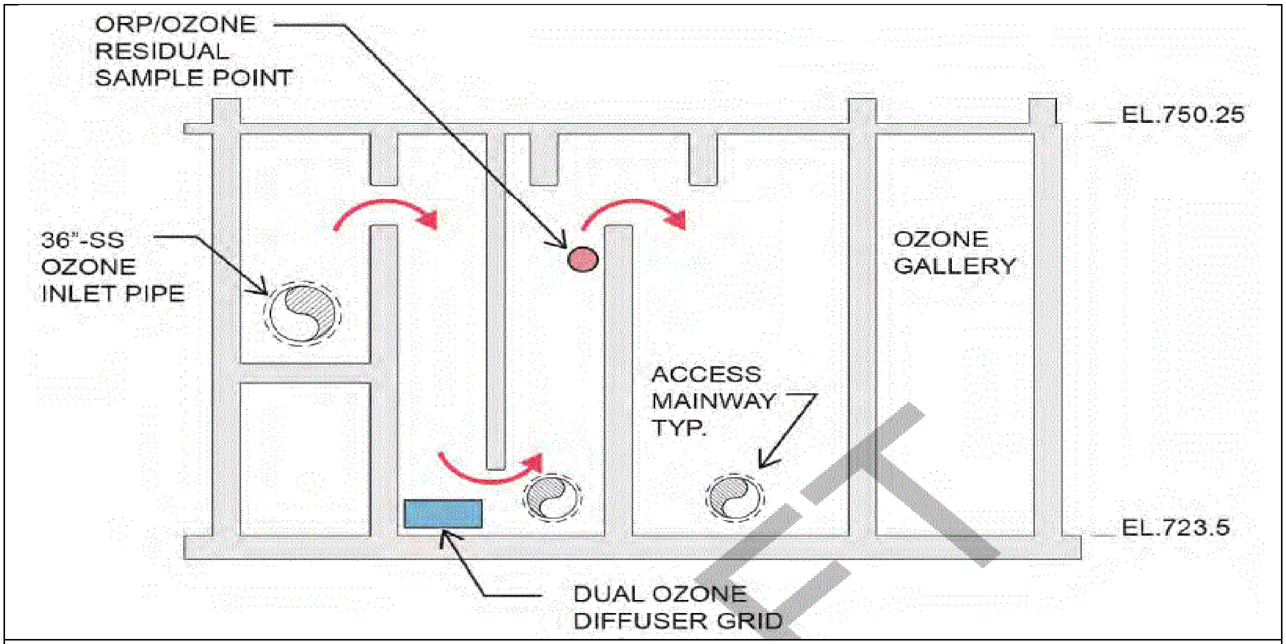
Bromates will become an issue due to relatively low levels of Bromides in the KWA Water Supply. The CDM-Smith plan is to operate only one of the Ozone Contactors – the other two will either remain as offline standby units, or will be decommissioned. They mention also that if a decision is made to use per-chlorination instead of Ozonation, the storage and feed equipment could be placed in the Ozone area, and the contactor can be repurposed for chlorine contact time. The unit would be equipped with an ORP meter and chlorine residual monitoring capability.

The CDM-Smith plan is to do away with the activated carbon in the filters and replace it with a deeper amount of anthracite. They believe that this decision will allow for reduced sludge production, longer filter runs, and less cost for solids handling because one sedimentation basin can be retrofitted to handle the small amount of solids they think will be reduced.

The Ozone system has in the past proven to be difficult to maintain, and Flint staff members, as well as the Plant Manager of the Ann Arbor WTP, have said that getting replacement parts from Ozonia is difficult to impossible. If true, this will need to be addressed, as will the safety issues that are a part of operating an Ozone system. These will be addressed here.

Operation of Ozone System

This section will be addressed when the final decision is made to use or not to use the Ozone system.



Graphic of existing Ozone contactor #1

The above picture shows the Ozone contact chamber for unit #1. Note the baffling, and the addition of the diffuser grid and the Ozone sampling point.

Ozone safety issues

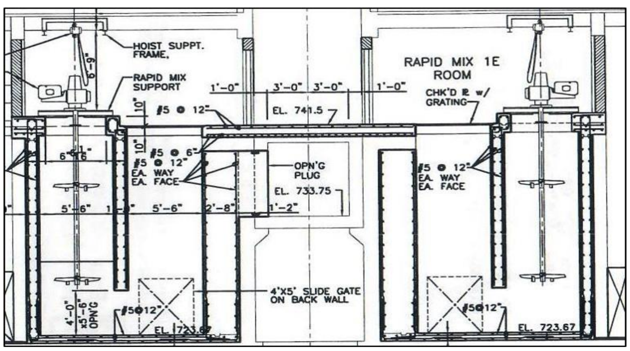
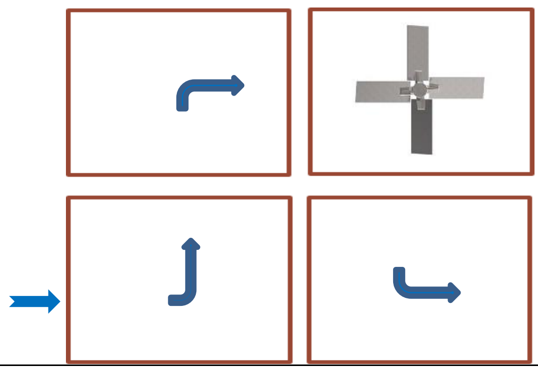
Ozone is very toxic, and the use of it demands that we offer specialize training classes for the protection of all operating staff. If Ozone is to be used, training will include:

- Enclosed space entry safety training, including the procedures needed to check for Oxygen and Ozone concentrations
- The steps needed to check for Ozone leaks with monitoring and Ozone meter equipment
- The use of self-contained air packs for use when leaks occur

3.3 Rapid Mixers

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	NO
			See last Chapter		

The WTP has two rapid mix units that were designed for parallel operation. Each mixer has been retrofitted (circa 2000) with a vertical shaft and mixer that has two propellers mounted on it. Water enters an adjacent chamber and makes its way upward past the propellers while at the same is injected with coagulant before it falls over a weir on its way to flocculation. The chamber holding the two propellers is 5.5’ X 5.5’ X 16 feet deep, for a total volume of 484 ft^3, or 3,620 gallons each. At a flow rate of 14 mgd (9,722 gpm) with both units in service, the detention time is approximately 45 seconds.

Schematic of existing Flint WTP Rapid Mixers	Depiction of East Mixer Flow Pattern
	

The coagulation of the water starts here when the operator adds alum into the rapid mix tanks. The aluminum portion of the coagulant reacts with the natural alkalinity to form particles called “floc” which help to trap or enmesh naturally occurring particles in the raw water which need to be removed.

When adding coagulant chemicals to raw water, it is essential to provide rapid agitation to distribute the coagulant evenly throughout the water. This is particularly true when alum or ferric salts are being used. The water must be briefly and violently agitated to encourage the greatest number of collisions between suspended particles. The Flint WTP rapid mix tanks have motor driven mixers installed in them. As such, they are called mechanical mixers. Each tank is fed by its own raw water pipe, and can be isolated and taken out of service for maintenance or to maintain an optimal detention time.

Mechanical mixers are widely used for rapid mixing because of their good control features. They are usually placed in a small chamber or tank and include the propeller, impeller, or turbine type. The detention time in these chambers is designed to be very short, on the order of 15 to 45 seconds.

Two SDWA rules are addressed in this process. At this plant, alum is fed into the mixers on a continuous basis in order to help the plant comply with two SDWA Regulations. The coagulant helps to remove turbidity, and so it is needed to comply with the IESWTR turbidity requirements. The coagulant also helps to remove TOC. This plant is required to remove 25% of the raw water TOC on a continual basis in order to comply with the D/DBP Rule. For Lake Huron Water, it typically takes more coagulant to comply with the latter than it does for the former. Operators can easily measure the turbidity level, but not the TOC level. For this reason, plant management will set a bottom limit for coagulant dosage even if it appears that the turbidity levels are easily being met. This bottom limit, likely to be around 20mg/L dry-basis Alum, will remove as much TOC as possible. The low molecular weight TOC found in Lake Huron does not get removed much beyond this point. Of course, during rare higher turbidity events, operators may need to add a higher amount of Alum. This dosage should be verified by performing a jar test.

The feed of coagulant is dripped into each mixer, and operators can verify that feed is actually taking place as planned by using the calibration column that it provided at the mixer site. The dosage of coagulant is expressed as mg/L dry basis Alum, so the operator needs to view amount of chemical flowing into the mixer per a set amount of time, and then convert that amount into mg/L dosage by using the flow rate of water through the mixers. This step should be performed while making rounds, and also when making raw water pump changes. A disruption in flow of coagulant is a major problem for the operations, and so the operator is cautioned to pay close attention to these steps.

Use the "control-click" method on the next two phrases if you choose to return.

This is the return point to the beginning of the Table of Contents.

Rapid Mix Return Point

SOP for Coagulant Dosage Calculation

The proper method of determining correct dosage is through the jar-test method which is discussed later. An SOP for jar-testing is provide to the operators, and a class has been taught in its use. Alum dose is expressed as "mg/L dry-basis Alum". There is a prescribed way to measure and calculate the coagulant dosages at the Flint WTP, and it is shown here with an example.

The general formula for determine the strength of liquid alum expressed as dry-basis is:

(liquid strength as % X (8.34 x Sp. Gr. of the liquid)) = pounds dry basis alum/gal.

This calculation should be made each time a load of liquid alum is received.

For example, most commercial liquid alum is obtained at a strength of 48.8% and a weight of about 11 pounds per gallon (specific gravity of 1.325), and so it contains about 5.36 pounds per gallon (ppg) dry basis Alum. The calculation to convert from ppg to Grams per Liter (G/L) is:

5.36 lbs dry Alum/gal X (1 gal/3.785 Liters) X 453.6 grams/lb = 642 G/L

or

642 mg/mL

An example dosage calculation is as follows:

The flow through the plant is 12.5 MGD. The operator makes a coagulant feed check by observing the change in the level of Alum in the 1,000 mL graduated cylinder. After 60 seconds, the operator notes that 820 mLs has been used. What is the dosage of dry basis Alum in mg/L? (note: if volume permits, it 1s is better to use a time of two or three minutes for the check, but that may not be possible for large amounts of alum)

- Answer in two steps:
    1. Convert plant flow to Liters/min

Plant flow = 12,500,000 gals/Day X (Day/1440 min) X (3.785L/gal) ≈ 32,856 Liters/min

2. Calculate dosage

820 mLs/min X 642 mg/mL X (min/32,856 L) = 16 mg/L

SOP for adding coagulant – feed rate check

1. Perform a coagulant feed rate check once each shift and at each pump change.
2. Fill the cylinder with alum by opening the ball valve so that it is level to the 1,000 mL mark.
3. Shut off the ball valve on the discharge side of the feed pump while simultaneously opening the ball valve on the discharge side of the cylinder.

4. Using a stop watch or timer, observe the rise in coagulant level in the cylinder for exactly one minute.
5. At the one-minute mark, note the amount used – write it down.
6. Re-open the ball valve on the discharge side of the feed pump while simultaneously closing the ball valve on the calibration tube.
7. Use the example above to calculate the dosage as mg/L dry-basis Alum.
8. Adjust rate of feeder if more or less Alum flow rate is needed.

The following table is an aid for operators. It shows the amount – in mLs per minute – of liquid alum feed needed to achieve various dry-basis dosages at several plant flow rates. It is based on the formula for calculating feed rate of Alum:

Dosage, mg/L = (mLs alum fed X 642) / (Plant flow rate in L/min)

Table showing liquid alum amount needed to achieve various dosages.

Plant flow rate mgd, and L/min→	10 mgd	12 mgd	14 mgd	16 mgd	18 mgd	20 mgd
	26,285 L/min	31,542 L/min	36,798 L/min	42,056 L/min	47,313 L/min	52,569 L/min
Mg/L dry-basis dose ↓						
15 mg/L	614	737	860	982	1,104	1,222
17 mg/L	696	835	974	1,114	1,253	1,392
19 mg/L	778	932	1,089	1,245	1,400	1,556
21 mg/L	860	1,032	1,203	1,376	1,548	1,720
23 mg/L	942	1,130	1,318	1,507	1,695	1,883
25 mg/L	1,024	1,228	1,432	1,637	1,842	2,047
27 mg/L	1,105	1,326	1,548	1,769	1,990	2,210

Operators are encouraged to use the table as a check on the Alum feed-rate changes that they make.

Some examples of Alum feed rate table use:

- At a plant flow rate of 14 mgd, how many mLs per minute Alum feed is necessary to achieve a dose of 21 mg/L dry-basis alum? Locate the 21 mg/L row and follow it across to the 14 mgd column, and read the cell at the intersection of the two. The result is 1,203 mLs/min.
- At 15 mgd, how many mLs per minute Alum feed are necessary to achieve a dose of 23 mg/L? Locate the 23 mg/L row, and follow it across to the 14 mgd and the 16 mgd columns and note the two intersections. They show 1,318 mLs/min and 1,507 mLs/min. add the two together and divide by 2 to get the answer of 1,412 mLs/min.

- At 9 mgd, how many mLs per minute feed of liquid Alum are necessary to achieve a 20 mg/L dry-basis dose? Locate the 19 and 21 mg/L dosage rows and follow them across to the 18 mgd flow rate column. At those two intersections, the feed necessary would be 1,400 and 1,548 mLs/min. Add those and divide by two to get 1,474 mLs/min needed for 18 mgd flow rate. Divide that by 2 for a 9 mgd flow rate, and the answer is 737 mLs/min.

Coagulation theory

Operators have been taught in class that particles in suspension come to the plant in a stabile state: they resist settling and want to stay in suspension. Coagulant is added to "destabilize" the suspension so that these particles will aggregate into larger, more easily settled or filtered particles.

Generally, operators find that the suspended particles in the source water are negatively charged, so they add a coagulant that brings positive charges with it. Technically speaking, the Flint WTP uses the practice of sweep flocculation, brought about by adding enough coagulant to make large floc particles that "sweep" up other smaller naturally occurring particles and settle them out. We have introduced the concept of mixing intensity – or G value – to the operators so that they understand the importance of making the correct choices both at the plant scale and at the jar scale. In doing so, we ensure that they will optimize this unit process.

The rapid mixers have a relatively low G value of 300 sec^{-1}. Changes to the mixers and feed system are planned for the future, but for now, we will use the present system for calculations and for jar test procedures so that operators can become familiar with the generic process. These mixers were chosen at a time when the importance of mixing intensity was less understood. By today's comparisons, they are slightly more useful than the beginning stage of a flocculator, but nevertheless, they should be used. Some mixing is better than none – and operators can compensate by adding extra coagulant to offset the lack of mixing intensity.

Changes in dosages of coagulant are best determined by use of jar testing. The plant manager will set the protocol for jar testing parameters. In general, jar test parameters will differ with water temperature and with flow rate.

