CITY OF FLINT, MICHIGAN

Flint Water Treatment Plant
Improvements Plan

January 30, 2017

FINAL REPORT

CDM Smith

Flint Water Treatment Plant Improvements Plan

City of Flint, Michigan

January 30, 2017

CDM Smith®

Table of Contents

List of Tables

List of Figures

List of Acronyms

AL	Action Level
AWWA	American Water Works Association
amp	Amperes
$CaCO_3$	Calcium Carbonate
CDC	Centers for Disease Control and Prevention
CEC	Chemicals of Emerging Concern
CECs	Chemicals of Emerging Concern
cf	Cubic Foot
CFE	Combined Filter Effluent
Cl2	Chlorine
CMAR	Construction Management at Risk
CMMS	Computerized Maintenance Management System
CO2	Carbon Dioxide
CT	Product of Disinfectant Concentration (C) times Contract Time (T)
CT_{calc}	Calculated CT
CT_{req}	Required CT
D/DBPR	Disinfectants and Disinfection By-Products Rules
DAF	Dissolved Air Flotation
DBB	Design-Bid-Build
DBB+EP	Design-Bid-Build with Procurement of the Design Engineer
DBP	Disinfection By-Product
EBCT	Empty Bed Contact Time
EC	Endocrine Disruptors
EDCs	Endocrine Disrupting Compounds
Eds	Endocrine Disruptors
EPA	Environmental Protection Agency
FBBR	Filter Backwash Rule
FBRR	Filter Backwash Recycling Rule
Fe_2	Iron
$FeCl_3$	Iron Chloride
FRP	Fiberglass Reinforced Plastic
ft/s	Feet per second
GAC	Granular Activated Carbon
GCDC	Genesee County Drain Commissioner
GLWA	Great Lakes Water Authority
GMP	Guaranteed Maximum Price
gpd	Gallons per Day
gpm	Gallons per Minute
gpm/sf	Gallons per Minute per Square Foot

G-value	Velocity Gradient
H_2O	Hydrogen Monoxide (water)
HAA	Haloacetic Acid
HAA5	Five Regulated Haloacetic Acids
HAA9	Nine Haloacetic Acids
HF	Hydrofluosilicic Acid
HGL	Hydraulic Grade Line
HI	Hydraulic Institute
HP	Horsepower
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFE	Individual Filter Effluent
IGBT	Insulated-Gate Bipolar Transistor
in	Inch
IPS	Inclined Plate Settler
KWA	Karegnondi Water Authority
L/d	Liters per day
lb/day	Pounds per Day
LCR	Lead and Copper Rule
LCR	Lead and Copper Rule
LHPWSS	Lake Huron Primary Water Supply System
LIMS	Laboratory Information Management System
LPHO	Low Pressure High Output
LRAA	Locational Running Annual Average
LT1ESWTR	Long Term Stage 1 Enhanced Surface Water Treatment Rule
LT2ESWTR	Long Term Stage 2 Enhanced Surface Water Treatment Rule
LT3ESWTR	Third Long Term Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goals
MDEQ	Michigan Department of Environmental Quality
MG	Million Gallons
mg/L	Milligrams per Liter
MGD	Million Gallons Per Day
MIB	Methyl Isoborneol
mJ/cm2	Millijoules per square centimeter
mm	Millimeter
MP	Medium Pressure
MRI	Muerer Research, Inc.
NDMA	Nitrosodimethylamine
ng/L	Nanogram per Liter
nm	Nanometers

NPDWR	National Primary Drinking Water Regulations
NPSH	Net Positive Suction Head
NSDWR	National Secondary Drinking Water Regulations
NTU	Nephelometric Turbidity Units
O&M	Operations and Maintenance
OCL	Hypochlorite
ORP	Oxidation-Reduction Potential
PAC	Powdered Activated Carbon
PACl	Polyaluminum Chloride
PDB	Progressive Design-Build
pH	Potential of Hydrogen
Ph	Phase
PhACs	Pharmaceutically Active Compounds
PPCP	Pharmaceutically Active Personal Care Products
ppd	Pounds per Day
psig	Pounds per Square Inch Gauge
PSU	Power Supply Unit
PVC	Polyvinyl Chloride
RAA	Running Annual Average
RED	Reduction Equivalent Dose
Reg-Det3	Third Regulatory Determination
rpm	Revolutions per Minute
SCADA	Supervisory Control and Data Acquisition
scfm	Standard Cubic Feet per Minute
SDS	Simulated Distribution System
SDWA	Safe Drinking Water Act
SMMWSC	Saginaw-Midland Municipal Water Supply Corporation
SO_4	Sulfate
SWD	Supersonic Wave Drive
SWTR	Surface Water Treatment Rule
TCR	Total Coliform Rule
TCR/RTCR	Total Coliform Rule/Revised Total Coliform Rule
TDH	Total Dynamic Head
THM	Trihalomethane
TOC	Total Organic Carbon
TON	Threshold Odor Number
TTHM	Total Trihalomethanes
UCMR4	Fourth Unregulated Contaminant Monitoring Rule
UFRV	Unit Filter Run Volume
UV	Ultraviolet Irradiation
UV_{254}	Ultraviolet Absorbance at 254 nm
UVDGM	Ultraviolet Disinfection Guidance Manual

V	Volts
VFD	Variable Frequency Driver
w.c.	Water Column
WTP	Water Treatment Plant
XLPE	Crosslinked Polyethylene
µg/L	Micrograms per Liter

Acknowledgements

CDM Smith wishes to acknowledge the valuable contributions and collaboration of the City of Flint and the Michigan Department of Environmental Quality (MDEQ) in preparing the City of Flint Water Treatment Plant Improvements Plan. Specifically, CDM Smith would like to acknowledge the efforts of:

City of Flint

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Section 1

Executive Summary

The Flint Water Treatment Plant (WTP) will be receiving raw water from Lake Huron, through the Karegnondi Water Authority (KWA). This report provides an evaluation of the WTP and recommendations regarding process, mechanical, structural, electrical, and instrumentation improvements to the WTP intended to achieve the following objectives:

- Production and delivery of treated water that exceeds all drinking water primary and secondary standards with an appropriate margin of safety at minimum, average, and maximum plant production rates of 5, 14, and 24 million gallons per day (MGD) respectively.
- Operation and maintenance of the WTP with enhanced ease/simplicity, flexibility, safety, and reliability.
- Improved treatment, pumping, and operational efficiency.

CDM Smith worked with the City of Flint and the Michigan Department of Environmental Quality (MDEQ) to determine the scope, cost, and implementation schedule of improvements to meet these objectives.

The first step was to gather and review the existing plant design drawings, engineering reports, and operational data, along with related information such as the Genesee County Drain Commissioner (GCDC) existing pilot plant data and information from other WTPs treating Lake Huron source water.

Water quality goals were next developed for the plant. After developing the water quality goals, an extensive analysis of the plant facilities was conducted based on site visits and condition assessments. Based on the results of these activities, feasible alternatives were identified for the water treatment process facilities and other plant components. These alternatives were evaluated based on regulatory and water quality issues, cost, operational simplicity, flexibility, efficiency, system reliability and safety. Preliminary recommendations were prepared and presented in workshops with MDEQ and the City of Flint. Final recommendations were then developed.

The remainder of this section summarizes the recommended improvements, capital cost estimates, the recommended project delivery approach and schedule, and the work remaining to complete the initial phase of the Flint WTP Improvements project.

1.1 Summary of Alternatives and Recommended Improvements

The total estimated capital cost of the recommended improvements to the Flint WTP is $108 million. This estimate is based on the assumption that the plant residual solids are discharged to the City's sewer system. The estimated capital cost by work category is presented in **Table 1.1**. The alternatives considered and the specific recommended improvement within each work category are described following the table.

Table 1.1 – Recommended Improvements by Category

	Category	Estimated Cost
1	Demolish WTP No. 1	$5,800,000
2	Raw Water Storage	$37,000,000
3	Raw Water Pump Station	$6,400,000
4	Transfer Pump Station and Filtered Water Control Structure	$7,400,000
5	High Service and Backwash Pump Station	$10,400,000
6	Pre-oxidation with Ozone	$900,000
7	Rapid Mix Basins	$900,000
8	Flocculation Basins	$1,300,000
9	Inclined Plate Settler Basins (Sedimentation)	$3,000,000
10	Granular Media Filters	$1,600,000
11	Management of Used Filter Washwater - Equalization Basin and Pump Station	$4,000,000
12	Disinfection and Dort Reservoir Rehabilitation	$2,000,000
13	Chemical Storage and Feed Systems	$7,000,000
14	Improvements Identified by Condition Assessments	$15,200,000
15	Other Ancillary Improvements	$4,800,000
	Total (Rounded)	**$108,000,000**

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1. **Demolition of Water Treatment Plant No. 1 –** Demolition of Water Treatment Plant No. 1 is necessary to provide sufficient space to construct 42 million gallons (MG) of raw water storage.

   Cost - $5.8 million for demolition and transport and delivery of rubble to appropriate disposal sites (e.g., landfills with the proper regulatory certification).

2. **Raw Water Storage** – Provides 42 MG of on-site storage, which is 3 days of storage at the average treatment production of 14 MGD.

   Alternatives

   - Earthen impoundment.
   - Two (2), 21 MG open-top prestressed concrete tanks.
   - Two (2), 21 MG closed-top prestressed concrete tanks.

   Recommendation – Open-top prestressed concrete tanks: The tank options provide greater operational energy efficiency than an earthen impoundment given that tanks can be built at a higher elevation, and require less long-term maintenance than an earthen impoundment. An open-top tank is lower in cost than a closed-top tank.

   Cost - $37.0 million

3. **Raw Water Pump Station** – Three (3) pumps at 14 MGD and two (2) pumps at 5 MGD.

   Alternatives

   - Upgrade existing raw water pump station.
   - New pump station.

   Recommendation – New pump station: use of existing pump station would require major modifications and would include risk of over-pressurizing the suction chamber; new pump station is close in capital cost and much easier to operate and maintain. Note that the raw water pump station is not necessary if raw water storage is eliminated.

   Cost - $6.4 million

4. **Transfer Pump Station and Filtered Water Control Structure** – This is a new pump station required to pump filtered water to the Dort Reservoir: Three (3) pumps at 14 MGD and two (2) pumps at 5 MGD.

   Alternatives

   - New pump station.

   Recommendation – New pump station, new filter piping, and new filtered water control structure to supply the pump station.

Cost - $7.4 million

5. **High Service and Backwash Pump Station** – Three (3) high service pumps at 14 MGD and two (2) high service pumps at 5 MGD; two (2) backwash pumps at 22 MGD.

   Alternatives

   - Upgrade existing high service pump station and build a separate backwash pump station.
   - New pump station that has both high service and backwash pumps.

   Recommendation – New pump station: lower cost and easier to operate and maintain.

   Cost - $10.4 million

6. **Pre-Oxidation** – Improves water quality and enhances downstream treatment processes.

   Alternatives

   - Upgrade existing ozone system.
   - Pre-chlorination.
   - No pre-oxidant.

   Recommendation – Upgrade existing ozone system: lower annual operating cost, will address potential future water quality regulations, provides greater water quality reliability should Lake Huron water quality deteriorate in upstream storage, and significantly enhances downstream treatment processes.

   Cost - $0.9 million

7. **Rapid Mix** – Near instantaneous dispersion of chemical coagulants needed to reduce chemical use and improve efficiency and effectiveness of downstream treatment processes.

   Alternatives

   - Upgrade existing vertical shaft mixer.
   - Install pump diffusion hydraulic mixing system.

   Recommendation – Install pump diffusion hydraulic mixing system: improves dispersion of coagulants; enhances downstream treatment processes; and reduces operations and maintenance (O&M) costs.

   Cost - $0.9 million

8. **Flocculation** – Aggregate particles into larger particles for improved removal by settling and filtration.

   Alternatives

   - Existing 3-stage flocculation basin.
   - Modified 3-stage flocculation basin.

   Recommendation – Modified 3-stage flocculation basin: improves mixing and enhancement of downstream treatment processes by reducing floc shearing and deposition in the flocculation basins; and reduces O&M on mixing equipment.

   Cost - $1.3 million

9. **Inclined Plate Settler Basins (Sedimentation)** – Remove suspended particles by settling to reduce particle loading on downstream filters and improve filtration performance and efficiency.

   Alternatives

   - Existing inclined plate settler (IPS) basins with new solids-removal equipment.
   - Modified IPS basins with new solids-removal equipment.

   Recommendation – Modified IPS basins with new solids removal equipment: better flow distribution to improve particle settling and enhance downstream filtration performance; new solids removal equipment will reduce O&M requirements.

   Cost - $3.0 million

10. **Granular Media Filters** – Removes remaining suspended solids and colloidal solids to enhance water quality and improve disinfection.

    Filter Media Alternatives

    - Continue usage of existing Granular Activated Carbon (GAC) media.
    - Replace GAC with deeper, coarser anthracite media.

    Recommendation – Replace GAC with deeper, coarser anthracite media: will improve filter run duration during periods of challenging water quality; using anthracite filter media is less expensive than GAC in a life-cycle cost comparison.

    Cost - $1.6 million

    Backwash Supply Alternatives to Replace Existing High-Pressure Supply

    - New dedicated elevated tank.
    - New dedicated backwash pumps.

Recommendation – New dedicated backwash pumps: more cost effective and reduces O&M cost.

Cost - The cost for these backwash pumps is included under High Service and Backwash Pump station cost.

11. **Management of Used Filter Washwater** – To maintain reliable plant production and water quality performance it is necessary to effectively and efficiently capture and recycle the washwater used to clean the filters.

    Alternatives

    - Recycle used washwater to the plant inlet without first clarifying the water.
    - Recycle after clarification.
    - No recycle – discharge to the sewer.

    Recommendation – Recycle used washwater to the plant inlet: Discharge used washwater to a new basin for flow equalization, with a new pump station and piping to convey the washwater to the ozone inlet channel. This improves plant performance, and overall plant efficiency.

    Cost - $4.0 million

12. **Disinfection and Dort Reservoir Rehabilitation** – To utilize the existing 20 MG Dort Reservoir to provide the disinfection contact time required. A condition assessment of Dort Reservoir was performed which found that, overall, the structure is in fair condition with localized corrosion of the vertical wall reinforcing, deteriorated and leaking expansion joints in slabs and wells, and deterioration of concrete columns observed. The findings and recommendations of the structural condition assessment are found in the appendix.

    Cost - $2.0 million

13. **Chemical Storage and Feed Systems** – Proper storage and feeding of chemicals is essential for the safety of the plant staff.

    Alternatives

    - Modify and expand the existing chemical storage and feed system.
    - A new chemical storage facility with all chemicals in one location.

    Recommendation – A new chemical storage facility with all chemicals in one location: more cost effective; reduces O&M; and improves plant safety.

    Cost - $7.0 million

14. **Improvements Identified by Condition Assessments** – Upgrades and investments in the Supervisory Control and Data Acquisition (SCADA), electrical, and heating, ventilation, and air conditioning (HVAC) systems; repair and replacement of the roof, doors, windows and exterior; structural upgrades to WTP basins and buildings.

    Cost - $15.2 million

15. **Other Ancillary Improvements** – Upgrades to plant spaces such as locker rooms, restrooms, laboratories; upgrade to maintenance and laboratory information management systems; and other plant improvements.

    Cost - An allowance of $4.8 million is recommended to implement ancillary improvements at the WTP.

1.2 Recommended Project Delivery Approach and Schedule

Two delivery approaches were evaluated for the Flint Water Treatment Plant Improvements Project:

- Progressive Design-Build (PDB).
- Design-Bid-Build (DBB).

PDB is recommended as the most advantageous project delivery method for the Flint Water Treatment Plant Improvement Project based on the factors outlined below.

- Schedule – The PDB delivery method would facilitate a shorter project duration. It is estimated that Phase 1 construction could be completed through PDB by May 2018, allowing initial performance testing and pipe loop testing to begin in April 2018. The estimated completion date for Phase 2 construction is May 2019, allowing completion of final performance testing and delivery of water to the system by August 2019. It is estimated that the project duration utilizing DBB would be 9 months longer, with final performance testing and delivery of water to the system by May 2010. The preliminary project schedules for the PDB and DBB options are shown in **Figure 1.1**.
- Cost Savings – PDB is generally considered to provide greater opportunity to develop lower cost solutions compared to DBB. As stated in the MDEQ Office of Drinking Water and Municipal Assistance Project Delivery Methods Guidance document, "PDB is frequently preferred … when the applicant is looking to minimize the time and cost of the design-build procurement. This delivery method is most valuable when owners believe they can lower cost or otherwise improve the outcome by participating directly in design decisions." Cost savings can also be realized through schedule savings. Assuming 3 percent annual inflation, a schedule savings of 9 months equates to a cost saving of over $100,000 for every $10 million in project cost, based on estimating costs to the midpoint of construction.
- Collaboration and Innovation – The PDB structure provides the greatest opportunity to maximize collaboration between the owner and design-builder, and thereby develop innovative and cost-saving solutions.

- Transparency – PDB projects are executed in a transparent manner, meaning that the design-builder shares with the owner the construction cost backup, including competitively bid subcontractor costs, and reviews the information with the owner in an open book manner. The owner is fully aware of all cost inputs and is able to change project components in collaboration with the design-builder based on the information provided.

1.3 Remaining Work

The work remaining to complete the initial phase of the Flint Water Treatment Plant Improvements Project is:

- Project Delivery, Procurement, and Value Engineering Workshop – Tentatively scheduled for February 2017.
- Develop the Compliance Testing Procedure.
- Begin monthly jar testing in February 2017.

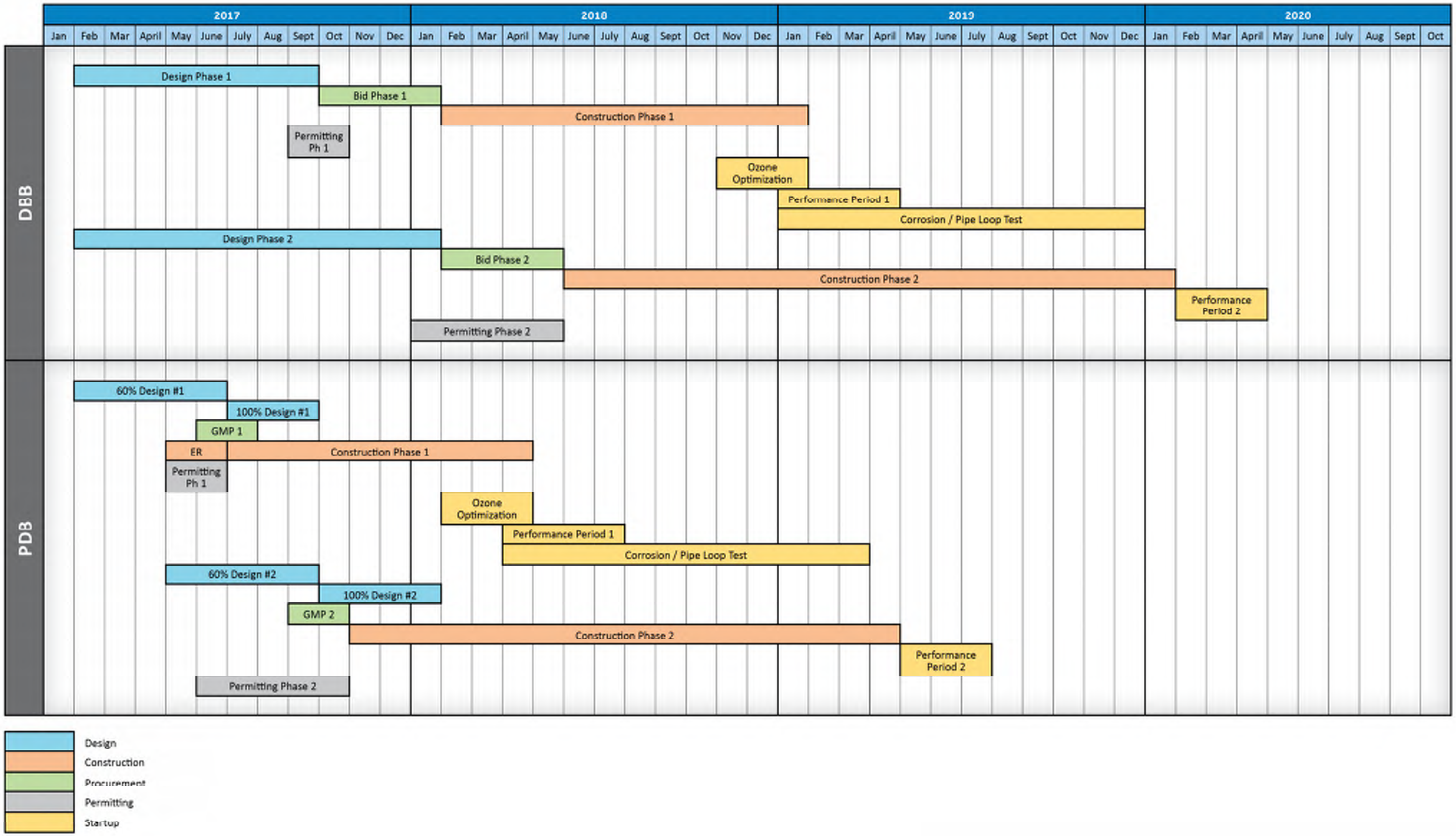

Figure 1.1 – Comparison of Estimated Design and Construction Durations

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Section 2

Introduction

2.1 Background

The Flint Water Treatment Plant (WTP) will be receiving raw water from Lake Huron, through the Karegnondi Water Authority (KWA). This report provides an evaluation of the WTP and recommendations regarding process, mechanical, structural, electrical, and instrumentation improvements to the WTP intended to achieve the following objectives:

- Production and delivery of treated water that exceeds all drinking water primary and secondary standards with an appropriate margin of safety at minimum, average, and maximum plant production rates of 5, 14, and 24 million gallons per day (MGD) respectively.
- Operation and maintenance of the WTP with enhanced ease/simplicity, flexibility, safety, and reliability.
- Improved treatment, pumping, and operational efficiency.

CDM Smith worked with the City of Flint and the Michigan Department of Environmental Quality (MDEQ) to determine the scope, cost, and implementation schedule of improvements to meet these objectives.

2.2 Work Completed To-Date

The following work has been completed to prepare this report:

- Site Visits – A team of senior engineers conducted four visits to the plant to observe existing conditions.
- Review Available Data – The team (with assistance from City staff) gathered and reviewed the existing WTP design drawings, engineering reports, and operational data. Existing pilot plant data developed by the Genesee County Drain Commissioner (GCDC) to support design of the GCDC WTP was also reviewed. The team further reviewed information from other WTPs treating Lake Huron water.
- Raw Water Reservoir – Developed a planning-level concept of the reservoir configuration based on the identified volume of 42 million gallons (MG).
- Treatment Process Alternatives – Water quality goals were reviewed with the City and MDEQ. Feasible water treatment process alternatives were identified with respect to individual treatment process systems and the capability of the overall treatment process train to meet the water quality goals. These alternatives were evaluated based on their advantages and disadvantages. Based on this evaluation, a water treatment process train

for the WTP was developed along with a planning-level conceptual configuration. The following process systems were evaluated:

- Pre-oxidation.
- Rapid mix.
- Flocculation.
- Plate Settlers.
- Recarbonation basins.
- Filters.
- Filter backwashing.
- Residuals handling and disposal.
- Plant hydraulics.
- Chemical systems – Note that the required finished water quality parameters with respect to distribution system corrosion control will be provided to CDM Smith by Flint/MDEQ at a later date. For the purposes of this study, assumptions were made regarding corrosion control chemicals and chemical dosages.

- Pumping System Alternatives – Existing pumping conditions for raw water, filtered water, and finished water pumping systems were evaluated. Based on this evaluation, alternative improvements were identified and evaluated. Recommended planning level configurations were developed for each pumping system.
- Workshop on Treatment Process Alternatives – A workshop was conducted with MDEQ and the City to discuss the alternatives relative to the treatment process required for treating Lake Huron water.
- Workshop on Raw Water Reservoir and Pumping System Alternatives – A workshop was conducted with MDEQ and the City to discuss the available options for providing backup and pumping within the WTP and to present initial findings and recommendations.
- Condition Assessment Inspections – Condition assessments and condition evaluations were conducted on the following WTP components:
  - Structural inspections of the PS #4 Reservoir, Dort Reservoir, and the Ozone and WTP Buildings.
  - Architectural inspections of the Ozone and WTP Buildings.
  - Building mechanical inspections of the Ozone and WTP Buildings.
  - Electrical inspection of the plant power distribution system.

- Automation inspection of the existing supervisory control and data acquisition (SCADA) system.
- Process inspection of the existing mechanical equipment.

The condition assessments consisted of non-destructive visual assessment methods and discussions with WTP operations and maintenance staff. Recommendations were made regarding existing equipment repair or replacement. These condition assessments are found in the appendices of this report.

- Define Delivery Options – Project delivery options for the WTP improvements and the schedule impacts of each option were identified and evaluated.
- Design and Construction Schedules – In conjunction with the development of project delivery alternatives, preliminary design and construction schedules were developed for the improvements program.
- Cost Estimates – Preliminary opinions of probable construction cost were developed for each recommended improvement.

2.3 Work Remaining

The work remaining to complete the initial phase of the Flint Water Treatment Plant Improvements Project is:

- Project Delivery, Procurement and Value Engineering Workshop – Tentatively scheduled for February 2017.
- Compliance Testing Procedure – The WTP improvements may be brought on-line in phases with early completion of the process improvements to facilitate full-scale performance testing and operator training. A draft plan containing the key criteria for operation and performance testing of the WTP improvements will be developed.
- Jar Testing – An initial jar test will be conducted to assess the proposed treatment train for process operations and chemical needs. Raw water will be gathered from the existing pilot plant at the KWA raw water pumping station at Lake Huron and jar testing will be performed in the WTP laboratory.

2.4 Organization of this Report

This report is organized as follows:

- Section 1 – Executive Summary
- Section 2 – Introduction
- Section 3 – Raw Water Storage
- Section 4 – Water Treatment Improvements

- Section 5 – Chemical System Improvements
- Section 6 – Pumping System Improvements
- Section 7 – Cost of Recommended Improvements
- Section 8 – Project Delivery and Schedule

Section 3

Raw Water Storage

3.1 Introduction

A backup source of water is required so that the Flint Water Treatment Plant (WTP) can continue to supply potable water to customers in case there is a failure in the raw water supply system.

3.2 Backup Sources of Supply

Three potential backup water sources were evaluated to serve the Flint system should the pipeline supplying raw water to the WTP become inoperable. These three sources are:

- Onsite Raw Water Storage.
- Finished Water Storage.
- Connection with Adjoining System.

These options are discussed in more detail below.

3.2.1 Onsite Raw Water Storage

The WTP will be receiving water from Lake Huron, through the Karegnondi Water Authority (KWA). The raw water will be supplied via a new transmission main between the GCDC WTP and the Flint WTP. One option for a backup source of supply is a new onsite raw water storage reservoir at the Flint WTP. This option is discussed further below, beginning in Section 3.4.

3.2.2 Finished Water Storage

The WTP includes up to 20 million gallons (MG) of treated water storage onsite in the Dort Reservoir. This reservoir contains two separate 10 MG compartments. This reservoir provides disinfectant contact time to achieve the required disinfection credit prior to pumping to the distribution system. The WTP also includes an elevated storage tank for storage of finished water. The distribution system includes a number of ground storage and elevated storage facilities.

However, it is generally not recommended to use distribution system storage as emergency backup water supply because of water age issues. In order to ensure that a sufficient volume of water is available for emergency use, the total storage volume in the distribution system would need to be increased beyond what is necessary to address daily demand fluctuations and fire flow requirements. This increases the time that the water resides in the system before use and makes the maintenance of proper finished water chemistry more difficult. This is a particular issue for large systems serving a population that is smaller than that for which the system was originally designed, such as Flint. For this reason, finished water storage is not considered further.

3.2.3 Connection with Adjoining System

The GCDC is constructing a new WTP located at Stanley and Marathon Roads, scheduled to be operational in the fourth quarter of 2017. Once completed and following startup testing, this new WTP will produce finished water that will discharge into an existing 72-inch transmission main that currently conveys Great Lakes Water Authority (GLWA) water to GCDC and Flint. It would be possible to have the 72-inch transmission main serve as an emergency connection between the two systems. This is a common means by which adjoining utilities provide for emergency supply.

The City of Flint could negotiate an agreement with GLWA or GCDC to provide finished water directly to the Flint distribution system until the WTP improvements can be constructed and startup testing has been completed. After completion of the WTP improvements, the City of Flint could purchase 1 to 2 MGD of finished water from GLWA or GCDC to maintain water quality in the 72-inch transmission main so it can be used as an emergency source to meet the City of Flint's water demand with minimal prior notification.

3.3 Raw Water Transmission Components

The system that will convey raw water from Lake Huron to the Flint WTP will serve a number of communities, and includes multiple components. The overall system is shown schematically in **Figure 3.1**. It has been estimated that the water age from the time of withdraw at Lake Huron until it reaches the WTP may range from approximately six to 18 days depending upon flow rates and how the system is operated. The time between withdraw and treatment should be minimized as much as feasible to avoid potential water quality degradation. The different components are described in the following sections.

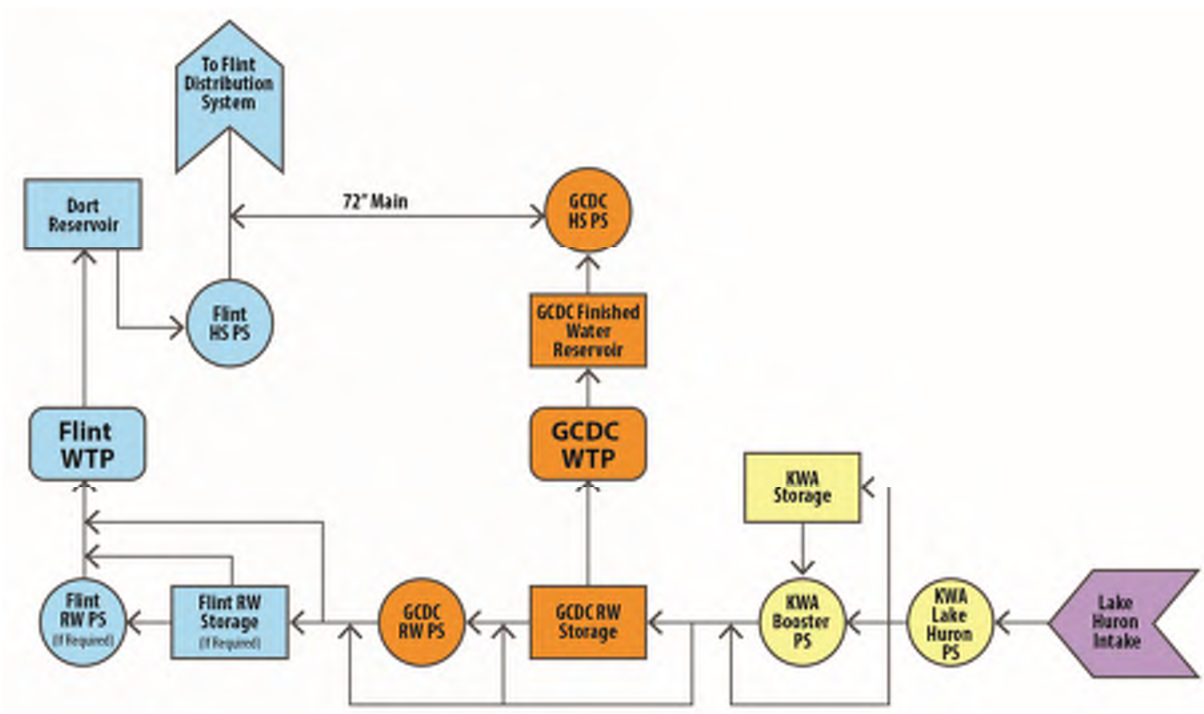

Figure 3.1 – Flint WTP Raw Water and Finished Water Conveyance Systems

3.3.1 KWA Lake Huron Intake

Lake Huron water enters the KWA raw water conveyance system through an intake which includes an intake crib approximately 1.5 to 2 miles off shore at a depth of 30 feet and a pipeline located on the floor of Lake Huron.

3.3.2 KWA Lake Huron Pump Station

Raw water entering the Lake Huron intake is pumped at the raw water pump station located at the Northwest corner of Fisher Road and Lakeshore Road just west of the Lake Huron shoreline. The pump station can pump up to 85 MGD. The pump station discharges flow into a 24-mile-long, 66-inch diameter raw water pipeline that carries raw water west along Fisher Road to the KWA Booster Pump Station. The volume in this discharge pipeline is approximately 22.5 MG.

3.3.3 KWA Booster Pump Station

The KWA Booster Pump Station is located at Hull Road and Martin Road. This pump station includes a closed raw water storage basin of 4 MG and discharges into a 25.5-mile-long, 60-inch diameter raw water pipeline that conveys flow to the GCDC WTP. This pumping station is configured so that under lower flow conditions, it can be bypassed. The volume in this discharge pipeline is approximately 19.8 MG.

3.3.4 GCDC Raw Water Impoundment and Pump Station

A 125 MG open impoundment at the GCDC Raw Water Pump Station provides a backup raw water supply in case there is an interruption to the raw water supply from Lake Huron.

The GCDC Raw Water Impoundment and Pump Station are configured as shown in **Figure 3.2**.

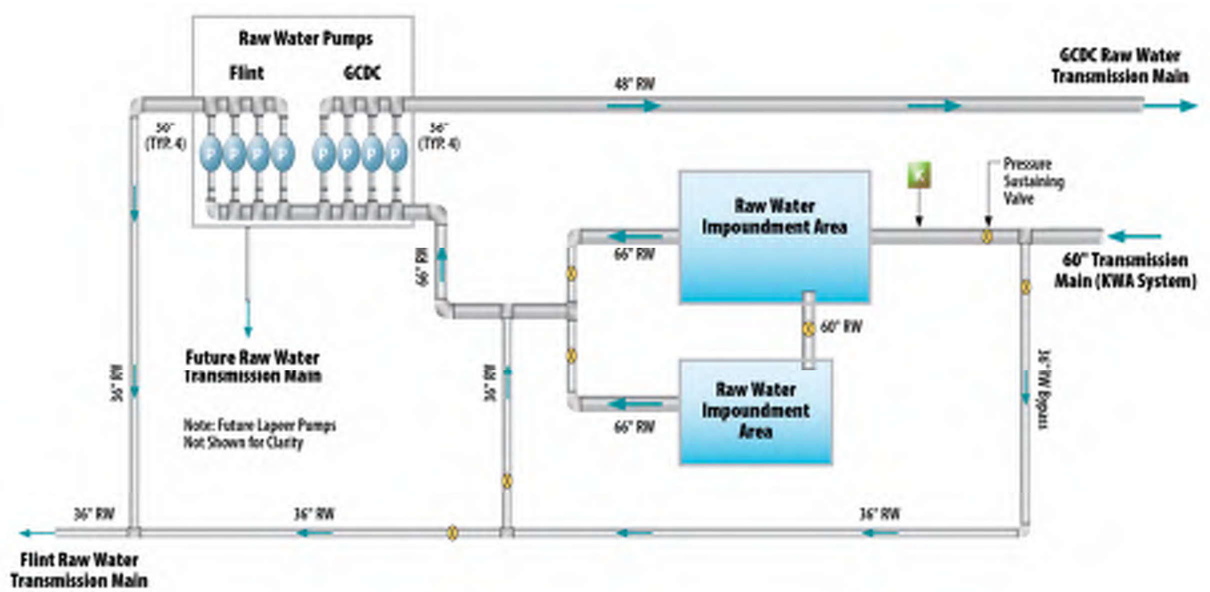

Figure 3.2 – GCDC Raw Water Pump Station Configuration

It is anticipated that raw water will typically be conveyed to the raw water impoundment and from there pumped to the GCDC WTP. A separate set of raw water pumps are provided to convey raw water from the impoundment to the Flint WTP. Raw water can also bypass the raw water impoundment and be conveyed directly to the Flint WTP through the Flint raw water pumps, and, if sufficient head is available, bypass the GCDC Raw Water Impoundment and Pump Station and be conveyed to the Flint WTP directly from the KWA Booster Pump Station. The transmission main connecting the GCDC Raw Water Impoundment and Pump Station and the Flint WTP is 17.3-mile-long, 36-inch diameter. The volume in the main is approximately 4.8 MG.

There are 4 pumps in the GCDC Raw Water Pump Station serving the City of Flint, each with a design capacity of 6 MGD, with a firm capacity of 18 MGD.

3.4 Raw Water Storage Issues

The Michigan Department of Environmental Quality (MDEQ) requires that reliable drinking water is provided to customers of public water treatment systems. As described above, if there is a disruption in the raw water supply to the WTP, reliability in the drinking water supply could be provided by either onsite raw water storage or an emergency connection arrangement between the City of Flint and GCDC. With respect to the storage option, the following issues impact the development of alternative design approaches.

3.4.1 Flint WTP Capacity

The City of Flint WTP is being configured to provide a maximum daily flow of 24 MGD, average daily flow of 14 MGD, and a minimum daily flow of 5 MGD.

3.4.2 Transmission Main Repair Time

The raw water pipeline from the GCDC WTP to the Flint WTP is 17.3-mile-long, 36-inch diameter, and is being constructed of ductile iron pipe. Given the size and material, spare fittings and pipe components can be kept on hand to facilitate a rapid response to a break. It has been estimated by others that a repair could be completed within 3 days of a break along this section of pipeline.

Repair to sections of the raw water transmission main upstream of the GCDC Raw Water Impoundment and Pump Station may take additional time given the 60-inch and 66-inch pipeline size, but, as discussed above, the GCDC Raw Water Impoundment includes 125 MG, which could be utilized if a break were to occur in this section. Therefore, a duration of 3 days is assumed as the time during which an emergency supply of raw water should be provided.

3.4.3 Storage Volume Requirements

Given an average daily flow at the Flint WTP of 14 MGD, 42 MG of raw water storage would provide 3 days of emergency supply.

3.4.4 WTP No. 1 Demolition

While the space available at the Flint WTP site is limited, locating the raw water reservoir off-site presents other potential failure modes, such as failure of the pipelines between the reservoir and the Flint WTP. Therefore, this evaluation focused on on-site options for raw water storage.

The Flint WTP site includes the abandoned WTP No. 1, which covers an area of almost 10 acres. The facility is unused for any purpose and has recently had some façade structural failures. It would be necessary to remove this WTP and associated underground tanks, if raw water storage were to be constructed at the Flint WTP.

The WTP No. 1 building structures were constructed in multiple phases, and extend about 80 feet above the surrounding area. The demolition of this facility would likely include the adjoining sedimentation tanks with a bottom elevation of about 720 feet, as well as the filter gallery and clearwell, with a bottom elevation of about 710 feet.

With respect to the environmental issues of asbestos and lead paint, it is understood that asbestos abatement has been completed. Typically, lead paint on interior equipment can be managed during construction with air monitoring. The debris from the demolition would be handled by crushing the concrete, providing the rebar and other metals to scrap metal recyclers, and the remaining materials disposed of in demolition landfills. It is likely that the demolition can be completed in 4 to 6 months.

3.5 Raw Water Storage Options

There are several raw water storage options that can be considered for the Flint WTP site that would work within the available space and provide adequate storage. Each of these options must meet the following requirements:

- Provide minimum storage of 42 MG, with additional storage providing some operational flexibility.
- Fit on the available 10 acres of available space of the WTP property.
- Be configured is such a way as to minimize the time raw water resides in the facility to help maintain consistent raw water quality.
- Include means for cleaning out any accumulated sediment.
- Provide means to chlorinate to remove colonizing algae, plants, or mussels.
- Include multiple cells if possible to provide some storage while maintenance is performed to each cell.

3.5.1 Surface Impoundment

Surface impoundments are often used to store raw water prior to treatment. Since the raw water is not treated, open storage is not a significant issue; however, potential degradation of the water quality by algae or plants that colonize the impoundment would need to accounted for.

From the available soil borings taken from the various phases of the construction of WTP No. 1, and more recent soil borings taken adjacent to this site, the soils appear to be variable clay and silty clay soils. Given the limited information, it appears that these soil types vary across the site. Therefore, there could be some variable long-term settlement of the impoundment. In addition, the typical pool elevation of the Flint River is about 709 feet, suggesting that the groundwater level on the site is above that elevation. It is recommended that the bottom of the impoundment not extend below approximately elevation 715 feet, to allow for construction and emptying of the basin for maintenance at times of normal water levels. The basin would need to store a minimum volume of water when the Flint River elevation is above normal levels to prevent heaving of the bottom of the impoundment caused by higher ground water levels.

To accommodate these variable settlement conditions, a geomembrane is recommended for the liner material. Additionally, the berms around the basin should incorporate an impervious core and possibly a cutoff wall to lower the groundwater below the footprint of the impoundment. A maximum 3:1 slope is recommended for both sides of the berm to allow maintenance of the facility. The slope stability considerations of the river bank, seepage and piping potentials beneath the proposed berms have to be considered in the detailed design of the impoundment in selecting final slopes and configurations of the berms. A crest roadway of about 12-foot width is recommended to allow maintenance of the berm. The elevation of typical water level should be protected by a layer of rip rap to prevent damage from erosion from wave action or by ice acting on the soil-water interface.

Using these design criteria and the maximum available site area, a water depth of 25 feet is required to provide 42 MG of storage. This would extend the normal water level to elevation of 740 feet, which is 10 feet above the surrounding area. The berm should extend to approximately elevation 745 feet around the perimeter of the impoundment. **Figure 3.3** shows a proposed layout of the impoundment on the WTP site, which maximizes use of the site, but retains the ozone facility and the new electrical substation located to the north of the site. This arrangement also prevents the need to relocate any existing yard piping.

Figure 3.3 – Earthen Berm Impoundment Plan View

Considering the assumptions used in the development of this concept, the proposed earthen berm impoundment appears to be feasible; however, the concept needs to be further investigated and refined by considering the actual topography of the site, site specific geotechnical investigations especially by the riverbank, geomorphology considerations in the river channel, and the stability of the river bank. The proposed facility does not include multiple cells because there is not space available to bifurcate the impoundment without reducing the volume of the facility below the required 42 MG. Draining and maintenance would have to be performed during low demand periods to minimize the impact on operations. A profile view of the impoundment relative to the other facilities located at the WTP site is shown in **Figure 3.4**.

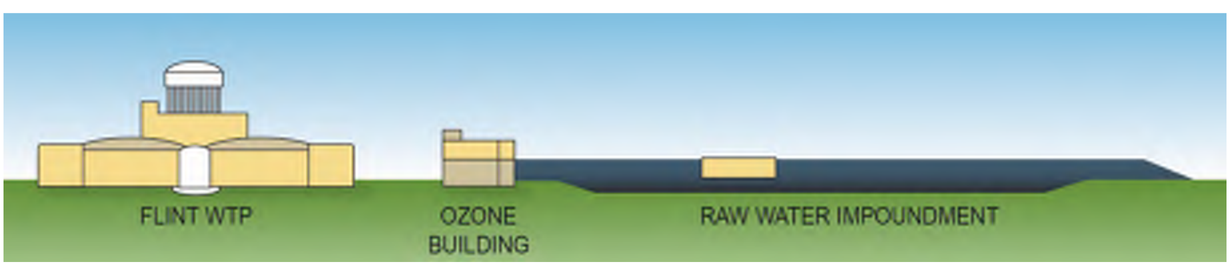

Figure 3.4 – Earthen Berm Impoundment Profile View

3.5.2 Open Top Prestressed Concrete Tank(s)

Different types of structural tanks can also be used to store raw water prior to treatment. Typically, the most economical type of structural tanks are prestressed concrete panel tanks that utilize a steel membrane cast into structural concrete panels. The panel sections are arranged in a circular pattern on a base membrane slab and then are wound with reinforcing wire arranged in layers. Gunite is applied to protect the reinforcement as additional layers of reinforcement are added. The wires are arranged to provide the correct amount of reinforcement for the water pressure forces exerted on the concrete panels. These concrete tanks can be constructed with or without tops.

As noted before, the available soil borings taken from the various phases of the construction of WTP No. 1 and more recent soil borings taken adjacent to this site indicate that the soils appear to be variable clay and silty clay soils, and it appears that these soil types vary across the site. An engineered fill would be required to provide a proper foundation for the tanks and prevent variable long-term settlement beyond what the system can accommodate. Since it is assumed that the demolition will excavate to about elevation of 720 feet, an additional 5 feet of engineering fill should be provided as a base for the foundation slab for the prestressed tanks.

As noted before, these tanks are built with a concrete membrane base, including a concrete foundation ring under the panel walls to provide a uniform base. Inlet and outlet pipes typically enter through this foundation, and internal piping is provided to convey water to the inlet and outlet locations within the tanks as required.

Figure 3.5 shows a proposed layout of open tanks on the WTP site, which utilizes a portion of the WTP No. 1 site east of the existing WTP. The remainder of the WTP No. 1 site can be made available for other uses. The tanks have been located adjacent to the ozone facility and the placement allows a larger buffer from the new electrical substation located to the north of the WTP site. This arrangement prevents the need to relocate any existing operational yard piping. The figure also shows a potential location for the raw water pump station just west of the tanks.

Using a tank floor elevation of 725 feet, and an assumed diameter of 300 feet, two tanks with a sidewater depth of 40 feet can provide the needed volume of 42 MG. The normal water level in these tanks would be at elevation 765 feet, with the top of wall elevation extending to elevation of 770 feet to provide 5 feet of freeboard. **Figure 3.5** and **Figure 3.6** show a plan view and profile view, respectively, of the tanks on the Flint WTP site.