Jar Test SOP

		
Flint WTP Jar Testing Apparatus	Square 2 Liter jar. Note the sample port at the 10 cm mark	Syringe type pipettes suitable for use with jar test stock solutions

The operating staff are being provided classroom training and an SOP for jar testing based on a theoretical scenario for plant operation using the following assumptions (which are for training purposes only):

> Alum as a coagulant, cold water, 2 mixers, 4 compartmentalized flocculators, and two plate settler units in service. Rapid mix G value of 300 sec^{-1}, and tapered flocculation with 90, 60, and 30 sec^{-1} G values. An effective SOR rate of 0.3 gpm/ft^2, and a raw water flow rate of 14 mgd. Test for 15,20, 25, and 30 mg/L Alum. Use 1 mg/L Cl_2.

The calculations for this scenario are as follows (14 mgd flow rate):

	Detention time	Plant Scale G value; jar scale rpm	Settling time, mins
Rapid mix	45 seconds	300 sec^{-1}; 220 rpm	
1st stage of floc	10.3 mins	90 sec^{-1}; 95 rpm	
2nd stage of floc	10.3 mins	60 sec^{-1}; 70 rpm	
3rd stage of floc	10.3 mins	30 sec^{-1}; 45 rpm	
Settling			7 mins

Making stock solutions for chemicals used in Jar Test

Alum

Liquid alum is 11 pounds per gallon (ppg), and it is 48.8% strength. Therefore, 48.8% X 11 ppg = 5.36 ppg dry basis. Converted to the metric system:

5.36 ppg X (1 gal/3.785 L) X 453.6 grams/lb = 642 grams per Liter, or 642 mg/mL.

Therefore, to make a stock solution of alum for jars, pipette 15.6 mLs into a 1 Liter volumetric flask and make up to 1 Liter with laboratory grade water. This 15.6 mL X 642 mg/mL ≈ 10,000 mg/L. Each mL of this stock transferred to a 2 Liter square jar beaker is a dose of 5 mg/L dry basis Alum.

Chlorine

Use commercial bleach (Clorox), which is 5.25% NaOCl, to make a 2,000 mg/L stock chlorine solution. Be sure it is not the product with detergent in it. Sometimes the Clorox can be purchased at 6%.

At 5.25%, the amount of available chlorine is

$$52{,}500 \text{ mg/L NaOCl X } (71/74.5) = 50{,}034 \text{ mg/L as Cl2}$$

To make a 2,000 mg/L stock, add 40 mLs bleach to 1 L DI water in a volumetric flask. The calculation then becomes (40 mL) (50,034 mg/L) = (1000 mL) (X). X = 2,000 mg/L.

At 2,000 mg/L, a 1 mL portion of this stock contains 2 mg of chlorine. Each mL of this stock transferred to a 2 Liter square jar beaker is a dose of 1 mg/L chlorine.

Note: until raw Lake Huron water is available from the KWA source, it is impossible to write an appropriate SOP for Jar Testing for the Flint WTP because not all off the needed information is available as of this writing. However, the Jar Test skills of operators will likely be important during the startup and subsequent operation of the newly redesigned facility, and the opportunity to practice these skills during the 90-day test period should not be wasted.

Jar Test Scenario Discussion

Therefore, this Jar Test scenario has been developed as a starting point, and was used in the operator classes that are being offered to the staff. It should be remembered that the actual scenario will change, as in fact a true Jar Test SOP must change for each flow rate, dosage change, and water quality change. When the KWA water is available, these changes can be determined for the staff by the DEQ "Operator Trainer" contractor.

<u>Two people</u> should team up to perform the jar test for the above criteria. Follow these steps:

Step by step sample Jar Test scenario

1. Start by making sure all glassware and jar test equipment is clean and dried, and that no residues from previous test remains.
2. Make stock solutions as needed. Obtain fresh raw water for the test – make sure it is sampled prior to any chemical addition in the plant.
3. Put 2 Liters of raw water into each of 4 square 2 Liter jars on test apparatus. Turn on the stirring mechanism, and set the rpms to 220 rpm.

4. Add 1 mL of stock chlorine solution to each of the four jars. Continue to mix for a period of 3-4 minutes to satisfy the chlorine demand. This is an arbitrary step to facilitate training. The WTP may not be using pre-chlorine, and in that scenario, this step would be omitted.
5. Simultaneously add Alum stock to the jars: 3 mLs into the first jar, 4 mLs into the 2nd, 5 mLs into the 3rd, and 6 mLs into the 4th. These represent dosages of 15, 20, 25, and 30 mg/L dry basis Alum. Begin the timer sequence, and allow the jars to mix for 45 seconds at this rotational speed.
6. Set jar test rotational speed down to 95 rpm. Continue this mixing for 10.3 minutes.
7. Set jar test rotational speed down to 70 rpm. Continue this mixing for 10.3 minutes.
8. Set jar test rotational speed down to 45 rpm. Continue this mixing for 10.3 minutes.
9. Stop the paddles from rotating. Allow jars to settle undisturbed for 7 minutes.
10. Using 4 - 100 mL beakers, sample each jar as quickly as possible. Test for turbidity.

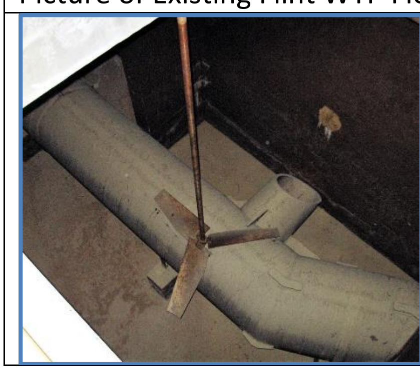
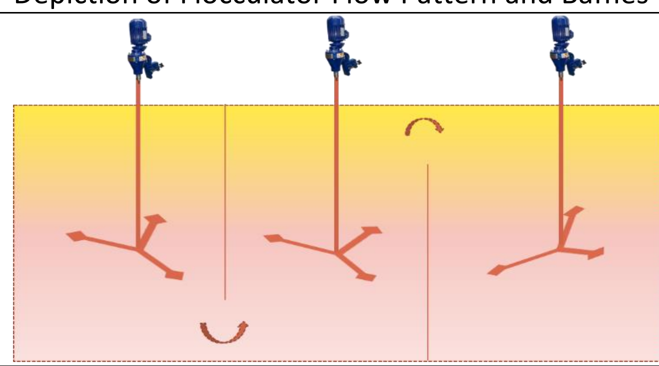
This is the return point to the beginning of the Table of Contents.

3.4 Flocculators

Does SOP Exist?	Yes	Pertinent Regulation?	YES See last chapter	Does Flint Goal Exist?	No

The WTP has two flocculator basins with 5 trains each. These two large basins are going to be partitioned into 4 tapered mix flocculators rated at 3.5 MGD each. At 14 MGD, the detention time in each is 30 minutes. Coagulated water is brought from the rapid mixers and made to undergo the process of flocculation here. Flocculation is an important step in the treatment process where smaller floc particles grow in size and are made ready for the sedimentation process.

Flocculation follows coagulation and usually takes place in a chamber that provides a slow, gentle agitation of the water. In the flocculation stage, physical processes transform the smaller particles of floc formed by the rapid mix into larger aggregates of floc. The rate of aggregation is determined by the rate at which the particles collide. But, as the aggregates grow in size, they become more fragile, so the mixing force applied must not be so great as to cause the floc particles to break up or shear. Baffles are usually provided in the basin to slow down the water flow and reduce short circuiting. In conventional WTPs, most flocculation basins are designed for tapered flocculation, which involves a reduction in velocity gradient (G value) as the water passes through the basin. This promotes the development of a readily settleable floc. The Flint WTP has baffles and three stages of flocculation with decreasing energy input to accomplish this.

Picture of Existing Flint WTP Flocculators	Depiction of Flocculator Flow Pattern and Baffles
	

The speed of the paddle in the final flocculator stage is very important, and should be controlled to produce the best floc possible. The speed is controlled at the flocculator drive motor and can be set to create a range of speeds from 0.76 to 2.3 feet per second (fps). A conventional water treatment plant will likely **operate its flocculators in the range of 0.8 to 1.2 fps**. Typically, the plant ought to operate at the lower end of the range in warmer, low turbidity periods. High periods of turbidity will require a higher flocculator speed to prevent floc from prematurely settling in the floc basins.

This is the return point to the beginning of the Table of Contents.

SOP for Flocculator Tip Speed Determination

To determine the tip speed of the final flocculator paddles, the operator should stand at the effluent end of the flocculator and use a stopwatch to determine the rate at which the paddle indicator shows one full revolution (travel the circumference). The revolution of the paddle sweeps out a circle, the diameter of which is 5.75 feet. The circumference of the circle therefore is 18.06'. So at a pace of 1 fps, it should take about 18 seconds to make the revolution. Operators should adjust accordingly. The calculation is:

- 1 rotation is 18.05 feet
    - Step 1 – determine the desired tip speed – for example by jar testing
    - Step 2 – measure the actual tip speed
        - Step 2.1 – measure the time it takes to travel around once
        - Step 2.2 – divide 18.06 by the number of seconds you measured
        - Step 2.3 – adjust speed as necessary
- Example: you want 1 fps. You measure 1 rotation at 19 seconds. (18.06 ft/rotation)/19 seconds/rotation) = 0.95 fps.
    - You must adjust the speed at the motor drive

The tip speed of the other two paddles should be set for a faster rotation than the last paddle. When KWA source water is available for processing, we will use the 90-day trial period to determine what those tip speeds should be. As a starting point, a suggested G value sequence for the paddles might be 80,50, and 20 G sec^{-1}.

Note: **Do not make adjustments when drive is off.** When coming down on tip speeds, go past the desired setting, then adjust back up to desired setting.

This is the return point to the beginning of the Table of Contents.

*Flocculator Return **Point***

Detention time is very important, and to the extent possible, operators should take basins out of service and put them back into service in an effort to keep the overall flocculation detention time within the range of 15-45 minutes. The CDM-Smith design of the retrofit will need to take place in order for the operators to be able to accomplish this optimization effort.

The retrofit will provide for 4 total flocculator trains with three compartments each. Each compartment will have its own paddle mixer and controller. Each of the compartments has a volume of about 3,570 cubic feet, or a total flocculator volume of 10,710 cubic feet per flocculator. With all four flocculators in service, the total volume through flocculation would be 42,840 cubic feet.

At an average daily rate of 14 mgd (9,722 gpm or 1,300 ft^3/min), the total detention time would be:

$$42{,}840\ ft^3 \times (1\ min/1{,}300\ ft^3) = \text{about } 33 \text{ minutes}$$

Since there will be 4 units, that means that each flocculator will be designed to handle about ¼ of the flow. At the average rate (14 mgd) that CDM projects, the capacity of a unit would be about ¼ X 14 mgd or 3.5 mgd if the time is kept to about 30 minutes. A simple matrix can be constructed to help operators in their choices to take units in and out of service.

Table for Flocculator unit detention times

Units in service →	1	2	3	4
Plant flow ↓				
4 mgd	28.8	57.6	86.4	115.2
6 mgd	19.2	38.4	57.6	76.8
8 mgd	14.4	28.8	43.2	57.6
10 mgd	11.5	23.0	34.5	46.1
12 mgd	9.8	19.6	29.4	39.2
14 mgd	8.2	16.5	24.7	32.9
16 mgd	7.2	14.4	21.6	28.8
18 mgd	6.4	12.8	19.2	25.6
20 mgd	5.8	11.5	17.3	23.0

The body of the table shows detention time, in minutes, at various flow rates and with all or some of the flocculators in service. The blue-gray colored cells show the intersection of rows and columns that represent an optimal number of units to be placed into service at various flow rates.

SOP for choosing number of Flocculators in service

The number of flocculators should be paced into or out of service based on the attempt to maintain a detention time through the units in the range of 15 to 45 minutes.

1. Determine the plant flow rate in mgd from the plant metering. Round that value to the nearest one tenth mgd.
2. Using the chart above, locate the flow rate on the left-most column. If necessary, extrapolate between rows.
3. Follow the row across the table until you can find a detention time in minutes which is in the gray-shaded area. Note that there may be more than one gray-shaded cell for any given flow rate.
4. Once a gray-shaded cell is found, follow the column of that cell straight up until you find the row called “units in service”. The number there is the number of flocculator units that should be in service during that particular flow rate period.
5. When two or more gray-shaded cells are found for that flow, always choose the cell that more closely provides the 30-minute ideal flocculation detention time.
6. Place units in and out of service accordingly. Note the time and decision on tour log sheets.

This is the return point to the beginning of the Table of Contents.

3.5 Sedimentation Basins with Plate Settlers

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
			See last chapter		See Supt.

The WTP has three sedimentation basins which were retrofitted with plate settlers in 2000. The total plate surface area per basin is 34,873 square feet. At the estimated 80% efficiency of the plates, the effective surface area is (0.8 x 34,873) about 27,900 ft^2. Using the existing approved loading rate of 0.3 gpm/ft2, each basin is then rated at 8,370 gpm, or 12 mgd. CDM-Smith is planning to use basin #3 as a spent filter backwash water holding tank, so that leaves two basins for water treatment under normal conditions. Two basins at 12 mgd each sets the plant pretreatment capacity at 24 mgd. At the average flow rate of 14 mgd, two basins will not be stressed during treatment. With good planning for maintenance and cleaning, there should be no problems with this unit process.

The picture above is taken from the basin influent end and shows the plate settlers with attached weirs.

The weir length per basin is 560 feet. At the average flow of 14 mgd (9,722 gpm) the weir overflow rate is 17.4 gal per min per foot with one basin in service. The rate drops to half of that with two basins on line.

CDM-Smith also plans to change out the existing sludge collection equipment, and install newer hose-less cable-vac units such as the MRI unit shown in the picture below. Operators from other systems give good reports for these units. They are variable-speed driven. That provides the operators with the opportunity to run the drives at higher speeds when the solids loading on the basin is light. The drives can then be slowed down when the solids loading is heavy, and they can also be programmed to operate at specific times and durations.

This is the return point to the beginning of the Table of Contents.

Sedimentation Theory

Sedimentation (clarification) depends on gravity to remove, or separate, solids from water. The basins constructed for this purpose are rectangular. In a conventional water treatment plant, sedimentation is situated after flocculation and before filtration. The basins are designed to allow water to flow through them very slowly, and care is taken to ensure minimum turbulence at the inlet and outlet. The sludge, or residuals, that accumulates on the bottom of the basin must be periodically or continuously removed to waste in order to preserve basin depth and to prevent the solids from “going septic” and creating taste and odor problems. The outlet of the basins is equipped with weirs, or launders, that collect the clear water from the top of the basin and carry it to the filters.

Particles suspended in water must settle to the bottom of a basin in order for the sedimentation process to be effective. In conventional settling basins, this often means that a particle must travel 15 ft (4.5 m) or more before it is truly removed from the process. As gravity pulls the particle to the bottom of the basin, it resists settling because of the horizontal flow of water, and so may be carried to the filters. Consequently, basins must be large enough to provide long detention times.

Detention Time

As mentioned, sedimentation basins have basic design parameters that operators should understand. They are built with a minimum flow-through time, or detention time. This detention time is the theoretical amount of time that a quantity of water would take to pass through the basin and exit at the outlet. Most clarifiers are constructed to have 4 hours of detention time at the maximum flow rate of the plant, although here at the Flint WTP there is less detention time available due to the small size of the basins.

Based on the calculations shown the CDM report, each basin provides about 67 minutes of detention time with a flow of 7 mgd (4,861 gpm) going through it. Using the formula for detention time, which is

Dt = Vol/flow

Where volume of a rectangular basin is L x W x H, or of a circular basin Pi x R squared x H

We can approximate the volume of a basins by multiplying the Dt X the flow rate. Or

Time X flow = volume

67 minutes X 4,861 gals/min = 325,687 gals.

Therefore, at the average flow rate of 14 mgd (9,722 gpm) and with all basins in service, the detention time would be:

Dt = (3 X 325,687 gals) / 9,722 gpm = 100.5 minutes

Surface Overflow Rate (SOR)

Another useful design parameter for clarifiers is the surface overflow rate (SOR), which is given in gallons per minute per square foot (meter per hour). Simple basins are usually designed for an SOR of 0.5 gal/min/ft^2 (1.2 m/hr). Basins that are operated in excess of the design SOR tend to load the filters with greater amounts of suspended solids, which can reduce filter run times and increase the probability of turbidity breakthrough in filters. The formula used to calculate the SOR is:

$$SOR = Q_{flow}/\text{square feet of surface}$$

where Q is the flow rate, in gallons per minutes, and square feet is the area of the basin. Note that the depth of water in the clarifier is not used in this calculation.

Because the settling units have plates installed in them, the traditional SOR has little meaning for this plant.

Weir Overflow Rate (WOR)

The weir overflow rate is determined by dividing the rate of flow in the basins by the total weir length in lineal feet. Remember that the weirs in the Flint WTP are double-sided, so that each weir length must be multiplied by two to get total lineal length. The weirs at the Flint WTP are 560 total feet in length. At 14 mgd (9,722 gpm), and two units in service, the WOR would be calculated as this:

WOR = 14,000,000 gal/Day ÷ 1,440 min/Day ÷ (560’ X 2 basins) = 8.68 gpm/foot

Plate Settlers

That small amount of detention time in the basins (67 minutes at 14 mgd) would not be sufficient for producing low turbidity water for the filters. The carry-over of larger flocs to the filters would produce very short filter runs, and perhaps impact water quality. However, the Flint basins are equipped with plate settles which can handle higher loading rates (flows) while still producing low turbidity water for filtering.

Settling basins use gravity to allow particles to fall a required distance through the water column. When they have fallen a far enough distance, they won’t be carried over to the filters. At any given flow rate, a particle must settle through that distance in order for it to be considered “settled”.

One way to reduce the distance that a particle must travel to settle is to insert tubes or plates into the basin at angles; a practice that increases the effective surface area of the unit. The result is shallow-depth sedimentation, which can increase the effective SOR of the basin several times over. Typical SOR rates for basins equipped with tubes can be 2.0 gpm/ft^2 (4.8 m/hr), and for plates it can be 0.5 gpm/ft^2 (1.2 m/hr). The Flint WTP has installed plate settler units into their basins. This has increased the capacity of the basins – each basin now can safely handle flows of about 7 to 8 mgd according to the CDM report.

As built, the three basins in service would provide an overflow rate of 2.6 gpm.ft^2 at the design flow rate of 36 mgd. At the projected average flow rate of 14 mgd, the overflow rate would be 1 gpm/ft^2. However, the basins are equipped with plate settlers that are 80% efficient, and provide an effective overflow rate of 0.12 gpm/ft^2 at the average flow of 14 mgd.

Plate Settler Maintenance

Cleaning of the plates is usually accomplished by slowly lowering the water level in the basin, allowing the solids to slough to the bottom where they are wasted. The plate settlers at the Flint WTP are situated in a way that cleaning can easily be accomplished with a hose. The Plant Manager will establish a cleaning cycle for the tubes.

The Flint WTP sedimentation basins can be thought of as the last or final phase of flocculation, which is taking place at the inlet of the sedimentation basin. **As such, the Flint WTP has – for operational purposes – five zones of physical flocculation**. They are: the rapid mix, the three zones of the flocculators, and the first few feet of the sedimentation basin.

This reality is important and should be used when constructing a meaningful Jar Test protocol.

Sedimentation Basin O&M

In water treatment plants with multiple basins, operators should carefully manage the process so that these design parameters are not exceeded. All sedimentation basins must be taken out of service periodically for cleaning and maintenance, even if the units are provided with automatic sludge-removal equipment. When basins are removed from service, operators should calculate the resulting detention times and overflow rates of the remaining basins and adjust the operation as necessary. A basin outage should be a planned event, and all operations staff should be aware of its ramifications.

This is the return point to the beginning of the Table of Contents.

Basin Return Point

3.6 Filters

Does SOP Exist?	YES At filter panel	Pertinent Regulation?	YES See last chapter	Does Flint Goal Exist?	YES See Supt.

The WTP has twelve dual media gravity filters which were rebuilt with a new design in the fall of 2000. Each filter has 694 ft^2 of surface area. Rated at 3 gpm/ft^2, a filter can operate at 2,082 gpm, or about 3 mgd.

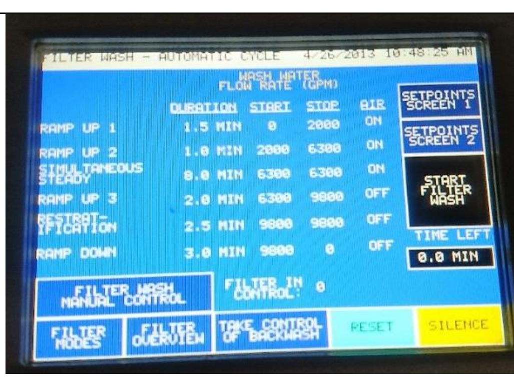
The filters should be able to achieve greater than 5,000 Unit Filter Run Volumes (UFRV) regardless of the rate at which they operate. This is a design characteristic which defines a UFRV as the least amount of gallons, per square foot, that a filter must be able to produce before it no longer meets the turbidity values of the Interim Enhanced Surface Water Treatment Rule. This is not an operational requirement; that is, Michigan DEQ does not dictate that the filter produce this much under operational conditions, but it is a good criterion to use as a historical reference for filter efficiency. **Therefore, each filter ought to be able to produce at least 3,470,000 gallons of water before needing to be backwashed regardless of the amount of time it takes.** Backwash is addressed later on in this section.

Future Filter Characteristics

The actual media characteristics of each newly rebuilt filter from 2000 are not shown here. However, the new design, according to CDM-Smith, will be:

- 36 inches of 1.15 mm anthracite with uniformity coefficient of 1.35
- 12 inches of 0.5 mm sand with uniformity coefficient of 1.65
- L/De ratio = 1,405

Each filter is equipped with a surface wash assembly and air-scour. The surface washers should be used each time a filter is washed. The plant manager will provide a protocol for filter backwash procedures that will include surface washer use. The surface washers will help to minimize or prevent mud-ball buildup.

	The filter and filter back wash sequence can be controlled using the graphic interface on the filter control panel. At each step, the operator has the capability to extend or shorten the time interval, or to raise and lower the wash RATE.

Typical sieve analysis report sheet

A typical sieve analysis report is shown here just for illustrative purposes. The filter designer will supply the "as-built" reports in the final drawings that are used to construct the new beds, and the staff is encouraged to refer to them for further information. This example is one for the sand in a Filter. When the Flint filters are rebuilt, we can substitute an actual report for the Flint filters.

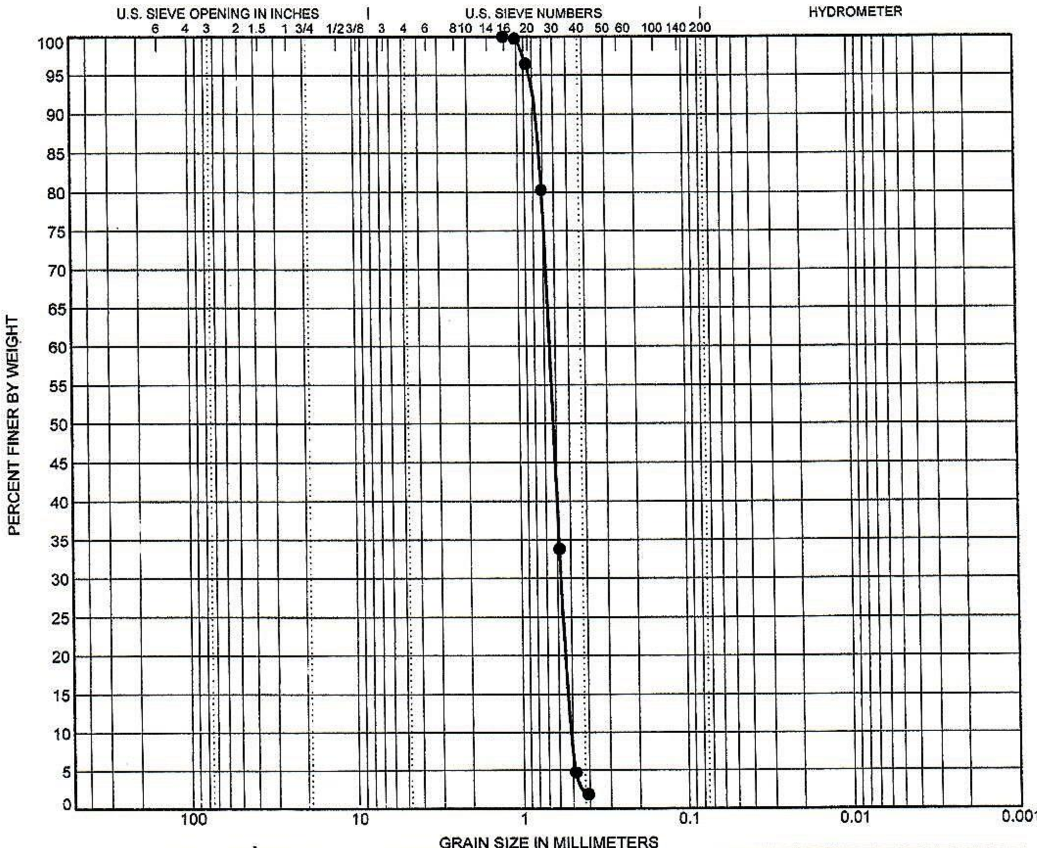
Note that the graph shows the typical curve depicting the sand distribution sizes found in the test that the laboratory performed. There are 7 dots on the graph, corresponding to the 7 sieve sizes on which the grains of sand were found. From this graph, the laboratory has supplied the analysis of the sizes which are needed to determine if the filter was constructed as designed. The graph shows that the smallest sand particles found were in the 0.5 mm range (D_{10}, or effective size), and that the largest sand particles found were slightly over 0.806 mm (D_{90} size). The D_{60} size is reported as 0.654 mm. We can use these numbers to calculate the uniformity coefficient, which is the D_{60} size divided by the D_{10} size (ES). The calculation is thus:

$$D_{60}/D_{10} = 0.654 / 0.5 = 1.308$$

This calculation agrees with the one found on the sheet listed as "C_u".

REPORT NO. 003

GRAIN SIZE DISTRIBUTION TEST REPORT



% +3"	%Gravel	%Sand	%Silt	%Clay
0.0	0.0			

LL	PI	D90	D60	D50	D30	D15	D10	Cc	Cu
		0.806	0.654	0.627	0.571	0.517	0.5	0.99	1.31

REMARKS	USCS	AASHTO

PROJECT NUMBER A11216

PROJECT NAME LAKE COUNTY WATER TREATMENT PLANT

LOCATION Tank #4

DATE 12/13/11

MATERIAL DESCRIPTION

Filter Sand

Solar Testing Laboratories, Inc
1125 Valley Belt Road
Brooklyn Heights, Ohio 44131
Telephone: 216-741-7007
Fax: 216-741-7011

CURVE # ____

This is the return point to the beginning of the Table of Contents.

Filter Theory

Filtration is used in water treatment plants to remove particulate material from the water and store it for eventual disposal. Particulates include those already present in the source water, such as clay and silt particles, bacteria, protozoans, viruses, organic substances, as well as those generated during the treatment process (by adding coagulants and activated carbon e.g.).

Proper operation of these rapid granular-bed filters depends on the passage of pretreated water through the bed at rates sufficient to drive the particulate material into the deeper layers. Cleaning of the filter, or backwashing, is accomplished by introducing water into the bottom or outlet end of the bed in sufficient quantities and with sufficient flow to fluidize and expand the media so that the stored particulate materials are dislodged. These particulates are then carried away in the stream for disposal or reuse.

Rapid sand filters that are open to the atmosphere are called gravity filters. Those that are closed and under pressure are referred to as pressure filters. This WTP employs gravity filters. The dual-media design allows for greater bed penetration by particulate material and therefore for longer filter runs at higher filtration rates. Operators should try to run these filters at or near the rates capacity (flow rate) in order to ensure that particulates are driven deep into the bed as intended by the design. Operating these filters at conservative rates may allow the particles to accumulate too quickly in the upper portions of the bed, which can prematurely increase head loss, which risks shortened filter runs. At the low flow rates currently being seen (fall of 2011), it is probably best to run two filters at all times. That way, when one is being taken out of service to be washed, the other can still be taking flow from the basins.

Ripening

When a cleaned filter bed is first put into service, it may not produce effluent of a quality that meets the water treatment plant’s goals. Particles in the applied influent water need to attach to the grains of sand or anthracite, otherwise, they will pass into the clearwell with the finished water. Properly treated water brings particles that are “sticky,” or destabilized, into the filter. These particles attach with a greater efficiency than those that are less sticky. At first, because the bed is so clean, the voids between the grains of sand or anthracite are large and particles have a greater chance of passing through them. As particles are attracted and attached, the bed usually becomes more efficient at attracting more particles: Each attached particle becomes an attractive site for more particles to come to rest. The voids get smaller and it becomes easier for the bed to collect more particles. This process is called ripening.

This simplified explanation of the ripening process is helpful for operators because it suggests that some steps are under their control. For example, an operator can see that the better the applied water has been conditioned, the better the effluent will be (usually). Also, it is implied that operating filters at slower rates will improve the attachment process since it will reduce the forces caused by drag through the filter. This is called fluid drag and too much of it will shear the attached floc particles. Perhaps the most important lesson is that filters are not just particle-removal devices but are particle-storage devices. Stored particles are in the filter temporarily and must be handled with care.

Head Loss

As the filter ripens and becomes more efficient at producing a clear effluent, head losses increase. Head loss can be defined as a decrease in the available pressure that drives the water through the bed. This loss of pressure is due to frictional pressures brought about by the continual buildup and accumulation (storage) of attached particles. After the filter has been in service for some time, the pressure available from the height of the water in the bed (static head) will equal the frictional pressure and the rate of filtration will be reduced. At this point, breakthrough may occur faster than particles can attach. Beds should be cleaned before this occurs. Operators usually have a maximum head loss at which they will no longer allow the bed to remain in service.