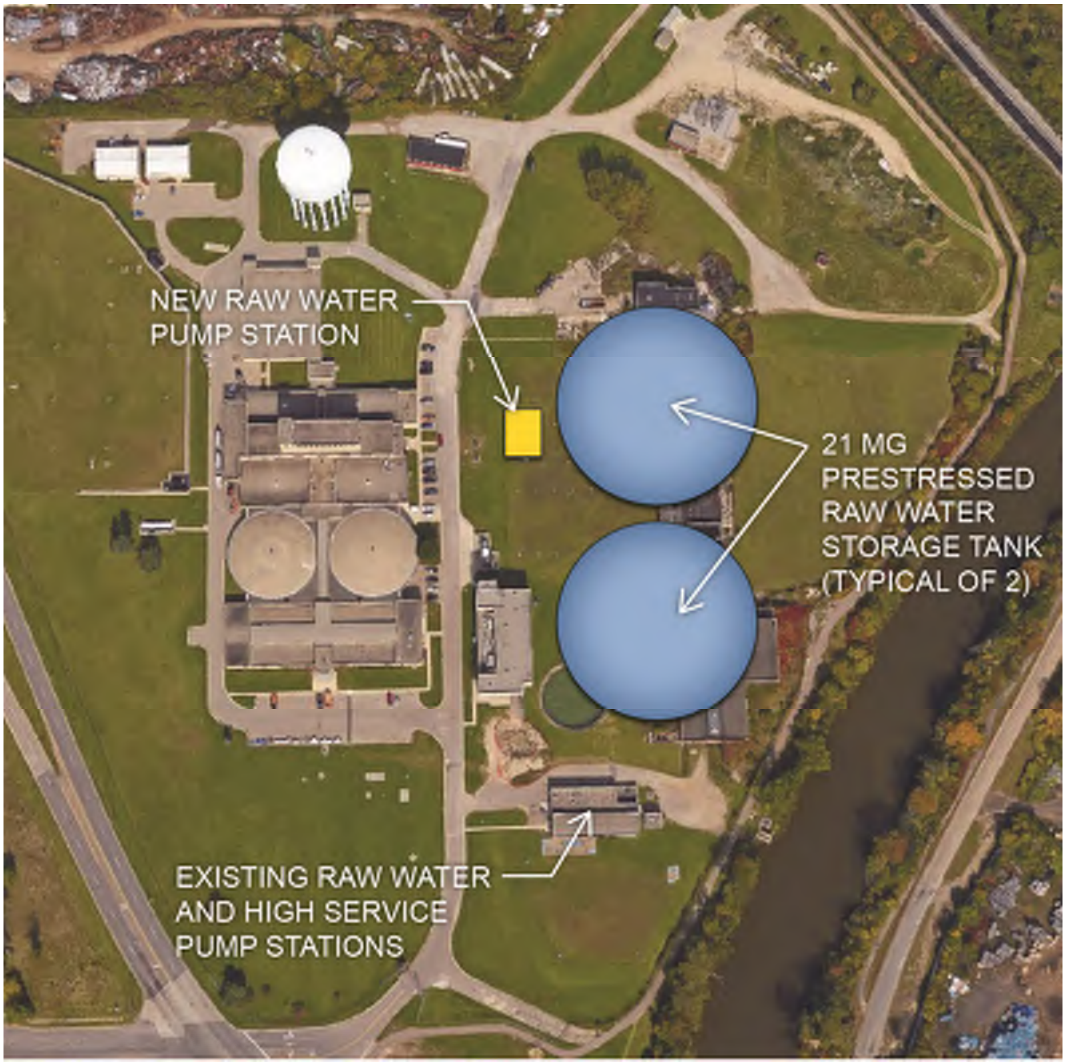

Figure 3.5 – Open Top Prestressed Concrete Tanks Plan View

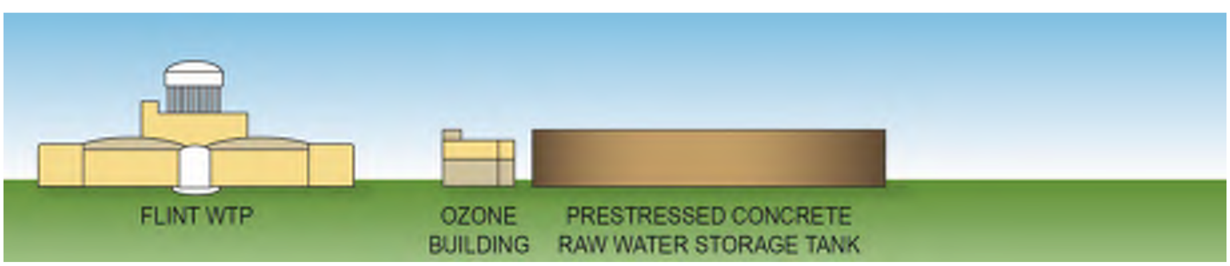

Figure 3.6 – Open Top Prestressed Concrete Tanks Profile View

3.5.3 Closed Top Prestressed Concrete Tank(s)

The closed prestressed concrete tank option is similar to the open top tank option, except that there is a reinforced concrete top slab provided. The size of these tanks exceeds the diameter that can support a domed concrete cover without internal supports. The cover would need to be constructed using a series of structural support columns, and, given the height of the tank, these columns would need to be self-supporting. The top slab would invariably sag slightly and develop low areas across the cover that may accumulate water. The slab would therefore require periodic maintenance to remove biological growth and repair the damage that can occur with the freeze-thaw cycle.

If a closed top prestressed concrete tank is desired by the City of Flint, the use of floating covers to reduce the capital cost of the tanks can be explored further during detailed design.

3.6 Operational Considerations

Raw water storage facilities need to be operated as part of the overall WTP system and design must take into account the following considerations.

3.6.1 Influent Flow Control

Flow into a raw water storage facility at the Flint WTP will be controlled by the GCDC raw water pumping station if raw water is pumped from the GCDC raw water impoundment. This design calls for a pressure sustaining valve to be located at the Flint WTP to maintain a hydraulic grade line (HGL) of approximately 835 feet. The raw water pumps at the GCDC would then pump against this head to provide the desired flow to maintain the desired inventory and level in the selected raw water storage facility. The exact KWA operational strategy for delivering water to the City of Flint still needs to be determined. The firm capacity of this pumping station is shown as 18 MGD in the available design report for the GCDC WTP Basis of Design report.

Table 3.1 provides the expected operating levels in the GCDC Raw Water Impoundment and the two options being considered for raw water storage at the Flint WTP.

Table 3.1 – System Tank Elevations

	GCDC Raw Water Impoundment	Flint WTP Impoundment	Flint WTP Prestressed Tanks
Empty Elevation (ft)	810	715	725
Full Elevation (ft)	837	740	765
Water Depth (ft)	27	25	40

It is notable that the full water level in the WTP impoundment option is 97 feet lower and the prestressed tank option is 72 feet lower than the normal operating level of the GCDC Raw Water Impoundment. Given these differences in elevation, it is possible that under typical operating conditions the line pressure available from KWA may also be used to convey the raw water to the WTP without repumping at the GCDC Raw Water Pump Station. As shown in Figure 3.2, there is an option for allowing flow from the KWA transmission system to bypass the GCDC Raw Water Impoundment and to be conveyed by line pressure to the WTP.

The control of this flow from GCDC to the City of Flint should be considered further in final design of the WTP to minimize power consumption of the system and reduce costs for customers. Depending on the selected raw water storage option for Flint, the raw water pumps at GCDC may only be needed for peak flow conveyance, and when sufficient line pressure is not available and raw water needs to be pumped from the GCDC Raw Water Impoundment.

3.6.2 Raw Water Pumping

At the Flint WTP, raw water pumping will be necessary to convey flow from the raw water storage facility to the treatment process. The ozone influent channel is at approximately elevation 747 feet.

If the surface impoundment is selected for raw water storage, raw water pumping will be required for all levels within the impoundment given the peak water surface of elevation 740 feet. However, if one of the prestressed storage tank options is selected, there is the option of using the stored head in these tanks, which could be up to elevation 765 feet. This would require a control valve to adjust the flow rate to the WTP process.

Raw water pumping would still be required to make use of the tank if flow variations take the tank water surface below elevation 750 feet, when the tank is being used during a disruption in the upstream supply, or when the tank is being emptied for maintenance. If not typically used, the raw water pumping system would need to be routinely exercised to maintain it in operating condition.

In all scenarios, the raw water piping can be configured to allow bypassing of the onsite storage reservoir and raw water pump station to deliver water directly into the ozone influent channel at an elevation of approximately 747 feet.

3.6.3 Baffling and Mixing

Given the raw water conveyance rates between 5 and 18 MGD from KWA to the Flint WTP, the volume contained in the raw water transmission pipelines and associated raw water storage will increase the age of the raw water prior to reaching the Flint WTP treatment process. The overall age for raw water entering the Flint WTP is expected to range between 4 and 18 days, depending on the operation of the GCDC Raw Water impoundment and the treatment rates at both of the WTPs.

To provide high quality raw water, flow should enter one end of the impoundment or tank and be withdrawn from the other end. For a two-tank configuration, flows from one tank should pass through the next in series to reduce dead spots in the storage system. Baffling could be installed in the storage systems, but for storage options that are open, potential damage by freezing should be considered.

To reduce the potential for dead spots in the raw water storage facilities, the inlet and outlet structures can be located to facilitate mixing and cross-flow through the reservoir.

3.7 Operational Costs

Operational costs for each of the raw water storage alternatives are described below along with an estimate of the annual cost where possible.

3.7.1 Earthen Impoundment

Annual operational costs associated with the earthen impoundment raw water storage include the following:

- Raw water pumping for all flows.
- Periodic mowing of the berm, crest, and interior turf areas.
- Woody plant, weed, and aquatic vegetation removal from the earthen berm.
- Inspection for seeps around the earthen berm.
- Inspection for animal burrowing into the earthen berm and removal of nuisance animals.
- Maintenance of the raw water pumps.

3.7.2 Prestressed Concrete Tank(s)

Annual operational costs associated with the concrete prestressed tank raw water storage includes the following:

- Raw water pumping for a portion of the flow.
- Aquatic vegetation inspection and potential removal from the tanks.
- Inspection for leaks around the tank perimeter.
- Maintenance of the raw water pumps.

3.8 Raw Water Storage Evaluation

The different raw water storage options described above are compared in **Table 3.2**. This evaluation includes the following criteria for each storage option:

- Regulatory and Water Quality Issues.
- Operational Simplicity.
- Flexibility and Efficiency.
- System Reliability and Safety.
- Site Considerations.

This table includes a score for each of these criteria using the scale: 4) Excellent, 3) Good, 2) Marginal, 1) Poor. All of the criteria are equally weighted. Scores for each option are included at the bottom of the table.

Table 3.2 – Technical Comparison of Earthen Embankment Impoundment and Prestressed Concrete Tank Raw Water Storage Alternatives

Evaluation Criteria	Earthen Impoundment	Prestressed Open Top Concrete Tanks	Prestressed Closed Top Concrete Tanks
Regulatory and Water Quality Issues	Can achieve needed volume (42 MG), but larger volumes would be problematic	Can achieve needed volume (42 MG)	Can achieve needed volume (42 MG)
	Requires all of WTP No. 1 site for 42 MG volume	Can provide additional storage volume if needed (50 MG)	Can provide additional storage volume if needed (50 MG)
	Open storage has a low risk for security breaches and contamination	High wall of Open storage tank lowers risk for security breaches and contamination	Closed top has the lowest risk for security breaches and contamination of raw water
SCORE:	3	4	4
Operational Simplicity	Flow in and pump out would reduce operational adjustments	Ability to flow by gravity or PS would require more operator attention, although could decide to operate without gravity flow function	Ability to flow by gravity or PS would require more operator attention, although could decide to operate without gravity flow function
SCORE:	4	3	3
Flexibility and Efficiency	Required pumping for all modes of operation	Can utilize gravity discharge to process reducing a pumping process under typical operation	Can utilize gravity discharge to process reducing a pumping process under typical operation
		Raw water pumping required for cases when tanks not completely full	Raw water pumping required for cases when tanks not completely full
		Two tanks allow for maintenance or storage of high turbidity water if needed	Two tanks allow for maintenance or storage of high turbidity water if needed
SCORE:	3	4	4
System Reliability and Safety	Earthen embankments would require maintenance to prevent woody vegetation from damaging liner	Concrete walls would require limited maintenance	Concrete walls would require limited maintenance
	Potentially subject to uplift under high river elevations	Confined space entry required for maintenance	Confined space entry required for maintenance
	Entry for inspections and solids removal is more easily done		
	Higher risk of failure due to potential flooding impacts the Flint River		
SCORE:	2	4	4
Site Considerations	Tight to fit within existing WTP No. 1 footprint requires complete excavation	More easily fits within the WTP site allowing some material to remain onsite	More easily fits within the WTP site allowing some material to remain onsite

Evaluation Criteria	Earthen Impoundment	Prestressed Open Top Concrete Tanks	Prestressed Closed Top Concrete Tanks
	Limits future use of other areas on old WTP No. 1 site	More compact storage allows other uses of remaining area around tanks, and provides more buffer to tanks	More compact storage allows other uses of remaining area around tanks, and provides more buffer to tanks
	Requires about 1 construction season to complete (8 months)	Requires about 1 construction season to complete (8 months)	Requires about 1 year to complete (12 months)
		Tank SWD can be increase from 40' to 50' with no cost increase to reduce site footprint	Tank SWD can be increase from 40' to 50' with no cost increase to reduce site footprint
SCORE:	3	4	3
TECHNICAL RATED SCORE:	**3.0**	**3.8**	**3.6**

Table 3.3 includes the estimated construction costs for each of the raw water storage alternatives. Note that implementation of any of the raw water storage alternatives at the Flint WTP site requires demolition of WTP No. 1, the cost of which is estimated at $5.8 million. In addition, a raw water pump station is also required, the cost of which is estimated at $6.4 million. These costs are not included in the table because they are the same for each alternative and therefore not used in developing the raw water storage recommendation.

Table 3.3 – Cost Comparison of Earthen Embankment Impoundment and Prestressed Concrete Tank Raw Water Storage Alternatives

Evaluation Criteria	Earthen Impoundment	Prestressed Open Top Concrete Tanks	Prestressed Closed Top Concrete Tanks
Capital Cost	Impoundment: $30.1M	42 MG tanks: $37.0M	42 MG tanks: $47.5M

3.9 Recommendation

The estimated capital cost and technical scores for each raw water storage option are summarized in **Table 3.4**. Based on the results of this analysis, open-top prestressed concrete tanks are recommended as the most viable option to provide raw water storage at the Flint WTP site.

Table 3.4 – Summary of Raw Water Storage Alternatives

Option	Technical Score	Capital Cost
Earthen Impoundment	3.0	$30.1M
Prestressed Open Concrete Tank	3.8	$37.0M
Prestressed Closed Concrete Tank	3.6	$47.5M

As noted in section 3.2.3, it is recommended that the option of maintaining a connection between the Flint and GCDC water systems as a mean to provide an emergency water source to Flint in lieu of constructing a raw water storage facility on the Flint WTP site be explored.

Section 4

Water Treatment Improvements

4.1 Regulations and Water Quality Goals

4.1.1 Summary of Drinking Water Regulations

Drinking water is federally regulated by the United States Environmental Protection Agency (EPA) under the authority of the Safe Drinking Water Act (SDWA). The SDWA was established by Congress in 1974 to protect human health by regulating the nation's public drinking water supply. The SDWA was extensively amended in 1986 and in 1996. The SDWA regulations have been adopted by the Michigan Department of Environmental Quality (MDEQ) which has been given primary enforcement responsibility (also called primacy) by EPA for enforcing these regulations in Michigan.

A principal focus of the SDWA has been to set national contaminant-based drinking water standards, including both primary and secondary standards. The National Primary Drinking Water Regulations (NPDWR) are legally enforceable standards that apply to all public water systems and consist of maximum contaminant level goals (MCLGs), which are non-enforceable goals, as well as maximum contaminant levels (MCLs). MCLs are enforceable limits set as close to the MCLGs as practical, considering cost and feasibility of attainment. National Secondary Drinking Water Regulations (NSDWR), also referred to as secondary standards, are federally non-enforceable guidelines regulating contaminants that may cause human cosmetic effects (such as skin or tooth discoloration) or aesthetic effects in drinking water (such as taste, odor, or color). EPA recommends secondary standards to water systems, but does not require systems to comply.

4.1.1.1 Existing Regulations

Under the 1996 SDWA amendments, the EPA developed several regulations that were made effective over the last 20 years. The amendment regulations of particular relevance to Flint include: the Interim Enhanced Surface Water Treatment Rule (IESWTR), Long Term Stage 1 and Stage 2 Enhanced Surface Water Treatment Rules (LT1ESWTR and LT2ESWTR, respectively), Stage 1 and Stage 2 Disinfectants and Disinfection By-Products Rules (D/DBPR), revisions to the Total Coliform Rule (TCR), revisions to the Lead and Copper Rule (LCR), Fluoride Rule, and Filter Backwash Recycling Rule (FBRR). These regulations require that water systems meet MCLs and/or use certain treatment techniques to protect against adverse health effects. The regulations apply to turbidity, primary disinfection, microbial quality in the water distribution system (secondary disinfection), disinfection by-products (DBPs), corrosion by-products, and fluoride.

The contaminants relevant to Flint Water Treatment Plant (WTP) and the controlling regulations are summarized in **Table 4.1**. More details can be found at http://www.epa.gov/safewater/. Taste and odor are included here because they are relevant to Flint and are covered by the NSDWR. **Table 4.2** provides a legend for all of the abbreviations in this table and subsequent tables in Section 4.

Table 4.1 – Existing Drinking Water Regulations applicable to Flint WTP

Water Quality Category	Federal Regulation	EPA/MDEQ Regulatory Baseline
Turbidity	IESWTR LT2ESWTR FBRR	▪ ≤ 0.3 NTU in 95% of CFE measurements each month. ▪ Maximum 1 NTU in CFE. ▪ ≤ 0.5 NTU in IFE after 4 hours of continuous operation. ▪ ≤ 1 NTU in IFE at any time. ▪ Collect and report information to MDEQ on filter backwash recycle practices.
Primary Disinfection	SWTR LT2ESWTR	▪ 3-log Giardia reduction required across plant. ▪ 4-log virus reduction required across plant. ▪ 2.5-log Giardia, 2-log virus and 3-log *Cryptosporidium* removal credit by conventional treatment, or 2-log Giardia, 1-log virus and 3-log *Cryptosporidium* removal credit by direct filtration. ▪ 0.5-log Giardia and 2-log virus inactivation CT credit by chemical disinfection for conventional treatment, or 1-log Giardia, 3-log virus CT credit by chemical disinfection for direct filtration. ▪ 0 to 2.5-log additional *Cryptosporidium* reduction credit depending on assigned “treatment bin” in “microbial toolbox”.
Microbial Quality in the Distribution System	SWTR TCR/RTCR Stage 1 D/DBPR Stage 2 D/DBPR	▪ <5% monthly samples positive for total coliform. ▪ No E. Coli detections. ▪ Chlorine residual > 0.2 mg/L at distribution system entry point. ▪ Chlorine residual detectable in 95% of monthly samples. ▪ Chlorine residual < 4 mg/L RAA.
Disinfection By-Products	Stage 1 D/DBPR Stage 2 D/DBPR	▪ Identification of IDSE locations. ▪ TTHM ≤ 80 ug/L LRAA of quarterly samples. ▪ HAA5 ≤ 60 ug/L LRAA of quarterly samples. ▪ Enhanced coagulation for TOC removal. ▪ Bromate ≤ 10 ug/L RAA of monthly samples. ▪ Chlorite: 1.0 mg/L monthly average.
Corrosion By-Products	LCR	▪ Lead <0.015 mg/L in 90^{th} percentile. ▪ Copper <1.3 mg/L in 90^{th} percentile. ▪ Optimized corrosion control practices as defined by LCR.
Taste and odor	NSDWR	▪ < 3 odor threshold number.
Fluoride	Fluoride Rule	▪ CDC health guidance value: 0.7 mg/L ▪ 2 mg/L secondary standard. ▪ 4 mg/L MCL.

Table 4.2 – Legend for Tables 4.1 and 4.3

Acronym	Description
AL	Action Level
CECs	Chemicals of emerging concern
CFE	Combined filter effluent
CT	Product of disinfectant concentration (C) times contact time (T)
D/DBPR	Disinfectant/Disinfection By-Products Rule (Stages 1, 2, and 3)
DAF	Dissolved air flotation
EDCs	Endocrine disrupting compounds
EPA	United States Environmental Protection Agency
FBBR	Filter Backwash Rule
GAC	Granular activated carbon
HAA5	Five regulated Haloacetic Acids
HAA9	Nine Haloacetic Acids
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule
IFE	Individual filter effluent
IPS	Inclined plate settlers
LCR	Lead and Copper Rule
LRAA	Locational running annual average
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MDEQ	Michigan Department of Environmental Quality
mg/L	Milligrams per liter
MIB	Methyl isoborneol
NDMA	Nitrosodimethylamine
NSDWR	National Secondary Drinking Water Regulations
NTU	Nephelometric turbidity units
PPCPs	Pharmaceutical and personal care products
RAA	Running annual average
Reg-Det3	Third Regulatory Determination
SWTR	Surface Water Treatment Rule
TCR/RTCR	Total Coliform Rule/Revised Total Coliform Rule
TOC	Total Organic Carbon
TON	Threshold odor number
TTHM	Total Trihalomethanes
UCMR4	Fourth Unregulated Contaminant Monitoring Rule
UFRV	Unit Filter Run Volume
ug/L	Micrograms per liter
UV	Ultraviolet irradiation
UV_{254}	Ultraviolet Absorbance at 254 nm

4.1.1.2 Potential Future Regulations

Table 4.3 presents possible changes to existing regulations and possible new regulations that are relevant to the City of Flint. Changes that might be anticipated include: tightening of filter effluent requirements; treatment of filter backwash water before it is returned to the head of the plant; establishing a minimum disinfectant residual throughout the distribution system; expanding the haloacetic acid (HAA) regulation to include all nine brominated and chlorinated HAAs; lowering the bromate MCL; setting MCLs for nitrosamines, chlorate and perchlorate; and, reducing the action level for lead.

There has been a lot of interest in the waterworks industry over the past 10 years concerning blue-green algae and cyanotoxins, especially in lakes and reservoirs. Ten cyanotoxins are currently listed in the EPA's fourth Unregulated Contaminants Monitoring Rule (UCMR 4; see https://www.epa.gov/dwucmr/fourth-unregulated-contaminant-monitoring-rule). It is possible that EPA will issue health advisories for several of them. A number of other chemicals of emerging concern (CECs), such as endocrine disruptors (ECs) and pharmaceutically active and personal care products (PPCPs) are also the subject of much research and are listed in UCMR4, but it is unlikely that a regulation will be proposed in the near future. However, a requirement to install granular activated carbon (GAC) might be considered for utilities withdrawing water from vulnerable water supplies. (This is not the case for Lake Huron.)

The high quality of Lake Huron water, in combination with recommended treatment process improvements such as ozonation and biologically active filters, will make meeting such future regulations on DBPs, CECs, ECs and PPCPs less challenging.

Table 4.3 – Potential Future Drinking Water Regulations applicable to Flint WTP

Water Quality Category	Federal Regulation	EPA/MDEQ Regulatory Baseline
Turbidity	LT3ESWTR? Revised FBRR	▪ Same as existing regulations for turbidity with potential tighter limits on IFE and CFE performance. ▪ Potential requirements for treatment of filter backwash water.
Primary Disinfection	LT3ESWTR?	▪ Same as existing regulations. AND ▪ 3-log Crypto disinfection credit when using UV? ▪ Revision of assigned Crypto credits for different "treatment bins"?
Microbial Quality in the Distribution System	RTCR2?	▪ Same as existing regulations AND ▪ Minimum disinfectant residual throughout distribution system (i.e., >0.1 or 0.2 mg/L free chlorine)
Disinfection By-Products	Stage 3 D/DBPR? UCMR4 Reg-Det 3	▪ TTHM ≤ 80 ug/L LRAA of quarterly samples ▪ HAA9 ≤ 80 ug/L LRAA of quarterly samples? ▪ Enhanced coagulation for TOC removal ▪ Bromate ≤ 5 ug/L RAA of monthly samples? ▪ Chlorite ≤1.0 mg/L monthly average ▪ NDMA: future Federation regulation likely (i.e., 10 ng/L?) ▪ Perchlorate: future Federal regulation likely (i.e., 6-15 ug/L?) ▪ Chlorate: future Federal regulation likely (i.e., 0.21 mg/L?)

Water Quality Category	Federal Regulation	EPA/MDEQ Regulatory Baseline
Corrosion By-Products	Revised LCR	▪ Lead <0.010 mg/L in 90th percentile? ▪ Copper <1.3 mg/L in 90th percentile ▪ Optimized corrosion control practices as defined by LCR
Taste and odor	NSDWR	▪ Same as existing regulation
Fluoride	Fluoride Rule	▪ Same as existing regulation
Cyanotoxins	UCMR4 Reg-Det3	▪ 10-day health advisories: ▪ children <6 years 0.3 ug/L for microcystins and 0.7 ug/L for cylindrospermosin ▪ children >6 years and adults 1.6 ug/L for microcystins and 3.0 ug/L for cylindrospermosin
CECs/EDCs/PPCPs	UCMR4 Reg-Det3	▪ No Federal regulation expected, although a requirement to install GAC might be considered for vulnerable water supplies

4.1.2 Water Quality Goal-Setting Process

The development and selection process for setting water quality goals for the WTP involved the following steps:

- Identify existing and future water quality regulations applicable to the WTP (see Tables 4.1 to 4.3).
- Identify key water quality and treatment considerations based on a review of Lake Huron raw quality data and experiences with other water treatment facilities withdrawing water from Lake Huron, in combination with the water quality regulations review.
- Establish two categories of water quality goals:
  - Current goals – Regulatory baseline, considering EPA and MDEQ regulations, and how they apply to existing Flint water treatment processes.
  - Future goals – Industry best practices based on progressive-utility operations, i.e., American Water Works Association's (AWWA's) Partnership for Safe Water, etc.; potential new regulations; process optimization; and, enhanced water treatment process implementation.
- Identify treatment process train alternatives to meet the water quality and treatment issues identified.
- Develop a bench-scale testing program and full-scale verification plan to achieve water quality and operational goals.

4.1.2.1 Recommended Initial Goals and Treatment Process Alternatives

Table 4.4 summarizes the processes alternatives considered to address the water quality and operational goals relevant at the WTP. The bullets below outline the reasoning for each of these goals.

- ***Turbidity Goals*** – For turbidity, the goals are expressed in terms of the combined filter effluent (CFE) and each individual filter effluent (IFE), filter run time and productivity (unit filter run volume (UFRV)), and filter backwash water. To achieve these goals, process options consist of: a) preoxidation with low doses of chlorine or ozone for purposes of aiding coagulation, b) high-rate sedimentation with inclined plate settlers (IPS), and c) dual media filtration with GAC over sand or anthracite over sand. In the latter case (anthracite/sand), chlorine can be applied ahead of or after the filters. The filters are expected to operate in a biological mode because there will be no residual disinfectant in the water as it is applied to the filters, unless the pre-filter chlorine option with anthracite/sand media is selected. To meet the specified goals with the selected process alternatives, bench-scale testing will be needed to optimize the type and dose of coagulants for KWA water preoxidized with chlorine or ozone, the optimal pH of coagulation, and the optimal dose of preoxidant. Subsequent full-scale verification will be needed to fine-tune the results from the bench-scale testing and to optimize filter operation to achieve the specified operational targets.

- ***Primary Disinfection*** – For primary disinfection, chlorine will be used to meet CT requirements, with a margin of safety of 50 percent as the goal, i.e., the CT achieved after the application of sodium hypochlorite should be 50 percent higher than the required CT for the given pH, chlorine residual, and temperature ($CT_{actual}/CT_{required} = 1.5$). The requisite CTs can be achieved in the Dort Reservoir, after filtration. No CT credit is expected from the low preoxidant doses of ozone or chlorine. To meet this goal, bench-scale testing of the kinetics of chlorine decay will need to be conducted for different seasons to determine the CT achieved for different doses of chlorine and different treated water pHs. The findings from the bench-scale studies will need to be validated with full-scale testing.

- ***Secondary Disinfection*** – Secondary chlorination will be used for control of microbial quality in the distribution system, after primary disinfection is achieved with free chlorine in the Dort Reservoir. The operational goal to assure that microbial quality is acceptable is that there should be no detection of total coliform bacteria or *E. Coli* during the monthly monitoring program conducted in accordance with the requirements of the revised TCR. An operational goal of a minimum detectable residual (i.e., 0.1 or 0.2 mg/L for free chlorine) at all locations is suggested, rather than a "detectable" residual as stated in the revised TCR. However, ongoing pipe loop investigations at the WTP under a separate project may require a higher minimum free chlorine residual as part of an optimized corrosion control strategy for the City of Flint water distribution system.

- ***Disinfection By-Products (DBPs)*** – For DBPs, the goal is to not exceed 80 percent of the MCL for bromate (a potential contaminant in hypochlorite solutions and a by-product of ozonation). Additionally, the goal is to comply with the TOC removal requirements specified in the enhanced coagulation matrix in the D/DBP Rules, unless raw water TOC values are less than 2 mg/L and the 30/40 THM/HAA exemption applies. An operational goal of 0.03 cm^{-1} for ultraviolet absorbance at 254 nm (UV_{254}) for filtered water is recommended to minimize DBP formation by subsequent chlorination. An alternative approach to achieve these goals is to delay chlorination until DBP precursors are removed. The latter can be accomplished by: a) applying chlorine after coagulation and IPS sedimentation, and carrying free chlorine through anthracite/sand dual media filters (non-biological filtration); or, b) applying chlorine after coagulation, IPS sedimentation, and biofiltration through either GAC/sand or anthracite/sand dual media filters. If free chlorine is to be used as a pre-treatment coagulant aid, low doses should be used to minimize DBP formation. The different coagulants and pH conditions being tested for turbidity removal should be assessed at bench-scale for their ability to remove DBP precursors (TOC, UV_{254}). If necessary, consideration should be given to enhancing TOC removal beyond the requirements specified in the enhanced coagulation matrix. DBP formation in the treated water should be measured under simulated distribution system (SDS) conditions.

- ***Corrosion Control*** – The water quality and operational goal for corrosion by-products is to meet the corrosion control indices established by the U.S. EPA and MDEQ. For homes exceeding the lead action level of 0.015 mg/L, a detailed follow-up is required. The treatment alternative to meet this goal is the corrosion control strategy directed by MDEQ.
- ***Taste and Odor Control*** – For taste and odor, the recommended water quality goals should be a taste and odor threshold number (TON) of less than 3, no objectionable taste and odor year-round, and maximum geosmin and MIB concentrations of 10 ng/L for each. Process alternatives employing GAC media should allow these goals to be met, whether ozone or chlorine is used as a preoxidant to assist in coagulation. If GAC is not employed, ozonation is an alternative barrier to taste and odor. To assure the specified goals are met, it is recommended that a routine sampling program for threshold odor number, geosmin, and MIB be implemented.
- ***Fluoride*** – The operational goal for fluoride is to meet the target dose based on daily monitoring, recognizing that the U.S. EPA recommends a concentration of 0.7 mg/L based on relatively recent reports from the Centers for Disease Control and Prevention (CDC).

Table 4.4 – Recommended Initial Water Quality and Operational Goals

Water Quality Category	Water Quality and Operational Goals	Treatment Process Alternatives	Treatment Refinements/Optimization
Turbidity	▪ Regulatory compliance ▪ Turbidity ≤ 0.10 NTU for CFE, 95% of the time ▪ Turbidity ≤ 0.30 NTU for IFE, 95% of the time ▪ Filter runtime of 72+ hours ▪ UFRV of 9,000 gal/ft²/run ▪ Limit filter recycle flows to < 5% of incoming plant flow	▪ Preoxidation with chlorine, IPS sedimentation and GAC/sand biofiltration ▪ Preoxidation with ozone, IPS sedimentation and anthracite/sand biofiltration ▪ Equalization and filter backwash recycle to head of plant ▪ Equalization and filter backwash clarification and recycle to head of plant	▪ Optimize coagulants ▪ Optimize coagulation pH (consider reuse of CO2 system) ▪ Optimize Cl2 dose for preoxidation ▪ Optimize ozone dose for pre-oxidation ▪ Optimize filter media selection and depth for longer run times and higher UFRV ▪ Optimize filter backwash sequence, clarification and recycle flows
Primary Disinfection	▪ Chlorine Inactivation Ratio of 1.5 (CT_{calc}/CT_{req})	▪ Chlorine CT in Dort Reservoir	▪ Optimize Cl2 dose and contact time for CT compliance

Water Quality Category	Water Quality and Operational Goals	Treatment Process Alternatives	Treatment Refinements/Optimization
			▪ Optimize pH to maximize CT with Cl2 ▪ Develop automated control strategy for chlorine CT compliance
Microbial Quality in the Distribution System	▪ Operational goal of 0 detects in distribution system for Total Coliform and E. Coli ▪ Maintain minimum free chlorine residual in distribution system of 0.1 to 0.2 mg/L ▪ Maintain minimum free chlorine residual of 0.4 mg/L, if required by corrosion control optimization study	▪ Free chlorine in distribution system	▪ Establish minimum free chlorine residual in distribution system
Disinfection By-Products	▪ Meet TOC removal requirements per enhanced coagulation matrix ▪ TTHM/HAA5 80% of MCL (64/48 ug/L) ▪ Bromate 50% of MCL (< 5 ug/L) ▪ Operate hypochlorite system to minimize by-product formation ▪ UV_{254} after filtration ≤ 0.03 cm^{-1}	▪ Preoxidation with chlorine, IPS sedimentation, GAC/sand filtration with or without pre-filter chlorine ▪ Preoxidation with ozone, IPS sedimentation, anthracite/sand biofiltration ▪ Minimal doses of Cl2 for preoxidation prior to coagulation	▪ Evaluate coagulants for precursor removal by clarification and filtration ▪ Exceed TOC removal requirements of the enhanced coagulation matrix (unless exempted) ▪ Reduce water age in distribution system ▪ Monitor hypochlorite delivery and storage time to avoid product degradation
Corrosion By-Products	▪ Meet corrosion control indices established by USEPA and MDEQ	▪ Implement corrosion control strategy, as directed by MDEQ	▪ Optimize corrosion control chemicals to meet corrosion control indices and pH targets
Taste and odor	▪ TON <3 ▪ No objectionable taste and odor year round ▪ Geosmin < 10 ng/L ▪ MIB < 10 ng/L	▪ Pre-chlorine with IPS sedimentation and GAC biofiltration ▪ Pre-ozone with IPS sedimentation with anthracite/sand biofiltration	▪ Initiate routine sampling program for threshold odor number, geosmin, MIB
Fluoride	▪ Meet fluoride dose target based on daily monitoring	▪ Fluoride chemical feed system	▪ 0.7 mg/L target (based on EPA risk assessment)

4.1.2.2. Potential Future Goals and Treatment Process Alternatives

Table 4.5 summarizes potential future water quality and operational goals and alternative processes to achieve each goal. As indicated in Table 3.5, it is possible that EPA will make rule changes during their congressionally-mandated Six-Year Review currently scheduled for (2022)., i.e., there may be a third Long-Term Enhanced Surface Water Treatment Rule (LT3ESWTR), a third Disinfectants/Disinfection By-products Rule (Stage 3 D/DBPR), a revised Filter Backwash Rule (FBRR), another Revised Total Coliform Rule (TCR), and another Revised Lead and Copper Rule (LCR). Additionally, the findings from the fourth Unregulated Contaminants Monitoring Rule (UCMR4) may lead to the third Regulatory Determination (Reg-Det 3), but it is likely that such new regulations are many years away. Table 4.5 outlines new goals currently under discussion, which would be prudent to anticipate for the WTP.

For turbidity, more stringent goals are anticipated for individual filter effluent, including filter productivity, and chemical and residuals handling costs. Algae removal may be an additional treatment goal. Treatment alternatives to achieve these more stringent goals will be deep-bed GAC filtration, dissolved air flotation (DAF), and treatment of filter backwash water by high rate clarification. Due to the low filtration rates at the WTP, the filters can be operated in a “deep-bed” mode with significant empty bed contact time under normal operating conditions.

Primary disinfection goals may include addition of 3-log *Cryptosporidium* inactivation beyond the removal credit achieved by conventional treatment, thereby providing an additional barrier for disinfection. Alternative processes to achieve this target may involve operating the ozone system to achieve disinfection credit in addition to UV irradiation following filtration.

The water quality and operational goals for microbial quality in the distribution system are expected to remain the same. Operational improvements to meet these goals include optimized operation of booster chlorination facilities to maintain a satisfactory chlorine residual, coupled with reservoir mixing devices to reduce water age.

Disinfection By-Products (DBPs) goals may include enhanced TOC removal beyond the requirements of the enhanced coagulation matrix; inclusion of all nine HAAs as part of the MCL for HAAs; and establishment of goals for chlorate, perchlorate, and new nitrogen-containing DBPs. Treatment alternatives to meet the initial water quality and operational goals include optimized enhanced coagulation, deep-bed GAC filtration, and DAF; however, due to the expected quality of Lake Huron water, additional removal of TOC is not expected to be required.

The State of Michigan is currently examining tighter corrosion by-products goals, including a more stringent action level for lead of 0.010 mg/L. If such a level is adopted as a goal, a revised corrosion control strategy should be implemented in accordance with directions from MDEQ.

While goal changes are not anticipated for water quality, taste and odor, achievement of these goals would be assured by implementing preoxidation with ozone, advanced oxidation with ozone/peroxide, or deep-bed GAC filtration. No changes are suggested for the fluoride goal or treatment.

The water quality goal for cyanotoxins is driven by health advisory limits. Preoxidation with ozone, GAC filtration, and DAF are the recommended treatment alternatives. For chemicals of emerging concern (CECs), such as endocrine disruptors (EDs) and pharmaceutically active compounds (PhACs), the water quality goal would be to meet the regulatory limits. Ozonation and biological filtration with GAC media are the technologies of choice for effective removal of these compounds.

Table 4.5 – Potential Future Water Quality and Operational Goals

Water Quality Category	Water Quality and Operational Goals	Treatment Refinements/Optimization
Turbidity	▪ Turbidity ≤ 0.10 NTU in IFE, 95% of the time ▪ Filter runtime of 96+ hours ▪ UFRV of 11,000 gal/ft²/run ▪ 20% reduction in coagulant and residuals handling costs ▪ Enhanced algae/diatom removal	▪ Deep-bed GAC filtration ▪ Dissolved air flotation (DAF) to replace IPS sedimentation ▪ High-rate clarification treatment of filter backwash recycle flows
Primary Disinfection	▪ Chlorine Inactivation Ratio of 1.5 (CT_{calc}/CT_{req}) ▪ 3-log Crypto disinfection credit ▪ Multiple barrier disinfection strategy	▪ Ozonation for CT in ozone contactors ▪ Automated control strategy for ozone CT compliance ▪ Post-filter UV for Crypto/Giardia inactivation
Microbial Quality in the Distribution System	▪ No change to initial goals	▪ Add booster chlorination facilities if required ▪ Install reservoir mixing systems for improved chlorine residual stability and reduction in water age
Disinfection By-Products	▪ No change to initial goals, plus: ▪ Meet 80% of future regulatory limits for NDMA, chlorite, perchlorate and chlorate	▪ Optimize enhanced coagulation ▪ Deep-bed GAC filtration ▪ Dissolved air flotation (DAF) to replace IPS sedimentation ▪ Implement bromate control strategy (if required due to increased ozonation CT) ▪ Operate preoxidation and post-chlorination processes to minimize NDMA formation, if required ▪ Implement nitrogenous DBP control strategy (if required)
Corrosion By-Products	▪ Consider < 0.010 mg/L action level for lead	▪ Implement corrosion control strategy, as directed by MDEQ
Taste and odor	▪ No change to initial goals	▪ Preoxidation with ozone ▪ Deep-bed GAC filtration ▪ Ozone/peroxide advanced oxidation
Fluoride	▪ No change to initial goal	▪ None
Cyanotoxins	▪ Meet health advisory limits	▪ Preoxidation with ozone ▪ GAC filtration ▪ Dissolved air flotation (DAF) to replace IPS sedimentation

Water Quality Category	Water Quality and Operational Goals	Treatment Refinements/Optimization
CECs/EDCs/PPCPs	▪ Meet future regulatory limits	▪ Provide ozone and biological filtration with GAC media for effective removal of these compounds

4.1.3 Summary – Water Quality and Operational Goal Matrix

Table 4.6 summarizes the recommended water quality goals based on the discussion above. The categories are based on the contaminants believed to be of greatest relevance for the City of Flint, taking into account existing and potential future regulations, Lake Huron raw water quality, the experiences of other utilities treating Lake Huron water, existing WTP treatment processes, and best practices in the waterworks industry.

Table 4.6 – Recommended Water Quality and Operational Goals

Water Quality Category	Treatment Refinements/Optimization
Turbidity	▪ Regulatory compliance ▪ Turbidity ≤ 0.10 NTU for CFE, 95% of the time ▪ Turbidity ≤ 0.30 NTU for IFE, 95% of the time ▪ Filter runtime of 72+ hours ▪ UFRV of 9,000 gal/ft^2/run ▪ Limit filter recycle flows to < 5% of incoming plant flow
Primary Disinfection	▪ Chlorine Inactivation Ratio of 1.5 (CT_{calc}/CT_{req})
Microbial Quality in the Distribution System	▪ Operational goal of 0 detects in distribution system for Total Coliform and E. Coli ▪ Maintain minimum free chlorine residual in distribution system of 0.1 to 0.2 mg/L, or ▪ Maintain minimum free chlorine residual of 0.4 mg/L, if required by optimized corrosion control strategy
Disinfection By-Products	▪ Meet TOC removal requirements per enhanced coagulation matrix ▪ TTHM/HAA5 80% of MCL (64/48 ug/L) ▪ Bromate 50% of MCL (< 5 ug/L) ▪ Operate hypochlorite system to minimize by-product formation ▪ UV_{254} after filtration ≤ 0.03 cm^{-1}
Corrosion By-Products	▪ Meet corrosion control indices established by USEPA and MDEQ.
Taste and odor	▪ TON <3 ▪ No objectionable taste and odor year round ▪ Geosmin < 10 ng/L ▪ MIB < 10 ng/L
Fluoride	▪ Meet fluoride dose target based on daily monitoring

4.2 Lake Huron Water Quality Trends

Establishment of an effective treatment process requires a full understanding of the source water quality. Source water quality and treatment process performance data from various water treatment plants on the Great Lakes were used as a reference. **Figure 4.1** shows a map of the Great Lakes region and the location of the reference utilities used in this report. Data was not obtained for the Great Lakes Water Authority's (GLWA) Lake Huron WTP, which currently supplies treated water to the City of Flint.

Figure 4.1 – Reference Water Treatment Plants in the Great Lakes Region

Table 4.7 lists the available raw water quality data obtained from the three Lake Huron utilities. The approximate location of each utility's intake is shown in **Figure 4.2** along with the location of the intake for GLWA's Lake Huron WTP.

Table 4.7 – Lake Huron Raw Water Quality

Description	Units	Lake Huron Primary Supply System (Ontario)[1]			Saginaw-Midland MWSC			KWA Pilot Plant		
		Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Source	--	Lake Huron			Lake Huron			Lake Huron		
Approx. Intake Length	ft	8,000			21,120			5,575		
Approx. Intake Depth	ft	30 - 40			30 - 40			25 – 27[2]		
Date Range	--	2002 - 2011			2012			August - November 2016		
pH	pH units	8.54	7.74	6.92	8.20	7.97	7.73	8.86	8.24	8.00
Turbidity	NTU	109.19	7.93	0.03	27.70	2.05	0.30	8.87	1.65	0.27
Total Organic Carbon (TOC)	mg/L as C	2.2	1.9	1.5	--	--	--	--	--	--
Hardness	mg/L as $CaCO_3$	100	95	90	138	104	96	96	91	87
Alkalinity	mg/L as $CaCO_3$	85	80	75	89	76	67	84	76	68
Temperature	deg C	24.7	10.5	0.0	22.8	10.1	1.1	16.7	13.9	11.7
Total Algae	#/mL	2372	1036	365	--	--	--	--	--	--

[1]Algae data for the LHPWSS were obtained from Foley, 1980. Hardness and alkalinity data were obtained from Hutchinson, 1975. TOC data was extrapolated from DOC data obtained from http://www.watersupply.london.ca/water_reports_archives.htm.
[2]At the deepest abstraction point

In general, Lake Huron water has low organics and generally low, but seasonally variable, turbidity. Turbidity values tend to spike between October and April, requiring increased coagulant and coagulant-aid polymer dosages. Some facilities utilize a filter-aid polymer to improve filterability. During winter, water temperatures can approach freezing, slowing down chemical reactions and making clarification more problematic. Experience on Lake Michigan has shown upsets caused by turbidity to be directly correlated to wind speed and weather patterns. Data from both Lake Huron and Lake Michigan show the most severe spikes occurring in the fall or spring.

Other challenges include taste and odor events and the proliferation of algae in the spring and fall months when water temperatures are ideal for their growth (10 to 15 degrees Celsius). The presence of diatom algae in the raw water can reduce the effectiveness of clarification and filtration processes. The presence of blue-green algae in Lake Huron can also result in the production of mycrocystin, a metabolic algal by-product which can be harmful to human health. In planning for the future, this report considers treatment technologies that can mitigate the risk for taste and odor episodes and the risks associated with toxic algae blooms in Lake Huron.

As the KWA intake on Lake Huron, which will ultimately be the source of raw water for the WTP, is currently under construction, water quality data for this facility are very limited. To complement these data, additional raw water quality figures were obtained from the Saginaw-Midland Municipal Water Supply Corporation (SMMWSC) and from the Lake Huron Primary

Water Supply System (LHPWSS) WTP in Canada. The SMMWSC serves raw Lake Huron water to the cities of Saginaw and Midland as well as the Bay Area WTP. The LHPWSS WTP provides treated drinking water from Lake Huron to the City of London, Ontario.

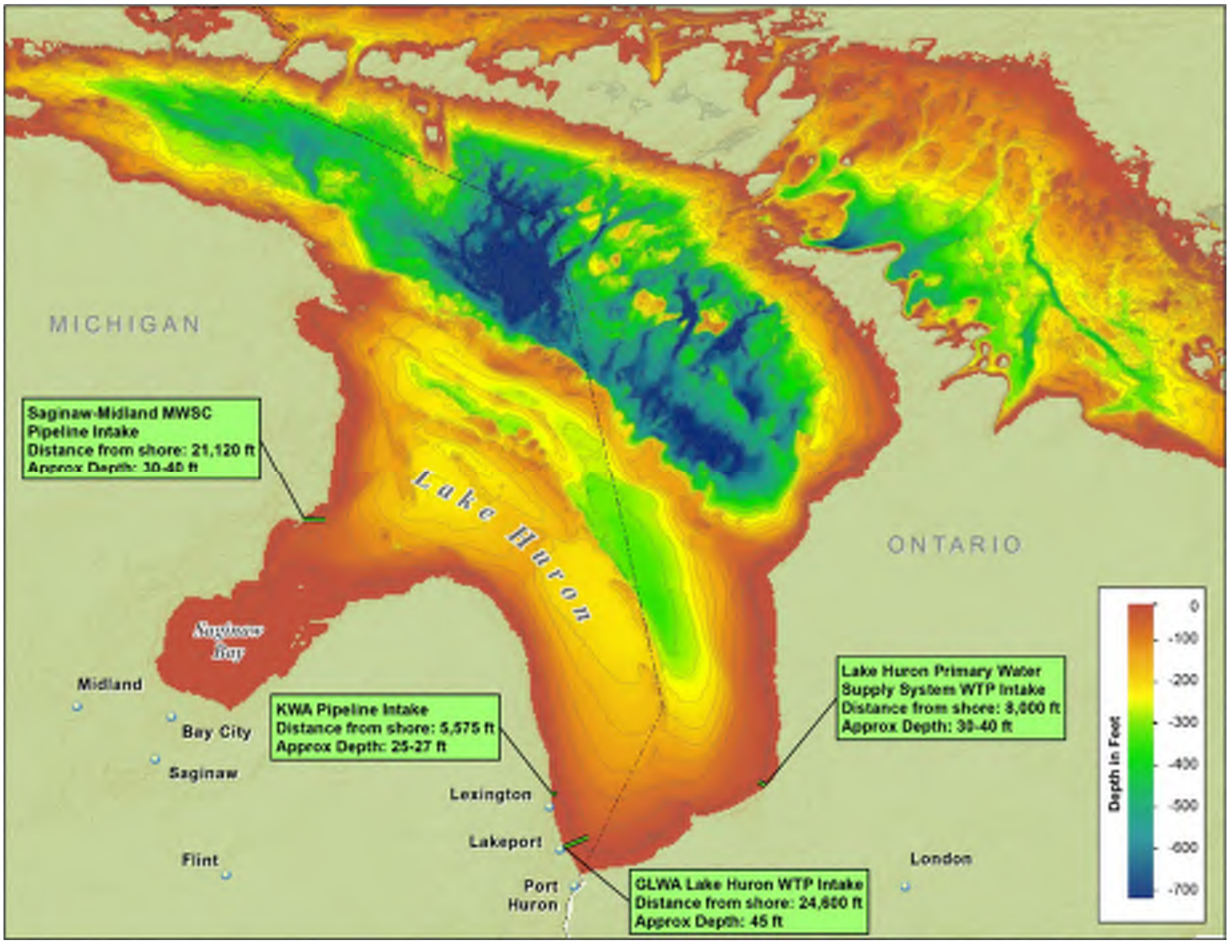

Figure 4.2 – Raw Water Intake Locations on Lake Huron

The raw water quality of these three plants is relatively uniform, except for turbidity. At the time of this report, algae and TOC data were not available for the SMMWSC and KWA intakes. The LHPWSS WTP shows a larger variance in the maximum and minimum turbidity values, as well as a higher average turbidity than the other two WTPs. Per the MDEQ, the east side of Lake Huron is subject to stronger currents, sediment loading, and wind upsets, thus is more prone to turbidity spikes. As shown in Figure 4.1 the LHPWSS WTP intake is located on the east side of the lake while the SMMWSC and KWA intakes are located on the west side of the lake. Officials from the KWA have indicated that the KWA intake will experience less turbidity spikes than the LHPWSS intake. However, when developing design criteria for coagulant dosing and residuals production, the range of turbidities for the LHPWSS are used as a reference.