If filters are allowed to operate at head losses that exceed the static head, a vacuum can result. This is called negative head and can cause air binding in the filter, i.e., dissolved gases in the water are released, gas bubbles are trapped, and the problem becomes aggravated. Operators of surface water plants often notice air binding in spring when the air temperature is rising but the water is still cold. At these times, operators are often tempted to “bump” the filter to release these trapped gases. Bumping is the act of allowing some wash water to travel through the bed in the hope of reducing head loss and increasing the filter run. This practice should be avoided because it will displace particulate contamination into the clear-well. Air-bound filters should be removed from service and backwashed thoroughly, regardless of the length of the run. A better practice is to allow the water level on top of the bed to remain at a height that will minimize head loss increases and therefore minimize air releases. The Flint WTP filtration system is enhanced with a higher rate design, and so each filter should be operated more aggressively. In doing so, head loss will increase more quickly. This is a normal situation.

Rate-of-Flow Control

The ability to control the rate of flow through filters is important. Plants with multiple filters may not distribute the total plant flow in a reasonably equal manner due to varying head losses among the filters. Also, without flow control, filters may accept sudden changes (increases) in flow, which can cause poor filtrate quality. In general, flow at the Flint WTP is controlled by use of automatic flow control valves that open and close slowly to maintain a set level in the channel which carries settled water to them.

Granular Bed Maintenance

Granular filtration beds tend to be maintenance-intensive. It is common for operators to ignore these important maintenance tasks, which can lead to filter problems that jeopardize filtrate quality. As these problems become more severe, they also become more expensive and difficult to remedy. Most maintenance tasks (e.g., Solids Retention analysis, Bed Depth Measurements, Sieve analysis, etc.) can be accomplished with the simple tools found in most water treatment plants. This is normally done in early fall. It is important to keep records of the results of inspections.

This is the return point to the beginning of the Table of Contents.

Filter Backwash

The most common problems associated with properly designed filters are those induced by the operator. The backwash procedures that operators do or do not follow will determine whether the filter produces quality effluent and can lead to early filter degradation. For this reason, it is important that each plant establishes clearly written backwash procedures and that all operators follow them as written. It is not uncommon to see water treatment plant operators in the same plant using different backwash procedures, with all operators convinced that their method is the proper one. In truth, there is nothing proper about dissimilar backwash procedures in the same plant.

The following are some general filter backwash recommendations to be considered by each operator:

- Surface washers are available at the WTP. Operators should use them with the start of the backwash and continue using them as the backwash rate is ramped up to a maximum. The SCADA program will ramp down the rate of flow, but operators should learn how to intervene when they feel it necessary. The system has been designed to allow the operator to override it. Be careful not to allow the surface washers to contribute to media loss. The filters are also equipped with air-scour, and this system is also pre-programmed into the SCADA
- It is advisable to ramp up the wash-water rate in stages, especially because there is more than one type of media in the bed (anthracite and sand); a ramped wash-water rate that expands each bed properly is advisable. For example, a typical dual-media bed of anthracite and sand requires two rates. The initial rate expands and cleans the anthracite but will not sufficiently clean the sand. However, if the operator ramps quickly to the high rate to clean the sand, the anthracite will be overly expanded and not cleaned properly. Each type of media has a different specific gravity and therefore will require different wash-water rates for expansion.

- Do not wash the filter too much. Most operators will backwash until the turbidity of the wash water coming through the bed is less than 10 ntu or until they can see the surface washers or other piping that is above the bed. Washing the filter too long will remove the necessary bed ripening; the filter will then have to be re-ripened for a longer period of time before it is useful. This also wastes wash-water pumping. It is normal for operators to want to do a thorough job when they clean the filter, but too much of a good thing can do harm. Operators should periodically collect samples of the backwash water at 1-min intervals for the length of the wash and analyze them for turbidity.
- Wash at a rate that will expand the bed properly under all wash-water temperature conditions. Since colder water has more lifting power than warmer water, it is usually necessary to adjust the wash-water rate from summer to winter for most surface water plants in the northern regions. The percent bed expansion should not change from season to season, but the wash-water rate needed to achieve the expansion must change. An insufficient wash-water rate will not properly clean a filter no matter how long it is washed. The turbidity of the wash water coming through the filter may lessen, leading the operator to believe that the bed has been cleaned, but this may not be so. This practice usually leads to mudball formation. Washing a filter at 15 gpm/ft^2 for 10 min requires the same amount of water as washing the bed at 7.5 gpm/ft^2 for 20 min, but the results will be different. Filters get cleaned by using the correct amount of wash water at the correct wash-water rate for the correct amount of time. That correctness is best determined at each individual plant using bed expansion tools for measurement. The Flint WTP management has set a goal of 30% for bed expansion when washing filters. Changes to that percentage will be communicated to staff when necessary. The table below shows temperature correction factors for backwash rate values if the rate at 25°C is known.

Temperature, °C	Multiply 25°C Value by
30	1.09
25	1.00
20	0.91
15	0.83
10	0.75
5	0.68

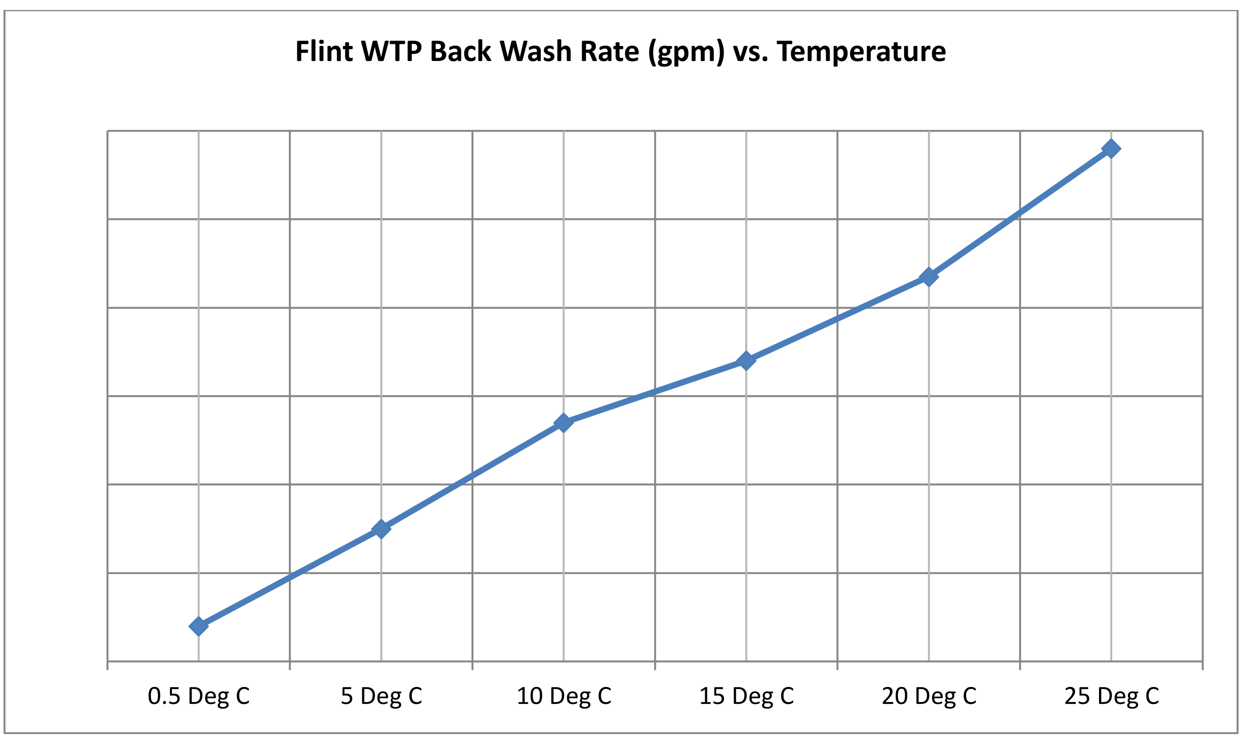
Example: If 7,500 gpm provides a suitable backwash at 25°C, an operator could expect to achieve the same bed expansion at 10°C by using 5,625 gpm (0.75 × 7,500).

Example Backwash Rate Graph

It is not possible to produce the ideal backwash rate graphic for operators to use at the Flint WTP until the filters are retrofitted and actual bed expansion measurements can be made at the seasonal temperatures which the plant will experience. The following is shown **AS AN EXAMPLE**, and the actual needed values will be put into this section of the SOP when that time arrives. This examples assumes that the GAC will be replaced with anthracite as proposed by CDM-Smith, and that washing would be accomplished without air-scour.

For example, with a total of 36 inches of media, a 30% bed expansion during backwash would produce a rise of about 11 (0.3 X 36) inches. If a backwash is initiated, and the expansion measurement shows the 11-inch raise, and the wash rate was about 14,300 gpm (20.6 gpm/ft^2 or 2.75 feet per minute or 0.005 meters/sec), then we would develop a wash rate curve in this way:

> The temperature of the water was 13.3 C^0 (56^0 F.). If the 30% bed expansion shows itself to be desirable over time, then it should be maintained year-round. Operators would need to adjust backwash flow rate as the temperature of the wash water changes from season to season.
>
> A suggested graph of backwash rates vs. temperature, based on the initial observations of expansion of the media in the filters, would might like this:



The values found in this chart will likely expand the bed 30%, which is the rate needed to clean the filters. This graphic can be refined as more observations are gathered. It is important to note that periodic solids retention analysis must be performed by operating staff to adjust the chart value as necessary.

This is the return point to the beginning of the Table of Contents.

SOP for the Flint WTP Backwash Sequence

1. This SOP is written from the existing SCADA control sequence that was programmed into the control panel that each operator would access using their employee code. It includes rate and timing sequence for both the air and water wash process. Additional information has been added so that the SOP can be shown in a step-by-step way. This SOP is therefore a placeholder only, and will change if the newly proposed filters are built. This sequence will need to be rewritten when and if the filters are redesigned.
2. Close the Filter Influent valve
3. Allow water level to drop to top of troughs.
4. Close the Rate Control Valve until the flow reaches zero gpm.
5. Close the Filter Effluent Valve.
6. Open the Drain Valve.
7. Turn on the air scour switch – let it run during the wash.
8. Ramp the back wash water flow up to 5,000 gpm. Be careful not to overly fluidize the media during surface wash otherwise it won't get properly cleaned. As time goes by, we will refine this step through experience.
9. Continue air scour as you ramp up the back wash water flow to the rate indicated in the above chart.
10. Shut off air scour 2 minutes after you achieve the high back wash rate.
11. Back wash at the rate until filter is clean – (about 10 ntu).
12. Ramp filter backwash flow down to 5,000 gpm for 1 minute, then down to 2,000 gpm
13. As an optional step for periods of heavy solids loading on the filters, try a quick rise in back wash rate at this point – up to the high rate and quickly back down again. This sometimes will dislodge extra floc particles. Don't overdo it. Leave some floc in the bed. Repeat step 8.

14. Close the drain valve.

15. Use the 2,000 gpm backwash rate to fill the filter to normal operating levels.

16. Close backwash Rate Valve.

17. Open the influent valve. Allow filter to rest for a day if possible before placing back into service.

The supply of backwash water comes from the backwash water tank that sits outside at the northeast corner of the plant. This tank is filled with water from the supply pump as discussed earlier.

Filter Backwash suggestions for operators

- A review of operational procedures for backwash at most water treatment plants that use conventional granular beds reveals that operators usually use 100–150 gal of wash water per square foot of surface media and, on average, use no more than 4 percent of the plant production to backwash filters.
- After backwash, leave the filter off-line or "rest" it if possible. Many operators report that a rested filter ripens more quickly when put online than will a filter that is washed and put immediately into service. This practice of resting filters also allows the operational staff to have a fresh filter in reserve that can be put online when another filter is removed for washing. This minimizes hydraulic shock in rate-controlled filtration schemes.
- An operator cannot perform a proper backwash without visually inspecting the process as it occurs. With today's newer sophisticated and automated backwash systems, it is tempting for the operator to control the sequence from a remote location. However, the operator cannot see and tend to problems that may be occurring at the backwash site. Operators should observe each wash event for uneven surface agitation and expansion, for "hot spots," and for changes in backwash water turbidity. During the wash, the operator should hose down the side walls of the filter box and the associated piping to remove any accumulated scums, which can harbor pathogens, notably *Legionella*.
- Think about how the filter wash event will affect all other plant operations such as pumping rates, wash-water return storage availability, maintenance, and any other planned activities. Operators should know in advance when they will be washing a filter and what may or may not happen when they do. Do not create the need for a backwash at the end of a shift, so that the next operator has to do it for you.

Other Important Operator Considerations

When filter effluent turbidities begin to increase above what is normal, the problem can usually be traced to one of two processes: the filter(s) or pretreatment. This may seem simple but it is often misdiagnosed, ***and operator actions sometimes worsen the problem***. The best designed and operated filters usually won't produce good-quality effluent if pretreatment is poor. It is instinctive for most operators to bring extra filters online when the pretreated water has deteriorated, but this may make things worse. **Unripened filters, in particular, won't handle poorly treated influent and may actually pass higher turbidities when brought online under these conditions.** Of course, if the elevated turbidities are due to compromised filters or if the filtration rate is too excessive, it may be wise to use other filters if available.

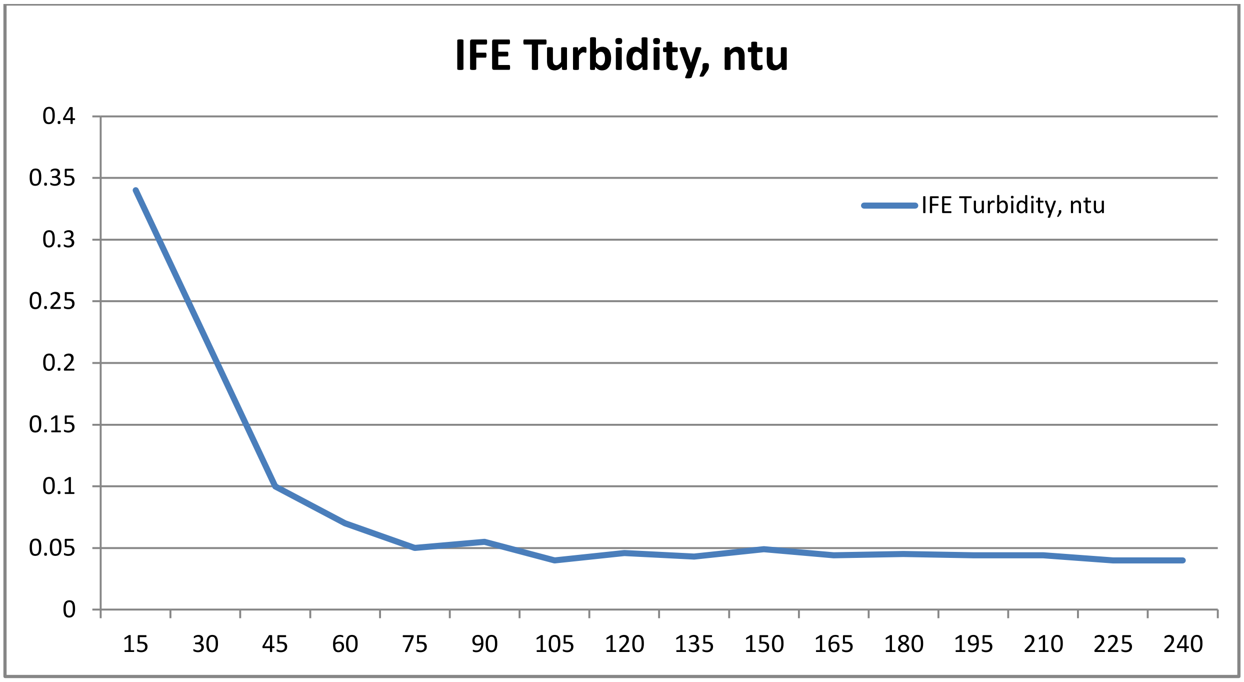
Don't be fooled into thinking that longer filter run lengths are more efficient. If filter washes are accomplished with 100 to 200 gal/ ft^2/wash (4 to 8 m^3/m^2/wash) and backwash downtime is about 30 min, no more efficiency will be gained after a unit filter run volume of 5,000 gal/ft^2/run (200 m^3/m^2/run). This is true over a wide range of filtration rates. Longer filter runs will increase the risk that larger amounts of particles will empty into the clearwell if the filter is upset. All other considerations being equal (water quality, filter rate, etc.), the longer the filter run, the larger the amount of particulates being stored in the filter. The plant manager will set a goal for unit filter run volumes.

Filter Regulatory Requirements

The IESWTR requires that each filter that is operating be monitored continuously for turbidity, and values must be recorded at least every 15 minutes. These values represent the Individual Filter Effluent (IFE) readings. There are two time-based turbidity limits that must be met once a filter is put into service (see Section 10.2):

- In the first four hours of the filter run, the IFE turbidity must be kept below a turbidity of 1.0 ntu. If a filter shows a turbidity value of greater than 1.0 ntu in two consecutive 15-minute readings, it would be a filter exception and it must be reported.
- In the remainder of the filter run, the IFE turbidity must be kept below a turbidity of 0.5 ntu. If a filter shows a turbidity of greater than 0.5 ntu in two consecutive 15-minute readings, it would be a filter exception and it must be reported.

Filter profiles must be kept for each filter run for a period of three years. A filter profile is a graphical representation of the IFE turbidity readings for the entire run of the filter. An example filter profile showing the first 2 hours of a run (15 minute intervals) might look like this:



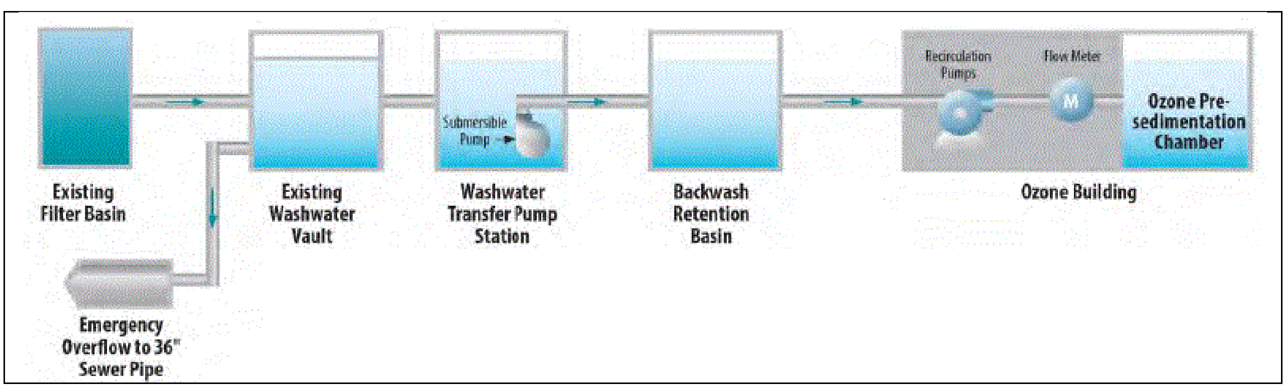
The IESWTR also requires that the combined filter effluent (CFE) turbidity be monitored and that the values be recorded. The CFE turbidity must be at or below 0.3 ntu in 95% of the readings that are recorded. It must never be over 1. There is no continuous monitor and recorder for the CFE values.

This is the return point to the beginning of the Table of Contents.

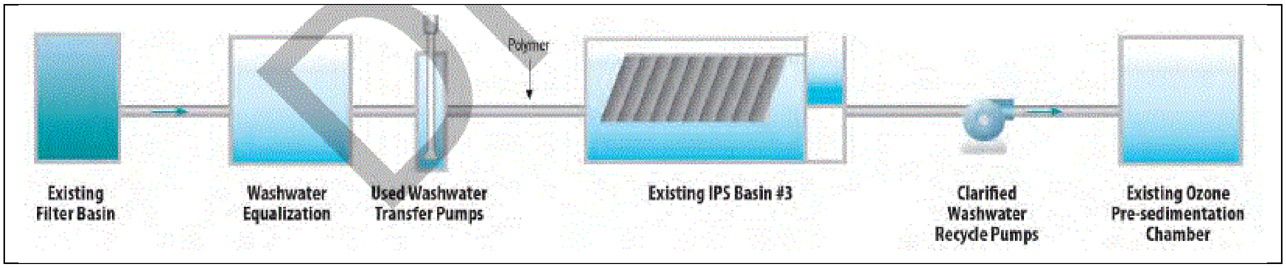
Existing and proposed SFBW system

The existing SFBW system relies on two below ground tanks that can hold a total of 82,000 gallons of water. Since a typical backwash event generate about 110,000 gallons, water must be recycled continually during the event, and this can have a drastic impact on the backwash sequence, and therefore also on the filtration performance capability.

The graphic of the existing system is shown here:



CDM-Smith is proposing that the #3 sedimentation basin be re-purposed to hold and recycle SFBW. The graphic of that proposed design is shown here:



Using basin #3 would provide storage capacity for SFBW of about 219,000 gallons, and provide clarification also. This could have a positive impact on overall filter function and quality.

Filter Backwash **Return Point**

Chemical Feeds

3.7 Disinfection Requirements - Hypochlorite

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See Supt.		See last chapter		See Supt.

Disinfection of the water is accomplished by use of liquid sodium hypochlorite. This unit process is regulated by the IESWTR, which requires several proofs that adequate disinfection is taking place, and that the distribution system is protected with a residual amount of disinfectant in the water. The rules require that:

1. A minimum amount of disinfection sufficiency is met each hour by applying enough chlorine to the water to establish a C X T value that provides 0.5 log inactivation of Giardia. The C X T value is calculated by multiplying the assigned baffling factor of the clearwell times the free chlorine residual of the water in the clearwells at the lowest level and at the highest flow rate through the wells. This calculation must be done each hour to assure that the minimum C X T is met.
2. The chlorine residual leaving the plant be no less than 0.2 mg/L free residual at all times,
3. The chlorine residual be recorded continuously with an approved measuring and recording device. This device may not be out of service for more than 5 working days, during which operators must measure chlorine residual manually,
4. The chlorine residual in the distribution system be detectable for free residual in 95% of the samples taken each month

It should be noted that the City maintains a target of 1.6 – 1.7 mg/L free chlorine leaving the plant in order to maintain consistent water quality values throughout the distribution system.

When the WTP is treating water, hypochlorite feed takes place at three plant-related application points:

1. At the rapid mixers to provide pre-oxidation which may assist the coagulation process
2. At the influent to the Dort Reservoir to provide ample disinfection residence time and thus satisfy the C x T requirements
3. At the effluent of the Dort Reservoir to provide a "boost" of chlorine residual for the distribution system

The distribution system also has capability to feed hypochlorite to the West Side and Cedar Street Reservoirs. This is to boost system levels, and does not figure into the needed C x T value.

Normally, the plant doses the water with about 3 mg/L chlorine. An example dosage calculation might be as follows:

> The plant is treating a raw water flow of 2.8 MGD. The chlorinator is set at 85 pounds per day. What is the dosage in mg/L chlorine?

$$\text{Answer: mg/L} = \frac{85\ pounds\ chlorine}{2.8\ MG \div \left(\frac{8.34\ lbs/MG}{1\ mg/L}\right)} = 3.6\ \text{mg/L}$$

To calculate the CT value, obtain the lowest clear well level and the lowest chlorine residual at the highest flow. CT value is expressed as milligram-minutes per Liter, or mg-min/L. For example, if there was 9 feet of water in the clearwells and the residual is 1.8 mg/L, what is the CT value using the 0.36 baffling factor and the 2.8 mgd flow rate?

> CT = mg/L X baffling factor X Detention time
>
> Detention time = (5,184 ft^2 X 2 cells X 9' depth) / (2.8 mgd X 1.55 ft^3/sec/1 mgd x 60 sec/1 min) = 358.4 minutes

$$\text{Therefore, CT} = \frac{(1.8\ mg/L\ X\ 0.36\ X\ (358.4\ \text{mins})}{1} = 232\ \text{mg-min/L.}$$

For practical purposes, the Flint WTP will normally require a CT value in the summer of about 7 to 9 mg-min/L, and somewhere near 40 mg-min/L in the winter depending on pH. Obviously, the maintenance of a sufficient CT value should be no problem in the near future, unless flows go way up and the water is cold. DEQ will determine the required amounts for Flint.

Current hypochlorite feed strategy

The goal for chlorination at the Flint WTP is to add enough chlorine to the GLWA water to increase the residual by another 0.3 mg/L. The plant operator is expected to test for chlorine residual and check on the feed rate of hypo while making rounds. There is also a continuous measuring and recording device at the plant that provides a visible trend of the chlorine residual. This allows the operator to see any deviations in the residual, and it provides a legal record of results which must be kept ready for inspection for 12 years. Operators are expected to react quickly to any of these deviations, and make adjustments to the chlorine DOSAGE in order to maintain the desired chlorine RESIDUAL. The water exerts a chlorine DEMAND as it undergoes treatment, and the operator should be aware of the demand for chlorine residual and should be able to anticipate changes in the DEMAND by paying attention to environmental conditions and source water quality.

The equation which governs chlorine residual is this:

Chlorine residual, mg/L = Chlorine Dosage, mg/L – Chlorine Demand, mg/L.

Hypochlorite and chlorine chemistry

Sodium hypochlorite is depicted chemically by the formula NaOCl. When liquid hypochlorite is added to the water, it produces hypochlorous acid (HOCl) which is the active disinfectant.

Sodium hypochlorite + Water → Hypochlorous acid + Sodium Hydroxide

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

HOCl is the same disinfectant that is produced when gaseous chlorine is added to water. The difference is that with gaseous chlorine, all of the chemical amount fed will be used satisfy the demand for chlorine. With hypochlorite, only a percentage of the chemical amount fed is available to satisfy that demand. Therefore, when calculating dosage, many operators calculate the hypothetical dosage needed in mg/L pure gaseous chlorine, and then use the percentage strength of the hypo to determine actual chlorine dosage

Note that the addition of hypochlorite solution to the water not only produces HOCl, but also NaOH. This will tend to increase the pH of the water.

The strength of sodium hypochlorite that is supplied to water treatment facilities can vary, usually between 5 – 15%. The solution is most stable at 6%, and will tend to decay over time especially if the hypo solution is not protected from sunlight or is not kept cool. For this reason, frequent checks of the hypo strength should be made by the lab staff so that operators can adjust their dosage. It is very important that these “strength tests” be performed in a timely fashion, otherwise the operators might attribute a chlorine residual - which is trending lower – to some sort of chorine demand from the quality of the raw water.

So we need to know the strength of the hypo solution being fed, and the density (specific gravity) of the solution. Currently, the material being shipped to the plant is testing out at about 18%, and has a density of about 10.2 lbs/Gallon (specific gravity of 1.223). At this strength, it is likely to decay quickly over a few short weeks.

SOP for the Determination of Strength of Hypochlorite Concentrated Solution

It is important that the strength of hypochlorite stock be known so that operators can use that value in the determination of their hypochlorite dosage calculations. Follow these procedure steps:

1. Prepare for the test by inserting a clean delivery tube into the 2.26 N Thiosulfate Titrant Solution Cartridge. Attach the cartridge to the titrator body.
2. Flush the delivery tube by turning the deliver knob to eject a few drops of titrant. Reset the counter to "zero" and wipe off the tip with a disposable Kim wipe cloth.
3. Fill a clean 125-mL Erlenmeyer flask to about the 75 mL mark with deionized or tap water. (The small amount of Cl_2 residual in tap water won't interfere with the test results).
4. Add the contents of one Potassium Iodide Powder Pillow to the flask and swirl to mix.
5. Add the contents of one Acid Reagent Powder Pillow to the flask and swirl to mix.
6. Attach a clean tip to the TenSette Pipet.
7. With the tip of the Pipet lowered into the solution, pipet 0.2 mLs of Sodium Hypochlorite sample and swirl to mix. The sample turns dark brown in color.
8. Place the Thiosulfate delivery tube tip into the solution and swirl the flask while titrating with the Thiosulfate titrant until the solution is pale yellow.
9. Add one dropper of starch solution to the flask and swirl to mix. The solution will turn a dark blue to blue-green color.
10. Continue titrating with the Thiosulfate titrant until the solution becomes colorless. Record the number of the amount of titrant used.
11. To calculate the g/L chlorine, multiply the amount used by 0.5, and divide that value by 10 to obtain the % by volume trade strength of the Hypochlorite concentrated solution.

Dosage control example of hypochlorite feed for incoming GLWA supply

An example dosage calculation for hypo addition is shown here. It assumed a 16% Hypochlorite Concentrated Solution, a density of 10.2 lbs/Gal, and a flow rate of 14 mgd. Calculate the amount of gaseous chlorine needed, and then calculate how many mLs per minute hypo solution must be fed in order to achieve a 0.3 mg/L feed rate.

- The needed feed for chlorine amount is 0.3 mg/L
- 0.3 mg/L X (8.34 lb/MG/1 mg/L) X 14 mgd = 35 lbs/Day chlorine needed
- 35 lbs/Day chlorine ÷ 16% = 218.75 lbs/Day hypo solution needed
- 218.75 lbs/Day X (1gal/10.2 lbs) X (3,785 mLs/Gal) = 81,173 mLs/Day needed
- 81,173 mLs/Day X (1 Day/1,440 min) = 56.4 mLs/min needed

SOP for operating, and feeding hypochlorite, at West Side and Cedar Street Reservoirs

These two system reservoirs are being operated to minimize water age and DBPs by optimizing mixing and by hypochlorite addition. The scheme is to pull water from the West Side Reservoir while filling the Cedar Street Reservoir using the pumps at West Side. In concert with flow coming in from GLWA, this creates a clockwise movement of the water in the system and helps achieve goals. The movement cannot work in a reverse motion.