Lake Huron has a relatively stable pH and alkalinity. Additional data will be needed to verify the upper bound pH values for the KWA intake as only four months of data were available at the time of this report. Typical pH values for the Great Lakes, and Lake Huron in particular, range between

7.0 and 8.5. This pH is above the range where alum is most effective. However, many Great Lakes utilities have fed alum successfully for years. Subsequent jar testing with Lake Huron water at the WTP will help to establish the appropriate and ideal coagulant chemical. This testing will also elucidate the benefits of pre-ozonation as well as the potential benefits of lowering the pH prior to coagulation to a level that is more effective for alum or ferric coagulation. If pH adjustment is found beneficial, the existing carbon dioxide feed system may be used for this purpose, as discussed in Section 5.

While alum has been successfully used at many Great Lakes utilities, other coagulants such as polyaluminum chloride (PACl) and ferric sulfate have been effective with the elevated pH levels of the raw water. The pilot plant for Genesee County is currently investigating several coagulants for use at the new Genesee County WTP with KWA intake water. The data from that pilot were not available at the time of this report. However, **Table 4.8** lists the type and range of coagulants used at other Lake Michigan and Lake Huron utilities.

Table 4.8 – Coagulant Types and Dosages at Lake Huron and Lake Michigan WTPs

Description	Units	Lake Huron WTP (Ontario)[1]			Lake Huron WTP (Ontario)[1]			Racine WTP			CLCJAWA WTP		
		Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min
Source	--	Lake Huron			Lake Huron			Lake Michigan			Lake Michigan		
Treatment Process	--	Conventional			Direct Filtration			Conventional			Conventional		
Alum	mg/L as $Al_2(SO_4)_3$-$14H_20$	47.5	22.8	11.9	20.0	14.7	7.0	--			23.4	8.3	2.2
Polyaluminum Chloride	mg/L as PACl	--			--			8.2			29.1	8.0	1.3
Ferric Sulfate	mg/L as $Fe_2(SO_4)_3$	--			--			20.4			--		
Ferric Chloride	mg/L as $FeCl_3$	--			2.9			--			--		

[1]The LHPWSS plant originally operated as a direct filtration facility. Data for the plant's operation as a direct filtration plant was obtained from Foley, 1980. Data for the plant's operation as conventional facility was obtained online at http://www.watersupply.london.ca/water_reports_archives.htm.

The coagulant dose ranges in the above table were used to establish chemical system design criteria and to calculate residuals quantities, as discussed in Section 4.8 and Section 5.

As discussed in Section 3, the water age from withdrawal at the Lake Huron intake until the water is treated at the WTP may range from approximately 6 to 18 days depending upon water demands and how the raw water storage reservoirs are operated. Water age in the system should be minimized to avoid potential degradation in water quality. If the water in the raw water reservoirs becomes stagnant, there is increased potential for algal blooms and the formation of taste and odor causing compounds. For this reason, it is recommended that the existing ozone facilities at the WTP be upgraded and used as part of the plant treatment process. This is discussed below.

4.3 Existing Process Description

4.3.1 Treatment Process Train

The WTP is a conventional treatment facility with rapid mixing, three-stage flocculation, sedimentation with inclined plate settlers, dual media (granular activated carbon (GAC) over sand) filtration, followed by disinfection using free chlorine. The plant also includes an ozone system which can be applied to raw water for disinfection or preoxidation. Lime softening reactor clarifiers are also available in the process train, but these are not required for treatment of the Lake Huron supply, which has relatively low hardness as discussed in Section 4.2. A simple process schematic of the WTP (with the softening process omitted) is presented in **Figure 4.3**. This was the starting point for CDM Smith's evaluation of process train alternatives for the Flint Water Treatment Plant Improvements Project, as discussed in the next section.

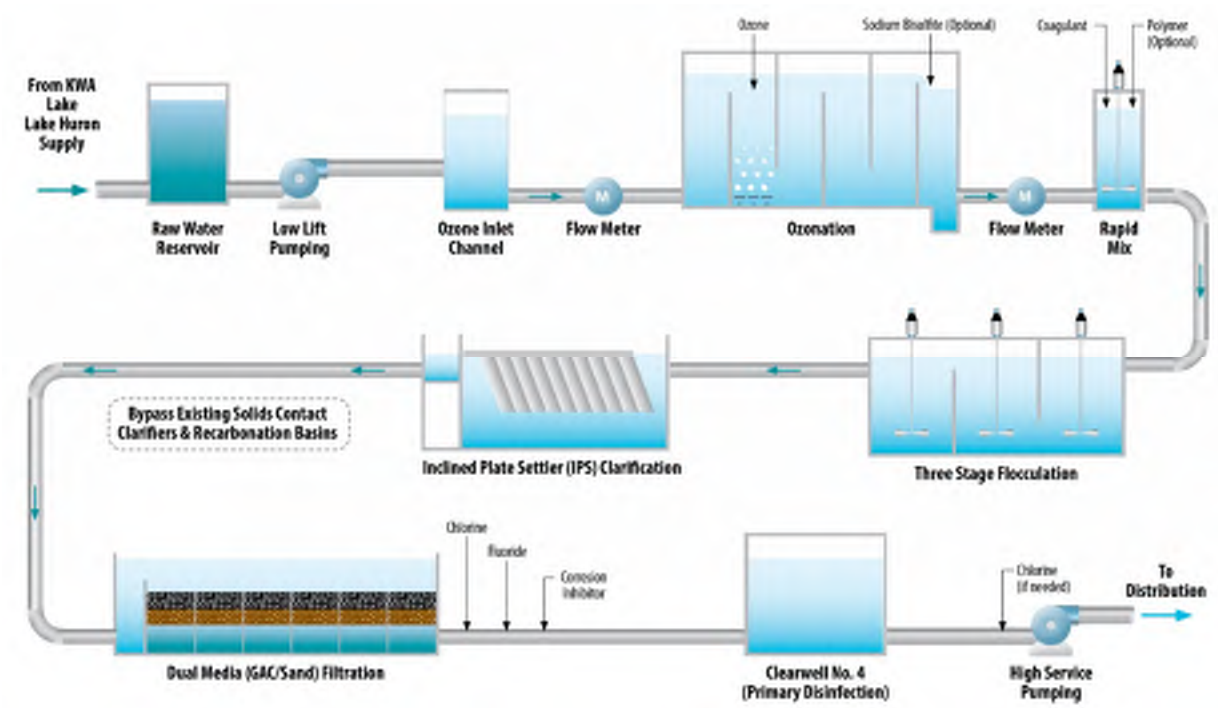

Figure 4.3 – Process Schematic for Existing Flint WTP (with softening clarifiers removed)

4.3.2 Chemical Systems

The existing chemical systems for the WTP include ferric chloride and cationic polymer for coagulation, hydrated lime and soda ash for softening, carbon dioxide for recarbonation, sodium bisulfite for ozone quenching, fluoride for dental health, gas chlorine for primary disinfection, and powdered activated carbon (PAC) for removal of taste and odor compounds. A description of the existing chemical storage and feed systems for the WTP and recommended chemical systems for treating the Lake Huron supply are covered in Section 5.

4.3.3 Process Design Criteria

Table 4.9 presents a summary of basic unit process design criteria for the WTP, based on the plant's current rated capacity of 36 million gallons per day (MGD). The unit process ratings assume that all units are operating with no basins or filters out of service. This was the starting point for CDM Smith's evaluation of the treatment capacity for each unit process, which is based on a peak instantaneous flow of 24 MGD – the design value established for the Flint Water Treatment Plant Improvements Project.

Table 4.9 – Unit Process Design Criteria for Existing Flint WTP

Description	Units	Design
Plant Capacity		
Maximum Design Flow	MGD	36
Rapid Mixing		
Number of Basins	No.	2
Detention Time	seconds	17.5
Impeller Type	--	3-Blade Hydrofoil
Motor HP	HP	5
G Value	s^{-1}	350 to 537
Flocculation		
Number of Modules	No.	2
Number of Trains	No.	10
Number of Stages	No.	3
Detention Time	Minutes	150.5
Impeller Type	--	3-Blade Hydrofoil
G Value, 1st Stage	s^{-1}	56 to 85
G Value, 2nd Stage	s^{-1}	35 to 53
G Value, 3rd Stage	s^{-1}	23 to 36
IPS Sedimentation		
Number of Installed Basins	No.	3
Surface Overflow Rate	gpm/sf	2.6
Detention Time	Minutes	78.5
Solids Loading Rate	gpm/sf	0.30
Total Plate Area	sf	104,620
Number of Plates per Basin	No.	1216
Sludge Collection Mechanism	--	Fixed-Grid
Filtration		
Number of Filters	No.	12
Filter Area	sf	700
Nominal Filtration Rate	gpm/sf	3.0
Type of Underdrain	--	Monolithic false-floor plenum style with nozzles
Air Scour System	--	Integral with underdrain
GAC Criteria		
Depth	in	18

Description	Units	Design
Effective Size	mm	0.65
Uniformity Coefficient	--	1.9
Sand Criteria		
Depth	in	12
Effective Size	mm	0.5
Uniformity Coefficient	--	1.65

4.4 Treatment Process Evaluation

4.4.1 Screening of Process Train Alternatives

The existing WTP was constructed as a lime softening facility to treat raw water from the Flint River. Switching the water source to Lake Huron will significantly improve the quality of the raw water supply and eliminate the need for softening. With this change to a higher quality source, the multiple treatment process units already in place at the plant (with the exception of the softening reactor clarifiers) can provide effective treatment and should continue to be used, with appropriate upgrades, to maximize the capital investments at the plant over the past 15 to 20 years. This approach will also help meet the requirements of an accelerated implementation schedule. Note that the screening of process train alternatives does not consider "greenfield" treatment solutions in combination with existing process units, such as micro- or ultrafiltration membranes and dissolved air flotation. While appropriate for treating the Lake Huron water supply, such processes are likely to result in higher capital costs, increased operations and maintenance (O&M) requirements, and significant schedule impacts for the Flint Water Treatment Plant Improvements Project.

In view of these constraints, CDM Smith in consultation with the City of Flint and MDEQ selected two basic process train alternatives to be evaluated in this report. These alternatives are shown in **Figures 4.4** and **4.5** and are described below.

- ***Alternative 1*** – Pre-ozone with rapid mixing, three-stage flocculation, high-rate settling, dual-media biological filtration (with GAC or anthracite media) and chlorine disinfection in the Dort Reservoir.
- ***Alternative 2*** – Pre-chlorination with rapid mixing, three-stage flocculation, high-rate settling, dual-media adsorption/biological filtration (with GAC media), and chlorine disinfection in the Dort Reservoir.

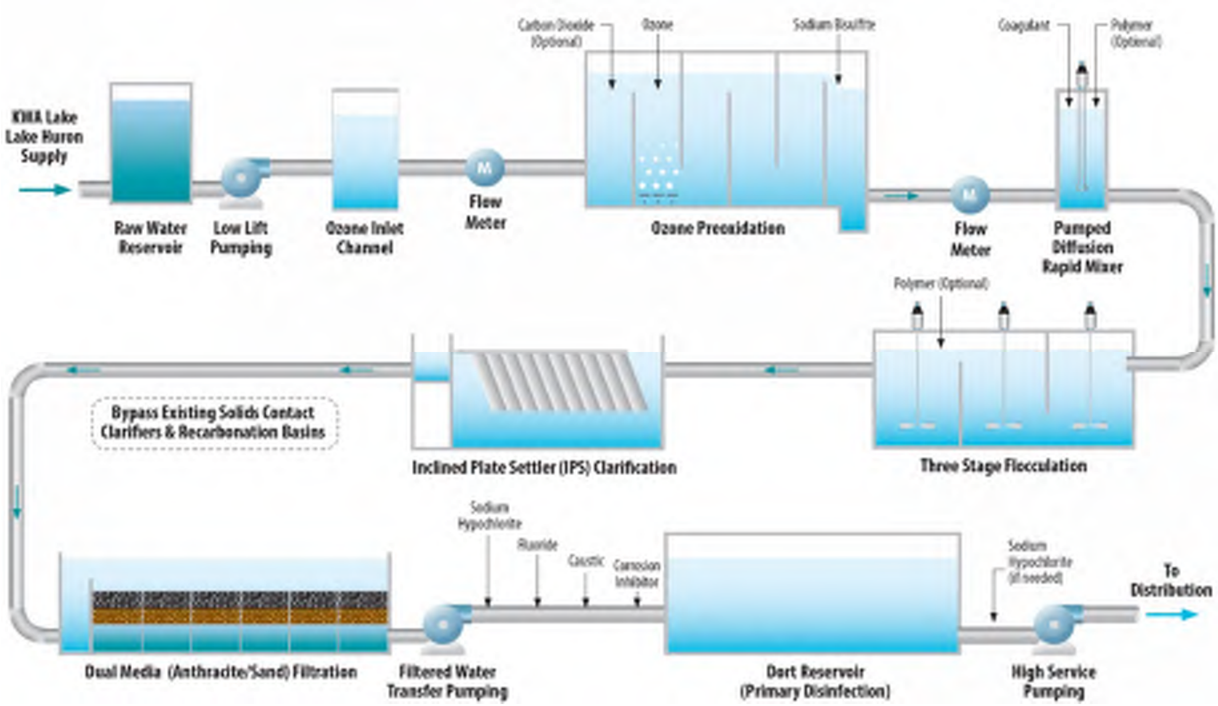

Figure 4.4 – Alternative 1 – Conventional Treatment with Pre-Ozone, Biological Filtration, and Post-Chlorine Disinfection

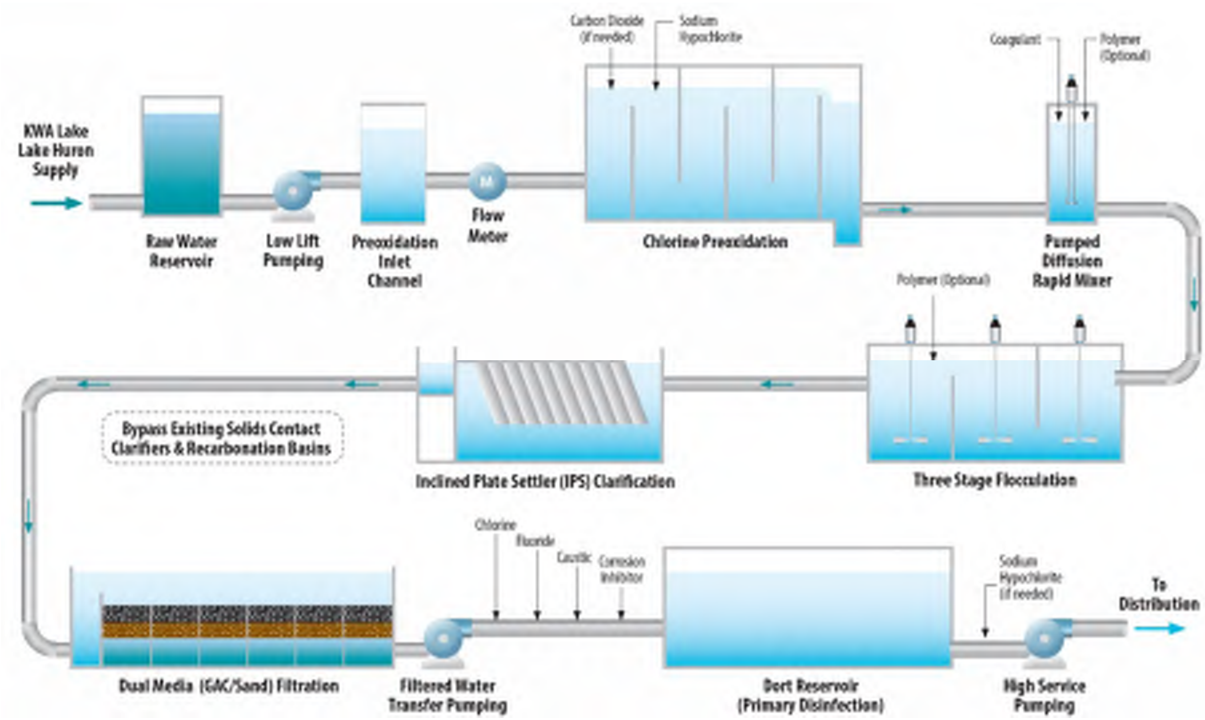

Figure 4.5 – Alternative 2 – Conventional Treatment with Pre-Chlorine, Adsorption/Biological Filtration, and Post-Chlorine Disinfection

4.4.2 Evaluation of Unit Process Alternatives

For the two process train alternatives described above, several types of chemicals, equipment components, and operational strategies were evaluated for each unit process.

The results of these unit process evaluations are presented in Sections 4.5 through 4.11. The recommended process train for the WTP is presented in Section 4.12.

4.4.2.1 Unit Process Evaluation Methodology

As described in Section 1, the overall objectives of this project are to upgrade the WTP so that it:

- Delivers treated water that exceeds all drinking water primary and secondary standards with an appropriate margin of safety.
- Can be operated and maintained with enhanced ease/simplicity, flexibility, safety, and reliability.
- Has improved treatment, pumping, and operational efficiency.
- Reliably produces water at minimum, average, and maximum plant production rates of 5, 14, and 24 MGD.

Based on these objectives, the following performance and operational evaluation criteria were used to score and rank the design alternatives for each unit process:

- Regulatory and Water Quality Issues.
- Operational Simplicity.
- Flexibility and Efficiency.
- System Reliability and Safety.
- Site Considerations.
- Water Quality and Treatment Impacts.
- Operation and Maintenance Impacts.
- Health and Safety Impacts.

The following numerical scoring system was used to rate each unit process alternative against the eight evaluation criteria:

- 4 = Excellent
- 3 = Good
- 2 = Marginal
- 1 = Poor

- 0 = Not Applicable

The alternatives were pre-scored by CDM Smith based on the advantages and disadvantages listed in the evaluation tables for each unit process. These scores and the recommended design alternative were then validated by the City of Flint, MDEQ, and other attendees at the Flint Water Treatment Plant Improvements Process Workshop held on December 8, 2016. The same scoring method and validation procedure was used to evaluate alternatives for the raw water supply, chemicals, and pumping systems for the WTP, as discussed in Sections 3, 5, and 6.

4.5 Preoxidation

4.5.1 Treatment Objectives and Approach

The preoxidation process is intended to oxidize both organic and inorganic constituents in the raw water prior to coagulation. Application of a strong preoxidant in conjunction with coagulation can achieve multiple water quality objectives:

- Enhanced turbidity and particle removal.
- Taste and odor control.
- Color removal.
- Iron and manganese removal.

While ozone has the highest oxidation potential for achieving these objectives and does not react with organic matter to form chlorinated by-products, one possible by-product of ozonation is bromate. However, the bromate formation risk for the Lake Huron supply is very low based on low raw water bromide ion levels and full-scale operational experience of plants treating water from the Great Lakes. While pre-chlorination of raw water introduces a higher risk of DBP formation than chlorination of filtered water, the low organic levels in Lake Huron and full-scale operational experience of plants treating water from Lake Huron indicate that trihalomethane (THM) and haloacetic acid (HAA) formation rates in the finished water should be well below regulatory limits.

The ozone facility for the WTP was constructed in 2002. It was intended for treating raw water from the Flint River, specifically to provide disinfection, taste and odor control, and oxidation of organic precursors, the latter to reduce chlorine demand and minimize formation of chlorinated disinfection by-products (DBPs) in the finished water. With the change to the Lake Huron supply – which has significantly lower organics and DBP formation potential than the Flint River – there is no longer a compelling reason to continue using the existing ozone system as a primary disinfection process. Instead, it should be used as a preoxidation process for taste and odor control (should water quality deteriorate in upstream storage reservoirs) and to improve performance of downstream treatment units. Accordingly, CDM Smith evaluated use of ozone vs. chlorine (delivered as sodium hypochlorite) for preoxidation treatment.

Figure 4.6 – Existing Ozone Generation Equipment for the Flint WTP

4.5.2 Description of Design Alternatives

The two preoxidation design alternatives are briefly described below.

- ***Ozone Preoxidation*** – This alternative considers that the existing pre-ozone system at the WTP is operated as a preoxidation treatment process. Only one ozone contacting basin is required for raw water preoxidation; the other two basins will be retained as off-line standby units or decommissioned. The ozone sampling and monitoring system will be simplified by replacing multiple ozone-residual analyzers with a single oxidation-reduction potential (ORP) probe and back-up ozone residual analyzer. Operation of the ozone system will be fully automated and the control logic will be reprogrammed to automatically adjust the ozone dose to satisfy the oxidant demand under changing flow rates and raw water quality conditions. The existing ozone generators will be de-rated to meet the lower ozone production requirements for preoxidation, and ozone gas flow instrumentation will be either rescaled or replaced to provide accurate measurements at lower gas flows.

Figure 4.7 – Ozone Residual Monitor in Ozone Gallery of Flint WTP and Typical ORP Probe

- ***Chlorine Preoxidation*** – This alternative assumes that a new sodium hypochlorite chemical storage and feed system, as described in Section 5, includes a dedicated day tank and feed pump for the chlorine preoxidation process. Hypochlorite will be applied at the inlet pipeline to Ozone Contactor No. 1 (which will be repurposed as a chlorine preoxidation contact tank). A chlorine residual monitoring system will be installed in the ozone contactor gallery, including an ORP probe and back-up chlorine residual analyzer. The chlorine dose control logic will be designed to flow pace the hypochlorite dose with a trim signal from the ORP meter.

4.5.3 Evaluation of Design Alternatives

Table 4.10 presents the technical evaluation of ozone and chlorine preoxidation design alternatives for the WTP. The scoring results (using the previously described performance and operational criteria and not considering cost) indicate that the fully automated ozone preoxidation alternative scored higher than the pre-chlorine alternative. The key technology tradeoffs relate to regulatory/water quality issues and operational simplicity criteria. As stated earlier, ozone has a higher oxidation potential than chlorine, may improve coagulation at lower chemical doses, and does not form chlorinated DBPs (although the THM and HAA formation potential for Lake Huron supply is low), so ozone is considered to be a better preoxidation process for treating the Lake Huron supply. Ozone also provides greater water quality reliability should Lake Huron water quality deteriorate in upstream storage. While the pre-chlorine alternative is viewed as a less complex system to operate and similar to other types of liquid chemical feed systems, the ozone system can be fully automated. It also can be remotely monitored from the ozone or plant-wide control rooms, as long as the ozone gas flow, ozone concentration, and ORP instruments are kept in calibration for accurate dose measurements. Only one set of ozone equipment (oxygen tank, nitrogen tank, ozone generator, ozone contactor and diffuser grid, and off-gas destruct unit) is required to meet the full range of plant flow and ozone dose requirements for preoxidation.

Table 4.10 – Technical Evaluation of Preoxidation Design Alternatives*

Evaluation Criteria	Ozone Preoxidation	Chlorine Preoxidation (using sodium hypochlorite)
Regulatory and Water Quality Issues	Produces lower filtered water turbidity and particle counts compared to chlorine	Produces higher filtered water turbidity and particle counts compared to ozone
	Reduces coagulant dose compared to chlorine	Reduces coagulant dose compared to no preoxidant
	Excellent preoxidation barrier for algal-derived taste and odors; eliminates need to install GAC media in filter bed	Does not provide significant reduction of algal-derived taste and odors; GAC media in filter bed or PAC may be required
	Breaks down organics into simpler biodegradable compounds for removal on downstream biological filters	Does not significantly break down organics for removal on downstream biological filters
	Effective oxidant for treatment of many emerging contaminants (pharmaceuticals, pesticides, etc.)	Not effective for treatment of most emerging contaminants
	Does not form chlorinated disinfection by-products (THMs, HAAs); bromate formation (an ozone by-product) is not a concern for Lake Huron supply	Does not form bromate; does form chlorinated disinfection by-products (THMs, HAAs), but formation rates are below regulatory MCLs
SCORE:	4	2
Operational Simplicity	More complex system, but can be operated in automatic mode with minimal daily operator attention	Less complex system, similar to other liquid chemical feed systems at Flint WTP
	Requires regular (weekly) calibration checks of instrumentation for accurate dose control in automatic mode	Single hypochlorite chemical storage and feed system can be used for both preoxidation and disinfection application points
	Requires only one ozone contactor in service for preoxidation treatment	Requires careful attention to bleach concentrations (which degrade over time) upon delivery and during storage for accurate dose control
	Senior Flint operations staff have experience in operating the existing ozone system	
SCORE:	3	4
Flexibility and Efficiency	Fully automatic, precise dose control possible with flow pacing and ORP trim control	Fully automatic, precise dose control possible with flow pacing (no residual trim control)
	Modified ozone system will meet full range of ozone production/dose requirements	New hypochlorite system will meet full range of preoxidation and disinfection dose requirements
	Large contactor volume available for ozone residual decay, eliminating need for ozone quenching system	Hypochlorite preoxidation application point can be upstream of ozone contactors or at rapid mix units
	Ozone system (3 contactors in service) is sized to provide up to 4-log Giardia disinfection for multi-barrier treatment if required in future	
SCORE:	4	4
System Reliability and Safety	Ozone system has adequate (N+1) equipment redundancy for reliable operation	Hypochlorite system has adequate (N+1) equipment redundancy for reliable operation

Evaluation Criteria	Ozone Preoxidation	Chlorine Preoxidation (using sodium hypochlorite)
	Ozone is generated on demand so gas volumes are below hazardous chemical storage classification	Requires dedicated day tanks for preoxidation and disinfection application points
	Ozone generators will automatically shut down in event of ozone leaks above health safety limits	Hypochlorite is stored on site so storage volumes may be subject to hazardous chemical storage classification
	Liquid oxygen and nitrogen storage vessels located outdoors and meet CGA safety requirements	Hypochlorite is very corrosive so storage tanks must be designed with special liners with capability to replace tanks on a 10-15-year cycle
	Plant staff should be vigilant in fixing minor ozone leaks when they occur	Hypochlorite leaks and exposure to ferrous metals can generate chlorine gas
	Ozone generators are sensitive to power quality fluctuations with automatic shutdown when limits are exceeded	
SCORE:	3	3
Site Considerations	Existing ozone facility is operational with no space requirements for any future ozone process upgrades	New chemical storage building must be expanded to accommodate additional hypo storage tanks and dedicated feed pumps
		Existing ozone facility must be decommissioned and modified to accept new hypochlorite application point
SCORE:	4	2
OVERALL SCORE:	**18**	**15**

*Based only on performance and operational criteria and not considering cost

4.5.3.1 Cost Considerations

The capital cost for the ozone system is primarily a sunk cost since the facility was constructed in 2002 and is operational. Based on preliminary discussions with Suez Treatment Solutions – the original supplier of the ozone equipment system – the cost of design modifications to upgrade and "derate" the ozone generation and off-gas destruct equipment to meet the lower design dose requirements for preoxidation is estimated at $600,000. This estimate includes the cost to check out the vessel (dielectric status), replace components in the PSU that are required based on the length of time the unit has been inactive, modifications to the destruct unit, and Ozonia's cost to startup and commission the equipment. Note that the additional cost to add plugs to block about a third of the dielectrics to meet generator production turndown requirement is fairly minor. Most of these equipment refurbishment costs will be required, regardless of whether the generator capacity is derated or not. By skipping the derating step, the ozone system would need to be operated at excessive ozone doses most of the time with the application of sodium bisulfite for ozone quenching, which will significantly increase the operating cost of the system. Therefore, it is recommended to proceed with the equipment upgrades and derating of the ozone generators.

The comparison of annual operating costs for ozone and chlorine preoxidation should consider the dose requirements for each alternative. Assuming a 1 mg/L dose for both chemicals at 14

MGD, the chemical cost is estimated at $75,000 per year for ozone and $25,000 per year for hypochlorite. In addition, the chlorine alternative, which is not an effective oxidant for taste and odor control, should assume that GAC media is placed in the filters to provide a reliable adsorption-based treatment barrier for algal-derived taste and odor compounds that may occur from time to time on Lake Huron. Powdered activated carbon (PAC) can be fed for removal of taste and odor compounds as an alternative to placing GAC media in the filters, although depending upon the type and concentration of taste and odor compound, it may not be as effective as GAC. In addition, PAC is not as effective as GAC in removing emerging contaminants. GAC filter media needs to be replaced every 2 to 3 years to restore adsorptive capacity. For the filters at Flint, the cost of replacing the GAC media in all of the filters is estimated to be $600,000. This is equivalent to an annual O&M cost of $200,000 if the GAC is replaced every 3 years. If GAC media is used in the filters the total annual operating cost for the chlorine preoxidation alternative is estimated at $225,000 – or approximately three times higher than the ozone alternative, which does not require GAC media in the filters for taste and odor control. If PAC is fed as an alternative to GAC media in the filters, it is likely the total annual operating cost will be significantly less, depending upon dose and frequency of use.

4.5.4 Recommended Design Alternative

The decision on whether to use ozone or chlorine as the preoxidant for the WTP will be deferred until the final design phase and following completion of jar testing and detailed inspections of the existing ozone equipment by Suez Treatment Solutions – the original supplier of the ozone system. The jar test results will determine the relative benefits of ozone and chlorine with respect to coagulation performance, filterability, solids production rates, disinfection by-product formation rates, and (potentially) taste and odor control if algal-derived taste and odor compounds are present in the raw water supply during the testing period. The ozone equipment inspections will determine the need for and cost to refurbish major equipment components for the oxygen feed gas, generation, diffusion, and off-gas destruct systems. This information, together with the information presented in Table 4.10 and updated life-cycle cost comparisons will then be used to make an informed decision on the most appropriate preoxidation chemical for the WTP.

4.5.5 Process Design Criteria

The ozone system for the WTP consists of the following equipment components:

- Liquid oxygen storage and feed gas system.
- Ozone generation and cooling water system.
- Ozone dissolution and contacting system.
- Ozone off-gas system.

The design criteria for the overall ozone system and individual equipment components are provided in this section.

Table 4.11 presents process design criteria for the ozone preoxidation system, including the ozone contacting and dissolution system. The design flows range from 5 to 24 MGD and ozone doses from 0.5 to 2 mg/L, resulting in ozone production design requirements of 20 to 400 lb/day. This corresponds to an ozone production turndown ratio of 20:1 which can be accommodated by the insulated-gate bipolar transistor (IGBT)-based power supply units for the ozone generators currently installed at WTP. The ozone contactor design criteria assume that only one contactor basin is in service for the full range of design flows. A single diffuser grid with 16 diffuser stones will be used to diffuse ozone gas into the water column in the first cell of the contactor. The contactor hydraulic retention time at average flow is approximately 15 minutes – ample time for ozone residuals to decay to non-detectable levels when the ozone system is operated in a preoxidation operational mode.

Table 4.11 – Ozone System Process Design Criteria

Parameter		Units	Design Flow	Average Flow	Min Flow
General Design Information					
Design Flows		mgd	24	14	5
Ozone Transfer Efficiency		%	92.0%	92.0%	92.0%
Design Applied Ozone Dose					
	Minimum Ozone Dose	mg/L	0.5	0.5	0.5
	Average Ozone Dose	mg/L	1.0	1.0	1.0
	Maximum Ozone Dose	mg/L	2.0	2.0	2.0
Design Transferred Ozone Dose					
	Minimum Ozone Dose	mg/L	0.5	0.5	0.5
	Average Ozone Dose	mg/L	0.9	0.9	0.9
	Maximum Ozone Dose	mg/L	1.8	1.8	1.8
Ozone Generation System Design					
Ozone Production Requirements					
	Minimum Ozone Production	lb/day	109	64	23
	Average Ozone Production	lb/day	218	127	45
	Maximum Ozone Production	lb/day	435	254	91
Ozone Generator Capacity Requirements					
	Number of Generators Installed (n+1 Redundancy)	#	2	2	2
	Number of Generators On-Line	#	1	1	1
	Optimal Ozone Concentration	% wt	10%	10%	10%
	Capacity Per Generator	lb/day	500	500	500
Ozone-in-Oxygen Gas Flowrate					
	Optimal Ozone Concentration	% wt	10%	10%	10%
	Minimum Gas Flow	scfm	9.1	5.3	1.9
	Maximum Gas Flow	scfm	36.4	21.2	7.6

Parameter		Units	Design Flow	Average Flow	Min Flow
	Minimum Ozone Concentration	% wt	6%	6%	6%
	Minimum Gas Flow	scfm	15.2	8.8	3.2
	Maximum Gas Flow	scfm	60.6	35.4	12.6
Ozone Contactor System Design					
Total Number of Contactors		#	3	3	3
Number of Contactors In Service		#	1	1	1
Number of Single Diffuser Grids per Contactor		#	1	1	1
Number of Diffusers per Single Diffuser Grid		#	16	16	16
Contactor Hydraulic Residence Time					
	Baffling Factor	NA	0.60	0.60	0.60
	Theoretical Hydraulic Residence Time	min	8.66	14.85	41.57
	T-10 Hydraulic Residence Time	min	5.20	8.91	24.94
Offgas Flow Rate per Contactor					
	Maximum	scfm	92.06		
	Minimum	scfm	1.92		
Ozone Gas Loading Rate Per Diffuser, Single Grid					
	Maximum Ozone Concentration	% wt	10%	10%	10%
	Minimum Diffuser Gas Loading Rate	scfm	0.57	0.33	0.12
	Maximum Diffuser Gas Loading Rate	scfm	2.27	1.33	0.47
	Minimum Ozone Concentration	% wt	6%	6%	6%
	Minimum Diffuser Gas Loading Rate	scfm	0.95	0.55	0.20
	Maximum Diffuser Gas Loading Rate	scfm	3.79	2.21	0.79

Table 4.12 presents equipment design criteria for the liquid oxygen and liquid nitrogen storage systems. Oxygen is the primary feed gas for producing ozone from oxygen, and nitrogen produces an important catalytic effect to form ozone molecules more efficiently at lower power consumption rates. A small amount of nitrogen in the feed gas is required to produce ozone molecules, and most ozone vendors (including Suez) will not warranty their equipment without supplemental nitrogen addition.

The existing pair of vertical tanks for each chemical at the WTP are oversized relative to the new oxygen/nitrogen production requirements for preoxidation. Therefore, only one set of tanks will be required for the modified ozone system.

Table 4.12 – Process Design Criteria for Liquid Oxygen and Liquid Nitrogen System

Liquid Oxygen System Design Criteria			
Parameter		Units	Value
LOX Tanks	Tank Type	--	Vertical Double Walled Cryogenic
	Number of Tanks	#	2
	Number of Tanks in Service	#	1
	Nominal Storage Capacity Per Tank	gallons	8,890
	Avg LOX Usage at 10% Ozone Concentration	lbs	1,284
	Days of Storage at Average Usage	days	62
	Normal Operating Pressure	psig	75
	Maximum Working Pressure	psig	175
LOX Vaporizers	Vaporizer Type	--	Ambient Air
	Number of Vaporizers	#	2
	Required Capacity Per Vaporizer	SCFM	92.1
	Minimum Period of Operation	hours	24
	Ambient Temperature (min/max)	deg F	5/105
	Maximum Working Pressure	psig	125
	Working Temperature (min/max)	deg F	-320F to +120F
LIN Tanks	Tank Type	--	Vertical Double Walled Cryogenic
	Number of Tanks	#	2
	Number of Tanks in Service	#	1
	Nominal Storage Capacity Per Tank	gallons	508
	Avg LIN Usage at 2% of LOX Usage	lbs	104
	Days of Storage at 2% of LOX Usage	days	32
	Normal Operating Pressure	psig	75
	Maximum Working Pressure	psig	250
LIN Vaporizers	Vaporizer Type	--	Ambient Air
	Number of Vaporizers Per Tank	#	1
	Required Capacity Per Vaporizer	SCFM	1.0
	Minimum Period of Operation	hours	24
	Ambient Temperature (min/max)	deg F	5/105
	Maximum Working Pressure	psig	125

Table 4.13 presents equipment design criteria for the ozone generation system. The ozone generator design capacity was assumed to be 440 lb/day, or 10 percent higher than the maximum ozone production design requirement. The actual generator rated capacity will be determined

based on generator and power supply unit (PSU) derating modifications to be completed by Suez Treatment Solutions.

Table 4.13 – Process Design Criteria for Ozone Generation System

Parameter		Units	Existing Generator	Modified Generator
Generator	Type of Generator	--	Horizontal Tube Medium Frequency	
	Number of Generators	#	1 Duty + 1 Standby	
	Rated Capacity per Generator (at 10% wt)	ppd	900	440
	Rated Capacity per Generator (at 6% wt)	ppd	1,300	570
	Operating Gas Pressure	psig	22	22
	Operating Coolant Pressure	psig	30	30
Cooling System	Type of Cooling System	--	Open Loop	
	Maximum Cooling Water Temperature	deg F	80	
	Maximum Cooling Water Temperature Rise	deg F	7.5	
	Cooling Water Flow Rate	gpm	130	
Power Supply Unit	Number of Units	#	1 Duty + 1 Standby	
	Type of PSU	--	Medium Frequency	
	Incoming Power	V/Ph/Hz/amp	480, 3, 60,	
	Power Factor	cos phi	> 0.98	
	Enclosure	--	NEMA 12	
	Type of Cooling System	--	Closed Loop	
	Cooling Water Flow Rate	gpm	~ 35	

Table 4.14 presents equipment design criteria for the off-gas destruct system. As discussed earlier, the existing off-gas destruct units and blowers may need to be modified to meet ozone production turndown requirements for preoxidation. Both blowers are on variable frequency drives (VFDs) which will not be sufficient to meet contactor headspace pressure requirements at lower off-gas flow rates and associated turndown requirements.

Table 4.14 – Process Design Criteria for Ozone Off-Gas Destruct System

Parameter		Units	Existing System	Modified System
Ozone Destruct Unit	Type of Destruct Unit	--	Skid Mounted Thermal Catalytic	
	Number of Destruct Units per Contactor Train (duty/standby)	#	1/1	
	Maximum Off-Gas Flow Rate	scfm	300	37
	Minimum Off-Gas Flow Rate	scfm	65	5
	Off-Gas Pressure	in w.c.	-6.6	
Catalyst	Type	--	Manganese Dioxide	
	Max Face Velocity	ft/sec	0.86	
	Min Face Velocity	ft/sec	NP	
	Min Empty Bed Contact Time	sec	1.40	
	Catalyst Quantity	lbs	405	
Heater Element	Type	--	Circulation Heater	
	Power	V/Ph/Hz/amp	480,3,60 - 6.9 KW	
	Number of Elements per Destruct Unit	#	1	
	Minimum Temp Rise	deg F	60	
Blowers	Type	--	Centrifugal	
	Number of Blowers	#	1 per ODU	
	Blower Inlet Pressure	in w.c.	-11.1	
	Motor Horsepower	HP	5	
	Min Static Pressure rating	in w.c.	20	

4.5.6 Major Equipment Components

Based on preliminary discussion with Suez Treatment Solutions, the following equipment design modifications will be required to meet ozone production and off-gas turndowns requirements for the preoxidation process:

- ***Liquid Oxygen and Nitrogen Storage Systems*** – Rescale all gas flow metering and control instruments to provide accurate measurements at lower gas flows. Operate only one set of storage tanks at a time to meet lower oxygen and nitrogen production requirements.

- ***Ozone Generators*** – Block approximately 33 percent of the dielectric tubes; retune the PSUs for accepting reduced power load; rescale or replace the oxygen and ozone gas flow instruments to provide accurate measurements at lower gas flows; operate duty ozone generator at lower ozone concentration (4 to 6 percent) under low dose/low flow operating conditions.

- ***Off-gas Destruct Units*** – Replace off-gas pressure control valve to maintain a set vacuum in the contactor headspace; replace destruct vessel with smaller unit to maintain minimum face velocity across catalytic media; replace air intake valve on inlet side of the destruct unit blowers.

- ***Contactor Diffuser Grid –*** Replace diffuser gaskets and any damaged stones; operate single diffuser grid for full range of plant flows.

Figure 4.8 shows the layout of the dual diffuser grid for Contactor Basin No. 1. Only the 16 diffuser stones highlighted in blue would typically be used for diffusion of ozone gas into the cell.

Figure 4.9 shows a section view of Contactor No. 1 and the preferred sample location for measuring the oxidation-reduction potential (ORP) for preoxidation, one chamber downstream of the diffuser grid.

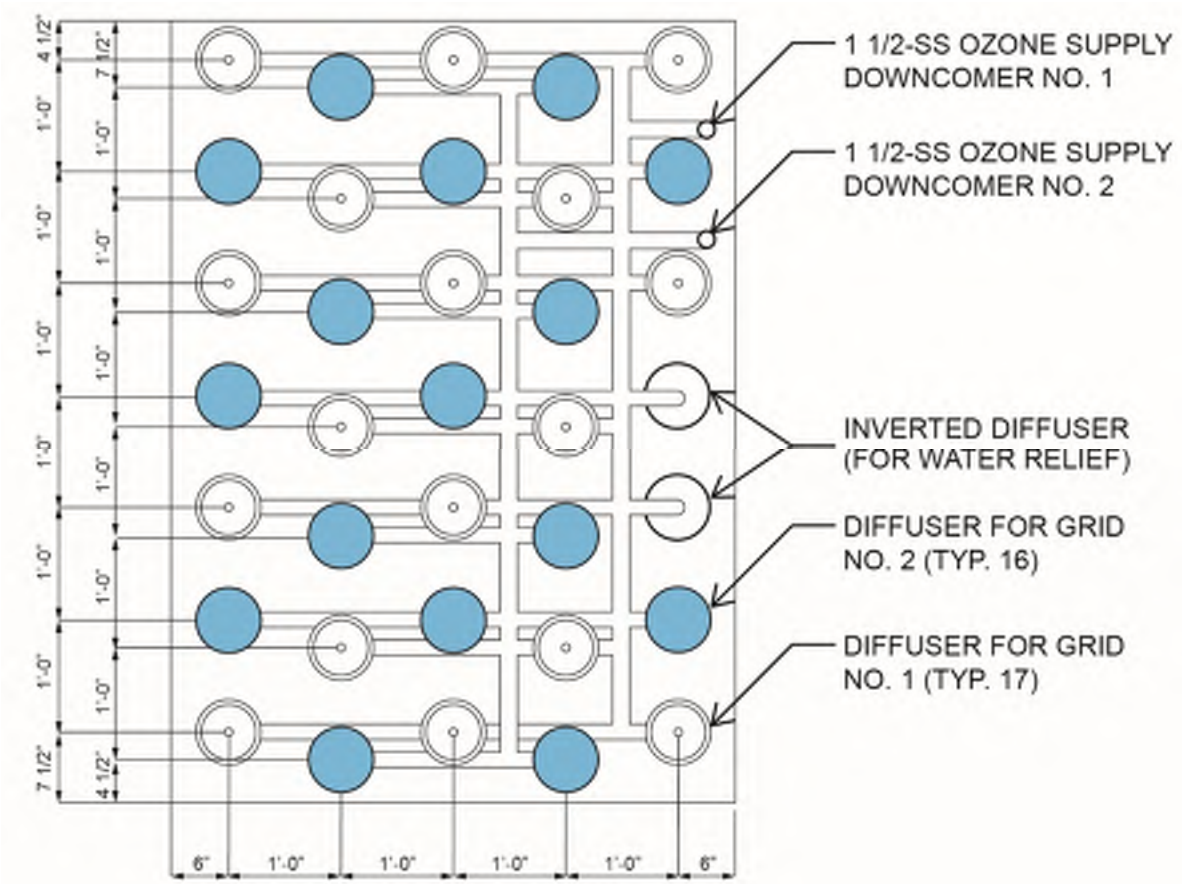

Figure 4.8 – Ozone Diffuser Grid Layout for Contactor Basin No. 1

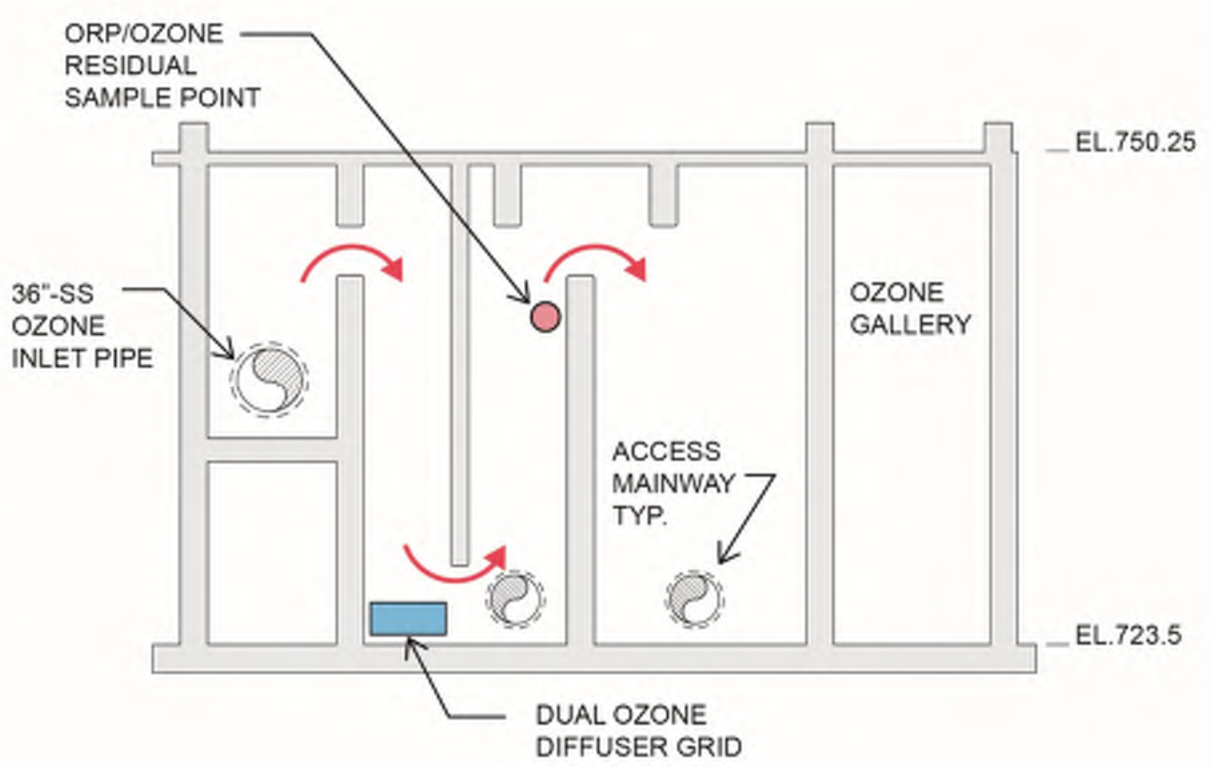

Figure 4.9 – Ozone Contactor No. 1 Showing Diffuser Grid and ORP Sample Locations

4.6 Rapid Mixing

4.6.1 Treatment Objectives and Approach

Rapid mixing is the first step in a conventional treatment process. Particle-destabilizing coagulant chemicals are added in the mixing chamber and thoroughly mixed as quickly as possible to provide uniform dispersion of chemicals throughout the raw water. Energy input is measured by the velocity gradient or G-value, with fully turbulent mixing occurring at G-values of 750 sec^{-1} or higher.

Research and full-scale operational experience have shown that rapid dispersion of chemicals in the raw water stream in seconds, or even fractions of a second, can improve the hydrolyzing reactions of the coagulant, achieving particle charge neutralization at lower chemical doses. Thus, "flash mixing" systems, which typically are designed within pipelines, are preferred for coagulant addition to establish a turbulent mixing zone in the water's flow pattern where chemicals are introduced. Traditional rapid mixers, which use mechanical mixers in concrete chambers, are satisfactory for dispersing other types of non-hydrolyzing chemicals.