1. Required operational procedures for West Side and Cedar Street Reservoirs:
    a. Maintain a free chlorine residual of 1.5 mg/L (+/-10%) in both reservoirs
    b. Target a free chlorine residual of 1.35 to 1.65 mg/L after chlorination
    c. Maintain system pressure of 40 psi (+/- 2 psi) when filling reservoirs
    d. Use a duration of 10-15 minutes when opening or closing valves at Cedar and West Side
    e. PS#3 reservoir level: high = 12’, low = 5’ – fill valve range 0-7% psi based
    f. PS#5 reservoir level: high = 14’, low = 8’ – fill valve range 0-25% psi based

2. Procedure for Filling Cedar Street with West Side pumping
    a. Open the fill valve with either a 4 mgd or an 8 mgd pump. To do this:
        i. Start by opening the fill valve at Cedar St. to 4%. While doing so, watch your pressure monitors at Cedar, West Side and Brown/Hadley St., and Saginaw & Atherton. Maintain all of these pressures above 40 psi. This will give you sufficient time to measure the incoming chlorine residual.
        ii. Wait 5 minutes and then turn on the small or the large pump. Your choice of pumps is based on the incoming flow from CS2 and the current demand for water (which is a changeable value).
        iii. When the pump comes on, it will increase the pressures, which will allow the operator to open the fill valve more at Cedar St. Open that fill valve to the desired working pressure. The choice of pressure is determined by the level of “fill” you are trying to achieve. The greater the percentage on the fill valve:
            1. the more you can fill, but
            2. the lower the system pressures will be.

3. At this point, the operator needs to use three pieces of information in order to set the stroke percentage at the Cedar Street Chlorinator. With: a) the incoming free residual at Cedar St., b) the fill rate, c) and the chlorinator’s percentage concentration, the stroke percentage can be set.
    a. Determine the incoming free residual at Cedar Street by taking the reading from the SCADA unit after the valve has been open for 45 – 60 minutes. Write this value down,
    b. Determine the fill rate per hour by noting the number of 1/10th hours that the reservoir has filled. 1/10th = 3 mgd; 2/10th = 5 mgd; 3/10th = 7mgd; 4/10th = 10 mgd; 5/10th = 12 mgd and so forth. Write this number down also.
    c. Determine the concentration of Calcium Hypochlorite in the Chlorinator by taking a sample of it before filling starts. You will make a dilution in the ratio of 1:10,000. This step is typically done on the first shift. Follow these steps:

i. Collect a 50 mL sample of the hypo solution into a clean bottle.
ii. Choose a 100 mL flask (marked “to contain” or “T.C.”) which has been rinsed well with DI water. Fill the flask to the past the mark with DI water.
iii. Using a clean 5 mL pipette and bulb, siphon 5 mLs of water from the flask.
iv. Using a 10 microliter pipette, collect 10 microliters of hypo solution from the 50 mL bottle.
v. Place the tip of the micro pipette below the water level in the 100 mL flask and eject the hypo into the water.
vi. Use the 5 mL pipette, filled with DI water, to carefully bring the level of the sample up to the mark with DI water.
vii. Analyze the sample you have just created for free chlorine residual. The value that you determine from that test is the strength, in %, of the Calcium hypochlorite. Use that value to set the hypo-chlorinator feed rate.

4. Determining free residual on the incoming water for PS#3
   a. If water has been pumped out of the reservoir within the last 8 hours, filling cannot be completed.
   b. Open Cedar Street’s fill valve to 3% or 4%. This is done while augmenting with a pump at PS#5.
   c. The system pressure must be maintained at 40 psi, which should not be a problem at the 3% or 4% opening.
   d. Allow filling to occur between 30-45 minutes.
   e. Take the chlorine residual reading from the SCADA – this residual will be used to calculate the pump % rate on chlorinator.

5. Pumping and filling dynamics and schedule
   a. Cedar Street is pumped out of on 1st shift between the hours of 7:00 am to 3:00 pm. Westside is pumped out of on 2nd shift between the hours of 3:00 pm to 11:00 pm.
   b. Cedar street or Westside Reservoirs are filled between the hours of 10:30 pm to 6:00 am.
   c. Exceptions to pumping and filling:
      i. Pumping – when filling a reservoir will be started within 8 to 10 hours.
      ii. Filling – 911 wants increased pressure – you must close the fill valve being used.

d. The targeted goal is to fill Cedar street and pump out of Westside simultaneously twice weekly.
e. Rule of thumb: you should start the filling cycle 6-10 hours AFTER pumping. This applies to both Cedar Street and Westside reservoirs.
f. Determining when to pump or fill is dependent on 1st and 2nd shift pumping schedule. For example: if 1st shift pumps out of Cedar Street, then filling that reservoir can't take place until 6-10 hours later. This will avoid filling with water you just pumped out.

3.8 Corrosion Control - Orthophosphate

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See supt.		See last chapter		See supt.

The Flint WTP staff adds orthophosphate (in the form of Phosphoric acid) to the water to inhibit the dissolution of Lead and Copper at the customer's tap, and to repair the damage brought on by the plant start-up issues in April 2014. That well-documented event caused leaching of Lead and other piping materials. The strategy being employed at present is to use phosphate in doses that are thought to repair that damage.

Dosage is expressed as mg/L PO_4, and is generally kept near 3.4 mg/L per USEPA requirement for Flint. To accomplish this, the Flint operators need to add phosphate to supplement that which is already present in the water coming in from the Detroit system. Detroit maintains a phosphate level of about 1 mg/L, so Flint operators need to add enough to increase that level to required level. This means that the Flint operational staff need to be able to analyze the amount of incoming phosphate in Detroit, as it may vary. And it also means that they will need to master the steps for accurate dosage control of the phosphoric acid.

Hach Series 5000 Phosphate Analyzer in Butler Building

Top picture: two LMI phosphate feeders

Bottom picture: the CS2 panel in Butler building which provides GLWA flow rate

Operator using the 1,000 mL calibration column

There is a Hach Series 5000 (shown in picture) online analyzer located in the Butler building complex that provides the phosphate value for this purpose. This section then provides background information on phosphate chemistry and dosage control for both the present scheme, and the possible future treatment of KWA water.

When the Flint WTP begins to take in and treat KWA raw water, the operators will need to add phosphate chemical to the treated water in sufficient amount to satisfy the required levels. Whatever amount is needed; the following steps hold true.

Phosphate chemistry

Phosphoric acid is depicted chemically by the formula H_3PO_4. The amount of phosphate in the chemical is derived by adding the atomic weights of each element present to calculate a total formula weight. The weight of PO_4 is then divided by the formula weight to calculate a % available PO_4. Therefore:

3 H = (3x1) = 3, and 1 P = (1x31) = 31, and 4 O = (4x16) = 64

PO_4 then is 64+31 = 95

% phosphate = 3 + 31 + 64 = 98, and (95 ÷ 98) ≈ 0.97, or 97%

So, 97% of the phosphoric acid molecule is available PO_4.

We also need to know the strength and density of the acid that is shipped to the plant. Currently, the information found on the container label states that this product is 75%. That can always change if the material is purchased from a different manufacturer. The density of the product is shown as 13.14 lbs/Gallon (specific gravity of 1.5755).

Dosage control of phosphate feed

For practical purposes, <u>an example calculation</u> for dosage control using the 75% strength is shown here:

> On a given day, the incoming water from Detroit has a phosphate level of 1.0 mg/L. Flint desires to boost the phosphate level to say 3.4 mg/L PO_4 by adding sufficient phosphoric acid to a flow of 14 mgd to accomplish this task. How many mLs per minute acid will need to be fed at the chemical feeders?

- The needed feed amount is 3.4 mg/L – 1.0 mg/L = 2.4 mg/L
- 2.4 mg/L X (8.34 lb/MG/1 mg/L) X 14 mgd = 280.2 lbs/Day PO_4 needed
- 280.2 lbs/Day PO_4 ÷ (0.75 X 0.97) = 385.15 lbs/Day acid needed
- 385.15 lbs/Day X (1 Gal/13.14 lbs) X (3,785 mLs/Gal) = 110,944 mLs/Day needed
- 110,944 mLs/Day X (1 day/1,440 min) = 77 mLs/minute needed

SOP for phosphate addition

It is very important to note that phosphates can impart turbidity to the water if the pH of the final product approaches 7.6 and higher. For this reason, operators are cautioned to pay close attention to phosphate dosage. There is a turbidimeter that measures turbidity values on the incoming GLWA water line. Studies show that for the typical water quality seen at the Flint WTP – (7.1-7.4 pH range, 22 mg/L Dissolved Inorganic Carbon (DIC), total ionic strength of 0.005, temperature range from 0.5 to 25 Degrees C) – phosphates can reduce the solubility of Lead in drinking water. Theoretically, operators should change the phosphate levels as the water temperature changes. Plant Management will provide the target points.

Dosage for the chemical is determined by adding the correct amount of chemical on a continual basis so that the amount of PO_4 in the water is about 3.4 - 3.6 mg/L as determined by the lab analyses. Therefore, this operation is driven by feedback from the lab that indicates whether or not the operator has hit the PO_4 target. When the operator gets this feedback from the chemist, adjustment to the speed of the feed pump should be made if necessary.

The equipment for phosphate addition is found in the Butler Building and consists of:

1. One 221-gallon tote of phosphoric acid with spill containment
2. Two LMI feed pumps – one to be in service and the other in standby
3. One 1,000 mL calibration column
4. Two digital timers to measure elapsed time of chemical used while making checks
5. Personal Protective equipment (PPE) including gloves, face shield, apron, eye wash station

Procedure steps:

1. Read the flow rate of supply from GLWA on panel CS-2. This reading is found in the upper right hand corner of the picture shown here. Record this value on the daily sheet.
2. Check the stroke and speed on feed pump. Record these two values on the daily sheet.
3. Determine the current feed rate in mLs per minute by this procedure:
    a. Open the fill valve and slowly fill the calibration column with acid to a level slightly above the 1,000 mL mark – the close the fill valve.
    b. Close the valve on the supply line from the tote and reopen the fill valve on the calibration column. The level of acid in the column will begin to drop.
    c. Observe the drop in the level of the acid, and start the digital timer when the level is at exactly 1,000 mLs.
    d. After 1 minute, close the valve to the calibration column and open the valve to the tote.
    e. Read and record the level in mLs in the calibration column. Subtract this level from 1,000 mLs. The value you derive is the mLs of acid used in one minute.

f. Record that value on the daily sheet.

4. Determine the feed rate in mg/L:
    a. Multiply the GLWA flow rate (mgd) by 8.34 to obtain the value of “million pounds of water” being treated per day. Divide this value by 24 to get the “million pounds of water” being treated in one hour.
    b. Take the mLs/min of acid used (found in procedure step 3e), and multiply it by 60 to get mLs acid used in one hour. Divide this value by 3,785. This provides the gallons of acid fed in one hour.
    c. Multiply the gallons fed per hour by 13.14 (weight of (phosphate) and then multiply by 0.75 (percent strength of the acid) to get the pounds of pure phosphate fed in one hour.
    d. Divide the value in pounds of pure phosphate fed in one hour by the million pounds of water (from procedure step 4a). This calculates the feed rate in mg/L phosphate.

Record this value on the daily sheet.

This is the return point to the beginning of the Table of Contents.

3.9 Fluoridation – Fluorosilicic Acid

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See supt.		See last chapter		See supt.

At present, the WTP does not need to add this chemical as the Detroit water already is at optimal Fluoride levels. When KWA source water is available to be treated, the Flint WTP will need to add Fluoride. Hydrofluosilicic acid is added to the water when regulating authorities require it in the drinking water supply. The USEPA has an MCL for fluoride set at 4.0 mg/L, and an SMCL for fluoride set at 2.0 mg/L.

The plan is to provide a bulk storage tank which will hold anywhere from 2,000 to 6,000 gallons of the acid. A day tank will also be supplied which will have a capacity of 50 gallons, and there will be 2 peristaltic pumps provided which will feed the acid from the day tank to the influent of the Dort Reservoir. Like phosphate, the dosage of fluoride is adjusted when feedback from the lab is given. Since there is a measureable background level of fluoride in the raw water from KWA, the typical dosage set point will be about 0.7 to 0.8 mg/L fluoride.

Each load of Fluoride acid brought to the plant will have a "percent strength" that varies by load, and operators can obtain this percent strength from the Plant Manager. This strength is generally going to be near 23%. The acid molecule itself, H_2SiF_6, yields the F^- ion, which is the material desired. Therefore, when computing dosage of fluoride, the operator has to take into account the percent strength of the acid, and the percent of available F^- ion in the molecule itself.

Hydrofluosilicic acid (H_2SiF_6) is a straw- or amber-colored, transparent, fuming, corrosive liquid. It has a molecular weight of about 144 (2 hydrogens = 2, 1 silicon = 28, 6 fluorines = 114) and can be purchased as a liquid in drums or bulk at 23 to 35 percent. The percent of available fluoride in (H_2SiF_6) is about 79 percent (114 ÷ 144).

Fluoride Dosage calculation

A dosage of 46 lb of 23 percent (H_2SiF_6) into 1 mil gal of fluoride-free water will produce a 1-mg/L F^- solution. The calculation for estimating the dosage of 1 mg/L F^- when using (H_2SiF_6) (23 percent strength) is:

$$\frac{46\text{ lb }(H_2SiF_6)\text{ X }1\text{ mg/L X }0.79\text{ available }F^-\text{ X }0.23\text{ purity}}{8.34\text{ lb/MG}} = 1.0\text{ mg/L }F^-$$

In other words, the pounds of acid being fed into the water for treatment must be multiplied by the percent strength and the percent F^- in the molecule to get a true amount of F^- being put into the water. To estimate the pounds being fed, the operator must know the number of pounds of chemical per gallon of Acid. Each load that comes to the plant will have a specific gravity shown on the bill of lading. The operator can obtain this information from the Plant Manager. A 25% solution of fluoride acid will have a specific gravity of 10.1 pounds per gallon according to AWWA Standard B703-06.

This is the return point to the beginning of the Table of Contents.

3.10 Adjustment of pH – Sodium Hydroxide

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See supt.		See last chapter		See Supt.

At present, the WTP is feeding caustic soda into the incoming GLWA supply. The current feed pump is too small to meet the needs of the USEPA goals, so a new feeder system is on site and waiting to be installed by staff. It will be capable of feeding up to 250 gallons per day, which will be sufficient. It is estimated that 140 gallons per Day of product will be typical.

A supply of Caustic Soda is planned, and it will be fed into the influent of the Dort Reservoir in order to maintain the desired distribution system pH. The actual system pH and the needed Caustic dosages will be determined at the conclusion of the corrosion control study.

Pure Caustic Soda is not used. Caustic strength is typically obtained in the 20% to 50% range. It is anticipated that the product will be purchased at 20% to minimize the chance of freezing, as 50% will begin to freeze at about 51^0 F. At 20%, CDM-Smith believes that a 3.0 mg/L dose will be needed on an average day. A 6,000-gallon storage tank will be supplied, along with a 150-gallon day tank.

The specific gravity of a 20% caustic solution is 1.22, so the solution weighs (8.34 X 1.22) 10.17 pounds per gallon. Operators don't typically dose caustic with a specific "mg/L goal" in mind: rather, they adjust dosage to meet the pH goal. If dosage calculations are desired for some reason, use a graduate cylinder to catch the stream of caustic for one minute and use the results to mg/L calculate dosage.