The east and west rapid mixing units for the WTP are conventional vertical shaft impellor type mixers installed in a concrete chamber with a deep inlet opening and weir outlet. The detention time at design flow is approximately 30 seconds, with calculated mixing gradients (or G-values) ranging from 350 to 530 sec^{-1} depending on water temperature. These mixing criteria are considered to be non-optimal when using metal salts for coagulation such as alum and ferric chloride.

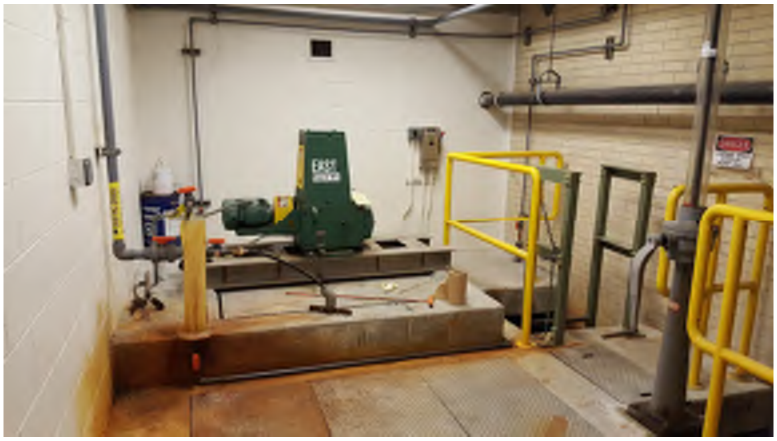

Figure 4.10 – Flint WTP Rapid Mixer Room

4.6.2 Description of Design Alternatives

The two rapid mixing design alternatives are described below.

- ***Vertical-Shaft Impellor Mixer*** – This baseline alternative considers that the existing rapid mixers for the east and west pretreatment basins are retained with no significant design modifications. Raw water enters the mixing chamber through a bottom inlet opening, flows upwardly through the double-impellor mixer, exits over a weir into an adjoining chamber, and flows through an inlet distribution pipeline into the flocculation basins. The mixer includes two stainless steel hydrofoil impellors on a common shaft driven by a 5-HP constant-speed motor. Coagulant chemicals are applied immediately below the lower mixer impellor to improve dispersion into the incoming water.

- ***Pumped Diffusion Mixer*** – This alternative considers that the existing rapid mixing equipment is replaced with a new pumped diffusion mixer, installed in the same mixing chambers. The main components of each system include a booster pump, mixing pipeline, spray nozzle, chemical diffuser quills, and interconnecting piping for mixing water. The booster pump is installed at the same chamber as the existing vertical shaft mixer. The mixing pipeline and other components are in a converted "dry space" chamber located adjacent to the pump chamber.

4.6.3 Evaluation of Design Alternatives

Table 4.15 presents the technical evaluation of the two rapid-mixing design alternatives. The scoring results (using only the previously described performance and operational criteria and not considering cost) indicate that the pumped diffusion mixing option outscores the vertical-shaft mixer option in four out of five evaluation criteria. The fifth criterion, site considerations, had no bearing on the evaluation. The deciding factors in favor of the pumped diffusion alternative include improved mixing efficiency (G-value up to 1,000 sec^{-1}) at very short detention times (a few seconds), less O&M requirements for the vertical turbine pump, and improved access to mixing equipment in the "dry space" chamber.

CDM Smith

Table 4.15 – Technical Evaluation of Rapid Mixing Design Alternatives*

Evaluation Criteria	Vertical Shaft Rapid Mixer	Pumped Diffusion Rapid Mixer
Regulatory and Water Quality Issues	Impellor mixer designed with G-values of less than 300 to 500 sec-1 in colder waters, which is not optimal for effective rapid mixing	Pumped mixer and dispersion nozzle designed with G-values of 750 to 1,000 sec-1, which is optimal for effective rapid mixing and potentially lowering the coagulant dose
	5-HP mixer motor is undersized to meet mixing energy requirements for colder waters	5-HP motor is properly sized to meet energy requirements for colder waters
	Existing chemical application points are not located below the impellor leading to inadequate dispersion of chemicals in the rapid mix chamber	Existing chemical application points are located immediately upstream of injection nozzle, providing immediate dispersion of coagulants in the mixing pipeline
SCORE:	3	4
Operational Simplicity	Impellor mixers require routine maintenance for shaft and gear lubrication	Pump mixers require less maintenance compared to mixer
	Mixing chamber must be isolated and drained to access submerged chemical lines, which are located below mixing impellor	Coagulants dispersed in mixing pipeline using Saf-T-Flo retractable diffusers, which can be accessed in new dry space of rapid mix area
	Mixer motor, shaft and impellors can be removed using fixed lifting hook above mixing chamber	Pump motor and suction column can be removed using fixed lifting hook above mixing chamber
SCORE:	3	4
Flexibility and Efficiency	Mixer uses constant-speed motor so mixing energy cannot be adjusted	Pump uses constant-speed motor, but discharge valve can be modulated to adjust mixing energy delivered to nozzle, if required
SCORE:	3	4
System Reliability and Safety	Fixed ladders and slide gate provided for isolation and access into “wet” mixing chamber after chamber is drained	New pumped diffusion mixing chamber is converted into “dry” space with fixed ladder for access
SCORE:	2	4
Site Considerations	No site impacts	No site impacts
SCORE:	0	0
OVERALL SCORE:	**11**	**16**

*Based only on performance and operational criteria and not considering cost

The capital cost for converting the two, existing rapid-mixing systems to pumped diffusion is estimated at $1.0 million. The annual operating cost will be the same for both alternatives based on continuous operation of the vertical turbine pump, which requires the same power input (5 HP motor) as the existing vertical shaft mixer.

4.6.4 Recommended Design Alternative

CDM Smith recommends that the existing vertical-shaft impellor mixers for the WTP be replaced with a state-of-the-art pumped diffusion mixing system. The additional capital cost for installing this system is justified based on improved coagulation and mixing, potentially lower chemical costs, improved access to mixing components, and lower overall O&M requirements.

4.6.5 Process Design Criteria

Table 4.16 presents the process design criteria for the pumped diffusion-mixing system. Two mixing trains are assumed to operate at average and maximum design flows, and one train at minimum flow. The G-values range from 750 to 1,000 sec^{-1} depending on water temperature, and mixing detention times range from 1 to 2 seconds; these are considered optimal design values for effective flash mixing. The pump motor size is 5-HP. This is the same size as the existing impellor mixer, but it achieves significantly improved mixing efficiency.

Table 4.16 – Process Design Criteria for Rapid Mixing System

Description	Units	Maximum	Average	Minimum
Plant Capacity				
Flows	MGD	24	14	5
Basin Geometry (for pump wet well)				
Number of Basins	No.	2	2	1
Capacity per Basin	MGD	12	7	5
Basin Length	ft	5.5		
Basin Width	ft	5.5		
Side Water Depth (H)	ft	16		
Volume	cf	484		
Rapid Mixing Criteria – Pump Injection Mixer				
Target G Value	s-1	750		
Pipe Diameter (D)	in	30		
Length of Mixing Zone (L)	ft	3.75		
Volume of Mixing Zone	cf	18.4		
Mixing Time (t)	secs	0.99	1.70	2.38
Gt	--	744	1275	1784
Nozzle Orifice Criteria				
Orifice Diameter	in	2.38 (Flange Size: 4 in)		
Required Pump Flow	gpm	269		
Injection Head Loss	ft	10.40		
Injection Velocity	ft/s	25.88		
Energy Input	HP	0.71		
Pump Design Criteria				
Required Pump Flow	gpm	269		
Percent of Plant Flow	%	3%	6%	8%
Type of Pump	--	Vertical Turbine		
Drive Mechanism	--	480 V/3 Ph/60 Hz		
Motor Efficiency (e)	--	80%		
Pump Brake HP	HP	2.00		
Pump Motor HP	HP	5.00		

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4.6.6 Major Equipment Components

Figure 4.11 presents a schematic drawing of a typical pumped diffusion system. The main components of the system include the booster pump, spray nozzle, chemical diffuser quills, and interconnecting piping for mixing water. The booster pump is located adjacent to the mixing pipe and is easily assessable for maintenance. The spray nozzle is a 4-inch stainless steel flange-mounted device with a 90-degree full-cone spray pattern opposing the direction of the mainstream flow, for effective flash mixing. The nozzle assembly can be removed through an access hatch on the pipeline. Multiple chemical quills are located directly upstream of the dispersion nozzle, one per treatment chemical with one or more spares.

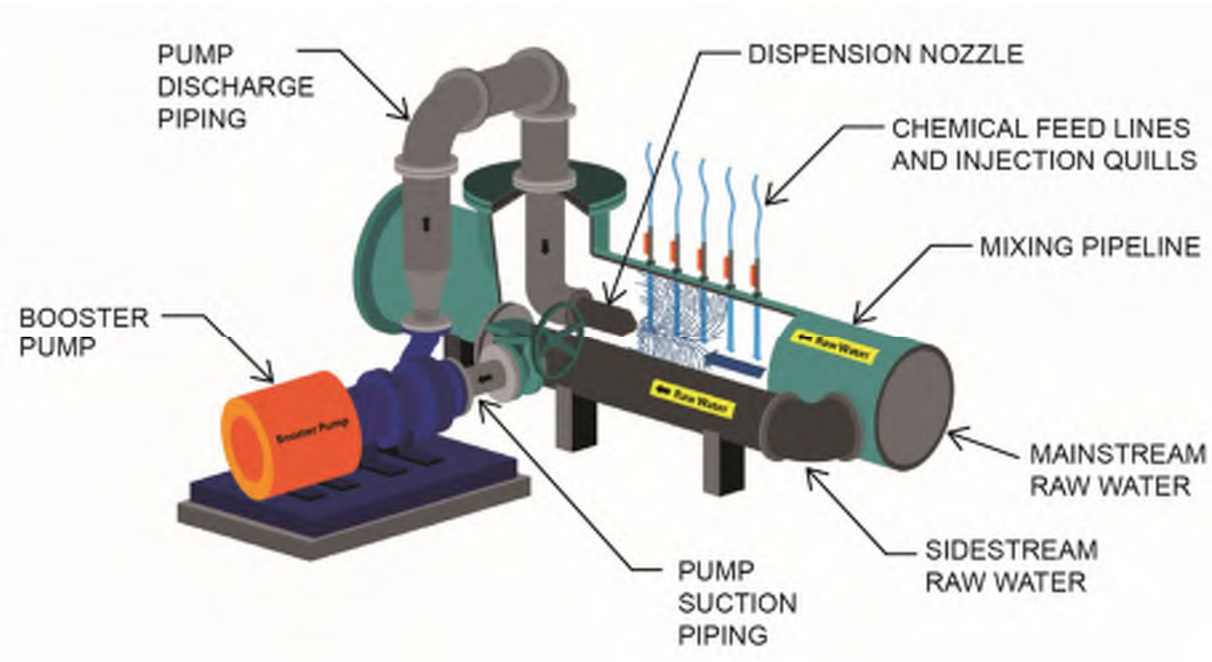

Figure 4.11 – Schematic of Pumped Diffusion Mixing System

4.6.7 Layout Design Concepts

Figure 4.12 presents the design concept for constructing a pumped diffusion system in the existing rapid-mixing chamber for the WTP. The vertical turbine pump is installed in the chamber currently occupied by the vertical-shaft impellor mixer. A lifting hook above the mixer allows for direct installation and removal of this equipment. The 30-inch mixing pipeline extends through an existing 48-inch wall pipe on the east side of the existing weir chamber and penetrates through the raw-water inlet chamber on the west side. A 30-inch butterfly valve with extended operator is installed in the inlet chamber for isolating the mixing pipe for maintenance. The weir chamber is converted into a dry space by extending the weir wall to the ceiling and filling the bottom of the chamber with mass concrete up to the top of the 30-inch mixing pipe. The concrete top surface provides a flat working space for the plant operator. The mixing pipe includes a 24-inch extended tee with blind flange to access the mixing nozzle; three 1.5-inch tees are located upstream of the nozzle for inserting Saf-T-Flo quills for coagulant chemical dispersion.

In operation, raw water flows from the raw-water inlet chamber through the 30-inch mixing pipeline, which continues as an inlet distribution header into the flocculation basin. A sidestream flow (3 to 8 percent of the total incoming flow) is diverted to the pump mixing chamber where it is pumped through the mixing nozzle, creating a full-cone spray pattern that opposes the main flowstream for effective flash mixing of coagulant chemicals.

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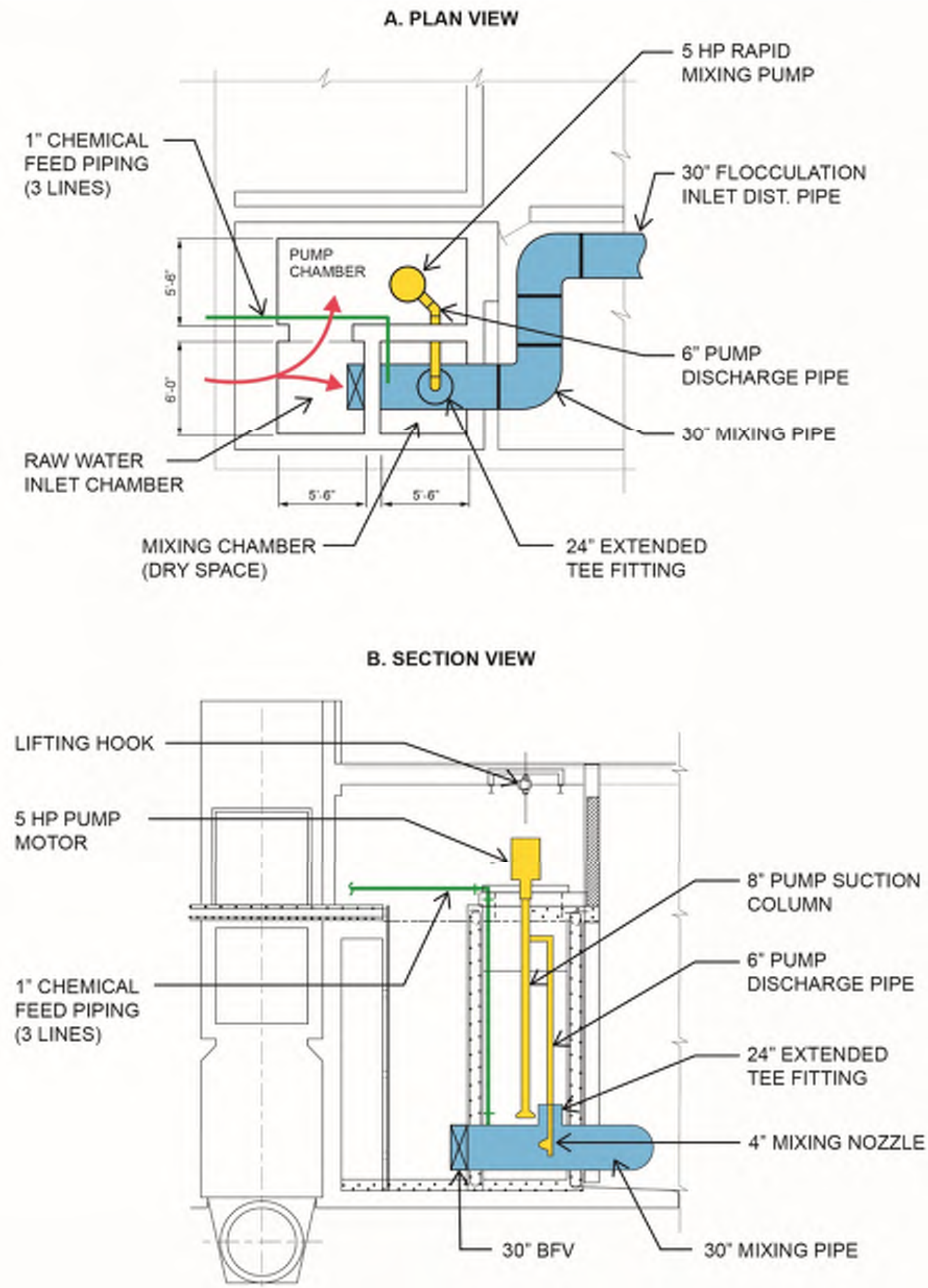

Figure 4.12 – Pumped Diffusion Mixer Layout for Flint WTP

4.7 Flocculation

4.7.1 Treatment Objectives and Approach

In conventional treatment, rapid mixing is followed by flocculation. The flocculation process aggregates particles into larger floc. These floc particles subsequently settle out by gravity in the sedimentation basins. Flocculation is a controlled, staged process, which allows chemically destabilized particles to attach to each other and grow in size. Mechanical mixing is the most common type of flocculation process and is used at the WTP. Its main advantage over hydraulic flocculation is that mixing energy can be imparted to water and controlled independent of changing flow, water temperature, and water quality conditions. Mixing energy is provided by vertical propeller blade mixers. The mixing energy in flocculation basins is far less than in rapid mix basins with typical G-values in the range of 20 to 80 sec^{-1}.

The east and west flocculation basins for the WTP have a total of 30 vertical shaft impellor-type mixers, which provide three-stage tapered flocculation in six parallel trains (three per basin), each separated by intermediate concrete baffle walls extending to mid-depth in each basin. The detention times in each basin range from 48 minutes to over two hours with both basins in service at the reduced design flows anticipated for the Flint Water Treatment Plant Improvements Project. The long detention times can promote shearing of the floc and solids deposition due to the low velocities in the basin. This configuration also lacks sufficient baffling (compartmentalization) within each flocculation stage, necessary to minimize flow short-circuiting and stagnant zones, and allow for effective slow mixing and floc formation. This is especially important for treating low turbidity raw water from Lake Huron, when it may be desirable to form a tight pinpoint floc for removal on the filters.

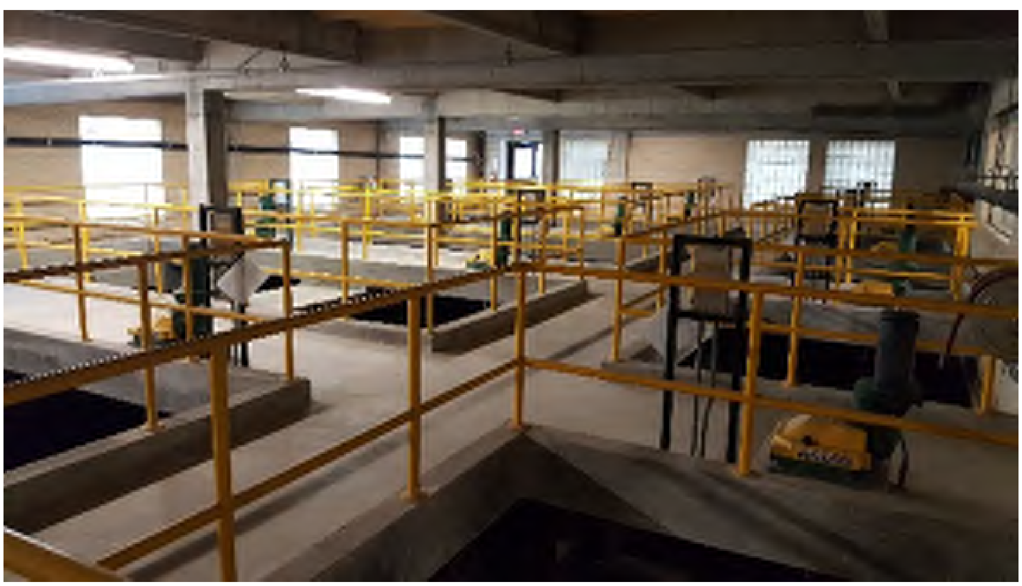

Figure 4.13 – Flocculation Basin

4.7.2 Description of Design Alternatives

The two flocculation design alternatives are described as follows:

- ***Existing 3-Stage Flocculation Basin*** – This baseline alternative considers that the existing east and west flocculation basins are retained with no significant design modifications. Raw water enters the first-stage flocculation zone in each basin through a 48-inch inlet distribution pipe header with five 30-inch pipe laterals to distribute the incoming coagulated water flow across the entire width of the basin. Three flocculation trains and 15 vertical-shaft flocculators are used in each basin for slow mixing. The existing variable frequency drives (VFDs) are retained for adjusting the rotation speed and mixing efficiency of the 30 flocculators.

- ***Modified 3-Stage Flocculation Basin*** – In this alternative, a new concrete divider wall is installed in the east and west flocculation basins to reduce the size of each basin and provide shorter detention times for effective tapered flocculation. The smaller basins are reconfigured to provide three parallel compartmentalized flocculation trains and nine vertical-shaft flocculators. The remaining flocculators on the other side of the divider wall are removed from service. A new 30-inch inlet distribution pipe header with three 24-inch pipe laterals is routed to the north wall of the first-stage flocculation zone to avoid conflicts with the first-stage flocculator impellors. The existing VFDs are used for adjusting the rotation speed and mixing efficiency of the 18 flocculators.

4.7.3 Evaluation of Design Alternatives

Table 4.17 presents the technical evaluation of the two flocculation design alternatives for the WTP. The scoring results (using the previously described performance and operational criteria and not considering cost) indicate that the modified flocculation basin option is preferred over the existing system due to improved mixing efficiency through the use of smaller basins and fully compartmentalized trains, elimination of the conflict between the inlet distribution pipe and the first-stage flocculator impellors, and reduced O&M requirements from elimination of 12 mechanical flocculators and associated VFDs. Additionally, the reduction in detention time in the modified 3-stage flocculation basin reduces the potential for shearing the floc and deposition of solids in the flocculation basins due to low velocities.

Table 4.17 – Technical Evaluation of Flocculation Design Alternatives*

Evaluation Criteria	Existing 3-Stage Flocculation Basin	Modified 3-Stage Flocculation Basin
Regulatory and Water Quality Issues	Two flocculation basins (each with 15 flocculators) are poorly baffled, with potential for significant flow short-circuiting	Two flocculation basins are retrofitted with FRP baffles to compartmentalize five flocculator trains per basin, improving mixing and flow patterns
	The ported baffle walls between each stage do not allow for tangential flow patterns to minimize flow short-circuiting	The ported baffle walls between each stage are modified to promote tangential flow and minimize flow short-circuiting
	The flocculation basins cannot be operated at shorter detention times for high-intensity flocculation	The flocculation basins are split into two sub-basins by new concrete wall to allow for operation at shorter detention times
	The 48-inch inlet distribution pipeline is located directly underneath the first-stage flocculator impellors, which negatively impacts mixing efficiency	A new 30-inch inlet distribution pipeline is relocated away from the first-stage flocculator impellor, to improve mixing efficiency

Evaluation Criteria	Existing 3-Stage Flocculation Basin	Modified 3-Stage Flocculation Basin
	Five 30-inch laterals distribute flow from the inlet distribution pipeline for each flocculation basin	Three 24-inch laterals with inlet valves on each inlet distribution pipeline allow flows to be routed to each of two sub-basins
SCORE:	3	4
Operational Simplicity	Vertical shaft flocculators are on VFDs, allowing easy adjustment of mixing intensity to optimize floc formation	Vertical shaft flocculators are on VFDs, allowing easy adjustment of mixing intensity to optimize floc formation
	The drive units and shaft bearings are located on walkways above the water surface, for ease of maintenance	The drive units and shaft bearings are located on walkways above the water surface, for ease of maintenance
	Drainage chamber with sump pump station provided for draining each flocculation basin	Drainage chamber with sump pump station provided for draining each flocculation basin
SCORE:	4	4
Flexibility and Efficiency	Flocculator VFDs allow for easy adjustment of mixing intensity to optimize floc formation	Flocculator VFDs allow for easy adjustment of mixing intensity to optimize floc formation
	No flexibility to operate each flocculator basin at shorter detention times	Incoming flows can be diverted to one or both sub-basins by opening and closing inlet valves
SCORE:	3	4
System Reliability and Safety	Fixed ladders provide access into flocculation basins and sump chamber	Fixed ladders provide access into flocculation basins and sump chamber
SCORE:	3	3
Site Considerations	No site impacts	No site impacts
SCORE:	0	0
OVERALL SCORE:	**13**	**15**

*Based only on performance and operational criteria and not considering cost

The capital cost for upgrading the two flocculation basins is estimated at $1.2 million. The power consumption for the modified flocculation system will be less than the existing system due to the elimination of 12 mechanical flocculators with 1.5 HP motors. The annual operating cost savings is estimated at $8,000 per year.

4.7.4 Recommended Design Alternative

CDM Smith recommends that the existing flocculation basins for the WTP be modified to reduce the flocculation detention time, compartmentalize each flocculation train, and improve inlet flow distribution to the first stage of each train. The additional capital cost for modifying the existing system is justified because it will improve floc formation during low and high turbidity events on Lake Huron, for improved settling, lower filtered water turbidities, and reduced O&M requirements.

4.7.5 Process Design Criteria

Table 4.18 presents the process design criteria for the three-stage flocculation system. Two flocculation trains are assumed to operate at average and maximum design flows and one train at minimum flow. The flocculation detention times vary from 27 to 65 minutes depending on plant flow, and tapered flocculation is achieved by gradually decreasing the velocity gradients in the three flocculation stages. The detention time and velocity gradient design values for flocculation are consistent with industry best practices for surface water treatment and can be adjusted in practice by operating one or two flocculation basins in parallel and using VFDs to adjust the rotation speed of each flocculator.

Table 4.18 – Process Design Criteria for Flocculation System

Description	Units	Maximum	Average	Minimum
Plant Capacity				
Flows	MGD	24	14	5
Basin Geometry				
Number of Modules	No.	2	2	1
Number of Trains	No.	3	3	3
Number of Stages	No.	3	3	3
Capacity per Train	MGD	4.0	2.3	1.7
Train Length	ft	40.5		
Train Width	ft	15.4		
Side Water Depth	ft	16.1		
Hydraulic Loading				
Detention Time	Minutes	27.1	46.5	65.1
Horizontal Velocity	Minutes	1.1	0.7	0.5
Flocculator Equipment				
Number of Flocculators Per Module	--	6		
Number of Installed Flocculators	--	12		
Number of Flocculators to be Decommissioned	--	18		
Impeller Type	--	3-Blade Hydrofoil		
Impeller Diameter	ft	5.75		
Impeller Shaft Diameter	in	2.00		
Motor Speed	rpm	1800		
Motor HP	HP	1.5		
Motor Efficiency	--	80%		
Speed Control	--	VFD		
Turndown	--	5:1		
Stage 1 – Mixing Criteria				
Basin Length	ft	14.5		
Basin Width	ft	15.3		
Basin Volume	cf	3570		
G Value Warm Water	s-1	71		
G Value Cold Water	s-1	108		
Gt Warm Water	--	1915	3283	4596
Gt Cold Water	--	2934	5030	7042

Description	Units	Maximum	Average	Minimum
Stage 2 – Mixing Criteria				
Basin Length	ft		14.5	
Basin Width	ft		15.3	
Basin Volume	cf		3570	
Speed Reduction – Stage 2	--		0.625	
G Value Warm Water	s-1		44	
G Value Cold Water	s-1		68	
Gt Warm Water	--	1197	2052	2873
Gt Cold Water	--	1834	3144	4401
Stage 3 – Mixing Criteria				
Basin Length	ft		11.5	
Basin Width	ft		15.3	
Basin Volume	cf		3570	
Speed Reduction – Stage 3	--		0.375	
G Value Warm Water	s-1		26	
G Value Cold Water	s-1		41	
Gt Warm Water	--	718	1231	1724
Gt Cold Water	--	1100	1886	2641
Inlet Conditions				
Header Diameter	in		30	
Velocity	ft/s	3.78	2.21	1.58
Number of Openings	No.	2	2	2
Opening Type	--		Pipe	
Opening Diameter	in	24	24	24
Velocity	ft/s	1.97	1.15	0.82
Intermediate Baffling Conditions – Stage 1 to Stage 2				
Number of Openings	No.	1	1	1
Opening Area	sf	20.25	20.25	20.25
Velocity	ft/s	0.31	0.18	0.13
Intermediate Baffling Conditions – Stage 2 to Stage 3				
Number of Openings	No.	1	1	1
Opening Area	sf	20.25	20.25	20.25
Velocity	ft/s	0.31	0.18	0.13
Flocculation Basin Outlet Conditions				
Weir Length	ft	54.0	54.0	27.0

4.7.6 Major Equipment Components

The major equipment components for modifying the flocculation basins include the following:

- FRP structural baffle panels for compartmentalizing two flocculation trains in each basin. These panels have a corrugated design for structural strength and are fastened to concrete walls and floors using FRP angles and stainless steel anchor bolts. Longer baffle walls may include FRP structural columns and slide guides for ease of assembly and removal (see photo).

- Butterfly valves with extended torque tube operators for the new inlet distribution pipe header. The torque tubes allow an extended operator to be used without the need for a floor standout to core through a concrete floor. The tubes can be supported on a concrete sidewall with standard pipe supports (see photo).

Figure 4.14 – Structural FRP Panel (by Enduro) and Torque Tube Operator Installed in a Flocculation Basin

4.7.7 Layout Design Concepts

Figure 4.15 presents the design concept for modifying the existing flocculation basins at the WTP. Two flocculation trains are provided for each basin. A concrete dividing wall separates the active trains from the remainder of the basin, which will be permanently drained and removed from service. Each train consists of three compartmentalized stages for tapered flocculation, formed by the basin perimeter walls and extended FRP baffles positioned above and below an existing intermediate concrete baffle. The effluent weir walls on the decommissioned side of each basin will be filled with concrete to avoid backflow of flocculated water into this area. The existing port openings on the concrete walls separating each flocculation stage will be retained, blocked off, or modified to provide a tangential, tortuous flow path as water flows from one flocculation stage to the next.

In operation, coagulated water from the rapid mixing basin will flow through a 30-inch inlet distribution pipeline running along the north side of the first-stage flocculation compartment (to avoid conflicts with the first-stage flocculator). From here, the water will be directed through two 24-inch pipe laterals, which will discharge to one corner of the first flocculation stage and then flow tangentially through each stage to maximize particle contact for effective flocculation.

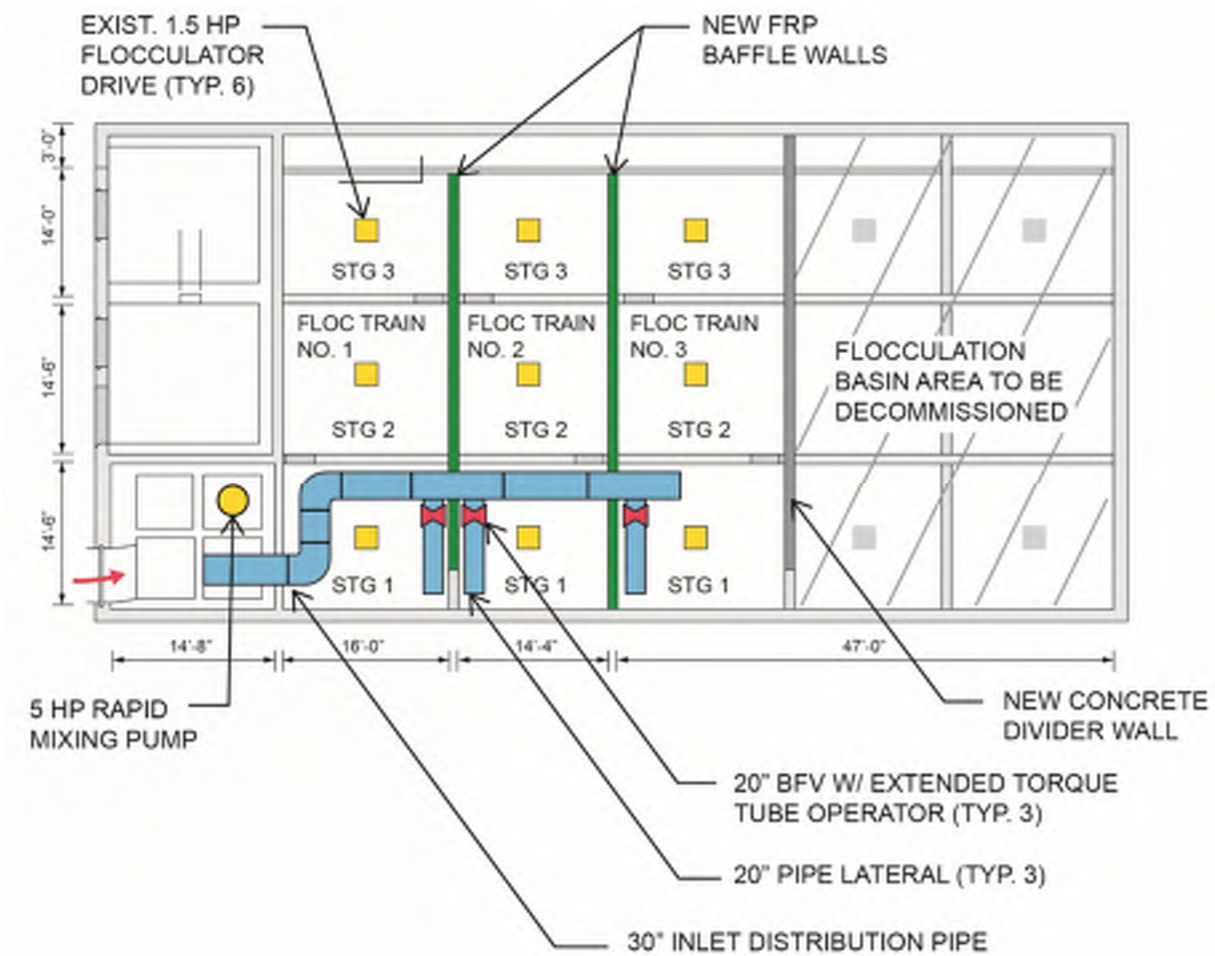

Figure 4.15 – Modified East Flocculation Basin Layout Plan View

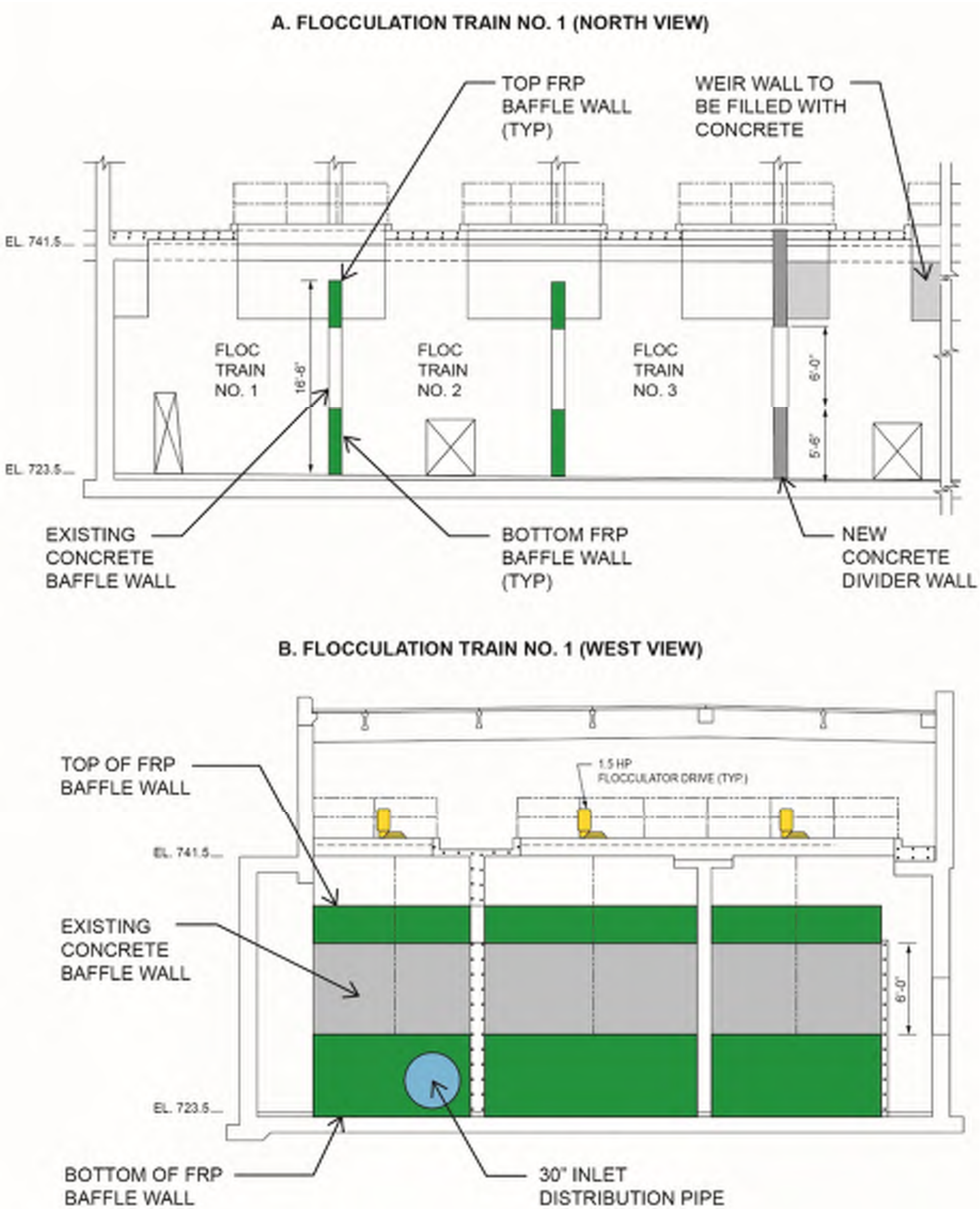

Figure 4.16 – Modified East Flocculation Basin Layout Section Views

4.8 High-Rate Sedimentation

4.8.1 Treatment Objectives and Approach

In the sedimentation process, floc that has been formed settles out in relatively quiescent basins. The sedimentation process at the WTP has been augmented with inclined plate settlers (IPS) which increase the available solids-settling area within the footprint of the basin. The IPSs allow the basin to function at a much higher hydraulic loading rate while maintaining the solids loading rate of a conventional overflow clarifier. Solids (also called sludge) must be removed from the clarification process by manual or mechanical methods. Typical mechanical methods include flight and chain collectors and fixed or travelling hydraulic sludge collectors. The WTP uses a fixed-sludge collection system in the IPS basins.

The IPS basins at the WTP were constructed in 2000 and are located at the far north end of the WTP building, directly north of the flocculation process. The IPS basins are fed from the east and west flocculation modules by six 36-inch pipes which convey settled water to a settled water inlet conduit. Water enters each basin through two 54-inch by 54-inch square butterfly gates. Each basin contains four plate settler trains and two fixed-grid sludge collection systems. The design solids-loading rate is 0.3 gpm/sf at 36 MGD plant flow or 12 MGD per basin. The IPS basins are numbered 1 through 3 from south to north.

Figure 4.17 – Inclined Plate Settler Packs in Basin No. 1

The existing plate packs and basins are in good condition. During the assessment of the WTP, CDM Smith observed the following regarding the IPS basins:

- The 33 percent reduction in plant design flow from 36 to 24 MGD means that the design loading rates and detention times for the IPS basins can be met with two out of three IPS basins in service.
- The velocity through the inlet gates is below the maximum recommended inlet velocity of 0.5 ft/s. However, the flow of water is not distributed evenly across the area of the basin, which could result in a treatment process upset.

- The existing sludge collection system does not function properly. Operators reported rat-holing during sludge withdrawal and the need to follow-up with pressure hosing of the basin floor.

- The existing pumped-sludge withdrawal system does not allow the operator to observe sludge withdrawal outside of the basin. Further, the pumped withdrawal may contribute to uneven distribution in flow between the various sludge collectors, resulting in poor withdrawal performance.

4.8.2 Description of Design Alternatives

4.8.2.1 IPS Basin Alternatives

Two IPS Basin design alternatives are described below.

- ***Use Existing IPS Basins for Water Treatment –*** This baseline alternative considers that the three existing IPS basins continue to be used for clarification of flocculated water at a reduced surface loading rate, with no design or operational modifications.

- ***Modify IPS Basin Inlet Configuration –*** This design alternative considers installation of a baffling system across the front of the plate packs to evenly distribute incoming flow across the width of each IPS basin. The baffling system will use FRP baffles similar to those in the flocculation tanks, to direct flow in an underflow approach condition to the plate packs. This baffle will improve the performance of the plate packs and provide two benefits: (1) it enables two of the IPS basins to treat the entire plant flow, and (2) thus, should future water quality regulations require that filter washwater be clarified prior to being recycled to the plant inlet, it allows one of the IPS basins to be used for clarification of filter washwater. Slide gates will be installed in the inlet and outlet channels between IPS Basins No. 2 and No. 3, to allow Basin No. 3 to be isolated from IPS Basins No. 1 and No. 2 and operated in the future for washwater clarification.

4.8.2.2 Solids (Sludge) Collection Alternatives

Two IPS sludge collection equipment alternatives are described below.

- ***Retain Existing Spyder Sludge Collection System –*** This baseline alternative assumes that the fixed-grid sludge-collection system, manufactured by Roberts Filter Company and called the Spyder system, is retained without modification. The sludge collection pipe headers are directly connected to the sludge transfer pumps for transferring residuals to remote holding tanks and eventually to the sanitary sewer.

- ***Install New Cable-Driven, Hoseless Sludge Collection System –*** This design alternative considers replacement of the Spyder fixed-grid sludge-collection system with a cable-driven, hoseless sludge-collection system manufactured by Meurer Research, Inc. (MRI), or equal. A new sludge holding tank will be constructed in the west gallery of the IPS facility to which the new sludge collectors will discharge by gravity. The existing sludge transfer pumps will draw from this tank and continue pumping to the sludge holding tank in the chemical area.

4.8.3 Evaluation of Design Alternatives

Tables 4.19 and **4.20** present technical evaluations of the IPS basin design and sludge-collection design alternatives. The scoring results (using the previously described performance and operational criteria and not considering cost) indicate that both the modified IPS basin and new sludge collection replacement alternatives are preferred over retaining the existing basin and sludge equipment system. Installation of the flow diversion baffles will allow a much lower and more uniform approach velocity to the plate packs across the whole basin width. This will minimize sludge upsets and other performance issues, especially during flow changes. The conversion of Basin No. 3 offers a cost-effective solution for future washwater clarification, thereby avoiding the need to construct a new (and costly) washwater treatment system on the plant site should future regulations require washwater clarification. The new cable-driven sludge collection system will significantly improve the efficiency of sludge collection and reduce O&M requirements. The plant operators are very dissatisfied with past performance of the existing Spyder system.

Table 4.19 – Technical Evaluation of IPS Basin Alternatives*

Evaluation Criteria	Existing IPS Basin	Modified IPS Basin
Regulatory and Water Quality Issues	Flow jetting through inlet gates may impact flow distribution to IPS plate packs and settling performance	FRP baffle wall redirects incoming flow downward and across basin to improve flow distribution to IPS plate packs
SCORE:	2	4
Operational Simplicity	No change to existing operation.	Improves performance of IPS Basins, which should improve operation.
SCORE:	3	4
Flexibility and Efficiency	2 out of 3 IPS basins in service at 24 MGD with 1 spare basin.	2 out of 3 IPS basins in service at 24 MGD with 1 spare basin.
	By continuing the use of all 3 IPS Basins for treatment of the entire plant flow, it necessitates the construction of a new clarification basin for washwater clarification should future regulations require this.	Allows existing IPS Basin No. 3 to be used for washwater recycle treatment should future regulations require this. Plant O&M requirements are not increased.
SCORE:	3	4
System Reliability and Safety	Same level of reliability and safety	Same level of reliability and safety
SCORE:	4	4
Site Considerations	No site impacts	No site impacts.
SCORE:	4	3
OVERALL SCORE:	**16**	**19**

*Based only on performance and operational criteria and not considering cost

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Table 4.20 – Technical Evaluation of Sludge Collection Alternatives*

Evaluation Criteria	Existing Spider Sludge Collection System	New MRI Sludge Collection System
Regulatory and Water Quality Issues	Spyder sludge collection system with fixed piping grids is subject to operational problems (plugging, rat-holing) which may impact IPS settling performance	New MRI sludge collection system with moving scrapers will improve sludge collection and avoid impacts on IPS settling performance
SCORE:	2	4
Operational Simplicity	Spyder sludge collection system is subject to operational problems (plugging, rat-holing) which often requires supplemental hose washing to keep basin floors clear of sludge	New MRI sludge collection system with moving scrapers will improve sludge collection and reduce O&M requirements and supplemental hose washing
	Sludge collectors hard piped directly to sludge transfer pumps which require more frequent pumping and may impact hydraulic performance of the collectors	Sludge collectors discharge by gravity to new sludge holding tanks which provide bulk storage and only need to be pumped out 1-2 times per year
	Hose wash stations are available for cleaning settler plates from walkway platforms, as needed	Hose wash stations are available for cleaning settler plates from walkway platforms, as needed
SCORE:	2	4
Flexibility and Efficiency	Spyder sludge collection system must be operated in conjunction with sludge transfer pumps, impacting sludge collection efficiency	MRI sludge collection system and associated sludge holding tank can be operated independently from sludge transfer pumps
SCORE:	2	4
System Reliability and Safety	Spyder sludge collection system has never worked properly and is an unreliable system according to plant staff	MRI sludge collection system has an excellent track record in water industry as a reliable system with minimal O&M requirements
SCORE:	2	4
Site Considerations	No site impacts	No site impacts
SCORE:	0	0
OVERALL SCORE:	**8**	**16**

*Based only on performance and operational criteria and not considering cost

The total capital cost for the IPS basin modifications is $0.5 million. The capital cost for the sludge collection equipment improvements is estimated at $2.5 million. The sludge drive mechanism operates on a fractional horsepower motor, so the additional operating costs for the cable-driven system are considered insignificant.

4.8.4 Recommended Design Alternative

CDM Smith recommends the following design improvements to the IPS Basins:

- Install flow diversion FRP baffle walls at the inlet to each IPS basin.
- Install slide gates in the common inlet and outlet channels of the IPS basins to isolate Basin No. 3 from the other basins, for future filter washwater clarification.

- Remove the existing Spyder sludge collection system and replace with a cable-driven sludge collector by MRI or equal.
- Install a new concrete sludge holding tank at the south end of the west gallery with approximately 300 cubic foot (cf) capacity.
- Reroute 6-inch sludge pump suction piping to withdraw sludge from the new sludge tank in the gallery; retain the existing sludge pumps, to transfer sludge to the existing remote sludge holding tank and eventually the sanitary sewer.

4.8.5 Process Design Criteria

Table 4.21 lists the process design criteria for the modified IPS basins. At the new maximum design flow of 24 MGD, the existing solids loading rate of 0.3 gpm/sf is maintained. At an average daily flow of 14 MGD, one basin could be operated at a solids loading rate of 0.35 gpm/sf, which in CDM Smith's experience is an acceptable loading rate for normal operation. Thus, up to the average daily flow, the sedimentation process will include a fully redundant basin even if the IPS Basin No. 3 is converted to a filter washwater clarifier.

The new sludge collector units will each withdraw sludge from the basin at a flow of 100 gpm. Each sludge collector will run in a staggered fashion. The sludge collector manufacturer estimates that each sludge collector will run for approximately 45 minutes per day assuming average solids loading. The estimated sludge discharge volume from the two IPS basins and the used washwater clarification basin is 80,000 gallons per day (gpd) and 517,000 gpd at the average and maximum day solids loading and flow conditions, respectively. This flow will be sent by gravity to the new sludge holding tank and then pumped to the upgraded solids-handling system, as discussed in Section 4.11.

Table 4.21 – Process Design Criteria for Sedimentation System

Description	Units	Maximum	Average	Minimum
Plant Capacity				
Flows	MGD	24	14	5
Basin Geometry				
Number of Installed Basins	No.	2	2	2
Number of Basins in Service	--	2	1	1
Basin Surface Area	sf	6478	3239	3239
Side Water Depth	ft	27		
Hydraulic Loading				
Surface Overflow Rate	gpm/sf	2.6	3.0	1.1
Detention Time	minutes	78.5	67.3	188.4
Horizontal Velocity	ft/s	0.02	0.02	0.01
Type of Weir	--	V notch		
Horizontal Weir Length per Basin	Ft	560		
Weir Loading	gpm/ft	14.9	17.4	6.2
Plate Settler Criteria				
No. of Plate Settler Trains per Basin	No.	4		

Description	Units	Maximum	Average	Minimum
Capacity per Plate Settler Train	MGD	3	3.5	1.25
Solids Loading Rate	gpm/sf	0.30	0.35	0.12
Total Plate Area	sf	69747	34873	34873
Plate Efficiency	%		80%	
Effective Plate Area	sf	55797	27899	27899
Number of Packs per Basin	No.		16	
Number of Plates per Pack	No.		76	
Number of Plates per Basin	No.		1216	
Plate Spacing	in		2	
Plate Inclination	degrees		55	
No. of Effluent Channels per Train	--		4	
Residual Solids Collector Criteria				
Sludge Collection Mechanism	--		Cable-driven Sludge Collector (MRI or equal)	
No. per Basin	No.		4	
Sludge Collector Length	ft		82	
Sludge Collector Width	ft		~9 ft	
Withdrawal Method	--		Pumped from new sludge discharge wet well	
Sludge Collector Withdrawal Flow	gpm		100 - 150	
Sludge Withdrawal Frequency	--		45 minutes per sludge collector per day	
Average Total Sludge Withdrawal Flow (Average day flow, turbidity, and coagulant dosage condition)	gpd		80,000	
Maximum Total Sludge Withdrawal Flow	gpd		517,000	
Sludge Pump Criteria				
Type of Pump	--		End Suction Centrifugal	
Manufacturer	--		Goulds	
No. of Units	No.		2	
Rated Flow	gpm		350	
Rated Head	ft		54	
Drive Mechanism	--		460 V/3 Ph/60 Hz	
Motor Horsepower	--		10	
Suction Piping Diameter	in		6	
Discharge Piping Diameter	in		4	
Drain Pump Criteria				
Type of Pump	--		End Suction Centrifugal	
Manufacturer	--		Goulds	
No. of Units	No.		2	
Rated Flow	gpm		350	
Rated Head	ft		64	
Drive Mechanism	--		460 V/3 Ph/60 Hz	
Motor Horsepower	--		15	
Suction Piping Diameter	in		6	

Description	Units	Maximum	Average	Minimum
Discharge Piping Diameter	in		4	
Inlet Conditions				
No. of Openings per Basin	No.	2	2	2
Opening Type	--		Square Butterfly Gate	
Opening Area	sf	20.25	20.25	20.25
Velocity	ft/s	0.46	0.53	0.19
Baffling Conditions				
Number of Flow Diversion Baffles	No.	2	2	2
Baffle Length	in		108	
Baffle Width	in		231	
Opening Area Per Basin	sf	162	162	162
Velocity	ft/s	0.11	0.13	0.05

4.8.6 Major Equipment Components

The improvements to the IPS basins will include the following major equipment:

- Four cable-drawn sludge collector tracks per basin (12 total). Each sludge collector will run the full length of the basin and cover approximately ¼ of the width of the basin. Each collector will have two collection zones. Two collectors will manifold together and discharge into the gallery through the existing sludge-collector wall penetrations.

- Six total (2 in each basin) flow diversion baffle walls. Dimensions of each baffle wall are approximately 9-foot tall by 19.25-foot wide.

- New 300 cf sludge tank at the south end of the west gallery. The tank will extend from the floor of the gallery level up to the ceiling. A hatch in the operating gallery level will allow operators to observe the sludge discharge from the basin. The dimensions of the tank are estimated at 3.5-foot wide by 17.5-foot long.

- Two new slide gates, one in the IPS basin influent channel and the other in the IPS Basin effluent channel.

Figure 4.18 – MRI Hoseless Cablevac Sludge Collector System (by Meurer Research) and FRP Baffle Wall (by Enduro)

4.8.7 Layout Design Concepts

Figures 4.19 shows the proposed inlet baffle improvements to the IPS basins. The FRP structural baffle (no perforations) will be mounted on top of an existing concrete beam which also supports the front end of the first set of plate packs. Two baffle walls will be installed, each located directly opposite the inlet gate. As shown, flow will impinge on the walls and be diverted through a submerged opening below the beam to improve flow distribution to the plate packs.

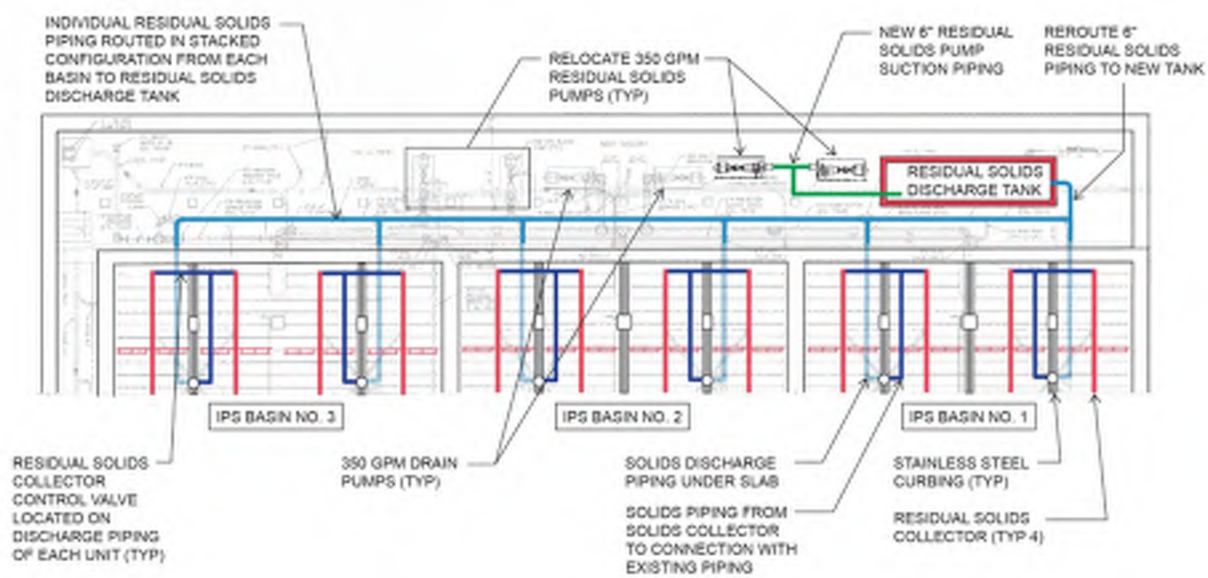

Figure 4.19 – IPS Basin Improvements Plan View

Figures 4.20 shows the area to be occupied by the new MRI sludge collection system. Four collector units will be required for each basin, a total of 12 collectors for the system. The collector discharge piping will connect to the existing 6-inch sludge pipes within the basin. In the gallery, an individual 6-inch sludge pipe for each basin will be installed and connected to the existing wall penetrations. This piping will convey solids from the sludge collection system by gravity to a new 300 cf holding tank located in the northeast corner of the gallery. The two existing sludge pumps in the gallery will be repiped to pump sludge from the holding tank to the upgraded solids handling system.

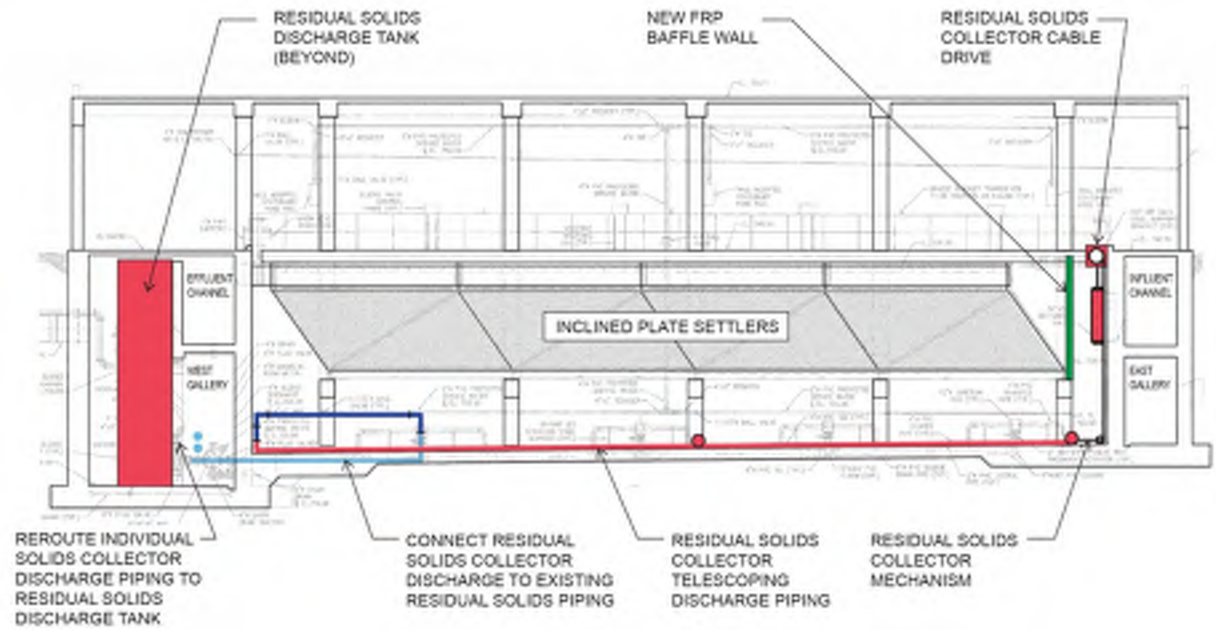

Figure 4.20 – IPS Basin Improvements Section View

4.9 Filtration

4.9.1 Treatment Objectives and Approach

Filtration is the final solids-removal process in a water treatment plant. The WTP operates a dual media (GAC/sand) biological filtration process with air-scour auxiliary wash and filter-to-waste capabilities. The biological filtration process serves the dual purpose of particle removal and removal of biodegradable organic carbon through biological oxidation. The efficiency of particle removal depends to a large extent on coagulation chemistry and the efficiency of upstream clarification processes. Biological filtration is often used downstream of ozonation for removal of biodegradable ozone by-products such as aldehydes and ketone acids. These by-products are easily biodegraded and thus enhance biological activity in the filter bed and the removal of other biodegradable organic compounds. Removal of these compounds reduces the potential for biological regrowth in the distribution system.

The WTP includes twelve 700-square-foot dual media filters which were installed as part of the original plant. The filters were rehabilitated in 2001, to include new false-floor monolithic-concrete nozzle-style underdrains and media retention troughs. The media profile consists of 18 inches of granular activated carbon (GAC) over 12 inches of sand. At the existing design capacity of 36 MG, the design firm filtration rate of the filters is 3.2 gpm/sf, well within the 2 to 4 gpm/sf range recommended by Ten States Standards. At the modified Flint WTP maximum day design flow of 24 MGD, the firm filtration rate will be reduced to 2.2 gpm/sf.

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The existing backwash process involves using distribution system pressure and is controlled with a throttling valve located in the filter gallery. Two 75-HP air scour blowers, one duty and one standby, provide auxiliary air during the backwash cycle. Used backwash water and filter-to-drain water flow out of the filter building by gravity and are pumped to an equalization basin before being recycled to the head of the treatment process.

Overall, the filters are in good condition and minimal improvements are required within the filter boxes. Evaluation of the filtration process further identified the following:

- The filter underdrain system is in satisfactory condition and includes air scour capabilities.
- Without any modifications, the filter box is deep enough to accommodate filter media 48 inches deep, while maintaining at least 30 percent media freeboard for expansion during backwash.
- The backwash system requires a new source of pressure and control of flow to minimize the risks associated with backwashing the filters with distribution system pressure.
- The existing filter media (GAC and sand) do not have compatible backwash rates. The existing high rate backwash of 14 gpm/sf exceeds the required backwash rate for the GAC media and is not sufficient to fluidize the existing sand. This has resulted in some GAC media lost during backwash, despite the presence of the media-retaining troughs.
- The existing backwash sequence is longer than necessary, with inappropriate backwash rates for the media in the filter. Optimization of the filter backwash rates for the media could reduce the filter backwash volume and still clean filters effectively.
- The effective size of the existing GAC media (0.65 mm) is not appropriate for a coarse media in a dual-media filter bed and filter run times may be limiting.
- To facilitate the flow path on the WTP site, a new weir chamber is required on the west side of the Filter Building. This will essentially be a mirror image of the weir chamber installed on the east side of the facility. The costs for the new weir chamber are included in the cost for the Transfer Pump Station.

4.9.2 Description of Design Alternatives

Improvements of the filtration system consider two filter media design alternatives and two backwash supply alternatives. The two filter media design alternatives are described as follows:

- ***Continue Using Existing GAC Media –*** This alternative considers no change to the existing media profile.
- ***Replace GAC with Deeper, Coarser Media –*** This alternative considers removal of the 18 inch GAC upper layer and replacement with 36 inches of coarse anthracite with an effective size of 1.1 to 1.2 mm.

The two design alternatives to replace the existing backwash supply system are described as follows:

- ***New Dedicated Elevated Tank –*** Provide a new elevated tank for backwash supply of the filters. The new tank will contain sufficient volume for at least two to three backwashes. A throttling valve for control of backwash flow will be installed with the tank. The tank will be filled with distribution system pressure.

- ***New Dedicated Backwash Pumps –*** Provide two new dedicated backwash pumps, one duty and one standby, to be installed in the new high-service pump station. The pumps will use the Dort Reservoir as storage for filter backwashes. The pumps will be controlled with variable frequency drives (VFDs).

4.9.3 Evaluation of Design Alternatives

Table 4.22 presents the technical evaluation of the two filter media design alternatives (using only the previously described performance and operational criteria and not considering cost). The scoring results indicate that replacement of the GAC with anthracite is preferred over maintaining the existing GAC media. The existing sand media will remain in place. Despite the good condition of the filters, the WTP operators reported that run times of under 24 hours were typical when operating with Flint River water. While the run times will increase with Lake Huron water, they can be further optimized by using a coarser and deeper media. In addition, replacement of the GAC with anthracite will eliminate the more frequent GAC replacement requirements (due to long-term abrasion of the softer media) and associated costs. While GAC media is typically more effective for biological treatment than anthracite, especially in colder waters, the overall percent removal of biodegradable organic carbon by either type of media is expected to be small (< 10%) due to the low organic carbon levels in the Lake Huron water supply.

Table 4.22 – Technical Evaluation of Filter Media Design Alternatives*

Evaluation Criteria	GAC/Sand Dual Media Filter	Anthracite/Sand Dual Media Filter
Regulatory and Water Quality Issues	L/d ratio > 1300 for ordinary dual media filter (18" GAC over 12" sand) is capable of producing low filtered water turbidity (< 0.1 NTU)	L/d ratio > 1300 for coarse dual media filter (36" anthracite over 12" sand) is capable of producing low filtered water turbidity (< 0.1 NTU)
	GAC media is effective for removal of biodegradable organic carbon and taste and odor control	EBCT > 10 min for anthracite dual media filter, preceded by ozone preoxidation, is capable of effective removal of biodegradable organic carbon and taste and odor control
	Filter backwash rate of 15 gpm/sf is not sufficient to fluidize lower sand bed, especially for colder waters	Filter backwash rate of 20.5 gpm/sf is sufficient to fluidize anthracite and sand beds for effective cleaning of filter bed
	Existing automatic backwash control logic uses more washwater than necessary (> 100,000 gal per backwash)	New automatic backwash control logic will reduce washwater volumes (approx. 75,000 gal per backwash)
SCORE	3	4
Operational Simplicity	Fine GAC media and higher coagulant doses have led to short filter runs (< 48 hrs) according to plant operators	Coarse anthracite media and lower coagulant doses allow for deeper floc penetration and longer filter runs (> 72 hours)

Evaluation Criteria	GAC/Sand Dual Media Filter	Anthracite/Sand Dual Media Filter
	Media retainer troughs have not prevented GAC media loss and require pressure hosing to loosen trapped GAC media from tube packs	Media retainer troughs will provide back-up protection to prevent anthracite media loss
	Backwash control logic includes extended concurrent low wash/air scour which may contribute to media loss	New concurrent backwash control logic will be designed to avoid media loss and use less washwater volume
SCORE	3	4
Flexibility and Efficiency	The number of filters in service can be reduced for lower plant flows, while still maintaining low filter loading rates (< 2 gpm/sf)	The number of filters in service can be reduced for lower plant flows, while still maintaining low filter loading rates (< 2 gpm/sf)
SCORE	4	4
System Reliability and Safety	Lower plant capacity (24 mgd) increases the number of redundant filters available for operation at design flow	Lower plant capacity (24 mgd) increases the number of redundant filters available for operation at design flow
SCORE	4	4
Site Considerations	No site impacts	No site impacts
SCORE	0	0
OVERALL SCORE	**14**	**16**

*Based only on performance and operational criteria and not considering cost

Replacing the current GAC media with a deeper and coarser anthracite media has a one-time cost of $1,200,000, If the current GAC is maintained it will need "topping off" every few years due to media loss caused by abrasion during washing and subsequent loss of GAC fines. Assuming 1 inch of GAC loss per year, the annual loss of GAC for all 12 filters is 700 cubic feet or approximately 20,000 pounds. The cost for this GAC replacement would be approximately $36,000. In addition, the current GAC media will require slightly more frequent backwashing than the deeper and coarser anthracite, and thus will have annual additional energy cost of approximately $1,000.

Replacing the GAC media with anthracite has a slightly higher net present value. Nonetheless, the media change is recommended, to take advantage of its operational and performance benefits.

Table 4.23 presents the technical evaluation of the two backwash supply alternatives (using only the previously described performance and operational criteria and not considering cost). Based on this analysis, the new pumped backwash supply makes more efficient usage of existing and proposed site infrastructure and is thus recommended over an elevated tank backwash supply.

Table 4.23 – Technical Evaluation of Backwash Supply Alternatives*

Evaluation Criteria	New Elevated Tank Backwash System	New Pumped Backwash System
Regulatory and Water Quality Issues	No regulatory impacts	No regulatory impacts
SCORE:	4	4
Operational Simplicity	Tank can be filled off of system pressure, minimizes risk of directly backwashing the filters off of system pressure. However, additional backwash storage provided by a tank is not necessary as the Dort Reservoir has sufficient volume.	Approximately 100,000 to 150,000 gallons is required per backwash. This volume will lower the reservoir level by approximately 1-inch to 1.5-inch and thus has a very minimal impact on the operations of the Dort Reservoir. Thus, additional backwash storage infrastructure is not necessary.
SCORE:	4	4
Flexibility and Efficiency	Control of backwash is relatively simple with one throttling valve	Control of pumps will be performed with a VFD which will require additional maintenance and operational complexity
SCORE:	4	4
System Reliability and Safety	No reliable redundancy for the elevated tank.	Pumps may require more maintenance than an elevated tank, however redundancy is included with a second backwash pump
SCORE:	3	4
Site Considerations	Requires additional infrastructure which does not make an efficient use of site space	Makes more efficient use of site space as the backwash pumps will be collocated with the new High Service Pump Station
SCORE:	3	4
OVERALL SCORE:	**18**	**20**

*Based only on performance and operational criteria and not considering cost

4.9.4 Recommended Design Alternative

Based on the evaluation presented in the previous section, CDM Smith recommends the following:

- Replacement of the existing GAC media with 36 inches of 1.15 mm effective size anthracite.
- Replacement of the backwash supply with two new backwash pumps in a duty/standby arrangement at the new High Service Pump Station.
- Construction of a new filtered-water weir chamber on the west side of the Filter Building. The filtered water piping will also be extended to the west on either side of the gallery to convey water to this new chamber.

4.9.5 Process Design Criteria

Table 4.24 lists the process design criteria for the filter improvements. The firm filtration rate will range between 0.5 and 2.2 gpm/sf across the range of design flows. In CDM Smith's experience with Great Lakes facilities, filter runtimes typically range between 72 and 100 hours or longer at these filtration rates. The empty bed contact time values are within a desirable range for operation of biological filtration which, in tandem with the ozonation process, will be effective at controlling taste and odor-causing compounds.

The required backwash rates for both media are more uniform than the existing media profile. The existing washwater troughs have a maximum capacity of approximately 3,600 gpm per trough or 14,400 gpm per filter, which is equivalent to a backwash rate of approximately 20.5 gpm/sf. Based on the Lake Huron water temperature, this backwash rate is sufficient to fluidize the anthracite media by 30 percent at a temperature of 20 degrees C. Approximately 90 to 95 percent of the time Lake Huron water is colder than this temperature, thus less backwash water is required. Provisions will be included in the new backwash sequence to extend the high rate backwash or air wash if necessary during 5 to 10 percent of the time when the water is warmer than 20 degrees C. A maximum design backwash rate of 20.5 gpm/sf (14,400 gpm) will be used when sizing the backwash system.

Table 4.24 – Process Design Criteria for Filtration System

Description	Units	Maximum	Average	Minimum
Plant Capacity				
Flows	MGD	24	14	5
Filter Geometry				
Number of Filters	No.	12	12	12
Number of Filters in Service	No.	11	11	11
Filter Area	sf	700	700	700
Total Filtration Area	sf	8400	8400	8400
Firm Filtration Area	sf	7700	7700	7700
Hydraulic Loading				
Nominal Filtration Rate	gpm/sf	2.0	1.2	0.4
Firm Filtration Rate	gpm/sf	2.2	1.3	0.5
Empty Bed Contact Time (EBCT)	minutes	14	24	66
Design Plant Filter to Waste Flow	MGD	18		
Design Plant Filter to Waste Flow	gpm	23,620		
Design Plant Filter to Waste Rate	gpm/sf	1.5		
Underdrain Criteria				
Type of Underdrain	--	Monolithic false-floor plenum style with nozzles		
Manufacturer	--	US Filter (now Westech)		
Nozzle Type	--	Direct media retention		
Air Scour System	--	Integral with underdrain		
Plenum Height	in	29		
False Floor Thickness	in	4.75		
Anthracite Criteria				
Depth	in	36		
Effective Size	mm	1.15		
Average Apparent Specific Gravity	--	1.7		
Uniformity Coefficient	--	1.35		

Description	Units	Maximum	Average	Minimum
Required Backwash Rate at 20ºC	gpm/sf		20.5	
Sand Criteria				
Depth	in		12	
Effective Size	mm		0.5	
Average Apparent Specific Gravity	--		2.5	
Uniformity Coefficient	--		1.65	
Required Backwash Rate at 20ºC	gpm/sf		16.4	
Filter Box Criteria				
L/D	--		1,405	
Bottom of Filter	fasl		720.75	
Top of Underdrain Elevation	fasl		723.56	
Top of Media Elevation	fasl		727.56	
Bottom of Backwash Troughs	fasl		728.81	
Top of Backwash Troughs	fasl		730.67	
Normal Operating Level	fasl		734.00	
Operating Gallery Floor	fasl		736.00	
Media Freeboard	ft		1.25	
Media Freeboard (% of Bed Depth)	%		31%	
Backwash Design Criteria				
Design Backwash Rate	gpm/sf		20.5	
Design Backwash Flow	gpm		14,350	
Type of Backwash Supply	--		Pumped from new transfer pump station	
Type of Pump	--		Vertical Turbine	
Number of Units	No.		2	
Speed Control	--		VFD	
Approximate Motor Horsepower	HP		150	
Backwash Trough Design Criteria				
Number of Troughs	No.		4	
Type of Construction	--		Round bottom with media retaining baffles	
Material of Construction	--		Stainless steel	
Trough Width	in		20	
Trough Depth	in		22.25	
Trough Capacity - no freeboard	gpm		3,600	
Design Spent Filter Backwash Flow	gpm		14,400	
Air Scour Design Criteria				
Design Air Scour Rate	scfm/sf		4	
Design Air Flow	scfm		2,800	
Type of Air Supply	--		Centrifugal Blower	
Manufacturer	--		Hoffman	
Speed Control	--		Constant with throttling valve	
Motor Horsepower	HP		75	

CDM Smith also recommends modifying the automated backwash sequence to include the following sequences:

- Close influent valve and drain filter box to 6 inches above the media with filter control valve.
- Close filter control valve and open waste backwash valve (approximately 2,000 gallons of used backwash water from troughs and gullet).
- Initiate air scour wash at 4 scfm/sf.
- Initiate low water wash at ~8-9 gpm/sf to fill the filter box to the bottom of the backwash troughs.
- Once water reaches bottom of backwash trough, turn off air and ramp up backwash rate to high.
- Begin high rate backwash, adjustable based on water temperature up to a maximum of 20.5 gpm/sf.
- End high rate backwash and start filter-to-waste cycle or second low-rate backwash.
- Filter-to-waste at max design filtration rate of 2.2 gpm/sf.

The above cycle assumes filter-to-waste will result in approximately 119,000 gallons of used backwash water.

4.9.6 Major Equipment Components

The new backwash system will require two new vertical turbine backwash pumps at approximately 150 HP each. These pumps are discussed in further detail with the design criteria of the High Service Pump Station in Section 6. The cost for these pumps are also included in the cost for the High Service Pump Station.

Air scour will be performed with the two existing 75 HP blowers located on the west side of the filter building. To prevent flooding of the air scour pipe, installation of a check valve is recommended on the individual air piping at each filter along with an automatic drain valve between the check valve and the isolation butterfly valve. This will minimize the risk of creating transient conditions in the event the butterfly valve leaks and floods the air drop pipe. These conditions can be disruptive to the filter underdrain system. The total estimated cost of these modifications is approximately $350,000.

4.9.7 Layout Design Concepts

Figure 4.21 presents a section of the filter box showing the revised media depths and available media freeboard for bed expansion.

Figures 4.22 and **4.23** present a plant of the filter gallery showing the extension of the filtered water piping to the new filter control weir chamber to the west of the filter building.

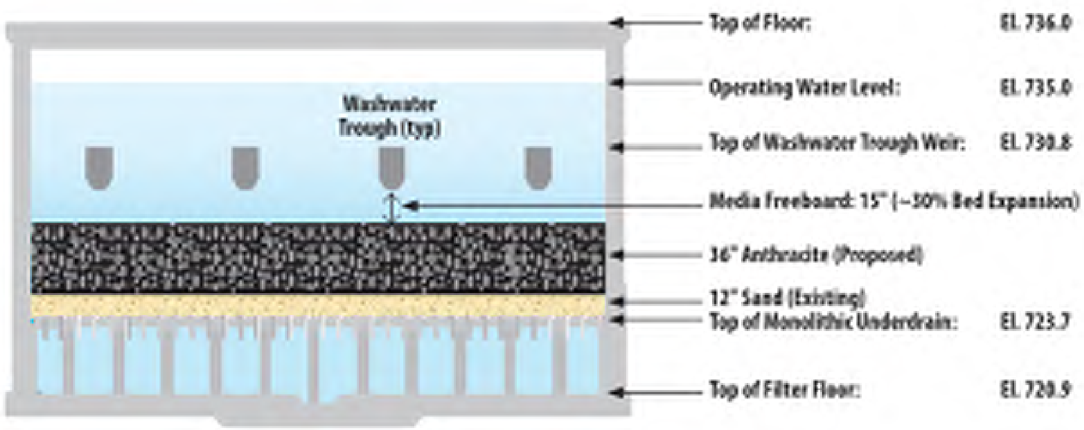

Figure 4.21 – Filter Box Section

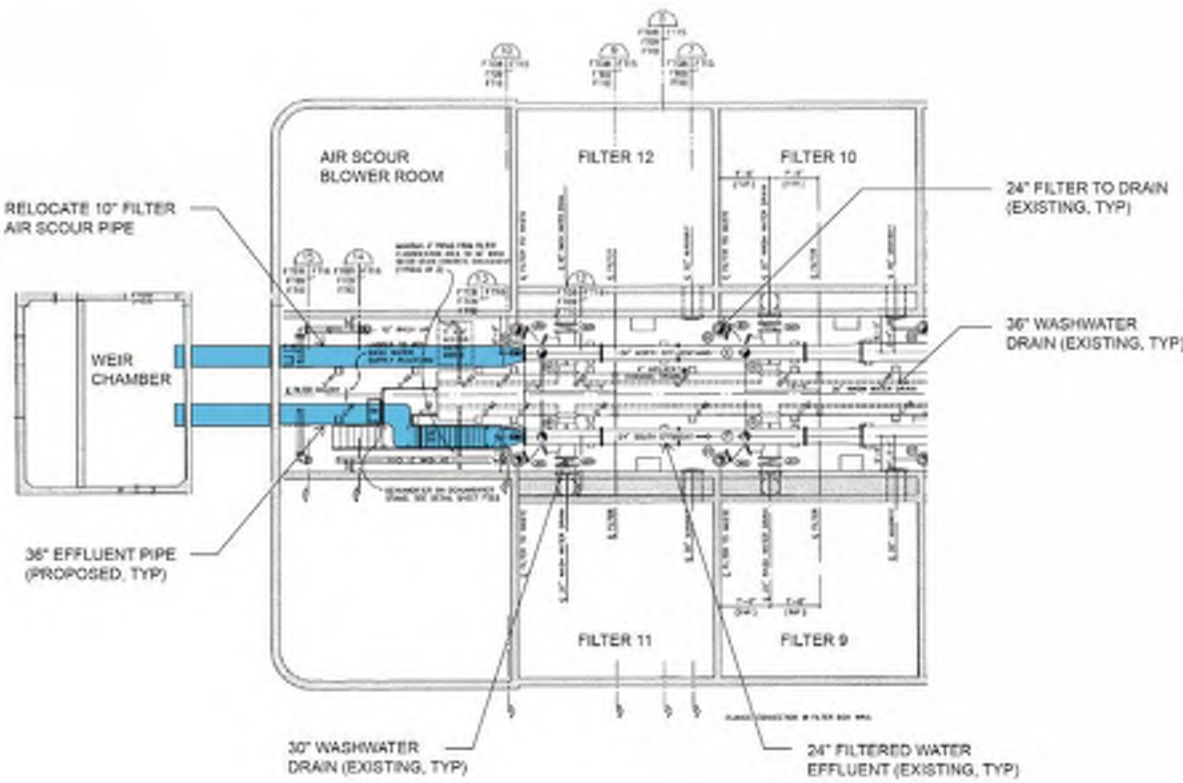

Figure 4.22 – Modified Filter Gallery Layout Plan View

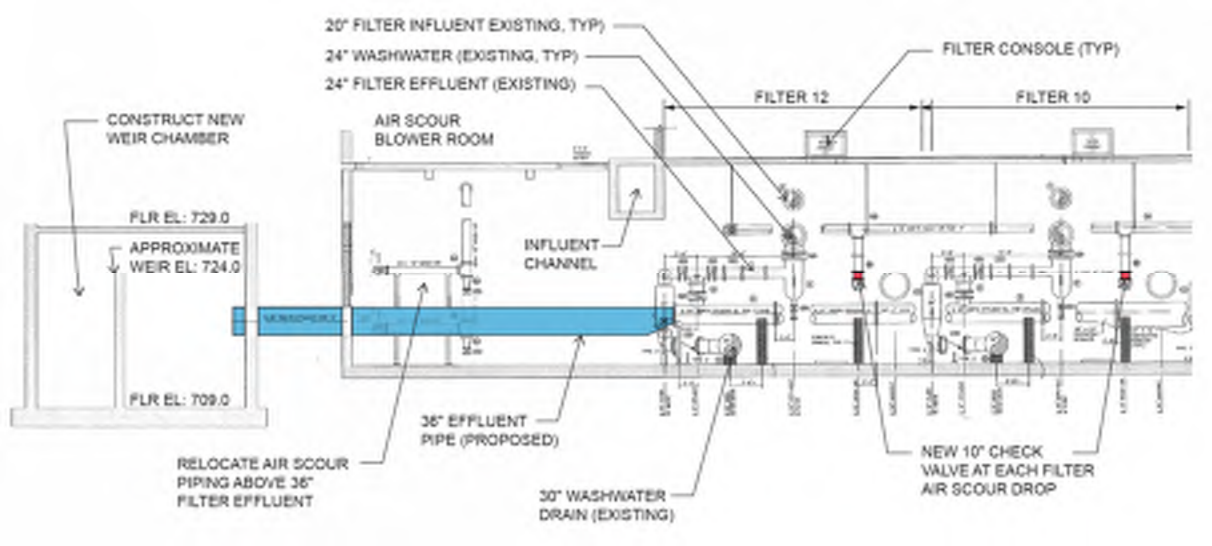

Figure 4.23 – Modified Filter Gallery Layout Section View

4.10 Disinfection

4.10.1 Chlorine Disinfection

To meet primary disinfection requirements for the upgraded WTP, chlorine will be used to meet CT requirements (disinfectant residual "C" in mg/L multiplied by contact time "T" in minutes) for 0.5-log Giardia and 2-log virus inactivation, with a 50 percent compliance safety factory, in accordance with recommended water quality goals discussed in Section 4.1.3. The required CTs will be achieved in the Dort Reservoir following filtration. No CT credit is expected from the ozone preoxidation process, which will typically be operated to maintain low ozone residuals in the contactor.

4.10.1.1 Dort Reservoir Layout

Figure 4.24 shows a plan view of the Dort Reservoir including the inlet and outlet piping and internal baffling configuration. The working volume of the reservoir was estimated to be 20 MG based on an approximate internal area of 134,000 square feet (sf) and maximum sidewater depth of 20 feet. The reservoir is divided into two irregularly-shaped compartments, separated by a full depth structural baffle wall. The working volume of each compartment was calculated to be approximately 10 MG. Two 36-inch inlet pipelines discharge into the two compartments of the reservoir on the southeast corner, and two 36-inch pipelines exit each compartment on the east side of the reservoir. The existing inlet and outlet piping arrangements allow the reservoir to operate with one or both compartments in service.

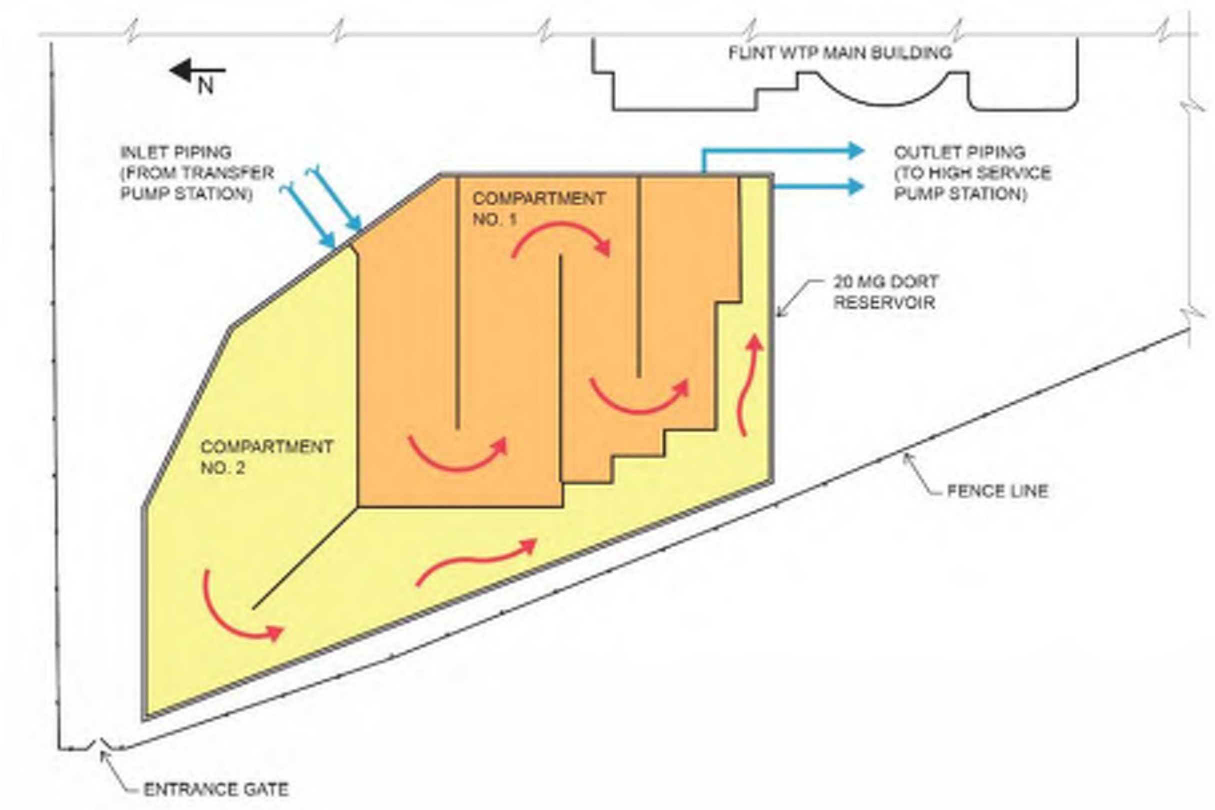

Figure 4.24 – Dort Reservoir Site Plan

The flow patterns in each reservoir compartment are defined by the internal baffle arrangements for each compartment, which are quite different. Compartment No. 1 has a relatively uniform serpentine baffle arrangement with similar (but not the same) length-to-width ratios for each pass, whereas Compartment No. 2 has a much less uniform flow path with a single turn and varying length and width dimensions. These differences will impact flow patterns, flow short-circuiting, and disinfection contact times in each compartment. A tracer study will be required to define the "T10" contact times available to meet CT disinfection requirements in each compartment.

4.10.1.2 CT Disinfection Analysis

A preliminary desk-top analysis was performed to determine the CT capacity of the Dort Reservoir to meet primary disinfection requirements using free chlorine. The analysis was based on the following design assumptions:

- Maximum hourly plant flow is 24 MGD.
- Minimum water temperature range is 0.5 degrees C.
- Maximum pH of chlorinated water entering the Dort Reservoir is 8.0.
- Minimum free chlorine residual exiting the Dort Reservoir is 1.5 mg/L.

- Giardia inactivation required is 0.5 log.
- Virus inactivation required is 2.0 log.
- Total storage volume for Dort Reservoir is 20 MG.
- Effective storage volume for each compartment of Dort Reservoir is 10 MG.
- A baffling factor of 0.3 for each reservoir compartment.
- CT compliance safety factor (or inactivation ratio) of 1:5.

Note that the baffling factor is characterized by the T10/T ratio where T10 is the time in minutes required for 10 percent of the water to pass through the reservoir; T is the time in minutes it takes the water during peak hourly flow to travel from the point of disinfectant application (inlet pipe to Dort Reservoir) to a point where residual concentration "C" is measured in mg/L (outlet pipe from Dort Reservoir). A baffling factor of 0.3 was assigned for the Dort Reservoir compartments as a conservative design value, even though the internal baffle arrangement may result in higher value (and more contact time credit) based on tracer test results.

Figure 4.25 presents the relationship between operating water levels in the Dort Reservoir and water temperature to meet primary disinfection requirements with one or both reservoir compartments in service, while maintaining a constant free chlorine residual of 1.5 mg/L. As the water temperature increases from 0.5 to 20 degrees C, the required reservoir water level drops significantly – from 40 percent full to 10 percent full with one compartment out of service, and one-half of those values when both compartments are operating.

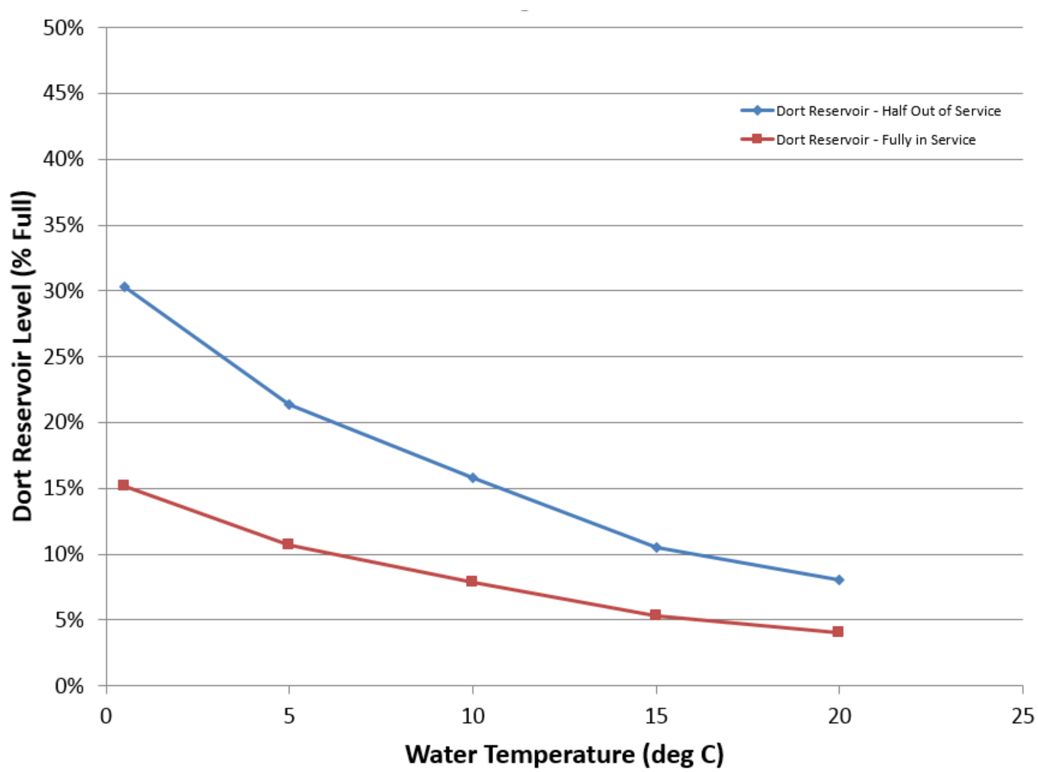

Figure 4.25 – Impact of Varying Reservoir Water Levels and Water Temperature on Meeting CT Disinfection Requirements

Figure 4.26 presents the relationship between chlorine residual measurements and water temperature to meet primary disinfection requirements with one or both reservoir compartments in service, while operating the reservoir at 80 percent of full capacity. In this case, as the water temperature increases from 0.5 to 20 degrees C, the minimum chlorine residual requirements drop significantly – from 0.75 mg/L to 0.2 mg/L with one compartment out of service, and one-half of the maximum residual value when both compartments are in service (the minimum residual value is limited to an assumed minimum detection limit of 0.2 mg/L for on-line residual analyzers.

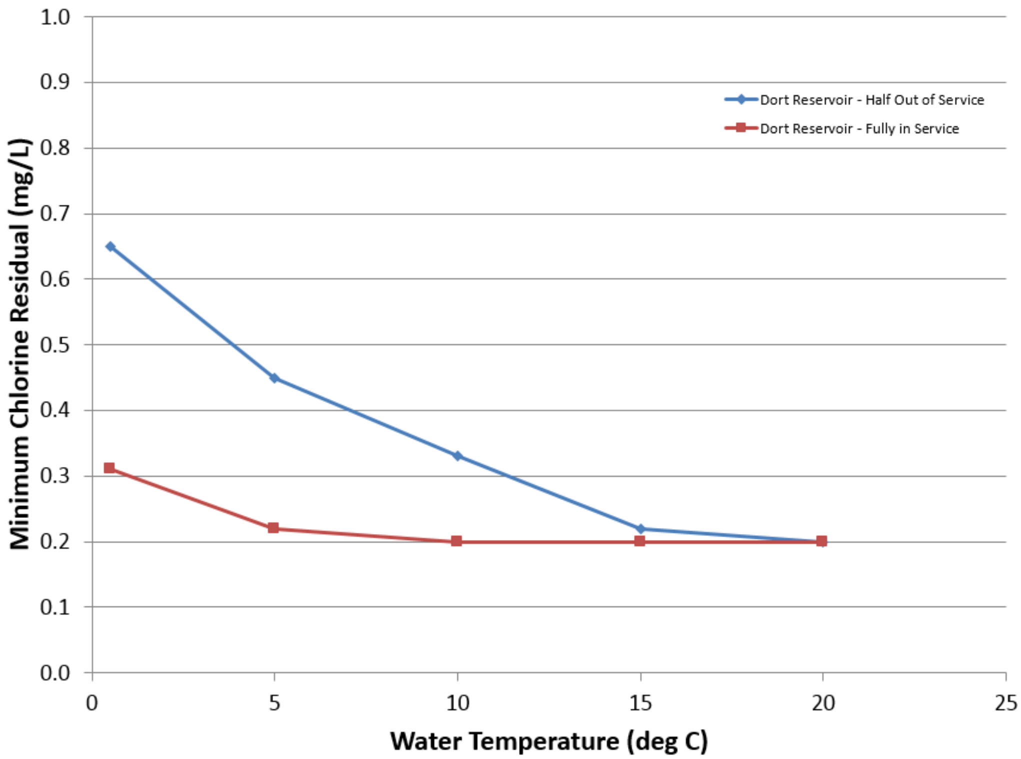

Figure 4.26 – Impact of Varying Chlorine Residual Levels and Water Temperature on Meeting CT Disinfection Requirements

In summary, the results of the CT analysis indicate that the Dort Reservoir has ample capacity to meet primary disinfection operational goals for the WTP (i.e., 50 percent higher than regulatory requirements) using free chlorine, even when only one reservoir compartment is in service. Minimum reservoir operating levels and chlorine residual set points will be established for the Dort Reservoir in final design based on this analysis.

4.10.2 Future UV Disinfection

The recommended treatment process improvements for the WTP include flexibility for constructing a new UV disinfection facility in the future. The UV disinfection process will be located in the plant process train, between the new post-filter transfer pump station and the Dort Reservoir. Future implementation of UV disinfection at the WTP will provide an effective disinfection barrier against *Cryptosporidium* and compliance with disinfection requirements of the Long-Term 2 Enhanced Surface Water Treatment Rule, should future source water monitoring indicate the presence of *Cryptosporidium* or other chlorine-resistant pathogens in Lake Huron. The combination of ozone (as a preoxidant or primary disinfectant in the future), chlorine, and UV disinfection processes will significantly improve public health protection by introducing multiple disinfection treatment barriers and additional regulatory disinfection credits against waterborne microbial pathogens of concern, as discussed in Section 4.12.2.

Two types of UV reactors are commercially available for municipal drinking water treatment applications: low pressure high output (LPHO) and medium pressure (MP) reactors. There are significant differences in capital and operating costs for these systems, with LPHO systems typically having higher capital costs and lower O&M costs than MP systems. The electrical requirements for MP systems can be 2 to 3 times higher than LPHO systems, due to differences in the germicidal efficiency of the UV lamps used. Both types of UV reactors will be considered in establishing the space, power, and head-loss requirements for the future UV facility.

Table 4.25 presents basic process design criteria for a future post-filter UV disinfection system. The UV system will be designed to comply with requirements of EPA's UV Disinfection Guidance Manual (UVDGM), including off-site validation testing to be completed by the selected UV equipment vendor, to determine the reduction equivalent dose (RED) for 3-log *Cryptosporidium* inactivation. Two LPHO or MP UV reactors (one duty, one standby) will be provided, each rated for a design flow of 24 MGD. A preliminary UVT design value of 90 percent was selected for the high-quality Lake Huron supply, but this "placeholder" design value will need to be revisited based on UVT sampling of Lake Huron during the design of the UV system.