Dosage of the pure chemical is calculated by using the following formula:

(mLs/min X 1,440 min/Day X 1Gals/3,785 mLs) = Gal/Day

and

(Gal/Day) X (10.17 lbs/gal X 0.2) ÷ MGD ÷ 8.34 = mg/L

Caustic soda is a dangerous chemical. Eye and skin protective clothing is necessary when working with this chemical. It should not come into contact with acids, flammable liquids, organic halogens compounds, nitro compounds, and amphoteric metals, such as aluminum, magnesium and zinc. Refer to the MSDS sheet which is posted at the safety information board.

This is the return point to the beginning of the Table of Contents.

3.11 Filter Aid - Polymer

Does SOP Exist?	YES	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See supt.		See last chapter		See Supt.

A coagulant aid polymer feed system will be made available to be used when the WTP is bringing in raw source water that is difficult to treat, which should be on rare occasions only. Polymers can be purchased in liquid form, or as a dry chemical that can be made into a specific solution strength. As coagulant aids or filter aids, operators typically use the solutions in small amounts. It is not known what polymer type will be chosen for the Flint WTP, or what type of equipment will be chosen as a feed system.

Polymer dosage tables

For reference, the following tables are provided. The first table shows various amounts of 1% polymer solution needed to maintain a 0.05 mg/L and a 0.10 mg/L dose into selected settled water flow rates when being used as a Filter Aid:

Flow rate of settled water, gpm	Feed rate of 1% polymer, mLs/min for 0.05 mg/L dose	Feed rate of 1% polymer, mLs/min for 0.10 mg/L dose
2,000	38	76
2,200	41.8	83.6
2,400	45.6	91.2
2,600	49.4	98.8
2,800	53.2	106.4
3,000	57	114

Example dosage calculation: an operator uses 57 mLs/min of a 1% polymer solution to treat a flow of 4.32 MGD settled water on its way to filtration. What is the dosage in mg/L?

Answer: Polymer solution is 1%, or 10,000 mg/L, or 10 mg/mL. The settled water flow of 4.32 MGD is (4.32 MGD ÷ 1,440 min/Day) = 3,000 gpm.

Therefore: $$\frac{(57\ mLs\ Polymer/\min)\times\frac{10\ mg\ polymer}{mL}}{3{,}000\ gpm\ X\ 3.785\ L/gal} = 0.05\text{ mg/L}$$

The second table shows various amounts of 1% polymer solution needed to feed a 0.5 and a 1.0 mg/L dose into raw water flow rates going through the rapid mixer units when being used as a Coagulant Aid:

Flow rate of raw water, gpm	Feed rate of 1% polymer, mLs/min for 0.5 mg/L dose	Feed rate of 1% polymer, mLs/min for 1.0 mg/L dose
2,000	380	760
2,200	418	836
2,400	456	912
2,600	494	988
2,800	532	1,064
3,000	570	1,140

Example dosage calculation: an operator uses 570 mLs/min of a 1% polymer solution to treat a raw water flow of 3,000 gpm going through rapid mix. What is the dosage in mg/L?

Answer: Polymer solution is 1%, or 10,000 mg/L, or 10 mg/mL. The raw flow is 3,000 gpm.

Therefore: $$\frac{(570\ mLs\ Polymer/\min)\times\frac{10\ mg\ polymer}{mL}}{3{,}000\ gpm\ X\ 3.785\ L/gal} = 0.5\ \text{mg/L}$$

This is the return point to the beginning of the Table of Contents.

3.12 Taste & Odor (T&O) Control – Powdered Activated Carbon

Does SOP Exist?	Yes	Pertinent Regulation?	YES	Does Flint Goal Exist?	YES
	See Supt.		See last chapter		See Supt.

It is not known at this time if Powdered Activated Carbon (PAC) will be fed into the raw water to adsorb taste and odors that may be found in the water supply. The PAC is usually stored in 35 – 50 pound bags on a pallet, or may be stored as bulk.

For safety purposes, staff needs to know that PAC kept in a closed area can be explosive. Operators should never bring a lit cigarette to the area. Also the bags of PAC should not be allowed to get wet, as moist carbon can absorb oxygen from the air and make the atmosphere non-breathable. It is best to feed a small maintenance dose of PAC all the time, and the dose taken higher if taste and odor tests indicate that more is needed. Dosage is expressed in mg/L.

To determine the actual dosage being fed, operators would need to capture the actual amount fed from the feeder for 30 seconds to 1 minute, and they weigh it on the pan balance. The amount in grams can be converted to pounds by multiplying by 0.0022. The dosage calculation is as follows:

$$\text{mg/L} = \frac{pounds\ fed\ per\ minute\ X\ 1{,}440\ min/Day}{(flow\ rate, MGD)/_{8.34}}$$

General operation of PAC feed systems will be explained here if it is determined that the plant will be using it.

This is the return point to the beginning of the Table of Contents.

Chapter 4 – Residuals Handling Processes

4.1 Residuals Theory

Historically, handling and treatment of waste streams in water treatment plants has been treated as a stand-alone management issue. However, due to rising design and disposal costs, and the potential for harmful impact on the treatment process, handling treatment plants wastes (residuals) has become so important that it now is considered a unit process with specific design and operational parameters associated with it.

National Permit Discharge Elimination System (NPDES)

The Clean Water Act (CWA) authorizes the USEPA to control water pollution by regulating point sources that discharge pollutants into waters of the U.S. Municipal and industrial facilities like WTPs must obtain permits if they are going to discharge any wastes directly to receiving waters. Unlike the Safe Drinking Water Act, the CWA regulates both liquid and solid waste streams. The USEPA develops these regulations for States to adopt and implement, which is a practice comparable to primacy.

Typically, a WTP will discharge some wastes into streams unless there is an agreement to discharge to the local sanitary sewer, in which case the WTP does not need an NPDES permit. When this method of discharge occurs, it comes under the jurisdiction of the local wastewater authority and its Industrial Pretreatment Program.

If the WTP does obtain a permit to discharge to a surface body of water, the permit will outline the sampling and analysis requirements for compliance. At a minimum, a WTP will need to monitor daily flow of waste streams, and take a grab sample for pH, chlorine residual, and Total Suspended Solids (TSS) at frequencies determined by the permit.

Residuals handling is a set of unit processes that helps store and eventually eliminate or dispose of the unwanted wastes that are created in the treatment process. Water treatment plants typically produce some type of waste stream, and the quality of these streams is related to the main treatment process. Waste streams can impact the finished water quality of the treatment process itself. This is especially true when wastes are stored internal to the process or are recycled.

The waste streams in a water treatment facility usually consist of some solid waste that is dissolved or mixed with copious amounts of water. Simply disposing of the entire mixture goes against the grain of what operators do in a WTP. Operators make drinking water safe for their customers by removing the contamination (separating the solids) in it before sending it out to distribution. The concept for treating sludge is similar – separate the solids from the liquid or slurry before distributing it to its eventual end.

There may be from one to as many as 4 or 5 steps in the process of **sludge thickening and dewatering** in any given WTP – but the general rule of thumb is that each step is designed and should be operated to remove more and more of the water before the solids are disposed. The number of steps and the eventual disposal sites of the separated liquid and solids will depend on several factors, and is site-specific. It is left to the operator to become acquainted with his or her own particular requirements.

Typical waste streams originating in conventional treatment plants are sedimentation basin sludge and Spent Filter Backwash Water (SFBW). Sedimentation basin sludge is characterized by a “low-volume, high-solids” nature, while the SFBW is usually just the opposite: it may have only 30-300 mg/L SS in it but typically is 3 – 10% of the treated flow for any given day.

Conventional treatment makes up for the majority of waste streams in older and larger WTP plants in the US and Canada, and are among the most difficult to treat. The source water for these plants ranges from water very low in settleable solids to sources that contain high amounts of suspended matter. Some plants have sources with unpredictable solids fluctuations (rivers e.g.) that are subject to run off from storms. These plants may resort to pre-sedimentation basins for gravity removal of solids prior to chemical treatment of the water.

The wastes generated in these plants are a combination of the solids found in the source water, and the chemicals added to it for treatment. Optimization of chemical coagulant use will help to minimize the sludge produced in the plant. Efficient backwash procedures will also minimize the amount of liquid wastes that are generated.

Concept of Total Suspended Solids (TSS)

The concept behind efficient disposal of wastes is that the operator needs to be able to remove more and more of the liquid of the waste before he or she disposes of the remaining solids. It is not efficient to throw away the entire waste stream because much of it is just water. At each step of the process therefore, the operator needs to test for solids content of the waste stream to determine if the thickening results are being achieved. Regardless of the final disposal point, there ought to be a goal for the minimum solids content for each process. The test most often performed to determine this efficiency is the TSS test.

TSS sampling and testing is a methodology that needs some practice. Operators need to become aware of the typical ranges of solids in their processes through some trial and error, but once established, the process becomes somewhat routine.

An amount of sludge coming from a sedimentation basin at an Alum WTP might be expected to have about 1 to 2% dry solids in it. If the amount of sludge removed from that basin is, say, 10,000 pounds, the operator should know that there are only 100 to 200 pounds of solids in it – the rest is water.

That "10,000 pounds" of sludge typically has a density similar to that of water. (Water has a specific gravity of 1.0; the alum sludge might be at about 1.03 or 1.04). So 10,000 pounds of sludge divided by approximately 8.6 pounds per gallons is 1,160 gallons. Therefore, to get rid of 100 to 200 pounds of dry waste material, the operator must dispose of 1,160 gallons of dilute sludge.

However, if that same operator can move that sludge into a simple gravity thickener, over time he or she could produce (thicken) a sludge that is 15% solids by decanting some of the water. (This sludge will be denser too, so there is a difference in specific gravity). Now – the same 100 to 200 pounds of dry solids is still there to be disposed of properly, but it is suspended in much less water. In fact, if the solids concentration is now 15%, it has increase 7 ½ times over the 2% - (but the weight of dry material is still the same) – so the resultant sludge must be about 1,333 pounds. If the specific gravity of this "new" sludge is about 9.4 pounds per gallon, then there are only about 140 gallons to dispose of (1,333 pounds divided by 9.4 pounds per gallon).

The local wastewater plant or receiving stream is sure to benefit from that type of effort.

"B" Value

In each WTP, there is a relationship between the turbidity in the source water and the amount of suspended solids in that source water. That relationship is called the "B" value, and it varies from plant to plant and from season to season. Developing the B value properly can help save time and effort. To develop a B value for this WTP, samples of the raw water should be analyzed for turbidity and TSS on a weekly basis. In time, the ratio of the two will become apparent; i.e., it will yield a reliable B value that can be used in place of the time-consuming TSS test.

Designers do not find it reasonable to design capacity into a unit that will handle 100% of all of the predicted loading rates because those units would be prohibitively large and expensive, and cannot be justified for use only for 10% of the time.

Nevertheless, operators must understand that there are days when flows and solids loading that are in the upper 10% range will occur, and they must find a strategy that prepares them for the extra loading. The best strategy is to keep all basins and thickeners as empty as possible, and to keep all working equipment in good working shape by means of an aggressive maintenance program.

Using the B value

Operators can use basic formulas to predict the amount of dry solids that will be produced as a result of the treatment processes they use. For alum, ferric and lime softening, they are:

For alum dry solids produced – $S = (8.34Q)(0.44Al + SS + A)$

Where S = dry weight sludge produced in pounds/Day

Q = plant flow in MGD

Al = dry alum dose in mg/L as 17.1% Al_2O_3

SS = raw water suspended solids in mg/L

A = solids from other treatment chemicals such as powdered activated carbon, etc., in mg/L.

For example – assume that the solids being created in the WTP were being sent to a lagoon for drying and future disposal. By using this equation carefully, and with suitable frequency (one that fits in logically with the frequency of sludge removal events), plant staff can produce a running value of the amount of dry solids that the plant produces. Also, a good estimate of how long it will take to fill a lagoon can be had if operational staff knows the amount of sludge produced per unit time and the final sludge concentration as percent solids. By using the formula for "before and after" sludge concentration, which is:

$$V_1 \times N_1 = V_2 \times N_2$$

Where V_1 and V_2 are the beginning and ending volumes, and N_1 and N_2 are the beginning and ending concentration or percent solids. Keep track of V_1 – the volume of sludge sent to the lagoons each day.

If the staff tests for the percent solids of each batch so that and average value can be determined, then all that is needed is to test the final concentration that is normally found in a dried area of the lagoon, and the formula can be used. The staff needs to know the ending volume that they are willing to accumulate in a lagoon.

The formula - $V_1 \times N_1 = V_2 \times N_2$ – works for every step in the processes of dewatering. Therefore, from sedimentation basins to thickeners, and from thickeners to lagoons, the final volume can be computed as long as the other three values are known. Here is an example: if batch of sludge at 12% TSS is pumped from the thickeners to the lagoons at a rate of 35 gpm for 10 hours, what is the resultant volume displaced to the lagoons after the sludge has dried to 45%?

Answer: 35 gpm X 60 min/hour X 10 hours = 21,000 gals.

21,000 gals X 12% = X gals X 45%, so X gals = $(21{,}000\ gals\ X\ 0.12) \big/ (0.45) = 5{,}600\ gals$

5,600 gallons divided by 7.48 gals/ft^3 = approximately 750 ft^3

Then, use the formula for detention time (DT = Volume/Flow) to determine lagoon timeline.

This is the return point to the beginning of the Table of Contents.

Residuals Handling Equipment at Flint WTP

Newly designed residuals handling equipment is being planned by CDM-Smith. The design would entail putting in new sludge collection equipment in the basins that is more reliable than the existing Spider units, and converting one of the sedimentation basins into a sludge holding unit. CDM-Smith feels that because the basins have plate settlers in them, and because the treatment process will most likely be flowing at an average rate of 14 mgd, only two sedimentation basins will be needed the majority of the time.

Basin #3 will be repurposed for solids handling by installing slide gates in the inlet and outlet channels. Spent Filter Backwash Water (SFBW) will be rerouted into basin #3, and from there it will travel through new piping to the suction side of the washwater recycle pumps. A new 3000 ft^3 (2,250 Gal) concrete sludge holding tank will be constructed to hold basin sludge. The existing sludge pumps will draw from this basin and send sludge through the existing system and out to sanitary sewer.

Previously, the operating staff has not dealt with sludge processes other than withdrawal from the basins. With the newly installed equipment, there will be some new concepts to learn and some operational frequencies that only be known as time helps to accumulate experience.

4.2 Basin sludge collectors/rakes

Each sedimentation basin will be equipped with newly installed submerged residuals collectors that can be operated automatically or manually. The picture shows an empty sedimentation basin with the collectors in place – these collectors are the same kind that CDM-Smith is proposing. The collectors travel in a back and forth path the length of the basin. When they are travelling outbound they are drawing sludge into them and up through the piping towards the holding tank. When they travel back, they squeeze out water in the opposite direction in order to clean themselves and prevent clogging. The collectors may need to make several passes, depending on the amounts of sludge produced in the basins. These collectors can be programmed to operate manually or automatically. The speed of travel as well as the duration of travel can be changed at any time to accommodate the thickness and the amount of the solids present.