Table 4.25 – Process Design Criteria for UV Disinfection System

Design Parameter	Units	Design Criteria
Design Flows		
Maximum	MGD	24
Average	MGD	14
Minimum	MGD	5
UV Process Criteria		
Cryptosporidium	--	3-Log Credit per UVDGM Validation Requirements
Validated Dose (VD)	mJ/cm2	12
UVT Design Value	%	90
Maximum Head Loss Across UV Reactor	In	18
Validation Testing Requirements		
Validation Testing Protocol	--	Meet UVDGM Requirements
Validation Challenge Organism	--	MS2 or T1 Phage
UV Dose Monitoring Strategy	--	Calculated dose Algorithm and Validation Factor per UVDGM
UV Equipment Criteria		
Reactor Vessel Type	--	Closed-Vessel, lamps Perpendicular to Flow
Number of UV Reactor Trains Installed	no.	2
Number of Standby UV Reactor Trains	no.	1
Design Flow Per Reactor	MGD	24
Lamp Type	--	Medium Pressure (MP) or Low-Pressure High-Output (LPHO)
Ballast Type	--	Electronic or electro-Magnetic
UV Intensity Sensor Type	--	Germicidal
UVT Monitor Type	--	On-Line, Flow-Thru Cell
Cleaning System	--	On-line Physical or Physical-Chemical Wiper System

4.11 Water Treatment Residuals and Disposal

4.11.1 Used Filter Washwater Treatment Objectives and Approach

The main residual streams in a drinking water plant are the solids generated during coagulation/flocculation/sedimentation/filtration and the used washwater generated in washing the filters. Effective and efficient handling of these residual streams is critical. Often the limiting factor in reliably producing both the quantity and quality of drinking water needed is the management of residuals. For example, if used washwater is not being processed, then dirty filters cannot be backwashed and placed back in operation, and the plant will not meet its production requirements.

Federal regulations state that the flow of used washwater recycled to the inlet of the plant cannot exceed 10 percent of the plant flow. Some states (but not Michigan) also require that used washwater be clarified to a turbidity of less than 2 NTU before it's recycled. CDM Smith's goals for the WTP are that the flow of recycled clarified washwater not exceed 5 percent of plant flow.

The current backwash sequence at the WTP generates approximately 110,000 gallons of used washwater. The current used filter washwater system is shown in **Figure 4.27**. The used washwater is discharged by gravity to two interconnected, below grade tanks that are south of the main plant building. The total volume of these tanks is approximately 82,000 gallons. A small below grade "washwater transfer" pump station lifts the used washwater to an open-top circular concrete "recirculation" tank that has a volume of 482,000 gallons. This tank serves as the wet well for pumps in the ozone building that recirculate the used washwater to the inlet piping of the ozone contactors.

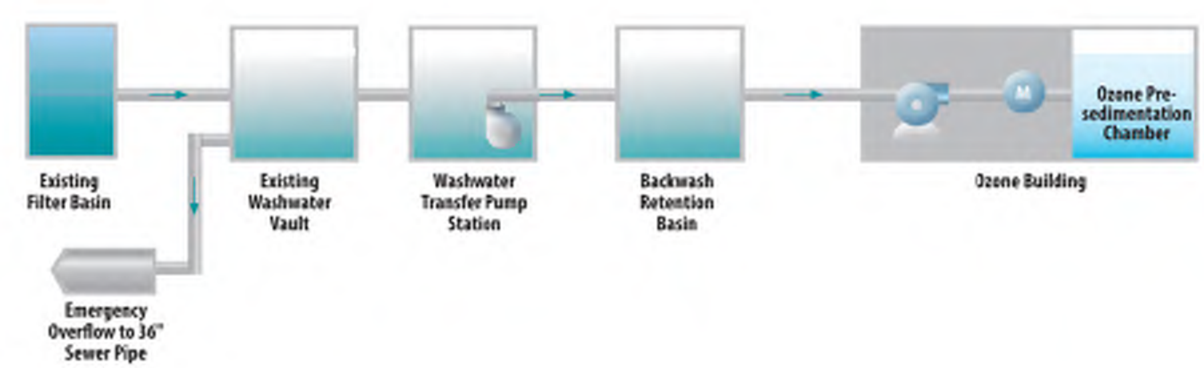

Figure 4.27 – Existing Used Filter Washwater System

The limitations of the current used washwater system are:

- The volume of the interconnected below grade tanks is only 75 percent of one filter backwash volume. Therefore, it is not possible to backwash a filter until the entire volume of these two tanks is pumped to the larger recirculation tank. Should the small washwater transfer pumps fail, the plant cannot backwash filters. Flint operating staff have stated that this limitation caused operational concerns.

- The recirculation tank is located within the footprint of the proposed raw water storage impoundment and the footprint of the alternative prestressed tanks. Therefore, if the raw water storage impoundment or prestressed tanks are constructed, this recirculation tank must be removed.

4.11.1.1 Design Alternatives and Recommendation

CDM Smith recommends that the used filter washwater system be modified to handle 2.5 backwash volumes. This will allow at least 3 successive backwashes without causing restrictions to plant production. Note that only 2.5 backwash volumes are needed because a portion of the first backwash volume will be recycled during the washing of the next 2 filters. As described in Section 4.9.5, changes to the filter washing procedure are recommended that will reduce the backwash volume to 125 gallons per square feet of media, which is equivalent to 87,500 gallons per backwash. The volume of 2.5 backwashes is approximately 219,000 gallons.

There are three alternatives that CDM Smith evaluated for handling of the used washwater:

- Discharge used washwater to the sewer.
- Discharge used washwater to the RW storage reservoir.
- Recycle used washwater to the inlet of the ozone contactors.

Table 4.26 evaluated each of these three alternatives.

Table 4.26 – Options for Handling Used Filter Washwater

Alternative No.	Description	Water Quality/Regulatory Issues	Operational Simplicity	Other Issues
1	Discharge used WW directly to sewer	None	Simple	Plant will discharge approximately 100 MG of used washwater per year. There is no discharge fee for the WTP to do so. Flow equalization is required so that the peak filter backwash flow rate (14,000 gpm) does not exceed the capacity of the sewer connection at the plant. Estimated cost of flow equalization and a pump station is $4.0 million. This approach would discharge 100 to 200MG per year to the sewer, which would require that a similar amount of additional water be purchased and conveyed to the WTP for treatment and delivery to customers.
2	Discharge used WW to RW reservoir	None	Simple	Will require a new pipeline and pump station to do so. Flow equalization also will be required to reduce the capacity of the pump station and pipeline and reduce the construction costs. Estimated cost of these facilities is $4.5 million. Some solids will settle in the reservoir and require removal periodically.
3	To improve filter performance, construct new larger washwater equalization basin before washwater is recycled to ozone contactors.	None	Simple	Estimated cost of these facilities is $4.0 million.

All three alternatives are similar in terms of water quality/regulatory issues (i.e., none) and operational simplicity (i.e., no significant operational requirements). Alternatives 1 and 2 would have other issues (i.e., water loss and sediment accumulation, respectively).
The cost of all three alternatives is similar.

CDM Smith recommends Alternative 3, since it will simplify operation for improved system efficiency and operational reliability. **Figure 4.28** shows the flow diagram for this new washwater handling approach.

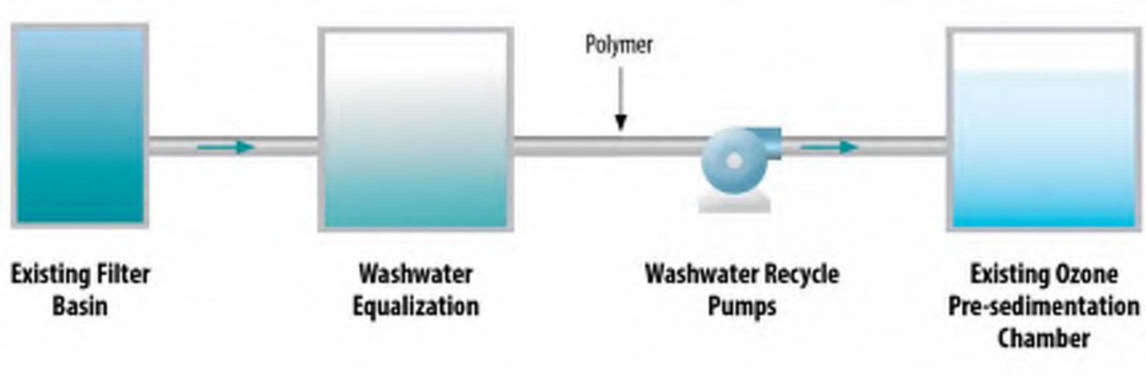

Figure 4.28 – Proposed Used Filter Washwater System

4.11.1.2 Process Design Criteria

The process design criteria for major equipment components of the used filter washwater system are shown in **Table 4.27**.

Table 4.27 – Process Design Criteria for the Used Filter Washwater System

Used Filter Washwater Equalization Tank		
Volume	Gallons	219,000
Diameter	Ft.	50
Water Depth	Ft.	15
Recycle Washwater Pumps		
Type of Pump	Submersible Pumps	
Number of pumps		3
Capacity (each)	gpm	500

4.11.1.3 Layout Design Concepts

Figure 4.29 shows the location and basic configuration of the used washwater equalization tank and associated pump stations.

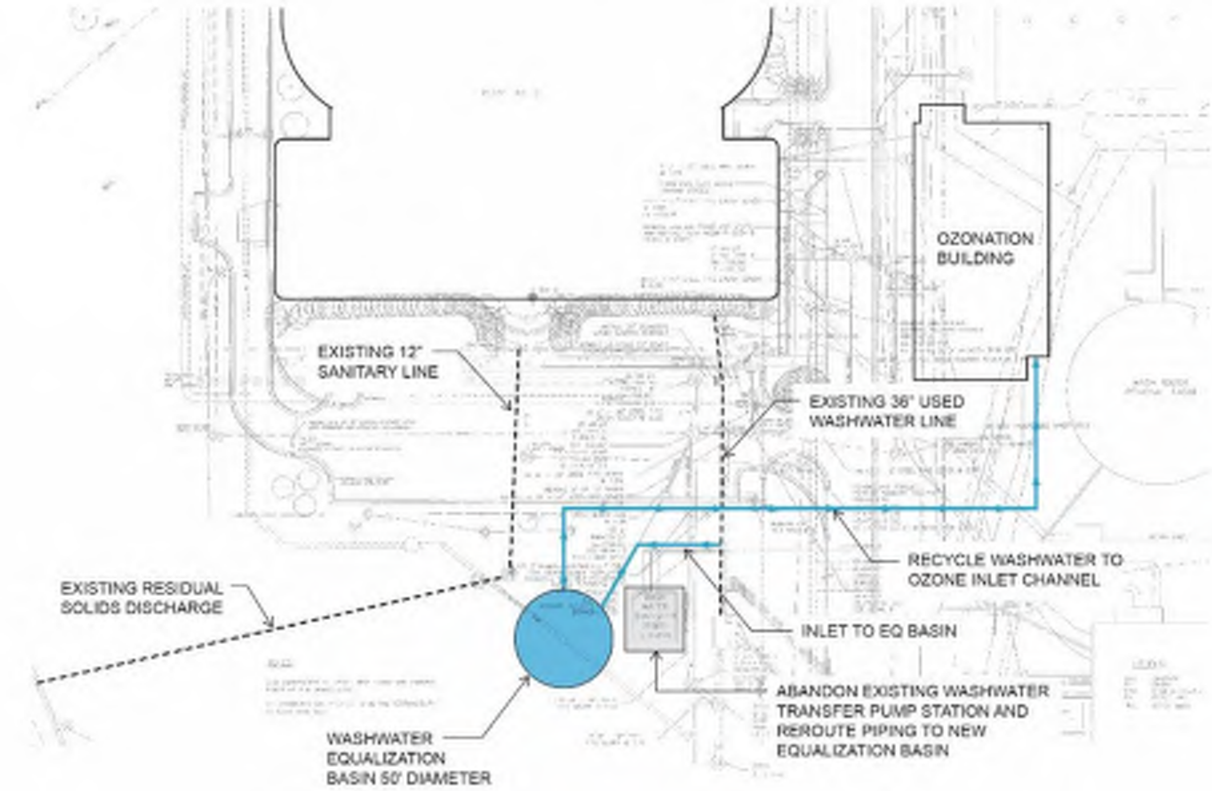

Figure 4.29 – Used Filter Washwater System Layout

4.11.2 Solids Treatment Objectives and Approach

Many drinking water plants dispose of their residual solids by discharging them to the local wastewater collection system. The collection system conveys them to the local wastewater treatment plant where they are effectively and efficiently processed with the solids contained in residential and commercial/industrial wastewater. Sludge from the IPS basins currently is handled in this manner.

Many wastewater utilities encourage drinking water plants to reduce the volume of solids that are discharged. Drinking water plants do this by first conveying their solids stream (which can be as dilute as 0.1 percent solids or less) to thickening basins where the solids can be concentrated and separated.

The proposed treatment process for the WTP will produce significantly fewer solids than the former softening treatment process. The solids will be captured in the inclined plate settler (IPS) basins. The current solids flow diagram from the IPS basins is shown in **Figure 4.30**.

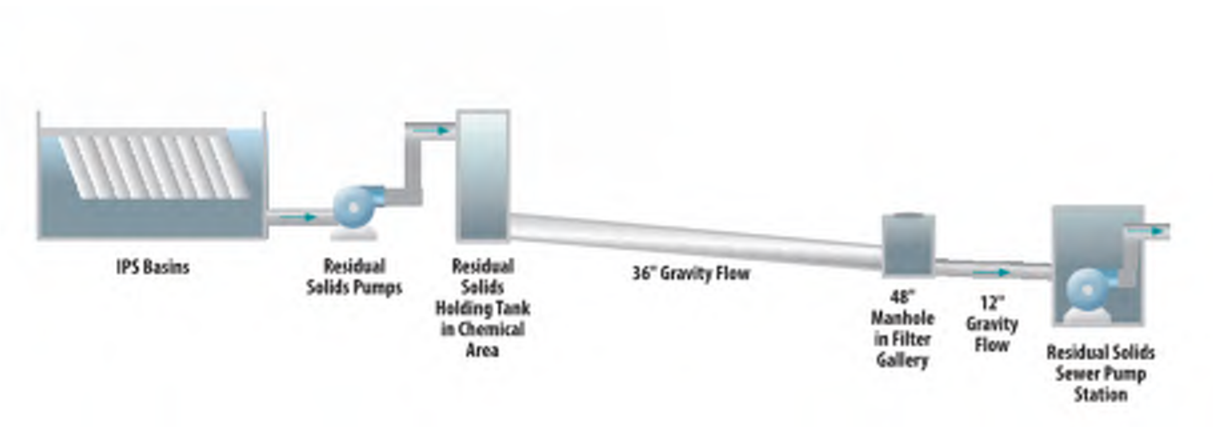

Figure 4.30 – Existing Solids Flow Diagram from the IPS Basins

Table 4.28 lists the range of solids that will be generated by the treatment plant. The table is based on alum being used as the primary chemical coagulant. Based on experience treating similar quality waters, CDM Smith expects that the amount of solids generated would be similar if ferric chloride or ferric sulfate were the primary coagulant.

Table 4.28 – Expected Solids Production at the Flint WTP

Parameter	Min	Ave	Max
Flow (MGD)	5	14	24
Alum Dose (mg/L)	5	10	25
Polymer Dose (mg/L)	1	1	1
Turbidity (NTU)	1	3	20
Dry Sludge Solids (lbs./MG)	39	83	350
Dry Sludge Solids (lbs./day)	195	1,162	8,400
Gallons per day at 0.2% solids	11,800	69,300	503,800
Gallons per day at 0.5% solids	4,700	27,700	201,500
Gallons per day at 1% solids	2,400	13,900	100,800
Gallons per day at 2% solids	1,200	6,900	50,400
Million Gallons per year at 0.2% solids		25.28	
Million Gallons per year at 0.5% solids		10.11	
Million Gallons per year at 1% solids		5.06	
Million Gallons per year at 2% solids		2.53	

In addition to the mass of dry solids produced (lbs/day), the table also lists the volume of solids produced at different solids concentration. Without first thickening the solids, the expected concentration of solids is expected to be 0.2 percent or less. If this is the case, the average volume of solids will be more than 69,000 gallons per day (gpd) and over 25 million gallons (MG) per year. Thickening the solids to 2 percent before discharge to the wastewater collection system will reduce this volume by 90 percent to 6,900 gpd and 2.5 MG/year.

4.11.2.1 Design Alternatives and Recommendation

For solids handling, the WTP has three alternatives:

1. Discharge solids captured in the IPS basins to the municipal sewer system.
2. Capture solids in the IPS basins, route them to a thickener, and then discharge thickened solids to the municipal sewer system.
3. Construct and operate a separate solids thickening and dewatering facility for WTP solids:
   a. Solids drying beds.
   b. Thickening tanks and mechanical dewatering equipment (i.e., centrifuges).

Alternative 1 – Discharge Solids to the City's Sewer System

Discharging the solids to the City's sewer system without first thickening would mean discharging up to 25 MG a year of solids with a concentration of 0.2 percent. Based on the source water quality and expected coagulant doses, it's expected the plant will produce approximately 200 tons per year of dry solids. CDM Smith has been told that there will be no discharge fee if the solids are are discharged to the sewer system. The 25 MG a year of water discharged to the sewer would be lost from plant production (i.e., water delivered to the distribution system) and would therefore require Flint purchase and treat an equivalent amount of water. However, the cost for this purchasing this additional water is a small cost compared to the cost of Alternatives 2, 3a, and 3b.

Alternative 2 – Thicken Before Discharging Solids to the City's Sewer System

The solids captured in the IPS basins could be thickened to as much as 2 percent solids in a 33-foot diameter thickening tank. The solids would settle to the tank bottom and then be discharged to the sewer. This approach would reduce the volume of solids annually discharged to sewer from 25 MG to 2.5 MG per year. Thickening would not reduce the mass of solids discharged annually. The estimated cost of a thickener is approximately $2.5 million.

Alternative 3 – Separate Solids Thickening and Dewatering Facility

Alternatives 3a and 3b are very expensive and do not make cost effective and efficient use of the City of Flint's wastewater treatment plant. The land requirement for drying beds is approximately 4 to 6 acres with a capital cost of $4 million to $5 million, and an annual operating cost of $63,000. The land requirement for the thickening tanks and mechanical dewatering is 1 to 2 acres at a capital cost of approximately $9.1 million and an annual operating cost of approximately $250,000. Both alternatives far exceed the cost of discharging to the City of Flint's sewer system.

CDM Smith recommends discharging the solids directly to the City's sewer system (Alternative 1).

4.12 Recommended Treatment Process Train

The WTP will soon be changing its water source to Lake Huron, which will be supplied through a new KWA intake and raw water transmission pipeline now under construction. This switch to the higher quality Lake Huron supply will require modifications to the plant process train, including elimination of the reactor clarifiers and recarbonation basins, which will no longer be needed for lime softening. Based on CDM Smith's assessment of drinking water regulations, finished water quality goals, Lake Huron water quality trends, and the existing unit processes for the WTP, as detailed in this section, CDM Smith recommends:

- A conventional treatment process train for the WTP, rated for a peak design flow of 24 MGD and relying to the maximum extent on existing treatment processes and upgraded as necessary for improved treatment performance, including: ozone preoxidation, pumped diffusion rapid mixing, three-stage mechanical flocculation, inclined plate settler (IPS) high-rate sedimentation, biological dual media (anthracite-sand) filtration, and free chlorine for primary disinfection.

- A new chemical storage and feed facility and piping delivery system, as detailed in Section 5, including the following treatment chemicals: a primary coagulant (alum, polyaluminum chloride or ferric chloride) a cationic polymer for coagulation, carbon dioxide for pH suppression during coagulation, a second anionic or non-ionic polymer as a flocculant or filter aid, sodium hypochlorite for primary disinfection, fluoride for dental health protection, and a corrosion inhibitor (possibly with pH adjustment with sodium hydroxide) as part of an optimized corrosion-control strategy.

- An upgraded filter washwater clarification and recycle system including: a new washwater equalization basin sized for 2.5 consecutive backwash events plus sludge thickener return flows, new washwater transfer pumping station, high-rate clarification process using repurposed IPS Basin No. 3, and use of the existing washwater pump station to recycle washwater flows to the ozone inlet channel.

- An upgraded sedimentation basin solids handling system including: new mechanical sludge collection system for the IPS basins, new sludge holding tank for IPS basin residuals, existing sludge transfer pumps, existing sludge transfer tank, new sludge thickener tank, and new pump station to transfer thickened flows to the sanitary sewer and gravity discharge of return flows to the washwater equalization basin.

Table 4.29 presents the treatment benefits of each unit process and the specific water quality goals they are intended to address.

Table 4.29 – Unit Process Description for Recommended Treatment Process Train

Unit Process	Treatment Objective
Ozone Preoxidation	Turbidity/Particle Removal Taste and Odor Control Oxidation of organic and inorganic compounds prior to coagulation Oxidation of cyanotoxins Oxidation of constituents of emerging concern
Pumped Diffusion Rapid Mixing	Disbursal of coagulant for charge neutralization/particle destabilization and dissolved organic carbon
3-Stage Tapered Flocculation	Aggregation of destabilized particles into settleable/filterable floc
Inclined Plate Settler (IPS) Sedimentation	Separation and removal of suspended, flocculated particles from water prior to filtration
Dual Media (Anthracite/Sand) Biological Filtration	Removal of turbidity/particles, DOC, taste and odor-causing organics, pathogens
Corrosion Inhibitor/Final pH Adjustment	Meet corrosion control, finished-water pH and alkalinity targets
Chlorine Disinfection in Dort Reservoir	Primary disinfection for Giardia and virus inactivation Introduction of secondary disinfectant for microbial quality in distribution system
UV Disinfection (Future)	Additional Barrier for Primary Disinfection Primary disinfection for *Cryptosporidium* inactivation

4.12.1 Process Train Schematic

Figure 4.31 presents a process flow schematic for recommended improvements to the WTP. It shows the sequence and arrangement of treatment units, pumping stations, and chemical application points for the water treatment and solids handling portions of the treatment plant. The major improvements to the plant process train, pumping, and water treatment units are summarized below.

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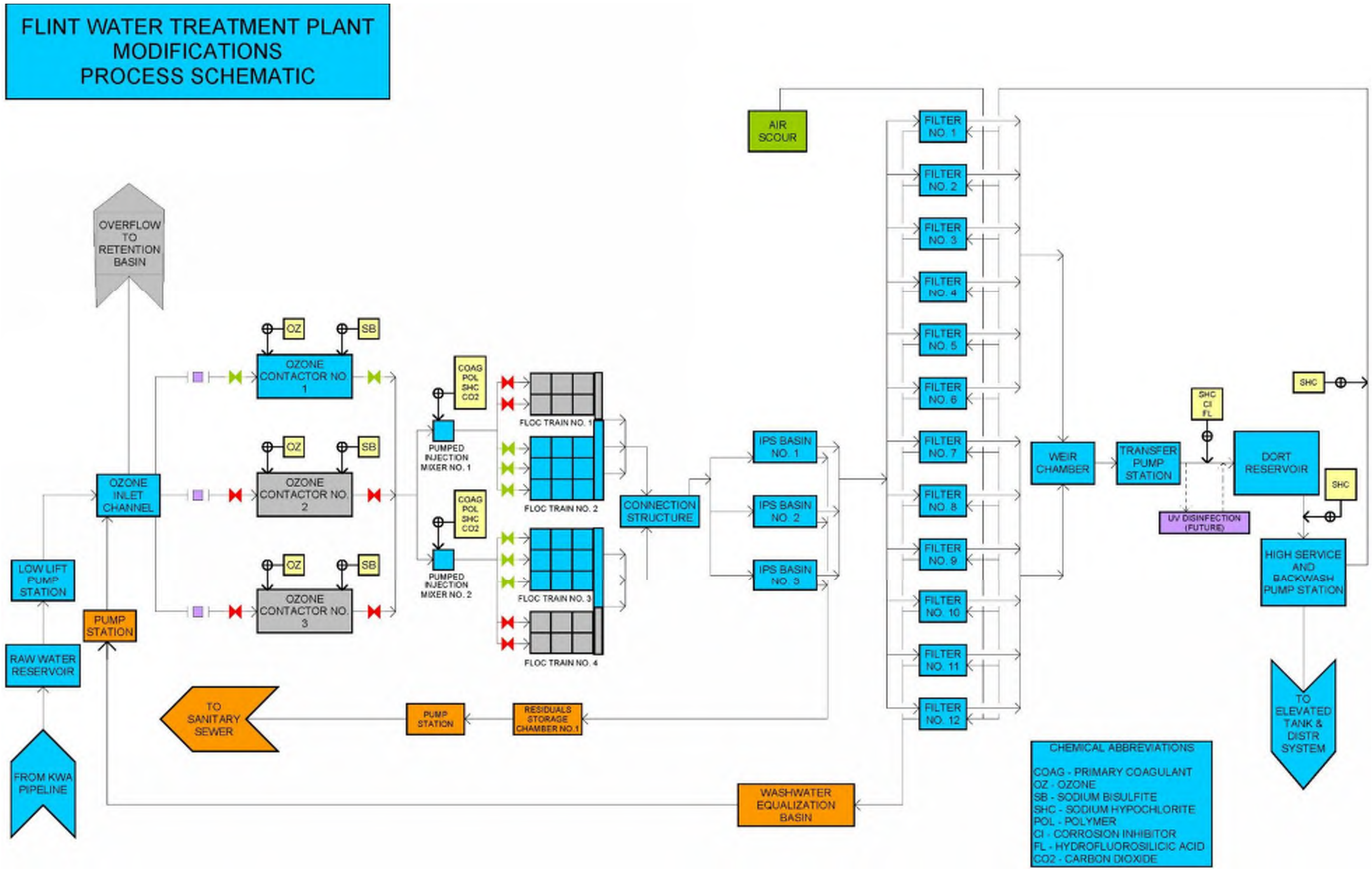

Figure 4.31 – Process Schematic for Flint WTP Recommended Improvements

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- New 42 MG raw water reservoir to store raw water transferred from the KWA pipeline.
- New 24 MGD low lift pump station to transfer flows from the reservoir to the ozone inlet channel. This pump station can be eliminated if raw water storage is eliminated.
- Upgrade Ozone Contactor Basin No. 1 for preoxidation treatment, with Basin No. 2 and Basin No. 3 either serving as standby units or decommissioned.
- Upgrade the east and west rapid mixing basins with pumped injection mixers.
- Upgrade the east and west flocculation basins to reduce their size and improve the compartmentalization of each flocculation stage; the unused areas of each basin will be decommissioned.
- Modify the IPS basins with an FRP baffle wall to improve performance.
- Replace the existing fixed sludge collection (Spyder) system in the IPS basins with a cable-driven hoseless sludge-collection system and gravity-fed sludge holding tank.
- Upgrade the 12 filters by replacing the existing GAC filter media (18 inches deep) with anthracite filter media (36 inches deep).
- New 24 MGD transfer pumping station to transfer filtered water flows to the Dort Reservoir.
- Use the Dort Reservoir to meet chlorine contact time requirements for primary disinfection in two baffles compartments.
- New high-service pump station to deliver finished water from the Dort Reservoir to the Flint distribution system, with backwash pumps provided for backwashing the filters.

The major improvements to the solids handling systems are summarized below.

- New washwater equalization basin sized to handle at least three backwash events.
- New washwater transfer pump station to transfer flows from the equalization basin to ozone inlet channel.

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Section 5

Chemical System Improvements

This section describes the design criteria for the proposed treatment process chemical system for the Flint Water Treatment Plant (WTP).

5.1 General Information

The following chemicals will be used at the WTP:

- Coagulant and polymer will be added to the rapid mixers prior flocculation to improve floc formation.
- Carbon dioxide and sodium hypochlorite may be added to the rapid mixers prior flocculation to depress the pH to optimize alum coagulation and preoxidation, respectively.
- Polymer is added prior to the inclined plate settler (IPS) backwash line to encourage further settling of particles out of the backwash water.
- Sodium hypochlorite, sodium hydroxide, corrosion inhibitor, and hydrofluosilicic acid will be added after filtration and the transfer pump station, and upstream of the Dort Reservoir, to provide primary disinfection, increase the pH, distribution system corrosion protection, and dental protection, respectively.
- Sodium hypochlorite will be added to the effluent of the Dort Reservoir to boost the chlorine residual for the distribution system.

The existing WTP sodium bisulfite system will be maintained for use in the case of an upset in which ozone residual is found at the downstream end of the ozone contactor tanks.

Table 5.1 lists the treatment chemicals along with the associated hazard classification and occupancy classification for the WTP. **Table 5.2** lists where each chemical will be added within the treatment process.

Table 5.1 – Chemical Classifications

Chemical Name	Hazard Classification	Occupancy Classification
Coagulant (Alum, Ferric, PACl)	Corrosive	H-4
Corrosion Inhibitor (CI, Phosphoric Acid)	Irritant	H-4
Hydrofluosilicic Acid (HF)	Corrosive	H-4
Polymer	N/A	N/A
Sodium Hydroxide (Caustic)	Corrosive	H-4
Sodium Hypochlorite (OCL)	Corrosive Toxic Oxidizer	H-4

Table 5.2 – Chemical Addition Points

Chemical	Location	Application
Coagulant (Alum, Ferric, PACl)	Rapid Mixers prior to the Flocculation System	Primary
Corrosion Inhibitor (Cl, Phosphoric Acid)	Treated Water Upstream of the Dort Reservoir	Primary
Hydrofluosilicic Acid (HF)	Treated Water Upstream of the Dort Reservoir	Primary
Polymer	Rapid Mixers Prior to the Flocculation System	Primary
	Treated Water Upstream of the Inclined Plate Settler (IPS) Backwash Line	Primary
Sodium Hydroxide (Caustic)	Treated Water Upstream of the Dort Reservoir	Primary
Sodium Hypochlorite (OCL)	Rapid Mixers prior to the Flocculation System	Secondary
	Treated Water Upstream of the Dort Reservoir	Primary
	Treated Water Downstream of the Dort Reservoir	Primary

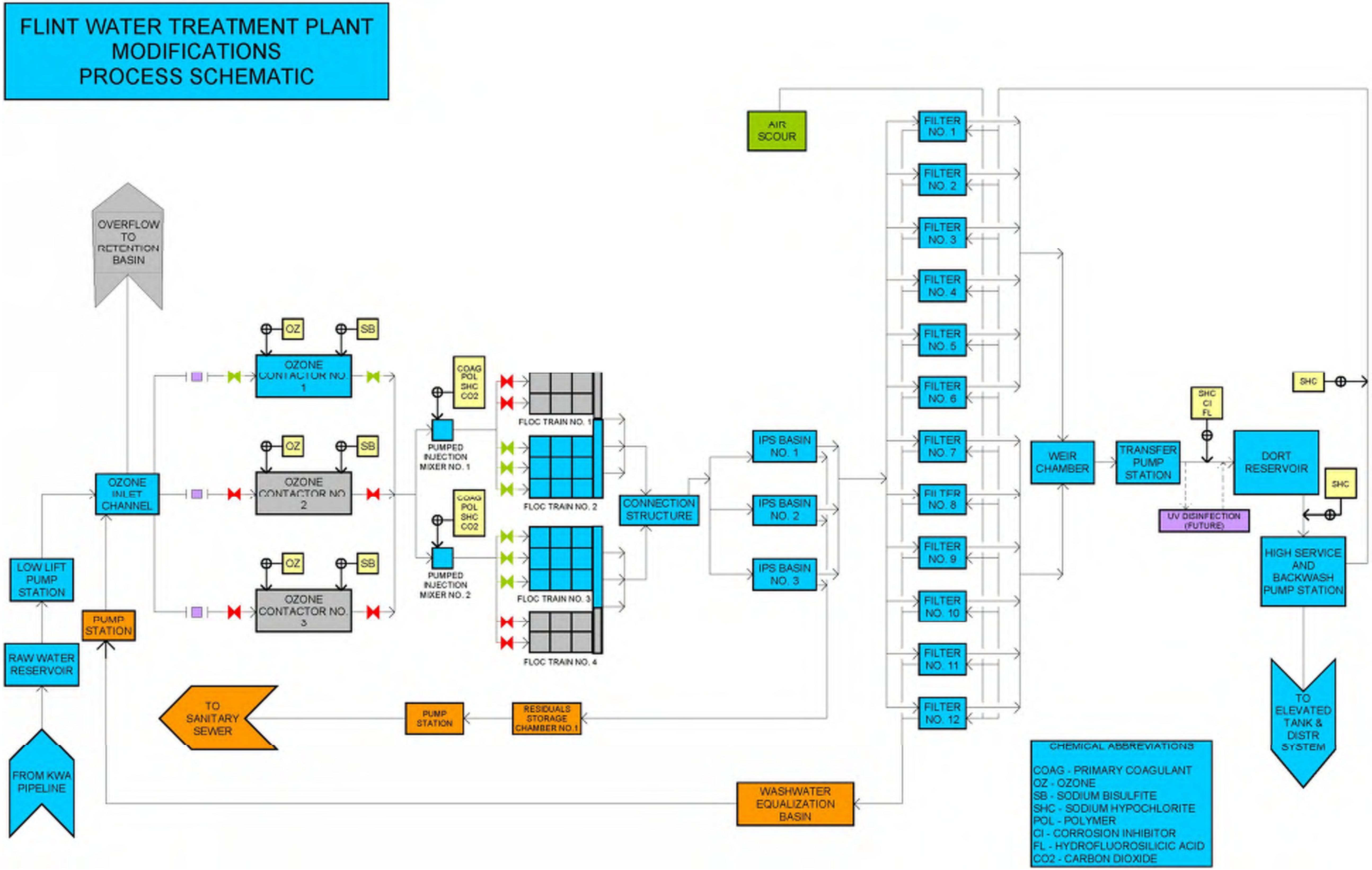

Figure 5.1 – Process Schematic for Flint WTP Recommended Improvements

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5.1.1 Chemical Storage Locations

The existing chemical storage systems at the WTP are obsolete (dry alum system) or no longer applicable to the treatment process (lime, soda ash and carbon systems). All new chemical storage and feed systems will be provided, and they will be located in one of two locations. These alternatives are discussed in further detail below.

5.1.1.1 Alternative 1 – New Centralized Storage Facility

The first alternative is a new centralized bulk storage facility located south of the Dort Reservoir. Day tanks and metering pumps for pre-treatment chemicals (coagulant and polymer) will be located where the dry alum feeders and lime slakers are currently. Post-treatment chemical day tanks and feed pumps will be located in the centralized storage facility. See **Figure 5.2** for the layout of the centralized storage facility.

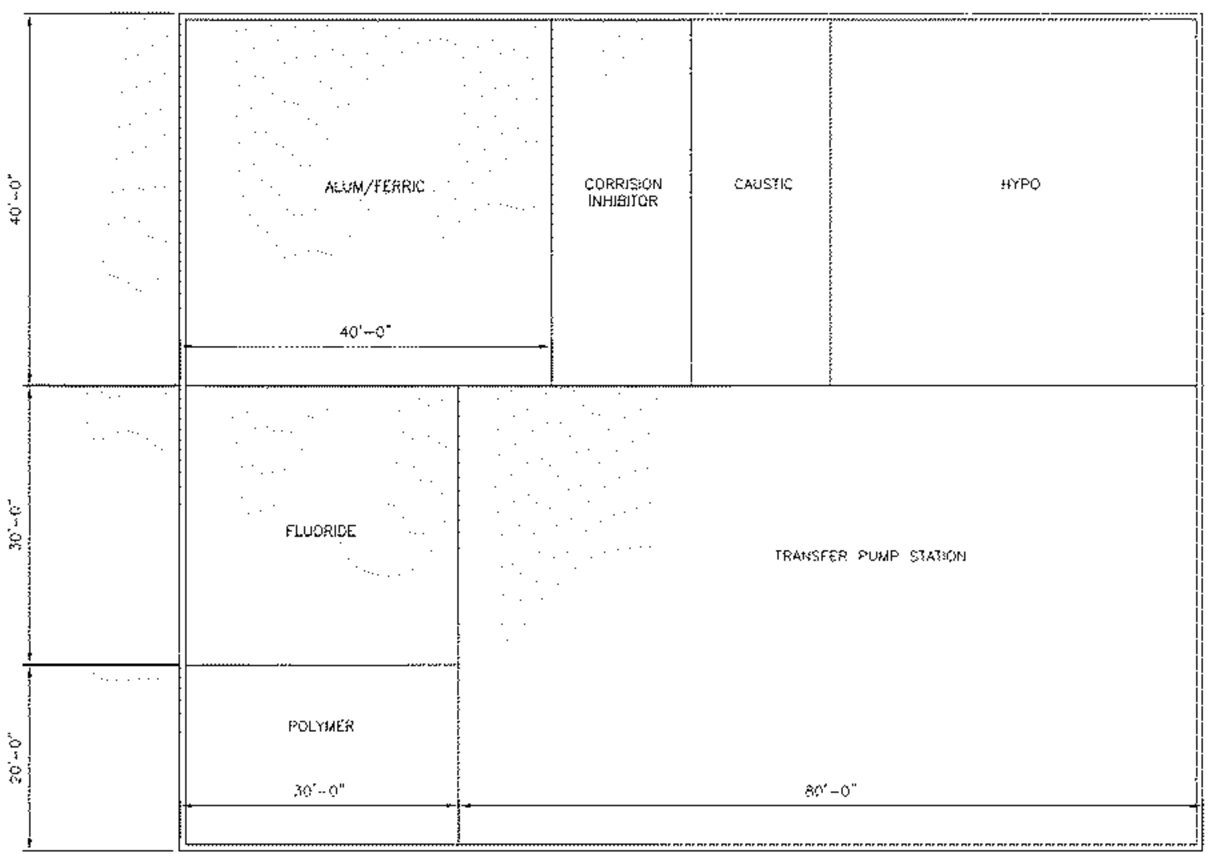

Figure 5.2 – Layout of the Centralized Storage Facility

5.1.1.2 Alternative 2 – Utilize Existing Space for Pre-Treatment Chemicals

The second alternative is to reuse the abandoned "slow mix" basins as the storage location for the pre-treatment chemicals. This reuse of space would require enclosing the basin area in order to provide proper ventilation. The existing basin layout provides spill containment; however, fiberglass reinforced plastic (FRP) stairs would be required to enter the basins. Chemical deliveries would arrive at the adjacent western exterior wall. See **Figure 5.3** for representation of this alternative.

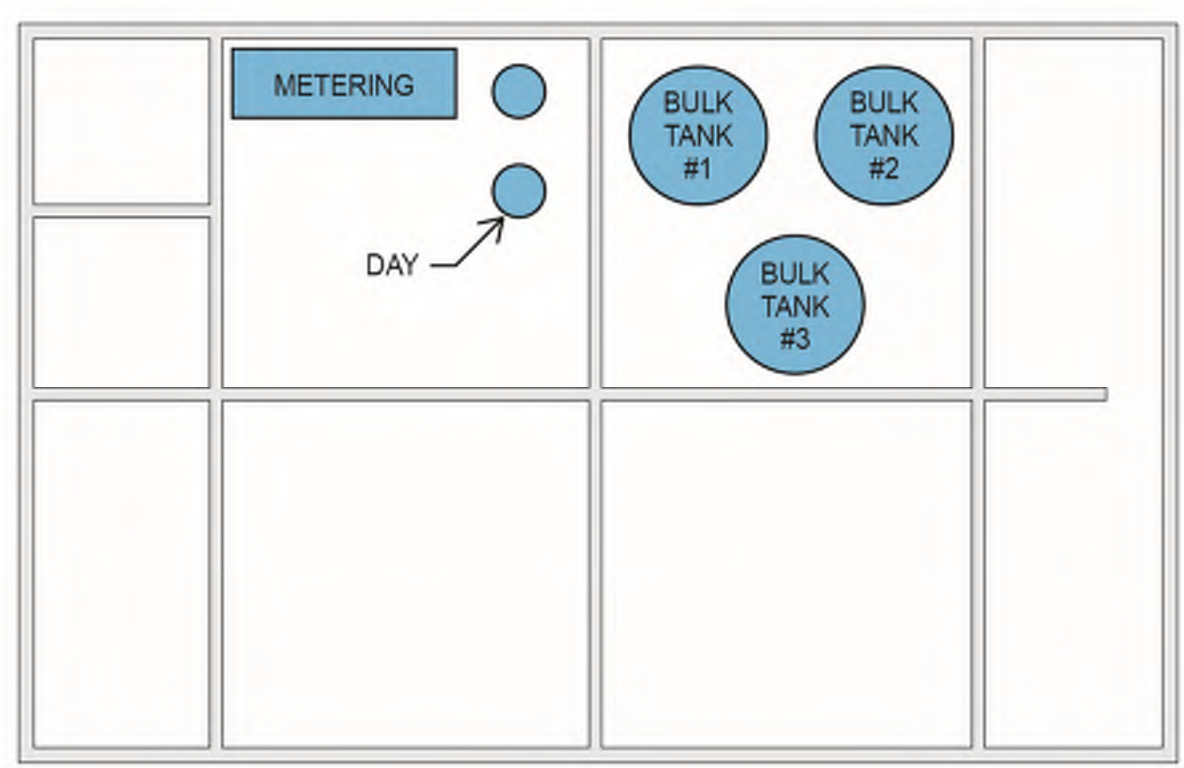

Figure 5.3 – Representation of Existing Space Utilization

5.1.1.3 Alternative Comparison

The two alternatives, a new facility and utilizing the existing space within the WTP, were evaluated using the following criteria: regulatory and water quality issues, operational simplicity, flexibility and efficiency, system reliability and safety, and site considerations. The new facility rated higher than the existing facility alternative in each evaluation category except for regulatory and water quality issues, where both alternatives were rated as excellent. The full analysis is included below in **Table 5.3**.

Table 5.3 – Comparison of Storage Locations for Pre-Treatment Chemicals

Evaluation Criteria	New Facility	Utilize Existing Space within WTP
Regulatory and Water Quality Issues	No water quality issues	No water quality issues
	New facility constructed to meet all current codes	Existing spaces retrofitted to meet all current codes
SCORE:	4	4
Operational Simplicity	Locates all chemical deliveries in a single location	Multiple locations for bulk chemical deliveries
	Locates all bulk chemicals in a single location	Bulk chemical storage located in multiple locations
SCORE:	4	3
Flexibility and Efficiency	Designed for easy bulk tank replacement, which occurs every 10 to 15 years (on average)	More challenging to replace storage tanks within the existing basins
	Requires operators to go outside to access the chemical storage and feed area	Significant stairs in order to enter the chemical storage and feed area
SCORE:	4	2
System Reliability and Safety	Bulk storage is completely isolated from occupied spaces	Any significant tank failure or delivery error may impact occupied spaces
SCORE:	4	3
Site Considerations	Larger building required south of the Dort Reservoir	No new structures required for pre-treatment chemicals, results in a smaller building
	Chemical delivery traffic consolidated in one location and isolated from the rest of the facility	Chemical deliveries accepted along the western edge of the existing WTP, which may partially block traffic
SCORE:	4	3
OVERALL SCORE:	**20**	**15**

5.1.2 Truck Unloading Area

The bulk chemical storage and day tank areas will each have the following features for safely transferring chemicals from the delivery truck tanks to the plant's bulk chemical storage tanks.

- One cam-lock pipe connection will be provided for each bulk chemical storage tank for transferring chemical from truck tanks to bulk storage tanks. The cam-lock connections will protrude from the chemical room exterior wall at a point nearest to the associated storage tank.
- Removable spill containers will be provided to contain small spills and drips that may occur at the hose/cam-lock connection.
- Emergency shower/eyewash stations and hose stations will be installed in the delivery areas.
- Lighting and signage will be installed for the safe delivery of chemicals to the storage tanks.

- Individual Truck Unloading Panels for each chemical will be mounted on exterior walls near the cam-lock connections (see general control descriptions).
- Doorways into each of the separate chemical storage containment areas will provide for easy access and egress.

5.1.3 Tank Volume Considerations

The 10 States Standards for Water Works requires a minimum storage capacity of 30 days at average dose and average flow rate. This volume was compared to the required chemical volume for 14 days under peak conditions (i.e., ultimate buildout maximum-day daily flow and maximum dose), and the larger volume was used for tank sizing. In some cases, storage tank size may have been increased to support a full truck load of chemical to reduce the overall chemical cost. The 10 States Standards require that in those cases, the storage tank be at least 1.5 times the delivery volume.

Day tanks will be provided for the coagulant, polymer, sodium hypochlorite, hydrofluosilicic acid, corrosion inhibitor, and sodium hydroxide. The day tanks will have a capacity for no more than 30 hours of supply. The day tanks typically do not have automated filling controls but have manual and automatic filling shutoff controls. Chemicals that are fed to both filtered and unfiltered water will have separate day tanks and metering pumps to prevent cross-connections.

All chemical storage tanks will be vertical and cylindrical in shape constructed of carbon steel, high-density crosslinked polyethylene (XLPE), or FRP, as is appropriate for individual chemicals.

5.1.4 Secondary Containment Considerations

Separate secondary containment areas will be provided for each of the treatment chemicals in the bulk storage chemical room. The coagulant and polymer will also be stored in both the bulk storage facility and the day tank facility.

The chemical containment will be designed to prevent mixing of incompatible chemicals. Concrete containment areas will be protected with a concrete coating system that is compatible with the stored chemical. No penetrations will be allowed in the containment walls between in compatible chemicals. Railings, stairs, and grating within the containment areas will be constructed of materials that are compatible with the chemical(s) stored in that room.

Table 5.4 shows the containment volume for each chemical room. The containment volume is the volume of the largest tank within the containment area plus fire sprinkler water (20-minute duration at 0.2 gpm/sf, equivalent to approximately 6 inches of water.)

Table 5.4 – Chemical Containment Volumes

Chemical Area	Largest Storage Tank (gallon)	Fire Sprinkler Volume (gallon)	Total Volume (gallon)	Maximum Liquid Height During Spill (feet)
Coagulant Room	12,000	6,400	18,400	1.5
Corrosion Inhibitor (CI) Room	1,000	2,400	3,400	0.76
Hydrofluosilicic Acid (HF) Room	6,000	3,600	9,600	1.43
Polymer Room		2,400		
Sodium Hydroxide (Caustic) Room	6,000	2,400	8,400	1.87
Sodium Hypochlorite, 12.5% (OCL) Room	6,000	6,400	12,400	1.04
Sodium Hypochlorite, 8% (OCL) Room	9,000	6,400	15,400	1.29

5.1.5 Chemical Metering Pump Considerations

The chemical metering pumps will be installed on concrete pedestals to elevate the pumps in the containment area. This will provide better access for operations and maintenance (O&M) staff and prevent damage from possible tank spills.

A metering pump will be provided for each primary application point. A standby metering pump will be used to backup primary metering pump(s) and to convey chemicals to secondary application points. Where systems have only one application point, a minimum of two metering pumps will be installed.

Peristaltic metering pumps or hydraulically activated diaphragm pumps will be used to transfer chemicals to application points. The metering pumps and all associated appurtenances will be skid mounted to facilitate convenient maintenance and access.

5.1.6 Chemical Piping Considerations

All chemical piping outside of containment areas will be secondarily contained. Secondary containment of the piping will be achieved by using flexible, chemically compatible tubing inside of a polyvinyl chloride (PVC) carrier (secondary containment) pipe. Multiple feed pipes will be installed in carrier pipes where compatible chemicals are routed to the same application area. Sample ports will be placed at intervals along the carrier pipe to allow monitoring for leaks in primary tubing. Adequate annular space will be provided in carrier pipes for removal, replacement, or additional chemical feed pipes.

5.1.7 Emergency Eyewash and Shower Stations

Emergency eyewash and shower stations shall be provided in both the containment area of each chemical storage room and at truck unloading areas. The station location will be within 10 to 50 feet from the potential exposure point and within a 10 second maximum walking travel time along normal egress routes with no doors or obstacles. Tepid water will be used with flow switches on the feed pipes to alarm if the station is triggered. For outdoor locations, a freeze proof shower and eyewash will be utilized.

5.1.8 General Description of Controls

The chemical systems typically have the following general control logic:

- Truck Unloading Panels at chemical delivery areas will indicate tank level, provide high and high-high level alarms, and control the associated outside storm water/truck unloading containment valve.
- Bulk storage tanks will have level elements with local and remote level indication and alarms. This will include a low-low level alarm for pump shutoff, a low-level alarm for tank refill reminder, high and high-high level alarms and a rapid-rate of level decline alarm.
- Day Tank Transfer Pumps will be initiated manually via local and remote systems. Shutdown of the transfer pumps will be manually.
- Day Tank level elements will provide:
  - Alarms at low-low, low, high, and high-high levels.
  - Alarm at rapid rate of level decline.
  - Metering pump shutdown at low-low level.
- Metering pumps will be peristaltic metering pumps and/or hydraulically activated diaphragm pumps with manual and automatic speed control based on plant/process flow rate. Chlorine metering pump speed will be based on plant/process flow and residual.
- Fluoride metering pump speed will be based on plant/process flow.
- Metering pumps will be shutdown based on:
  - Treatment and equipment OFF indication.
  - Plant/process flow going to near zero conditions.
  - Day tank low-low level indication.
- Containment areas will provide secondary containment of the stored chemical(s). A sump within the containment area will have a level element to provide a sump high and high-high level alarm.
- Containment sumps will have a sump pump for wash-down water that will be manually controlled locally with an automatic shutoff based on the sump low-low level. Chemical spills within the sump will need to be removed via a vacuum truck or a portable sump pump compatible with the chemical spilled.
- Chemical transfers outside of the containment areas will be secondarily contained in the piping system. Leakage to the annular space will be manually monitored.

- Emergency eyewash and shower stations will be located both outdoors at the truck unloading areas and indoors within the containment areas. Activation of a station will trigger a flow switch to provide a local and remote alarm.

5.2 Chemical Systems Design Criteria

Table 5.5 through **Table 5.9** present design criteria for the chemical systems at the WTP.

5.2.1 Coagulant (Alum, Ferric Chloride/Sulfate, PACl)

Coagulant will be applied at the rapid mixers, upstream of the flocculation basins. CDM Smith anticipates the initial use of alum due to compatibility with water from the Great Lakes Water Authority and the Genesee County Drain Commissioner. Note that coagulant selection and doses will need to be verified in jar testing.

Design dosages for the coagulant system are based upon alum at 49 percent by weight. The system is designed such that either ferric or PACl may be used in the place of alum.

Table 5.5 – Coagulant System Design Criteria

No.	Design Criteria	Unit	Values
1	Design Dose, Alum (1)		
	Minimum	mg/L as Al	0.1
	Average	mg/L as Al	2.1
	Maximum	mg/L as Al	4.5
2	Bulk Chemical Concentration	%	49
3	Feed System Requirements (Each Application Point) (2)		
	Minimum	gal/hr	0.2
	Average	gal/hr	10.4
	Maximum	gal/hr	38.3
4	Storage Tank Facilities		
	Bulk Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	Fiberglass Reinforced Plastic (FRP)
	Number of Tanks	number	3 (Two Duty, One Standby)
	Diameter	ft	12.0
	Height	ft	16.5
	Storage Capacity	gal	12,000
	Days of Storage (average dose and flow)	days	48
	Day Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	Fiberglass Reinforced Plastic (FRP)
	Number of Tanks	number	2 (One Duty, One Standby)
	Diameter	ft	4.0
	Height	ft	6.0
	Storage Capacity	gal	400

No.	Design Criteria	Unit	Values
	Hours of Storage (average dose and flow)	hrs	26
5	Metering Pumps		
	Metering Pumps (Set #1 – Larger)		
	Type	--	Larger
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (3)
	Nominal Capacity Range (per pump)	gal/hr	0.2 – 7.5
	Feeder Turndown Capability	--	37.5:1
	Power	HP	fractional
	Drive Type	speed	VFDs
	Metering Pumps (Set #2 – Smaller)		
	Type	--	Smaller
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (3)
	Nominal Capacity Range (per pump)	gal/hr	7.5 – 40
	Feeder Turndown Capability	--	5.3:1
	Power	HP	Fractional
	Drive Type	speed	VFDs

(1) Design dosages are based on Alum, 49% by weight
(2) Minimum: minimum flow at minimum dose
Average: average flow at average dose
Maximum: maximum flow at maximum does
(3) Or other industry standard materials of construction

5.2.2 Corrosion Inhibitor System

A corrosion inhibitor will be added to prevent lead and copper corrosion in the distribution system. The chemical to be utilized will likely be phosphoric acid or a ortho/polyphosphate blend. The actual type of corrosion inhibitor and doses to be utilized will be determined at the conclusion of the corrosion study and provided to CDM Smith by MDEQ. The corrosion inhibitor storage tank selected is 1,000 gallons in order to accept larger bulk deliveries of the corrosion inhibitor. If redundancy is desired, two bulk storage tanks may be provided.

Table 5.6 – Corrosion Inhibitor System Design Criteria

No.	Design Criteria	Unit	Values
1	Design Dose		
	Minimum	mg/L	0.5
	Average	mg/L	1.0
	Maximum	mg/L	1.5
2	Bulk Chemical Concentration	%	100
3	Feed System Requirements (1)		
	Minimum	gal/hr	0.08

No.	Design Criteria	Unit	Values
	Average	gal/hr	0.43
	Maximum	gal/hr	1.09
4	Storage Tank Facilities		
	Bulk Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	High-Density Crosslinked Polyethylene (XLPE)
	Number of Tanks	number	1
	Diameter	ft	5.0
	Height	ft	9.0
	Storage Capacity	gal	1,000
	Days of Storage (average dose and flow)	days	97
	Day Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	High-Density Crosslinked Polyethylene (XLPE)
	Number of Tanks	number	1
	Diameter	ft	3.0
	Height	ft	3.0
	Storage Capacity	gal	30
	Hours of Storage (average dose and flow)	hrs	27
5	Metering Pumps		
	Metering Pumps		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (2)
	Nominal Capacity Range (per pump)	gal/hr	0.08 – 1.3
	Feeder Turndown Capability at Average Feed Rate	--	3:1
	Feeder Turndown Capability at Minimum Feed Rate	--	16:1
	Power	HP	Fractional
	Drive Type	speed	VFDs

(1) Minimum: minimum flow at minimum dose
Average: average flow at average dose
Maximum: maximum flow at maximum does
(2) Or other industry standard materials of construction

5.2.3 Hydrofluosilicic Acid System

Hydrofluosilicic acid will be added to the Dort Reservoir influent. The dosages for the hydrofluosilicic acid were selected to maintain a final fluoride concentration of approximately 0.8 mg/L as F-.

Table 5.7 – Hydrofluosilicic Acid System Design Criteria

No.	Design Criteria	Unit	Values
1	Design Dose		
	Minimum	mg/L	0.5
	Average	mg/L	0.7
	Maximum	mg/L	0.85
2	Bulk Chemical Concentration	%	12.5
3	Feed System Requirements (1)		
	Minimum	gal/hr	0.48
	Average	gal/hr	1.86
	Maximum	gal/hr	3.88
4	Storage Tank Facilities		
	Bulk Tank (Option 1)		
	Type	--	Vertical Cylindrical
	Construction Material	--	High-Density Crosslinked Polyethylene (XLPE)
	Number of Tanks	number	1
	Diameter	ft	9.0
	Height	ft	15.0
	Storage Capacity	gal	6,000
	Days of Storage (average dose and flow)	days	134
	Bulk Tank (Option 2)		
	Type	--	Vertical Cylindrical
	Construction Material	--	High-Density Crosslinked Polyethylene (XLPE)
	Number of Tanks	number	1
	Diameter	ft	7.0
	Height	ft	9.0
	Storage Capacity	gal	2,000
	Days Storage (average dose and flow)	days	45
	Day Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	High-Density Crosslinked Polyethylene (XLPE)
	Number of Tanks	number	1
	Diameter	ft	3.0
	Height	ft	3.0
	Storage Capacity	gal	50
	Days Storage (average dose and flow)	days	26
5	Metering Pumps		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)

No.	Design Criteria	Unit	Values
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (2)
	Nominal Capacity Range (per pump)	gal/hr	0.5 – 4.4
	Feeder Turndown Capability at Average Feed Rate	--	2:1
	Feeder Turndown Capability at Minimum Feed Rate	--	8:1
	Power	HP	Fractional
	Drive Type	speed	VFD

(1) Minimum: minimum flow at minimum dose
Average: average flow at average dose
Maximum: maximum flow at maximum does
(2) Or other industry standard materials of construction

5.2.4 Polymer System

Polymer will be added to the system at the rapid mixers, prior to the flocculation tanks. Polymer will also be added to the treated water upstream of the inclined plate settler (IPS) backwash line. The polymer system may be anionic, cationic, and non-ionic. These products may be purchased in both liquid and dry form.

Polymers are added to the water as a coagulant and filter-aid to improve particle flocculation and particle removal. Projects with raw water characteristics similar to those of the WTP have experienced polymer dosages of 0.5 to 3 mg/L. Facilities will be provided to allow either liquid coagulant aid or dry/emulsion filter aid type polymers to be added.

5.2.5 Sodium Hydroxide

Sodium hydroxide (caustic soda) will be added to the Dort Reservoir influent to control distribution system pH. The actual distribution system pH and sodium hydroxide dosages required will be determined at the conclusion of the corrosion study and provided to CDM Smith by MDEQ.

Sodium hydroxide is commonly available in 20 percent and 50 percent (by weight) NaOH concentrations. A 50 percent sodium hydroxide concentration is not recommended for year-round use due to the high freezing point of 51 degrees F. Therefore, sodium hydroxide is assumed to be delivered at 20 percent concentration as the basis for the storage tank volume listed in **Table 5.8**. A concentration of 20 percent was selected due to the significantly lower viscosity (6.4 versus 110 centipoise) and the associated risks of handling a more concentrated chemical.

Table 5.8 – Sodium Hydroxide Design Criteria

No.	Design Criteria	Unit	Values
1	Design Dose		
	Minimum	mg/L	1.0
	Average	mg/L	3.0
	Maximum	mg/L	5.0
2	Bulk Chemical Concentration	%	25

No.	Design Criteria	Unit	Values
3	Feed System Requirements [(1)]		
	Minimum	gal/hr	0.7
	Average	gal/hr	5.7
	Maximum	gal/hr	16.4
4	Storage Tank Facilities		
	Bulk Tank		
	Type	--	Vertical Cylindrical
	Construction Material	--	Carbon Steel
	Number of Tanks	number	1
	Diameter	ft	9.0
	Height	ft	15.0
	Storage Capacity	gal	6,000
	Days of Storage (average dose and flow)	days	44
	Day Tank (Water Treatment)		
	Type	--	Vertical Cylindrical
	Construction Material	--	Carbon Steel
	Number of Tanks	number	1
	Diameter	ft	4.0
	Height	ft	4.0
	Storage Capacity	gal	175
	Hours of Storage (average dose and flow)	hrs	30
5	Metering Pumps		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer [(2)]
	Nominal Capacity Range (per pump)	gal/hr	0.7 – 18
	Feeder Turndown Capability at Average Feed Rate	--	3:1
	Feeder Turndown Capability at Minimum Feed Rate	--	26:1
	Power	HP	fractional
	Drive Type	speed	VFD

(1) Minimum: minimum flow at minimum dose
Average: average flow at average dose
Maximum: maximum flow at maximum does
(2) Or other industry standard materials of construction

5.2.6 Sodium Hypochlorite System

The sodium hypochlorite system is used at three application points: preoxidation at the rapid mixers, disinfection prior to the Dort Reservoir, and at the Dort Reservoir effluent as a distribution system residual boost. Sodium hypochlorite is purchased in bulk at 12.5 percent by weight and may be diluted to 8 percent strength (by weight).

12.5 percent sodium hypochlorite is delivered in bulk and applied directly to the treatment system without adjustment. Storage of 12.5 percent sodium hypochlorite, however, is limited because it is subject to temperature-dependent degradation producing chlorate. Additionally, 12.5 percent sodium hypochlorite has the potential to off-gas and over pressurize the pipes, possibly causing them to burst without the implementation of pressure relief devices. 8 percent sodium hypochlorite is a diluted form of 12.5 percent sodium hypochlorite that minimizes chlorate formation, allows for longer onsite storage duration, and minimizes the potential for off-gassing. The diluted water in this process is "moderately hard", resulting in calcium carbonate precipitation if no softening is performed. 8 percent sodium hypochlorite requires additional equipment to maintain the system such as softeners, a mixing pump, flow meters, and valves. A full evaluation of the two forms of sodium hypochlorite is included below in **Table 5.9**.

Table 5.9 – Comparison of 12.5% Hypochlorite versus Dilution to 8% Strength

Evaluation Criteria	Store and Feed at 12.5% Solution	Dilute to 8% Solution
Regulatory and Water Quality Issues	Degradation of sodium hypochlorite forms chlorate, which may be regulated in the future	Dilution to 8% minimizes the rate of degradation and chlorate formation
	Sodium hypochlorite degradation minimized by limiting the amount of storage kept onsite and frequently turning over the bulk tanks	
SCORE:	3	4
Operational Simplicity	12.5% hypochlorite is delivered in bulk and fed neat to the filtered water	Upon delivery, the hypochlorite would be diluted by adding softened water
	If hypochlorite solutions are stored onsite for too long, feed rates will need to be adjusted to account for degradation	Dilution process would be automated through SCADA
		Requires maintenance of additional water softeners, pumps, flow meters, and valves
SCORE:	3	2
Flexibility and Efficiency	Plant staff need to consider sequencing of hypochlorite bulk deliveries to minimize the amount of time that it is stored onsite	Allows plant staff to order a new hypochlorite delivery immediately when a bulk tank is fully utilized
	Requires a tight specification with hypochlorite required to be delivered at a pH between 12 and 13 to minimize degradation	
SCORE:	3	3
System Reliability and Safety	Higher potential for off-gassing over pressurizing piping systems and causing them to burst, if not properly designed, installed and maintained	Off-gassing is minimized at lower hypochlorite solution strengths, reducing the risk of over pressurizing and bursting the piping systems
	Provides minimal buffer against potential supply disruptions	Provides better buffer against supply disruptions when a new bulk delivery is received immediately after a tank is emptied

Evaluation Criteria	Store and Feed at 12.5% Solution	Dilute to 8% Solution
SCORE:	3	4
Site Considerations	No site impacts	No site impacts
SCORE:	0	0
OVERALL SCORE:	**12**	**13**

The design criteria for both 12.5 percent and 8 percent hypochlorite are presented in **Table 5.10**. The final decision on the sodium hypochlorite strength will be determined during final design.

Table 5.10 – Sodium Hypochlorite System Design Criteria

No.	Design Criteria	Unit	Values
1	Design Dose (Pre-Oxidation-Rapid-Mix)		
	Minimum	mg/L	0.5
	Average	mg/L	1.0
	Maximum	mg/L	1.5
2	Design Dose (Disinfection – Dort Reservoir Influent)		
	Minimum	mg/L as Cl_2	1.0
	Average	mg/L as Cl_2	2.0
	Maximum	mg/L as Cl_2	3.0
	Design Dose (Distribution System Residual Boost)		
	Minimum	mg/L as Cl_2	0.2
	Average	mg/L as Cl_2	0.5
	Maximum	mg/L as Cl_2	1.5
3	Feed System Requirements, 12.5% Solution (Pre-Oxidation-Rapid Mix)(1)		
	Minimum	gal/hr	0.8
	Average	gal/hr	4.7
	Maximum	gal/hr	12.0
	Feed System Requirements, 8% Solution (Pre-Oxidation-Rapid Mix)(1)		
	Minimum	gal/hr	1.3
	Average	gal/hr	7.3
	Maximum	gal/hr	18.7
	Feed System Requirements, 12.5% Solution (Disinfection – Dort Reservoir Influent)(1)		
	Minimum	gal/hr	1.7
	Average	gal/hr	9.3
	Maximum	gal/hr	24.0
	Feed System Requirements, 8% Solution (Disinfection – Dort Reservoir Influent)(1)		
	Minimum	gal/hr	2.6
	Average	gal/hr	14.6

No.	Design Criteria	Unit	Values
	Maximum	gal/hr	37.5
	Feed System Requirements, 12.5% Solution (Distribution System Residual Boost)(1)		
	Minimum	gal/hr	0.3
	Average	gal/hr	2.3
	Maximum	gal/hr	12.0
	Feed System Requirements, 8% Solution (Distribution System Residual Boost)(1)		
	Minimum	gal/hr	0.5
	Average	gal/hr	3.6
	Maximum	gal/hr	18.7
4	Storage Tank Facilities, 12.5% (Pre-Oxidation – Rapid Mixers)		
	Day Tank		
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	1
	Diameter	ft	2.5
	Height	ft	5.0
	Storage Capacity	gal	125
	Days of Storage (average dose and flow)	days	27
	Storage Tank Facilities, 8% (Pre-Oxidation – Rapid Mixers)		
	Day Tank		
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	1
	Diameter	ft	3.0
	Height	ft	5.0
	Storage Capacity	gal	200
	Days of Storage (average dose and flow)	days	28
	Storage Tank Facilities, 12.5% (Disinfection – Dort Reservoir Influent)		
	Bulk Tank		
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	2
	Diameter	ft	9.0
	Height	ft	15.0
	Storage Capacity	gal	6,000
	Days of Storage (average dose and flow)	days	53
	Storage Tank Facilities, 8% (Disinfection – Dort Reservoir Influent)		
	Bulk Tank		

No.	Design Criteria	Unit	Values
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	2
	Diameter	ft	10.0
	Height	ft	18.0
	Storage Capacity	gal	9,000
	Days of Storage (average dose and flow)	days	51
	Storage Tank Facilities, 12.5% (Disinfection – Dort Reservoir Influent and Distribution System Residual Boost)		
	Day Tank		
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	1
	Diameter	ft	4.0
	Height	ft	5.0
	Storage Capacity	gal	250
	Days of Storage (average dose and flow)	days	27
	Storage Tank Facilities, 8% (Disinfection – Dort Reservoir Influent and Distribution System Residual Boost)		
	Day Tank		
	Type	--	Vertical, Cylindrical
	Construction Material	--	FRP
	Number of Tanks	number	1
	Diameter	ft	4.0
	Height	ft	7.0
	Storage Capacity (per tank)	gal	400
	Days of Storage (average dose and flow)	days	27
5	Metering Pumps		
	Metering Pumps, 12.5% (Pre-Oxidation – Rapid Mixers)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer [(2)]
	Nominal Capacity Range (per pump)	gal/hr	0.8 – 14.0
	Feeder Turndown Capability at Average Feed Rate	--	3.0:1
	Feeder Turndown Capability at Minimum Feed Rate	--	17.5:1
	Power	HP	Fractional
	Drive Type	speed	VFD

No.	Design Criteria	Unit	Values
	Metering Pumps, 8% (Pre-Oxidation – Rapid Mixers)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (2)
	Nominal Capacity Range (per pump)	gal/hr	1.0 – 20
	Feeder Turndown Capability at Average Feed Rate	--	2.7:1
	Feeder Turndown Capability at Minimum Feed Rate	--	15.4:1
	Power	HP	Fractional
	Drive Type	speed	VFD
	Metering Pumps, 12.5% (Disinfection – Dort Reservoir Influent)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (2)
	Nominal Capacity Range (per pump)	gal/hr	1.7 - 26
	Feeder Turndown Capability at Average Feed Rate	--	2.8:1
	Feeder Turndown Capability at Minimum Feed Rate	--	15.3:1
	Power	HP	fractional
	Drive Type	speed	VFD
	Metering Pumps, 8% (Disinfection – Dort Reservoir Influent)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer (2)
	Nominal Capacity Range (per pump)	gal/hr	2.6 - 40
	Feeder Turndown Capability at Average Feed Rate	--	2.7:1
	Feeder Turndown Capability at Minimum Feed Rate	--	15.4:1
	Power	HP	Fractional
	Drive Type	speed	VFD
	Metering Pumps, 12.5% (Distribution System Residual Boost)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)

No.	Design Criteria	Unit	Values
	Construction Material of Tubing Element	--	Thermoplastic Elastomer [2]
	Nominal Capacity Range (per pump)	gal/hr	0.3 - 14
	Feeder Turndown Capability at Average Feed Rate	--	6.1:1
	Feeder Turndown Capability at Minimum Feed Rate	--	47:1
	Power	HP	fractional
	Drive Type	speed	VFD
	Metering Pumps, 8% (Distribution System Residual Boost)		
	Type	--	Peristaltic or Hydraulically Actuated Diaphragm
	Number	number	2 (One Duty, One Standby)
	Construction Material of Tubing Element	--	Thermoplastic Elastomer [2]
	Nominal Capacity Range (per pump)	gal/hr	0.5 - 20
	Feeder Turndown Capability at Average Feed Rate	--	5.6:1
	Feeder Turndown Capability at Minimum Feed Rate	--	40:1
	Power	HP	fractional
	Drive Type	speed	VFD

(1) Minimum: minimum flow at minimum dose
Average: average flow at average dose
Maximum: maximum flow at maximum dose
(2) Or other industry standard materials of construction

CDM Smith

Section 6

Pumping System Improvements

6.1 Design Flow Criteria

As noted in previous sections, the design flow rates for the Flint Water Treatment Plant (WTP) are as follows:

- Minimum day, 5 million gallons per day (MGD).
- Average day, 14 MGD.
- Maximum day, 24 MGD.

The raw water, filtered water, and finished water pump stations should be configured to closely match average day demand.

In order to achieve the flow rates noted above, the following pump capacities were selected:

- Three pumps at 14 MGD.
- Two pumps at 5 MGD.
- All pumps with variable speed drives to ensure even wear across all pumps and to allow the City to set a consistent flow rate without the use of throttling valves. Note that the number of variable speed drives provided will be verified during final design.

To achieve the minimum flow rate (5 MGD):

- Use one pump at 5 MGD.
- Second pump is standby.

To achieve the average flow rate (14 MGD):

- Use one 14 MGD pump.
- Second and third pumps are standby units.

To achieve the maximum flow rate:

- Use two 14 MGD pumps.
- Third pump is standby.

Pumps and pump stations will conform to pertinent Hydraulic Institute (HI) Standards, latest edition. In addition, the pumps will comply with American Water Works Association (AWWA) Standard E103 for Horizontal and Vertical Line-Shaft Pumps, latest edition.

6.2 Initial Screening of Pump Types

For this project, three types of pumps were considered:

- Submersible.
- Horizontal split case.
- Vertical turbine can pump.

Submersible pumps are commonly used in wastewater applications and in applications where handling solids in a liquid stream to be pumped is a necessity. In the case for Lake Huron water as a source of supply, solids handling is not a requirement. In addition, submersible pumps are normally less efficient than horizontal split case or vertical turbine can pumps. This is especially significant for the constant pumping conditions being considered for this project. For these reasons, submersible pumps will not be considered.

Figure 6.1 – Horizontal Split Case

A typical horizontal split case pump installation is illustrated in **Figure 6.1**. This type of pump offers excellent efficiencies and easy access to pump components. Disadvantages include sensitivity to net positive suction head conditions, larger/deeper footprints for installation, and longer lead times.

Figure 6.2 – Vertical Turbine Pump

A typical vertical turbine pump installation is shown in **Figure 6.2**. This type of pump also offers excellent efficiencies. In addition, this type of pump is less sensitive to net positive head suction conditions since the pump element/impeller can be as low as necessary to meet Net Positive Suction Head (NPSH) requirements. The major disadvantage of vertical turbine can pumps is the need to remove the pump motor and pump column from the can to access the pump bowl assembly. Since most components are fabricated, the fabrication lead times are shorter than that for horizontal split case pumps. A typical section of a vertical turbine can pump is shown in **Figure 6.3**.

During final design, a final decision will be made on the type of pumps to be utilized on the project. The layouts and costs presented in this report are based upon vertical turbine pumps.

6.3 Raw Water Pump Station

The alternative approaches for providing raw water pumping are described below. Raw water pumping could be eliminated if raw water storage is not provided.

6.3.1 Alternative 1 – Rehabilitate Existing Raw Water Pump Station

The existing raw water pump station is currently located in Pump Station #4 (see **Figure 6.4**). This pump station was originally designed to withdraw water from the Flint River through a series of intake screens into a suction chamber (see **Figure 6.5**). There are currently 4 available pump slots in this station. In order to accommodate the design flow rates, 4 new horizontal pumps (3 in use + 1 standby) at 8 MGD each would be required. Each pump would be variable speed drive. One of the pumps could be turned down to achieve a flow rate of 5 MGD. The HVAC system would have to be upgraded to provide cooling for the new variable speed drives and the existing electrical system would have to be evaluated. Given the age of the structure, there is a potential for lead paint abatement. Testing for lead would be required.

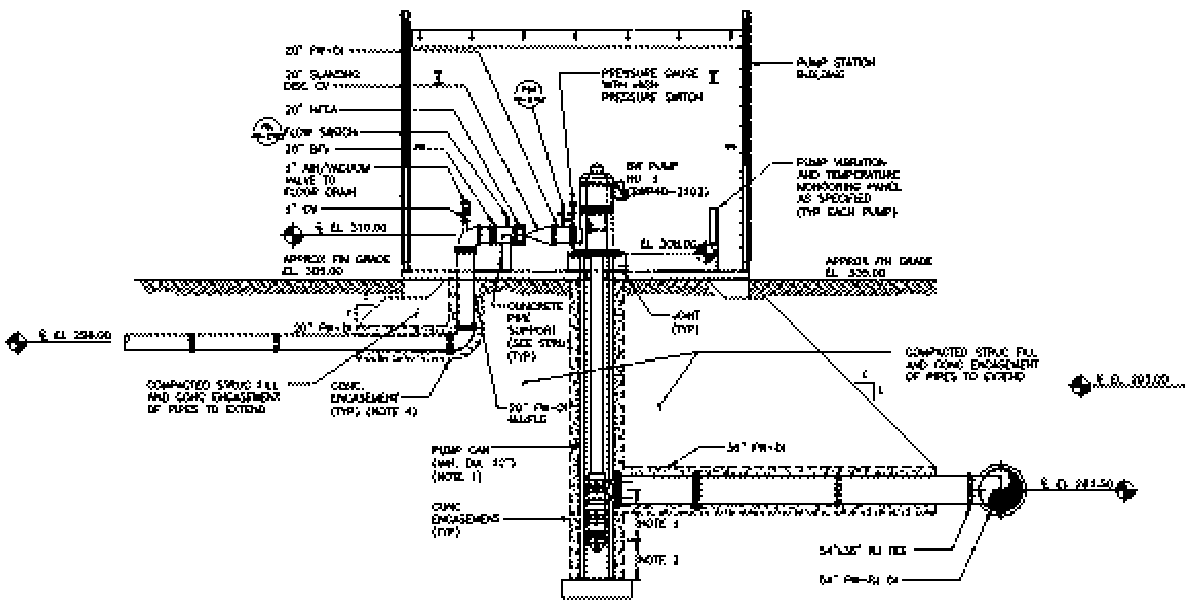

Figure 6.3 – Typical Vertical Turbine Can Pump Section

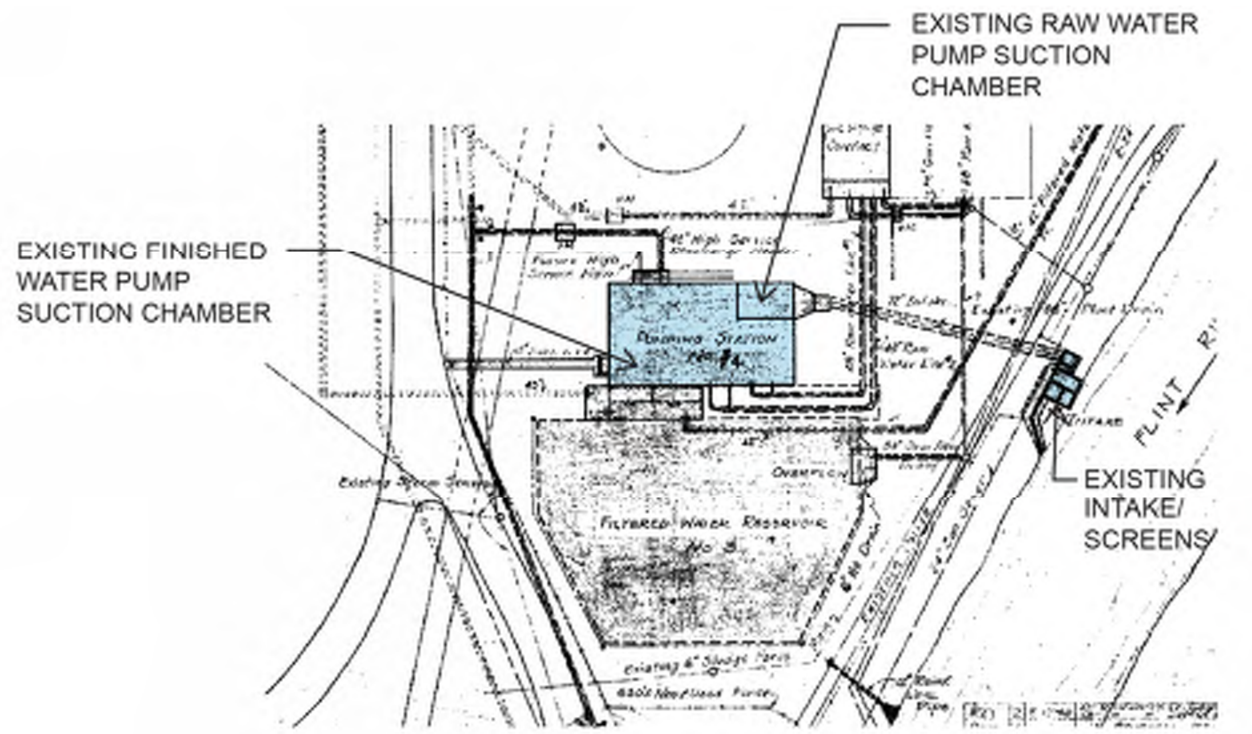

Figure 6.4 – Existing Raw Water Pump Station

This pump station was originally designed in the late 1940s. The existing suction well design does not conform to current HI Standards design. Because of the poor geometry associated with the suction chamber, the construction of a physical model is recommended to determine how the intake reacts to various flow conditions and to identify improvements required to meet HI Standards. This would impact project schedule.

Of greater significance is the relative elevation difference between the top slab of the raw water suction chamber and the raw water elevations in the proposed raw water storage options. As illustrated in **Figure 6.6**, the top slab of the suction chamber is at elevation 721, while the floor of the chamber is at elevation 699. The normal pool level of the Flint River, for which this pump station was originally designed, is elevation 709.

As indicated in Figure 6.6, the proposed raw water impoundment would have a high-water level of about 740 and a low-water level of about 721. If prestressed concrete tanks are utilized, the elevations would be 765 and 731, respectively. The majority of these elevations are above the top slab of the suction chamber. The major elements of concern are:

- The need for a throttling valve/flow meter arrangement to direct flow to the pump station, which would add complexity to plant operations.
- Failure of the throttling valve could result in an uplift of the top slab of the suction chamber due to the elevation differences, resulting in structural damage.
- Failure of the throttling valve could cause flooding and damage the suction chamber/pump station; it would take time to drain the impoundment or raw water storage tanks.

6.3.2 Alternative 2 – New Raw Water Pump Station

For prestressed concrete tank raw water storage, the pump station would be located symmetrically between the tanks. For the impoundment, the pump station would be immediately adjacent to the impoundment. The maximum water service level in the impoundment is 740. Pumping out of the impoundment to the ozone contact basin would be required at all times. The estimated pumping capacities are similar to those noted below for the prestressed tanks. From the tanks, it would be possible to flow by gravity to the ozone contact basin influent channel above elevation 747, depending upon the hydraulic grade line provided by Karegnondi Water Authority (KWA) at the plant property line. Pumping would be required below elevation 747. The estimated pumping capacities are as follows:

- Three pumps (2 + 1 standby) at 14 MGD, 175 horsepower (HP).
- Two pumps (1 + 1 standby) at 5 MGD, 50 HP.
- All pumps variable speed.

A non-economic comparison of alternatives is presented in **Table 6.1. Table 6.2** and **Table 6.3** compare vertical turbine can pumps and horizontal split case pumps for both the tanks and earthen impoundment. A new structure housing the vertical turbine can pumps would be approximately 70-feet by 60-feet (4,200 sq. ft.).

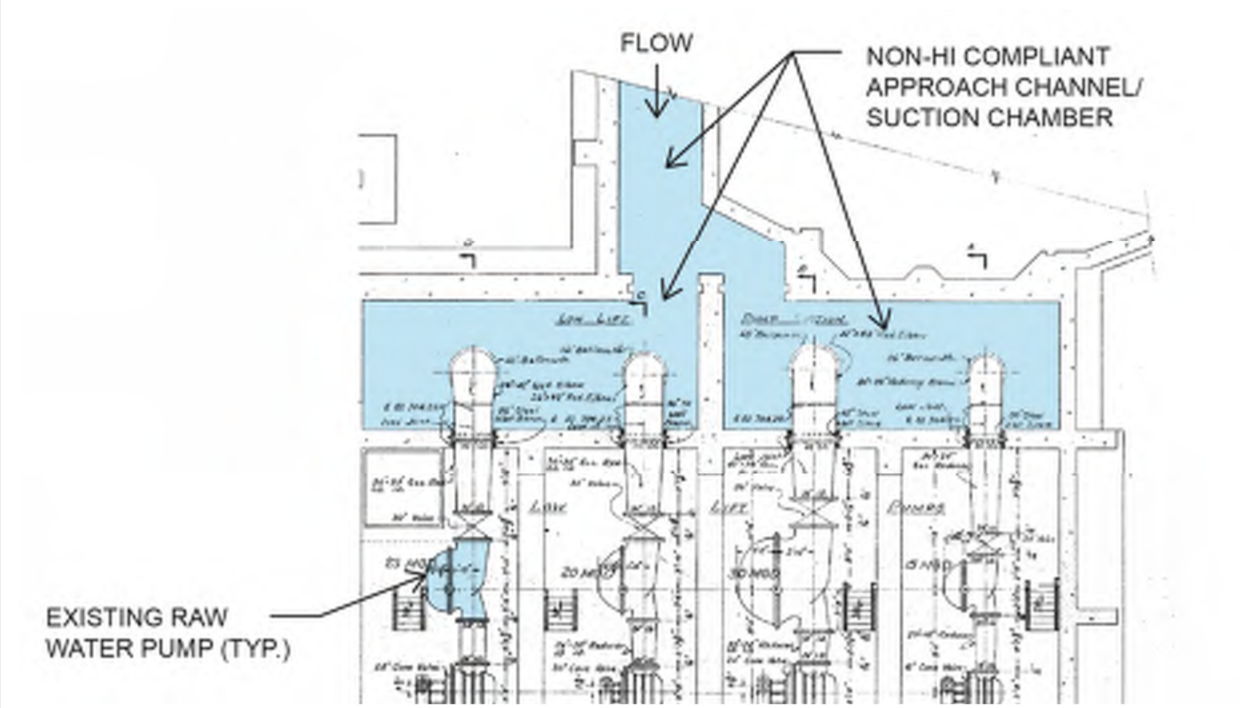

Figure 6.5 – Existing Raw Water Pump Station Plan View

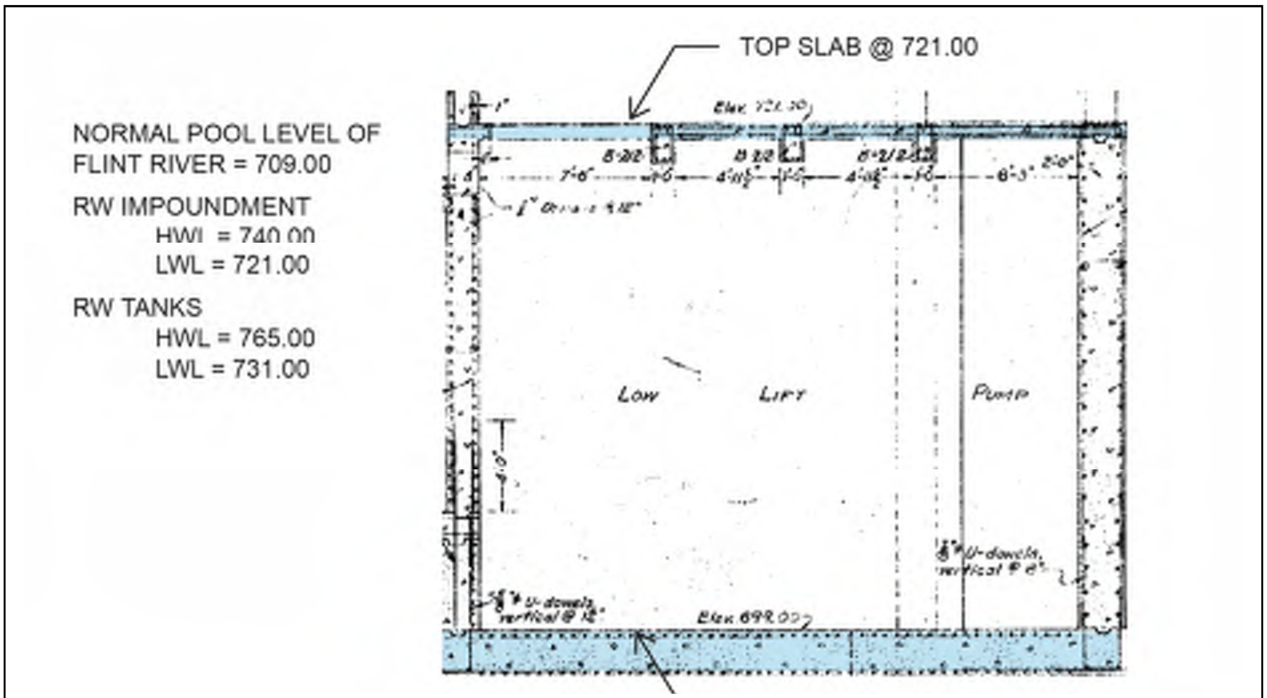

Figure 6.6 – Existing Raw Water Pump Station Suction Chamber Section View

The estimated cost to rehabilitate the existing raw water pump station is $5.2 million exclusive of any improvements required by the results of the physical model. The estimated capital cost of a new raw water pump station is $6.4 million of which pumps and appurtenances account for approximately 70 percent of the cost.

Table 6.1 – Raw Water Pump Station Non-Economic Comparison of Alternatives

Rehabilitate Existing Pump Station	New Pump Station
▪ No new structures required	▪ New structure at grade with limited buried infrastructure
▪ Modifications to suction chambers required to meet HI standards	▪ Easier access for maintenance, including removal of pumps/motors
▪ Constrained access for installation and maintenance of equipment	▪ Design will conform to latest HI standards
▪ Potential to over pressurize suction chamber and/or drain RW reservoir	▪ Pump bowl not visible within the can for inspection
▪ Requires complete replacement of existing piping and valves	
▪ Does not meet project goal of O&M simplicity	

6.3.3 Recommendation

Based on the elevation differences between the raw water reservoir and the suction chamber, issues this may cause with uplift on the structural slab, along with the minimal difference in cost, it is recommended that a new raw water pump station be constructed. A new raw water pump station would also be easier to operate and maintain. Note that if the raw water reservoir is not required, this raw water pump station can potentially be eliminated.

6.4 Finished Water Pump Station

6.4.1 Alternative 1 – Rehabilitate Existing Finished Water Pump Station

The existing finished water (high service) pump station is located in Pump Station #4. This pump station was originally designed to withdraw water from Clearwell #4 into a suction chamber (see **Figure 6.7**). There are currently 4 available pump slots in this station. To accommodate the design flow rates, 4 new horizontal pumps (3 + 1 standby) at 8 MGD each would be required. Each pump would be variable speed drive. One of the pumps could be turned down to achieve a flow rate of 5 MGD. The HVAC system would have to be upgraded to provide cooling for the new variable speed drives and the existing electrical system would have to be evaluated. Given the age of the structure, there is a potential for lead paint abatement, so testing for lead would be required.

This pump station was originally designed in the late 1940s. The existing suction well design does not conform to current HI Standards design. Because of the poor geometry associated with the suction chamber, the construction of a physical model is recommended to determine how the intake reacts to various flow conditions and to identify improvements required to meet HI Standards. This would impact project schedule.

Of greater significance is the relative elevation difference between the top slab of the finished water suction chamber and the elevations in the Dort Reservoir. As illustrated in **Figure 6.8**, the top slab of the suction chamber is at elevation 729 while the floor of the chamber is at elevation 704.

Table 6.2 – Comparison of Raw Water Pump Station – Tanks

Evaluation Criteria	VT Can Pumps	HSC Pumps
Approximate Design Capacity	3 @ 14 MGD, 150 HP, 35 TDH	3 @ 14 MGD, 150 HP, 35 TDH
	2 @ 5 MGD, 40 HP, 25 TDH	2 @ 5 MGD, 40 HP, 25 TDH
	Comply with HI standards, AWWA E-103	Comply with HI standards, AWWA E-103
SCORE:	0	0
Operational Simplicity	VFDs all pumps	VFDs all pumps
		Better access to all pump components
SCORE:	3	4
Flexibility and Efficiency	1-14 MGD matches average flow	1-14 MGD matches average flow
	2-14 MGD provides 24 MGD	2-14 MGD provides 24 MGD
	5 MGD matches low flow	5 MGD matches low flow
SCORE:	4	4
System Reliability and Safety	1 standby for large pumps	1 standby for large pumps
	1 standby for small pumps	1 standby for small pumps
		More sensitive to NPSH conditions
SCORE:	4	3
Site Considerations	Smaller footprint, less depth for structure	Deeper structure required, larger footprint required
	Shorter lead time	Longer lead time
SCORE:	4	3
TECHNICAL RATED SCORE:	**3.75**	**3.5**

Table 6.3 – Comparison of Raw Water Pump Station – Impoundment

Evaluation Criteria	VT Can Pumps	HSC Pumps
Approximate Design Capacity	3 @ 14 MGD, 175 HP, 45 TDH	3 @ 14 MGD, 175 HP, 45 TDH
	2 @ 5 MGD, 50 HP, 35 TDH	2 @ 5 MGD, 50 HP, 35 TDH
	Comply with HI standards, AWWA E-103	Comply with HI standards, AWWA E-103
SCORE:	0	0
Operational Simplicity	VFDs all pumps	VFDs all pumps
		Better access to all pump components
SCORE:	3	4
Flexibility and Efficiency	1-14 MGD matches average flow	1-14 MGD matches average flow
	2-14 MGD provides 24 MGD	2-14 MGD provides 24 MGD
	5 MGD matches low flow	5 MGD Matches low flow
SCORE:	4	4

Evaluation Criteria	VT Can Pumps	HSC Pumps
System Reliability and Safety	1 standby for large pumps	1 standby for large pumps
	1 standby for small pumps	1 standby for small pumps
		More sensitive to NPSH conditions
SCORE:	4	3
Site Considerations	Smaller footprint, less depth for structure	Deeper structure required, larger footprint required
	Shorter lead time	Longer lead time
SCORE:	4	3
TECHNICAL RATED SCORE:	**3.75**	**3.5**

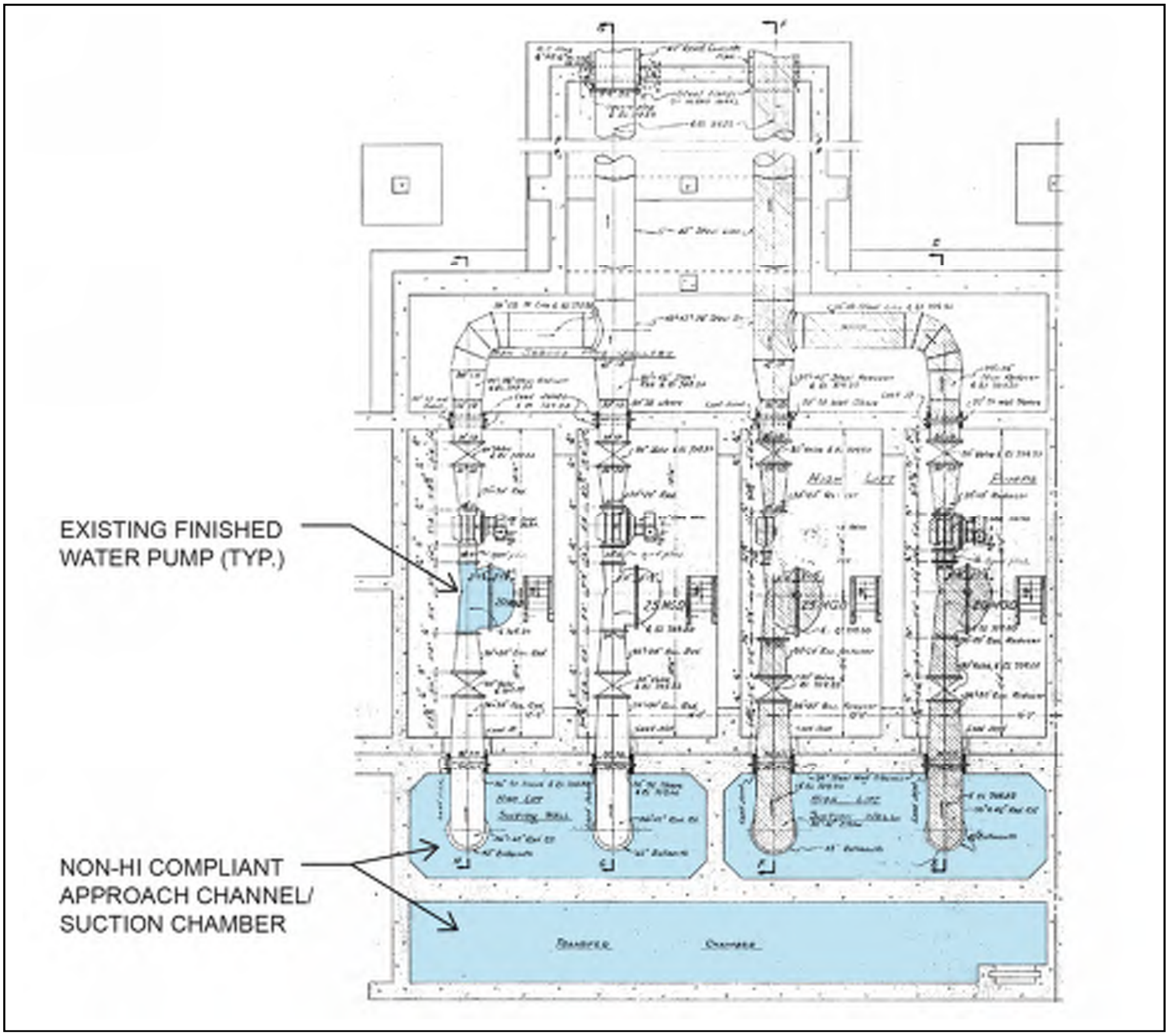

Figure 6.7 – Existing High Service Pump Station Plan View

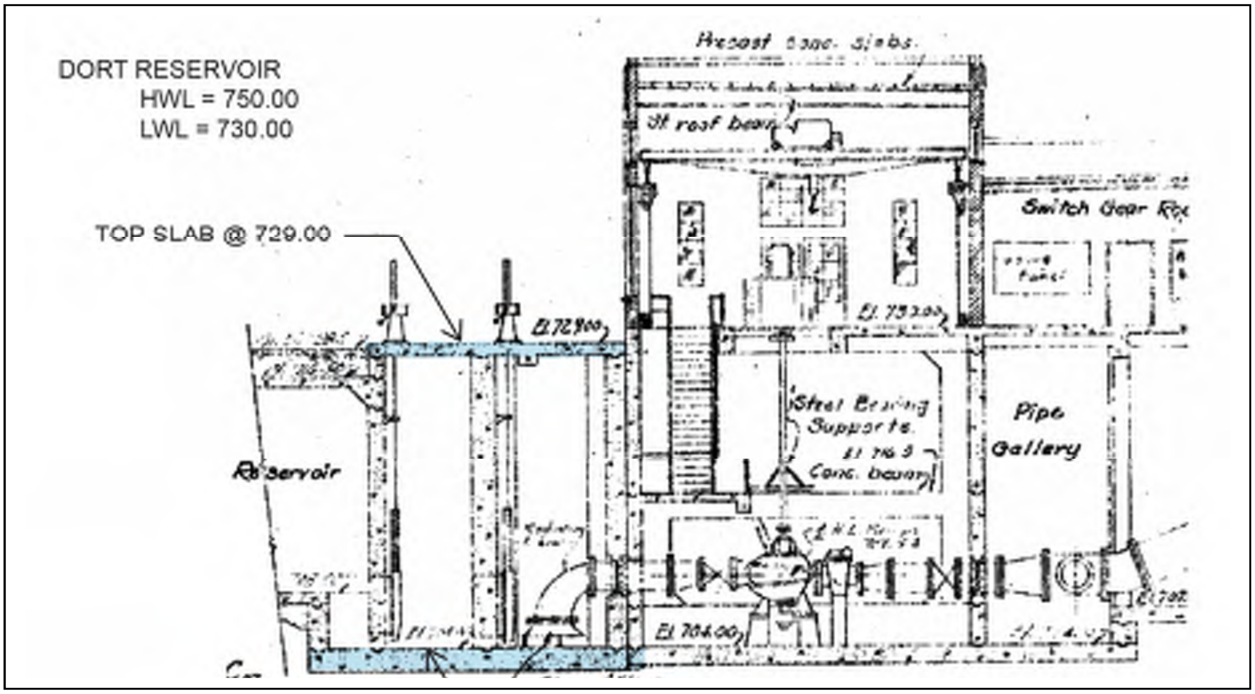

Figure 6.8 – Existing High Service Pump Station Section View

As indicated in Figure 6.8, the Dort Reservoir would have a high-water level of about 750 and a low water level of about 730, both of which are above the top slab of the suction chamber. The major elements of concern are:

- The need for a throttling valve/flow meter arrangement to direct flow to the pump station, which adds complexity to plant operations.
- Failure of the throttling valve may result in an uplift of the top slab of the suction chamber due to the elevation differences, with resulting structural damage caused by the uplift.
- Failure of the throttling valve could cause flooding, resulting in damage to the suction chamber/pump station and the need to drain the Dort Reservoir.