The sludge collectors are an integral part of the overall sludge handling process, and so the operation of them needs to be coordinated with the polymer feed system and the sludge thickening and disposal process. In time, plant operators will become experienced at sludge disposal operations just as they are with water treatment processes.

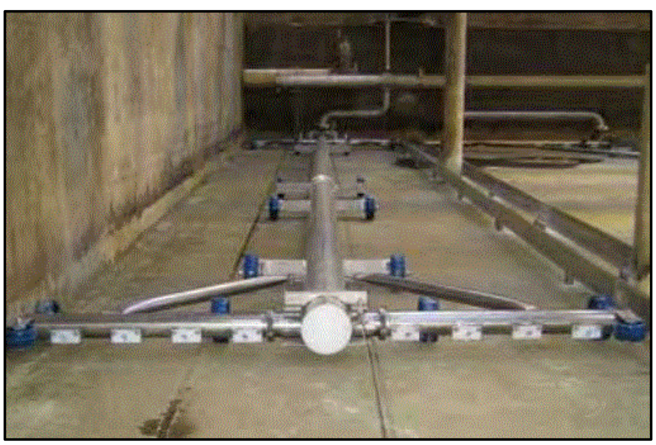
4.3 Sludge piping and transfer pumps

More material will be written into this section as we learn about the final decisions that will dictate design. A brief discussion follows in section 4.5.

Error! Reference source not found.

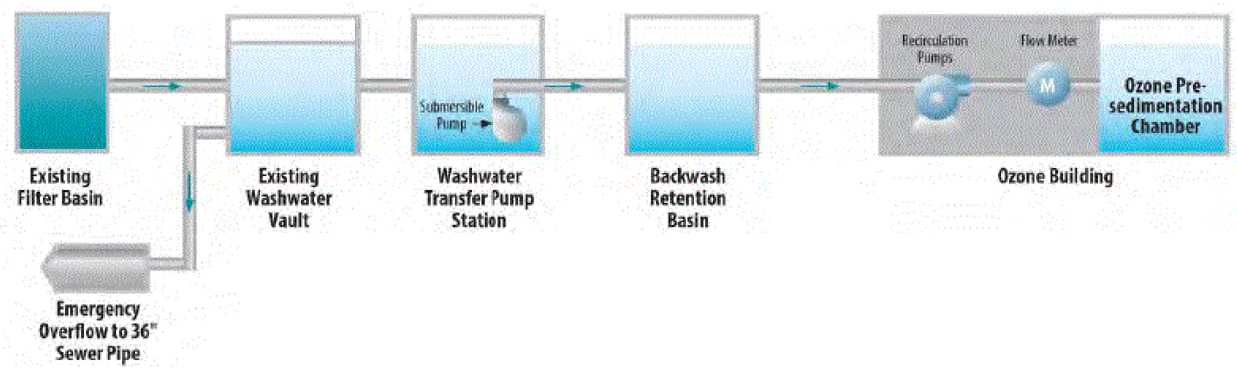
4.4 National Pollution Discharge Elimination System (NPDES)

The discharge permit allows the plant to discharge a stream of water to the creek North of the plant. The Michigan DEQ requires that the discharge from the plant be monitored and controlled. Operators need to make sure that there is no chlorine residual flowing into the stream, nor too much solids. Clear water from the lagoons and from the thickeners is discharged to this point. The technical term for this discharge is “supernatant”, and the act of operating the lagoons and thickeners in a manner which will discharge clear water to the end point is called “supernating” or “to supernate”. The clear water itself is also referred to as “the supernate”.

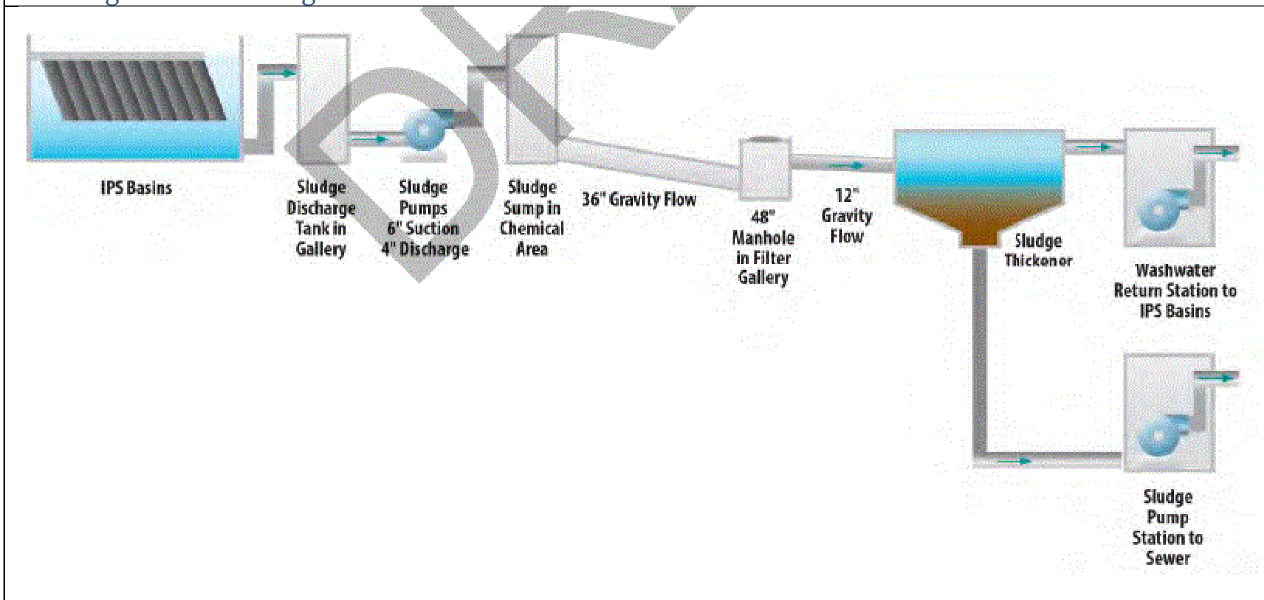


4.5 Proposed Solids Handling System

CDM-smith is proposing a new solids-handling system. The existing and the proposed design are show here:



Existing solids handling schematic

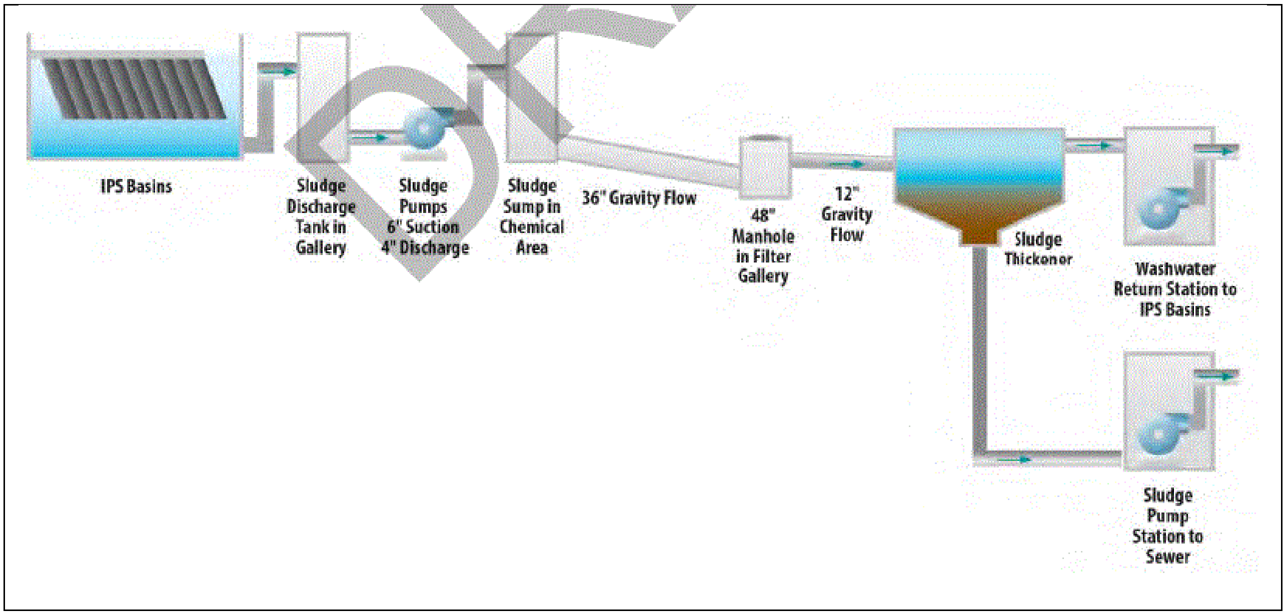


Proposed solids handling schematic

This existing system can hold only 82,000 of SFBW. Since the typical backwash uses generates 110,000 gallons, the present system can have big impacts on filter operations. The proposed system would re-route SFBW to basin #3, which will hold 219,000 gallons and remove a big portion of the solids while doing so.

CDM-Smith is also proposing a new system for treating the solids coming from the sedimentation process. It is depicted here.

They are proposing the construction of a 122,000 gallon holding tank fitted with two pump stations: one for wasting the thickened sludge, and one for sending decant water to the retrofitted basin #3.



This is the return point to the beginning of the Table of Contents.

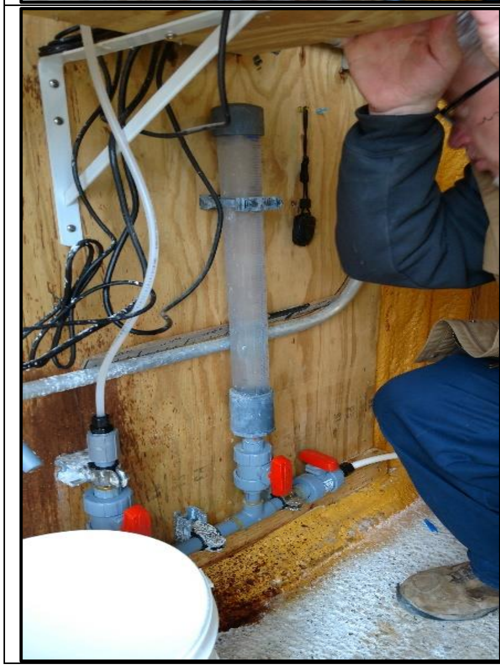
Appendix A – Graphics of facilities – (picture placeholders)

<table>
<tr><th>Graphics</th><th>Original Notes 1/17 and 2/17</th><th>Future Notes</th></tr>
<tr><td>
</td><td>Entrance to Flint WTP pre-treatment area from the filter area.</td><td></td></tr>
<tr><td>
</td><td>Existing rapid mixer and motor. Also seen is the feed point for coagulant with calibration tube.</td><td></td></tr>
<tr><td></td><td>Sedimentation basin effluent end with plates and weirs. See section on Sedimentation. Do not exceed 7 mgd through 1 basin.

Take basin out of service at least once each year. Hose down the tubes.</td><td></td></tr>
</table>

	There is a plan to install new sludge collection equipment in the basins which will replace the Spider system. This is a sludge collector drive motor with cut-off switch (red button). Equipment like this is planned by CDM-Smith	
	Example Sludge collector system in a dewatered sedimentation basin. Note the wall at the middle portion of the basin which forces settled water down to the bottom section and then up into the tube section – this forces the water to follow a vertical path providing attachment of flocs to the tubes.	
	Jar Testing Equipment in the lab at flint WTP Classes are given to operators for various scenarios they will face if KWA raw water is being treated	

		Filter Control Panel The sequences of air scour and washwater flow rates are displayed. This panel allows operators to manually override any sequence as needed.	
		Hach Series 5000 Phosphate Analyzer This is found in the Butler Building.	
		Panel CS2 that provides a readout of the flow rate of income GLWA supply. This rate is needed to calculate dosages.	

	Chemical feed pumps - LMI	
	Operator using the 1,000 mL graduated cylinder to perform a dosage check. This procedure is found in the chemical feeds section of the manual.	

Appendix B – Additional Information

This is the return point to the beginning of the Table of Contents.

Websites or References

1. **Ten States Standards**

   http://10statesstandards.com/wastewaterstandards.html

2. **Michigan Department of Environmental Quality – Water Division**

   http://www.michigan.gov/deq/0,4561,7-135-3313_3675---,00.html**IESWTR**

3. **American Water Works Association (Bookstore, Partnership for Safe Water, Standards)**

   http://www.awwa.org

4. **Michigan Operator Certification Materials**

   http://www.deq.state.mi.us/otcis/

5. **Michigan DEQ Lead and Copper Guidance**

   http://www.michigan.gov/deq/0,4561,7-135-3313_3675_76638---,00.html

6. **Michigan DEQ Staff Contact Information**

   https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=michigan+department+of+environmental+quality+staff+directory

7. **Karegnondi Water Authority (KWA)**

   http://www.karegnondi.com/

Appendix C – Acronyms, Conversion Factors, Formulas and Constants

Acronyms

Alk	Alkalinity
AWWA	American Water Works Association
DBP	Disinfection By-Product
DBPR	Disinfection By-Product Rule
ES	Effective Size
FBRR	Filter Backwash Recycle Rule
gpm	Gallons per minute
HAA	Haloacetic Acids
IESWTR	Interim Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental quality
NPDES	National Permit Discharge Elimination System
mgd	Million Gallons per Day
ntu	Nephelometric turbidity unit
PAC	Powdered Activated Carbon
SDWA	Safe Drinking Water Act
SFBW	Spent Filter Backwash Water
SMCL	Secondary Maximum Contaminant Level
SOR	Surface Overflow Rate
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
T&O	Taste and Odor
TSS	Total Suspended Solids
TT	Treatment Technique
TTHM	Total Trihalomethanes
UC	Uniformity Coefficient
UFRV	Unit Filter Run Volume
USEPA	United States Environmental Protection Agency
WOR	Weir Overflow Rate
WTP	Water Treatment Plant

SI and US Conversion Factors

Metrics Name	Symbol	→	←	Symbol	U.S. Name
Cubic meters per day	m^3/d	264.2	3.785×10^{-3}	gal/D	Gallons per Day
Cubic meters per second	m^3/s	15850.3	6.309×10^{-5}	gpm	Gallons per minute
Liters per second	L/s	15.852	0.0631	gal/min	Gallons per minute
Gram	g	0.0022	4.5359×10^2	lb	Pound
Kilogram	kg	2.2046	0.4359	lb	Pound
Liter	L	0.2642	3.7854	gal	Gallon
Milligrams per Liter	mg/L	8.34	0.12	lb/MG	Pounds per million gallons
Cubic Meters per day	m^3/d	2.642×10^{-4}	3.785×10^3	mgd	Million Gallons per Day
Kilograms per Day	kg/d	2.2046	0.45359	lb/d	Pounds per Day

Formulas: Q =A ·V Detention Time = Volume/flow Diameter of pipe or cylinder = $\pi r^2 \cdot H$

Constants: 1 ft^3 = 7.48 gals 1 MGD = 1.55 ft^3/sec 1 Day = 1,440 minutes