6.4.2 Alternative 2 – New Finished Water Pump Station

A new finished water pump station would convey water from the Dort Reservoir to the elevated tank/distribution system and would include new pumps for backwashing the existing gravity filters. An additional high service pump could be added in the new Finished Water Pump Station to allow the WTP to provide finished water to the Genesee County Drain Commissioner (GCDC) in the event of an emergency. The estimated pumping capacities are as follows:

- High Service Pumps:
  - Three (2 + 1 standby) at 14 MGD, 600 HP.
  - Two (1 + 1 standby) at 5 MGD, 200 HP.
- Backwash Pumps:

- Two (1 + 1 standby) at 22 MGD, 150 HP.

- All pumps variable speed.

The pump station would be located immediately south of the Dort Reservoir, requiring relocation of the existing CO_2 Storage Tank.

A non-economic comparison of alternatives is presented in **Table 6.4**. **Table 6.5** compares vertical turbine can pumps and horizontal split case pumps. A preliminary layout of the pump station utilizing vertical turbine can pumps is illustrated in **Figure 6.9**.

The estimated cost to rehabilitate the existing finished water pump station is $8.5 million exclusive of any improvements required by the results of the physical model. The estimated capital cost of a new finished water pump station is $9.4 million of which pumps and appurtenances account for approximately 70 percent of the cost. Approximately $1 million should be added for the new backwash water pumps.

Table 6.4 – Finished Water Pump Station

Rehabilitate Existing Pump Station	New Pump Station
▪ No new structures required	▪ New structure at grade with limited buried infrastructure
▪ Modifications to suction chambers required to meet HI standards	▪ Easier access for maintenance, including removal of pumps/motors
▪ Constrained access for installation and maintenance of equipment	▪ Design will conform to latest HI Standards
▪ Potential to over pressurize suction chamber and/or drain Dort Reservoir	▪ Pump bowl not visible within the can for inspection
▪ Requires complete replacement of existing piping and valves	
▪ Does not meet project goal of O&M simplicity	

Table 6.5 – Comparison of High Service and Backwash Pump Station

Evaluation Criteria	VT Can Pumps	HSC Pumps
Approximate Design Capacity	3 @ 14 MGD, 600 HP, 183 TDH	3 @ 14 MGD, 600 HP, 183 TDH
	2 @ 5 MGD, 200 HP, 181 TDH	2 @ 5 MGD, 200 HP, 181 TDH
	2 @ 22.1 MGD, 150 HP, 20 TDH	2 @ 22.1 MGD, 150 HP, 25 TDH
	Comply with HI Standards, AWWA E-103	Comply with HI Standards, AWWA E-103
SCORE:	0	0
Operational Simplicity	VFDs all pumps	VFDs all pumps
		Better access to all pump components
SCORE:	3	4
Flexibility and Efficiency	1-14 MGD matches average flow	1-14 MGD matches average flow
	2-14 MGD provides 24 MGD	2-14 MGD provides 24 MGD
	5 MGD matches low flow	5 MGD matches low flow

Evaluation Criteria	VT Can Pumps	HSC Pumps
	22.1 MGD for maximum backwash rate	22.1 MGD for maximum backwash rate
SCORE:	4	4
System Reliability and Safety	1 standby for large pumps	1 standby for large pump
	1 standby for small pumps	1 standby for small pumps
	1 standby for backwash pumps	1 standby for backwash pumps
		More sensitive to NPSH conditions
SCORE:	4	3
Site Considerations	Smaller footprint, less depth for structure	Deeper structure required, larger footprint required
	Shorter lead time	Longer lead time
SCORE:	4	4
TECHNICAL RATED SCORE:	**3.75**	**3.5**

6.4.3 Recommendation

A new high service pump station is recommended due to the elevation differences between the suction chamber and the Dort Reservoir. A new pump station would also be easier to operate and maintain. Additionally, a new high service pump station would allow for a new high service pump to be installed that could also serve GCDC in the event of a disruption within their system.

6.5 Filtered Water Transfer Pump Station

A new filtered water transfer pump station will be required to convey water from the gravity filters to the Dort Reservoir. A weir wall control structure will be provided to help prevent air binding of the filters. The top of the weir will be set at approximately elevation 724 (filter underdrains are at approximately 723.6). The estimated pumping capacities are as follows:

- Three pumps (2 + 1 standby) at 14 MGD, 200 HP.
- Two pumps (1 + 1 standby) at 5 MGD, 50 HP.

This pump station would be located due west of the filters and immediately west of the existing roadway.

Table 6.6 presents a comparison of vertical turbine can pumps and horizontal split case pumps. A preliminary layout of the pump station utilizing vertical turbine can pumps is presented in **Figure 6.10**. The estimated cost is $9.2 million, which includes the weir wall control structure.

Figure 6.11 illustrates the approximate locations of the new raw water pump station, new transfer pump station (and Chemical Building) and the new high service pump station (including backwash pumps).

6.6 Summary/Recommendations

It is not recommended that the existing raw water pump station and finished water pump station located in Pump Station #4 be utilized for the Flint WTP Improvements. Non-compliance with HI Standards, the necessity of constructing a hydraulic model, and the need to provide flow control to each station are negatives. The most problematic issues are potential structural uplift of the top slab of the suction chamber in each pump station and the resulting potential damage to the pump station. In addition, the potential to drain raw water storage and the Dort Reservoir are significant risks.

For these reasons, the use of the existing raw water pump station and finished water pump is not recommended.

It is recommended that a new raw water pump station and finished water/backwash pump station be constructed utilizing vertical turbine can pumps. The same applies to the filtered water transfer pump station. The use of vertical turbine can pumps will provide smaller pump station footprints, less buried infrastructure, and a shorter manufacturing/fabrication time.

Table 6.6 – Comparison of Transfer Pump Station

Evaluation Criteria	VT Can Pumps	HSC Pumps
Approximate Design Capacity	3 @ 14 MGD, 200 HP, 50 TDH	3 @ 14 MGD, 200 HP, 50 TDH
	2 @ 5 MGD, 75 HP, 50 TDH	2 @ 5 MGD, 75 HP, 50 TDH
	Comply with HI Standards, AWWA E-103	Comply with HI Standards, AWWA E-103
SCORE:	0	0
Operational Simplicity	VFDs all pumps	VFDs all pumps
		Better access to all pump components
SCORE:	3	4
Flexibility and Efficiency	1-14 MGD matches average flow	1-14 MGD matches average flow
	2-14 MGD provides 24 MGD	2-14 MGD provides 24 MGD
	5 MGD matches low flow	5 MGD matches low flow
SCORE:	4	4
System Reliability and Safety	1 standby for large pumps	1 standby for large pump
	1 standby for small pumps	1 standby for small pumps
		More sensitive to NPSH conditions
SCORE:	4	3
Site Considerations	Smaller footprint, less depth for structure	Deeper structure required, larger footprint required
	Shorter lead time	Longer lead time
SCORE:	4	4
TECHNICAL RATED SCORE:	**4.7**	**4.3**

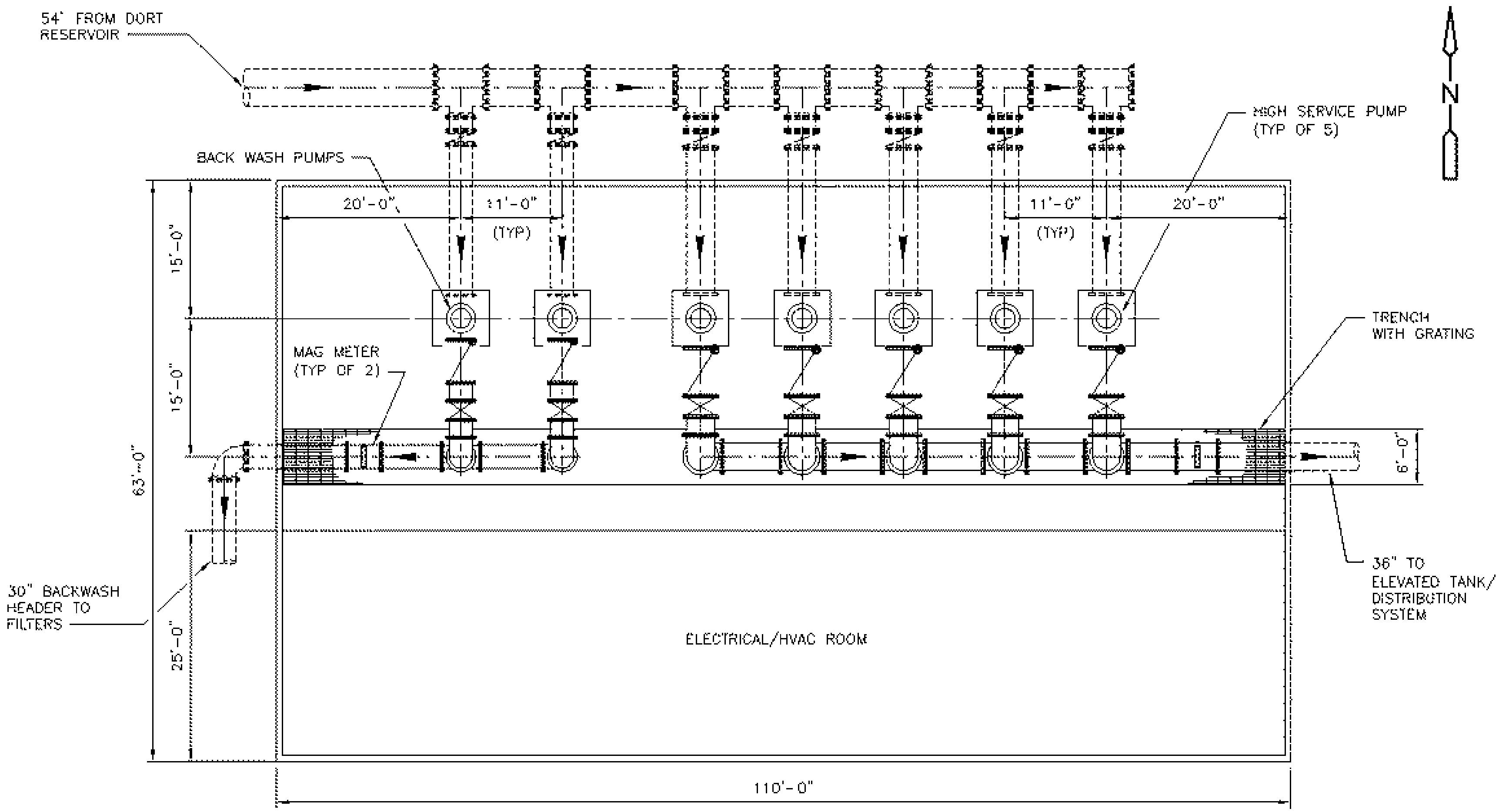

Figure 6.9 – Finished Water Pump Station (Alternative 2 – New Finished Water Pump Station)

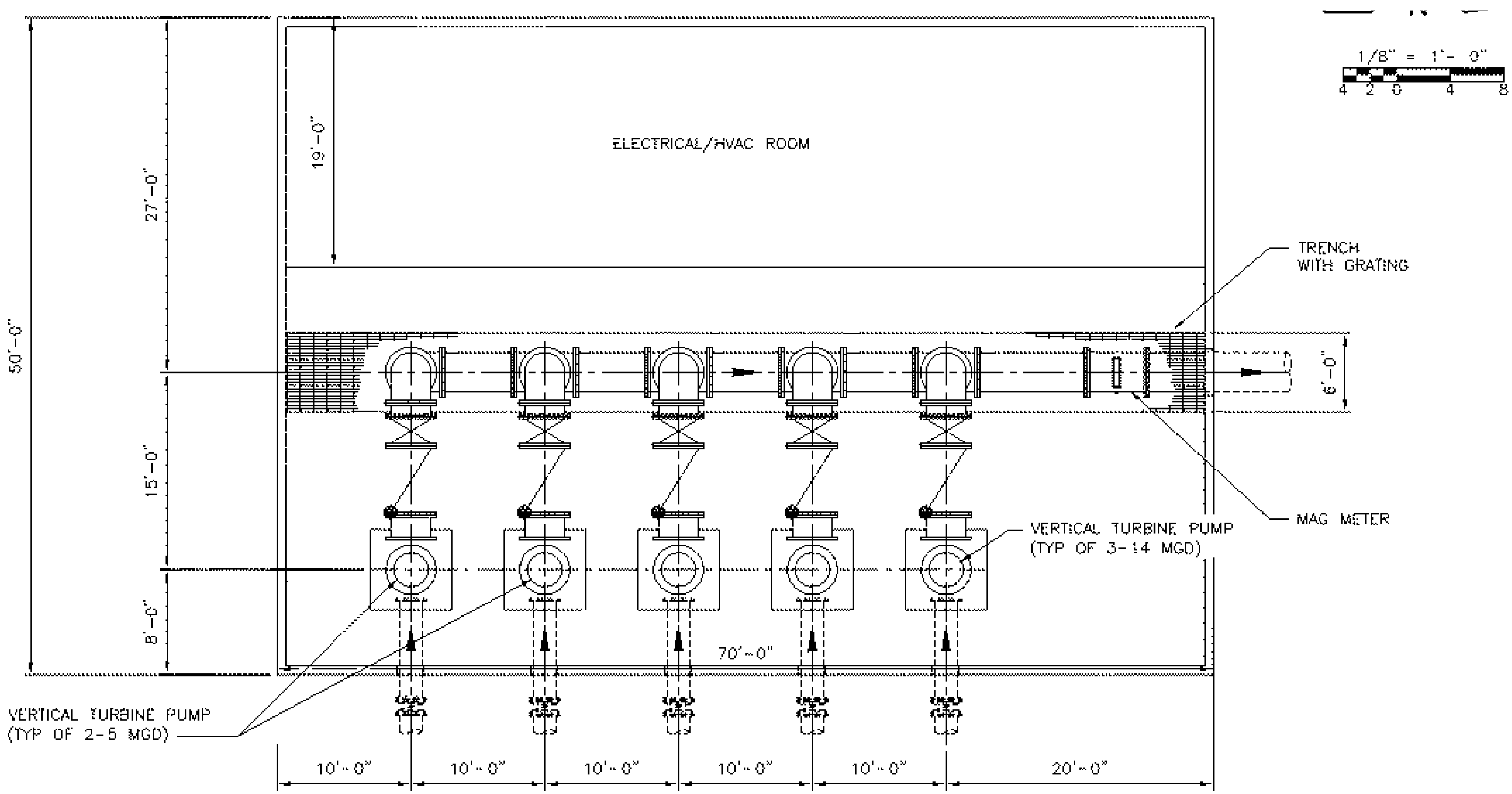

Figure 6.10 – Filtered Water Transfer Pump Station

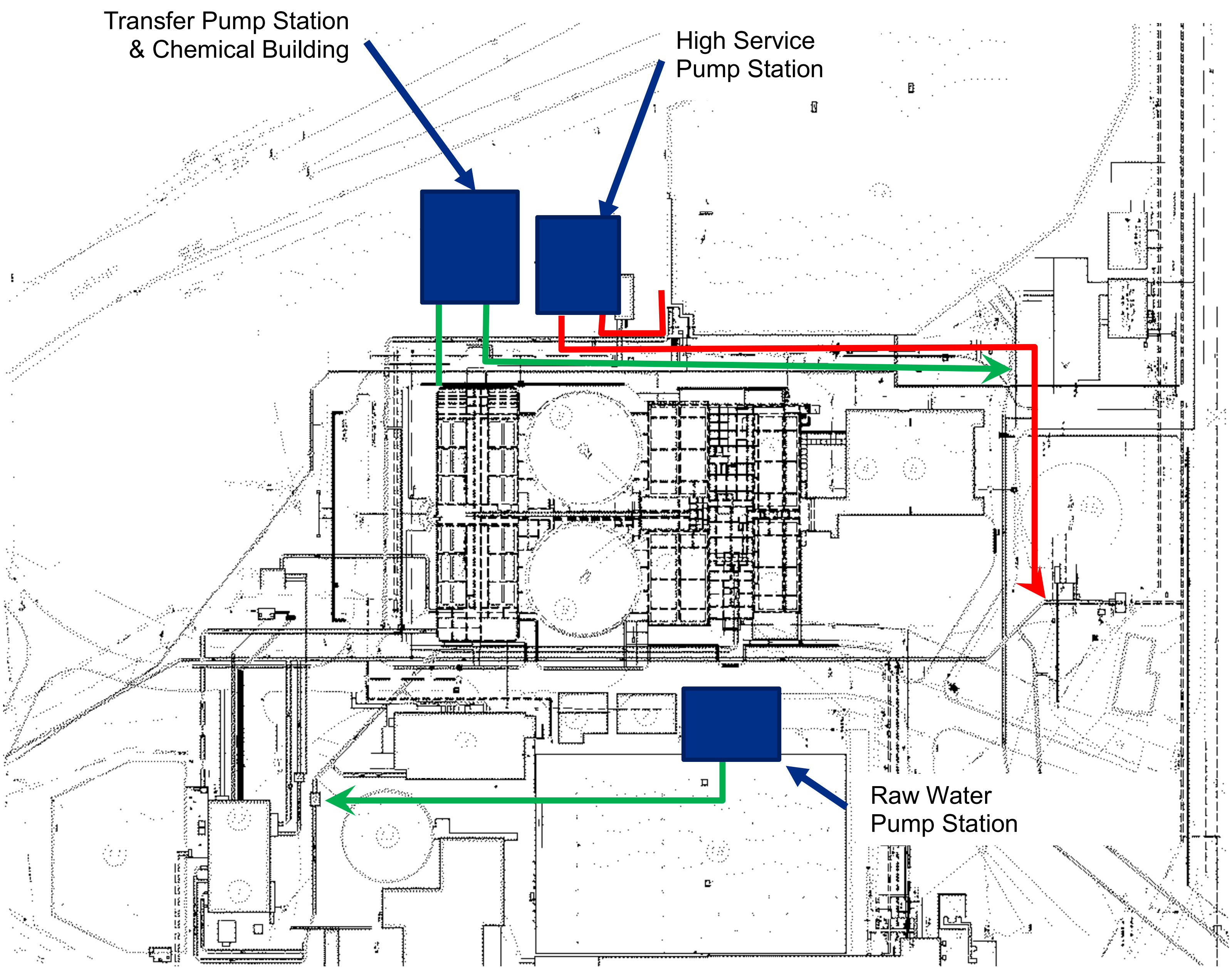

Figure 6.11 – Conceptual Pump Station Location

Section 7

Cost of Recommended Improvements

The purpose of this section is to present the estimated capital cost of the recommended improvements for the Flint Water Treatment Plant (WTP).

7.1 Definition of Capital Cost

The capital costs presented in this section include construction of the improvements and the engineering services associated with design and engineering during construction. The capital cost also includes all contractor overhead and profit, and includes escalation based on a construction mid-point of May 2017. An appropriate contingency factor has been applied based on the conceptual level of this report.

7.2 Recommended Improvements

The recommended improvements fall within the following categories:

- Demolition of WTP No. 1 – Necessary to provide sufficient space to construct 42 million gallons (MG) of raw water storage.
- Raw water storage – Two open-top prestressed concrete tanks, each with a capacity of 21 MG, and each with a diameter of 300 feet and a side water depth of 40 feet.
- New raw water pump station – 3 pumps at 14 million gallons per day (MGD) and 2 at 5 MGD. This pump station is not required if the raw water storage is eliminated.
- New transfer pump station – Convey filtered water to Dort Reservoir: 3 pumps at 14 MGD and 2 at 5 MGD, and a new filtered water structure to supply these pumps.
- New high service and backwash pump station – 2 high service pumps at 14 MGD and 2 at 5 MGD; 2 backwash pumps at 22 MGD.
- Ozone system and ozone contact basins – upgrades to ozone equipment.
- Rapid mix basins – new, more efficient rapid mix system.
- Flocculation basins – additional walls and baffling within basins to improve mixing efficiency.
- Inclined plate settler (IPS) basins – additional walls and baffling to improve settling efficiency.
- Filters – new anthracite filter media to improve filter performance and efficiency.
- Used filter washwater management – New flow equalization tank and pump station to convey used washwater to the ozone inlet channel.

- Disinfection and Dort Reservoir rehabilitation.
- Chemical storage and feed systems, with a building to house these systems.
- Improvements identified by the condition assessments, including:
  - SCADA system.
  - Structural repairs.
  - Facilities for handling off-spec water.
  - Compliance laboratory.
  - Maintenance shop.
  - Connections to the sanitary sewer.
  - Roof replacement/repair.
  - Window/door replacement.
  - HVAC system.
- Other ancillary improvements including:
  - Computerized Maintenance Management System (CMMS).
  - Laboratory Information Management System (LIMS).
  - Control room.
  - Plant security.
  - Sustainability and energy efficiency.
  - Locker rooms and restrooms.
  - Operator lab.
  - Administrative spaces.
  - Public visitor center and media room.

7.3 Capital Cost Summary

The total estimated capital cost is $108 million. This estimate is based on the assumptions that a progressive design-build delivery method is used and that the plant residual solids are discharged to the city's sewer system. The capital cost estimate for the improvements in each of the above categories is shown in **Table 7.1**.

Table 7.1 – Estimated Capital Cost for the Flint WTP Improvements

	Category	Estimated Cost
1	Demolish WTP No. 1	$5,800,000
2	Raw Water Storage	$37,000,000
3	Raw Water Pump Station	$6,400,000
4	Transfer Pump Station and Filtered Water Control Structure	$7,400,000
5	High Service and Backwash Pump Station	$10,400,000
6	Pre-oxidation with Ozone	$900,000
7	Rapid Mix Basins	$900,000
8	Flocculation Basins	$1,300,000
9	Inclined Plate Settler Basins (Sedimentation)	$3,000,000
10	Granular Media Filters	$1,600,000
11	Management of Used Filter Washwater - Equalization Basin and Pump Station	$4,000,000
12	Disinfection and Dort Reservoir Rehabilitation	$2,000,000
13	Chemical Storage and Feed Systems	$7,000,000
14	Improvements Identified by Condition Assessments	$15,200,000
15	Other Ancillary Improvements	$4,800,000
	Total (Rounded)	**$108,000,000**

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Section 8

Project Delivery and Schedule

8.1 Introduction

This section presents two options for delivery of the design and construction of the Flint Water Treatment Plant (WTP) Improvements Project: traditional Design-Bid-Build (DBB) and Progressive Design-Build (PDB). PDB is one of several alternative delivery methods common in the construction industry. The DBB and PDB options are compared and planning level schedules are presented for each. A recommendation regarding project delivery is presented based on this analysis, and a schedule for design and construction is provided, based on the recommended approach.

8.2 Description of Project Delivery Alternatives

8.2.1 Design-Bid-Build

Design-Bid-Build is the traditional method of delivering capital improvement projects. Design engineering work is completed to the 100 percent stage. Construction documents (plans and specifications) are then made available to construction contractors through an advertisement process, and the contractors provide bids to perform the construction work based on the documents. Typically, the lowest responsive bidder is awarded the construction contract.

The design process is usually conducted in phases beginning with a preliminary engineering study or conceptual design document, then proceeding through design development stages, typically 30 percent, 60 percent, 90 percent, and 100 percent. The owner typically retains an engineer, often the design engineer, to provide construction phase services, including review of construction submittals, addressing contractor questions and providing resident engineer, inspection, and other services. During the construction, the owner holds separate contracts with the contractor and the engineer.

8.2.2 Progressive Design-Build

Progressive Design-Build (PDB) is a delivery method in which the owner engages a design-builder under one contract to design and construct the project. The design-builder advances the design to an agreed upon level, typically 60 percent, at which point the design-builder establishes the cost of construction based on the design. The construction cost is combined with the cost of engineering services to complete the design as well as the cost of engineering and commissioning services during construction. This combined cost is submitted to the owner as a guaranteed maximum price (GMP).

The GMP is presented with backup including vendor and subcontractor quotes and cost breakdowns. The owner and design-builder review the GMP submittal and negotiate a final GMP in a fully transparent process. The design-builder then proceeds with final design, construction, and commissioning. If an agreement cannot be reached, the owner can utilize a contractual provision referred to as an off-ramp, to either complete the design and proceed with a DBB procurement or negotiate with another design-builder.

The majority of equipment, materials, and other direct construction costs (typically 70 to 80 percent of the total cost of construction) are competitively procured by the design-builder. Subcontractors are pre-qualified and competitively procured.

PDB is one of several alternative project delivery methods that have been successfully employed in the municipal public works and water/wastewater construction sectors. Other common alternative delivery methods include Lump-Sum Design-Build and Construction Management at Risk (CMAR). There are also several variations of CMAR. A significant amount of literature is available describing these alternative project delivery methods and their application to municipal water projects. (See www.dbia.org; www.waterdesignbuild.org; www.michigan.gov/documents/deq/deq-ess-mfs-formsguidance-PDMguide_485573_7.pdf).

PDB has been selected as the most advantageous alternative project delivery method for the Flint Water Treatment Plant Improvements Project. PDB is evaluated below and compared to DBB. Selection of PDB was based on the following factors:

- Collaboration and Innovation – The PDB structure provides the greatest opportunity to maximize collaboration between the owner and design-builder, and thereby develop innovative and cost-saving solutions.
- Transparency – PDB projects are executed in a transparent manner, meaning that the design-builder shares with the owner the construction cost backup, including competitively bid subcontractor costs, and reviews the information with the owner in an open book manner. The owner is fully aware of all cost inputs and is able to change project components in collaboration with the design-builder based on the information provided. CMAR also provides this level of transparency but Lump-Sum Design-Build does not.
- Single Point of Responsibility – The PDB structure provides the owner with a single point of responsibility – the design-builder. This is an advantage with respect to administrative obligations and the avoidance of "finger pointing." Lump-Sum Design-Build also provides a single point of responsibility but CMAR does not.

8.3 Evaluation of Project Delivery Alternatives

Two delivery approaches were evaluated for the Flint Water Treatment Plant Improvements Project:

- Progressive Design-Build (PDB).
- Design-Bid-Build (DBB).

PDB is recommended as the most advantageous alternative project delivery method for the Flint Water Treatment Plant Improvements Project, allowing the Flint Plant to deliver water by August 2019. Using DBB will delay project completion until the second quarter of 2020. PDB is evaluated below and compared to DBB. Selection of PDB is based on the discussion in the subsections below.

8.3.1 Schedule

Schedule is a key driver for the Flint Water Treatment Plant Improvements Project. The water treatment process upgrades must be constructed before the corrosion/pipe loop study can be initiated, and the study will, in turn, provide valuable information that will inform decisions relative to the ultimate finished water chemistry. This work must be completed, along with all training and compliance testing, before the WTP can go online. Schedule also impacts project costs associated with the time value of money as well as the premium paid for the purchase of finished water compared to the cost of purchasing raw water from KWA and treating it. For these reasons, it is advantageous to deliver the project in as short a timeframe as possible.

It is generally accepted within the literature that PDB provides an advantage over DBB with respect to schedule savings. For example, a study conducted by the Construction Industry Institute and Penn State University found that, on average, PDB projects are constructed in 12 percent less time and result in 11 percent less schedule growth compared to DBB projects.

Figure 8.1 provides a comparison of estimated design and construction durations based on DBB and PDB project delivery methods for the Flint Water Treatment Plant Improvements Project. For each method, it was assumed that the construction will be divided into two phases, with Phase 1 consisting of the water treatment process upgrades and Phase 2 consisting of the raw water reservoir, pump stations, SCADA, and other upgrades. This phasing of construction facilitates the earliest possible completion of the water treatment upgrades and the subsequent initiation of the corrosion/pipe loop study.

The PDB option allows for an earlier start of Phase 1 construction because this work can begin before the design is complete. The overall project duration is also shortened by initiating Phase 2 construction work before Phase 2 design completion, and by eliminating the need for a construction contract bid period, which is assumed to be four months from advertisement to Notice-to-Proceed.

The estimated completion date for Phase 1 construction under PDB is May 2018, allowing Performance Testing Period 1 and pipe loop testing to begin in April 2018. Phase 2 construction completion is estimated for May 2019, allowing Performance Testing Period 2 completion by August 2019, and allowing the WTP to deliver water to the system by August 2019. This is estimated to be 9 months earlier than DBB.

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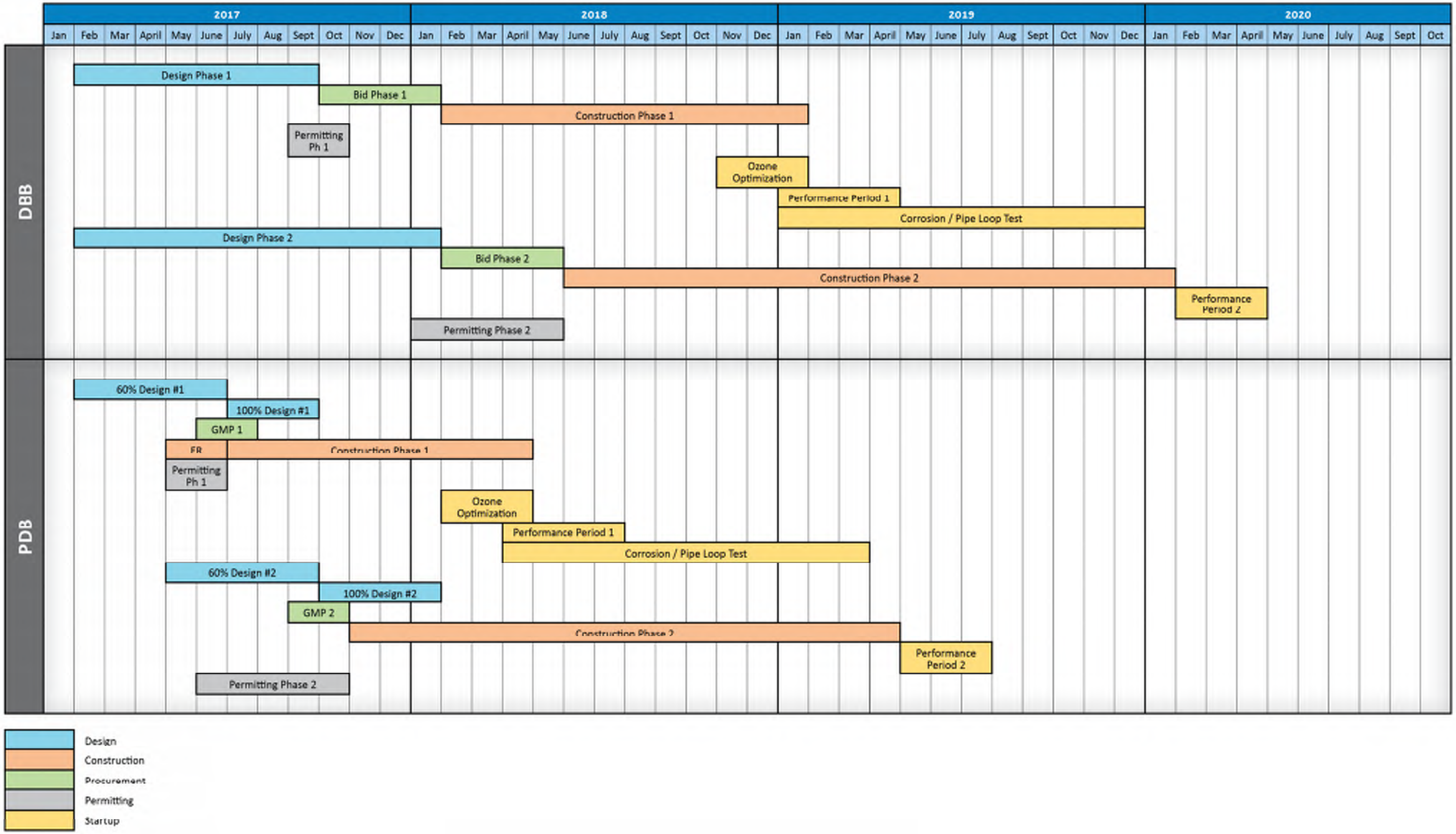

Figure 8.1 – Comparison of Estimated Design and Construction Durations

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8.3.2 Cost

PDB is generally considered to provide greater opportunity to develop lower cost design and construction solutions compared to DBB. As stated in the MDEQ Office of Drinking Water and Municipal Assistance Project Delivery Methods Guidance document, "PDB is frequently preferred … when the applicant is looking to minimize the time and cost of the design-build procurement. This delivery method is most valuable when owners believe they can lower cost or otherwise improve the outcome by participating directly in design decisions."

Cost saving opportunities with PDB often occur as a result of the team identifying a cost saving solution with respect to the work to be constructed or the construction sequencing or method, and implementing the solution, including design modification if necessary, quickly and seamlessly. The resulting savings can be shared with the owner through contractual cost sharing provisions.

Cost savings can also be realized through schedule savings. The estimated schedule durations for this project, shown above, reflects a 9-month shorter duration for PDB compared to DBB. Assuming 3 percent annual inflation, PDB saves $100,000 for every $10 million in project cost compared to DBB as a result of the shorter project duration.

8.3.3 Transparency

PDB is a more transparent delivery method than DBB because construction costs are shared with the owner in an open book manner during the GMP negotiation, compared to the owner receiving bids without backup. The transparency continues throughout the construction period. For example, if a change occurs requiring the design-builder to obtain subcontractor estimates, the design-builder can receive competitive bids for this work, share these with the owner, and make a collaborative decision on a path forward.

8.3.4 Other Issues

PDB provides greater opportunity for innovation than DBB because the design and construction disciplines work together with the owner from day one. The inclusion of the construction team in this collaboration can result in design approach and constructability insights that benefit the project and produce a better outcome.

Studies have shown that PDB can also reduce risk as a result of the collaboration between design and construction disciplines throughout the project. PDB also provides a greater degree of cost certainty because the ultimate project cost is established earlier in the delivery process. Additionally, PDB typically results in fewer change orders because the design-builder bears the risk of design completeness.

8.3.5 Recommendation

Based on the factors discussed above, it is recommended that the PDB delivery method be utilized for the Flint Water Treatment Plant Improvements Project.

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Appendix A

Architectural Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *Lee Lohman, CDM Smith*

Date: *January 13, 2017*

Subject: *Architectural Assessment*

General

The Architectural Building Assessment purpose is to perform a visual assessment the existing condition, including building envelope, interior walls, doors and hardware of the Flint Water Treatment Plant (WTP). The buildings reviewed are Plant #2, the Ozone Building, and the Substation Building. The report will examine the following:

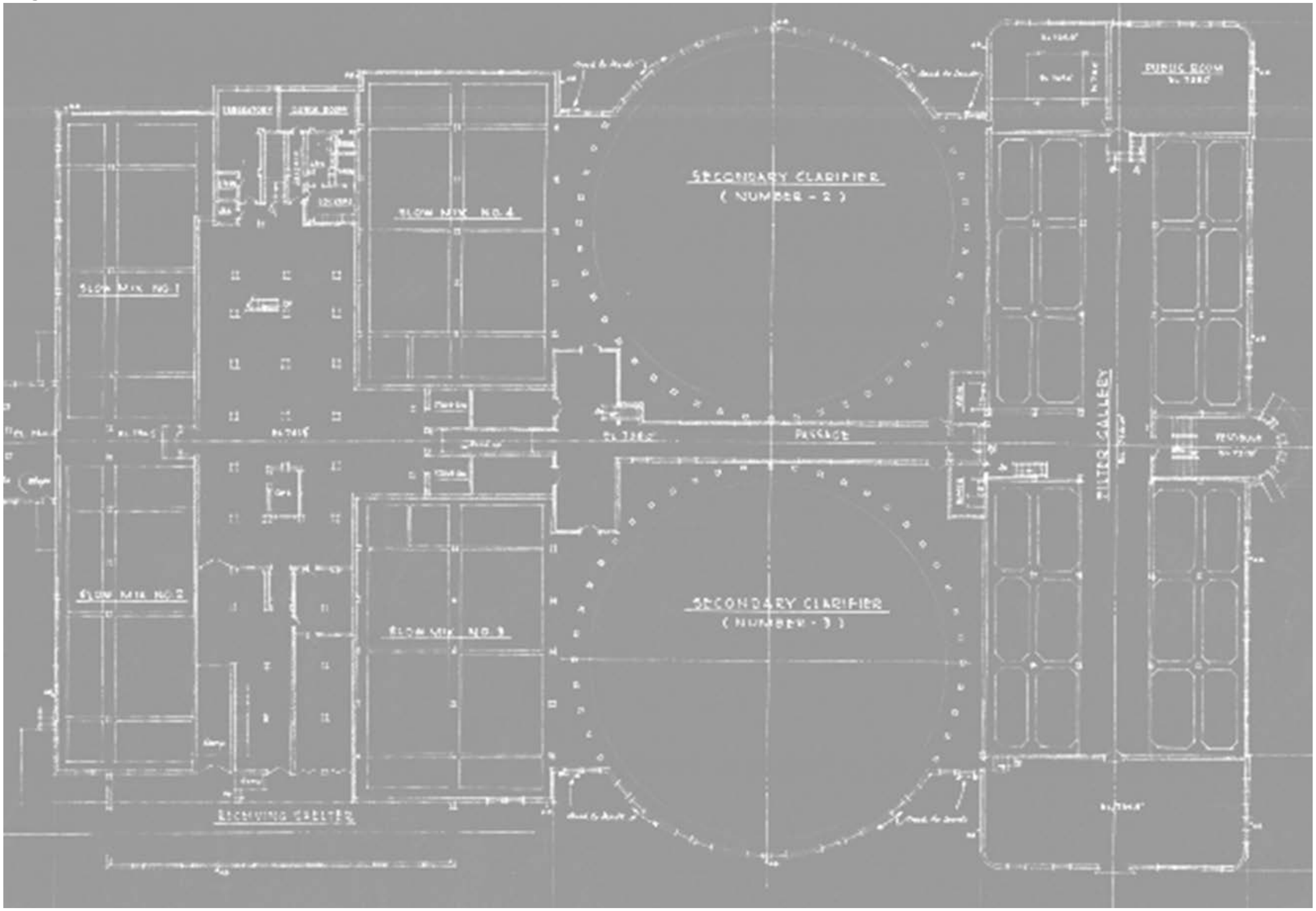
- Physical Condition and Suggested Repairs.
- General Accessibility.
- Future Programming Considerations.

The architectural assessment did not include environmental testing, so any suggested repairs must be done in conjunction with any potential environmental remediation that may need to take place. The report is also not to be considered a full code review of the existing building.

Physical Condition

Plant #2

Plant #2 was constructed in 1954 in the configuration shown below. It has had major improvements throughout its history, with the major changes being the work done in 2001, which included the clarifier addition, accessibility improvements, and major changes over the Slow Mix #2 tanks. The basic construction of the existing plant and addition consist of a concrete frame with masonry infill walls and either poured in place concrete roof, or precast concrete plank. This construction would be considered a Type 1 construction according to the Michigan Building Code.



Lower Level Plan Prior to Clarifier Addition and 2001 Renovations

Exterior

Walls

The exterior walls of the original plant #2 are composed of a masonry back-up with either yellow face brick interior and exterior or structural glazed tile as used in the filter gallery. This type of wall is considered a composite wall and doesn't include any interior insulation. The base structure is cast-in-place concrete frame and roof. There are some signs of deterioration, cracking, or spalling at two locations located on the east corners of the lime storage tower and at the walls by the overhead doors and loading dock located on the west side of the building. These areas will require removal and rebuilding of these corners.

South Elevation

Cracks at the Corner of Lime Area

Cracks at the Corner of Lime Area

Cracks at Corner by Door

The roof parapets are stone blocks set next to each other with caulked joints. These were being re-caulked as a continuous maintenance program; however, they currently are in an inconsistent state of repair and present a potential means of water infiltration.

Steel lintels over openings are showing signs of rust and expansion of the jambs, which is due to pack rust. This could be caused by water infiltration into the wall, perhaps from joints in the coping or from wind-blown rain over the history of the building.

Typical Coping Joints

Typical Lintels

Suggested Repairs

- General tuck pointing and cleaning of building with an assumption of 20 percent of the joints needed to be racked out and tuck pointed.
- Stone coping joints to have caulk removed and new backer rod and caulk installed.
- Steel lintels to be cleaned of rust and painted.
- Replace steel lintels that have pack-rusted at jambs.
- Re-build 2 corners of lime storage tower.
- Replace cracked brick at corners of loading dock.

Roofs

The existing roof system over the original 1950s building is composed of several types of systems. The oldest sections are build-up roof systems with stone ballast imbedded in tar. The second type is a thermoplastic polyolefin (TPO) roof system loosely applied with stone ballast. The concrete domes over the clarifiers do not have any roofing installed and are bare concrete. It is undetermined what form of insulation is installed. All built-up roofs are beyond their warranty and useful life and will likely not meet the current energy codes enacted since its original installation.

Roof Looking South

Roof at Sedimentation Gallery

The roof at the Primary Clarifier addition is a single-ply system with ballast. It is believed to be original from the 2001 addition. The southeast section of roof has pulled away from the parapet and there are signs of water infiltration at the walls. This roof would be close to its useful life and likely beyond its original warranty.

Roof at Clarifier Addition

Roof at Clarifier Area

Flashing and termination stripes are a combination of original and new where roof areas have been patched or replaced. These present prime locations for potential water infiltration.

Typical Counterflashing

Typical Counterflashing

Roof drain hubs are original and some have cracked. There is indication on the interior at some locations of water infiltration at these hubs.

Typical Roof Drain

Roof and Drain at South Entry

Suggested Repairs

- Remove entire roof system down to structural deck and replace entire roof system with new SPS Modified Bituminous roofing and tapered insulation to comply with energy code. Domed areas may utilize a spray-on insulation with acrylic coating due to its geometry.
- Install all new counterflashing and gravel stops.
- Install all new drain hubs at roof drains at cracked hubs.

Windows

The existing windows consist of glass block infill windows and aluminum frame windows with insulated glass and lower awning windows.

The glass block windows are in good condition, except for several areas at the west loading dock, in which several are broken. The sealant around the perimeter is dry and at risk of leaking.

The aluminum windows appear to be newer than 1950 and seem like they are in acceptable condition. Sealant around the windows is also getting old, but doesn't appear to be failing. Glazing seals appear to be in good condition with no fogging observed.

Typical Glass Block Window

Typical Aluminum Window

Suggested Repairs

- Replace broken glass block.
- Remove and replace all perimeter sealant of glass block (interior and exterior).
- Remove and replace perimeter sealant at some windows that may be close to failure.

Interior

Filter Gallery Area

The Filter Gallery area is composed of a filter gallery, east administrative area, and west blower room area.

Filter Gallery

The filter gallery has glazed tile walls, cast-in-place wall columns and ceiling structure, precast concrete plank ceiling over filters, and quarry tile floors. The overall condition is good. The hung ceiling at the front entry is showing signs of age and is not the best use of materials for an area with high humidity and potential chemical vapors.

There are some minor cracks in some of the tile at the railings, but these cracks are cosmetic. The railings are original to the design; however, they do not meet current guardrail height standards of 3-foot-6-inch. They appear to be 3 inches shorter than required by code.

Filter Gallery

Filter Gallery

The toilet rooms attached to the gallery have relatively new panels and fixtures. They have the original glazed tile walls and floors, and are in good condition. The ceiling is acoustical tile and in aged condition. Neither of these toilet areas are handicap accessible.

Men's Toilet at Filter Gallery

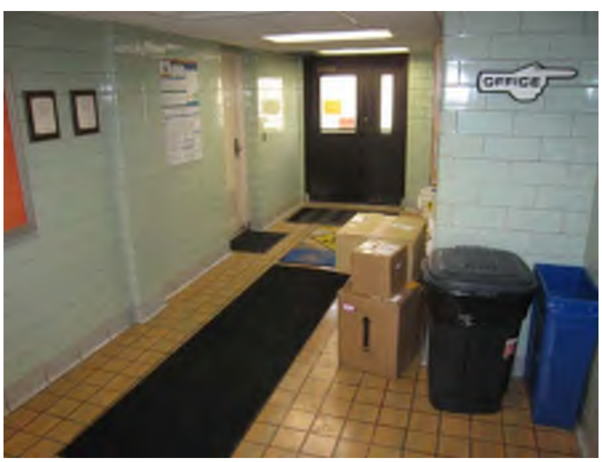
Women's Toilet at Filter Gallery

East Administration Area

This entry lobby is the primary entry for visitors. The walls are original glazed tile with quarry tile floors, which are in good condition. The offices and upper conference spaces were added later and are gypsum board walls, vinyl composition tile (VCT) floors, and acoustical ceiling tiles; all are in worn condition. The ground level entry was never originally designed to act as the prime entry into the building, but was an employee secondary access with an employee lounge area at the lower level and the upper level being the primary administrative area for the public, in which they would have entered via the front entry portico.

The administrative area is composed of the following rooms:

- Ground Floor
  - Office/Administrative Area.
  - Americans with Disabilities Act (ADA) Toilet.
  - Women's Toilet.
  - Water Supply Area.
  - Three Offices.
- Second Floor
  - Conference Room.
  - Construction Area.
  - Kitchen.
  - Electrical Closet.
  - Storage Room.



Entry Lobby at Administration Area

Ground Level Administration Area

Suggested Repairs

- Replace ceiling in main entry portico.

- Paint.
- Replace ACT ceilings in offices and conference rooms.
- Replace carpet and VCT in administrative area.
- Patch and paint administrative area.

Secondary Clarifier Gallery and Clarifiers

The secondary clarifier gallery is constructed of exposed concrete frame columns and beams with cast-in-place concrete roof structure and slab; all are in good condition. The walls are constructed of exposed face brick infill between the concrete structures. The walls have viewing windows on each side into each clarifier room. Glazing frames are original and have some deterioration.

The secondary clarifiers are identical in construction. They have been constructed of a cast-in-place concrete frame to support the flat roof and a separate circular frame to support the concrete dome. This concrete has not been painted. The concrete appears to be in good condition with no major spalling. The exterior walls are exposed brick with glass block windows, which are also in good condition. These rooms will not be required under the proposed improvements and can possibly be repurposed as a different use.

Clarifier Gallery

Clarifier Room

Suggested Repairs

- Clean and seal floor.
- Clean and paint window frames.
- Clean exposed concrete ceiling and structure.

Slow Mix Room #3

The Slow Mix Room #3 is constructed of exposed concrete frame columns and beams with non-painted cast-in-place concrete roof structure and slab; all are in good condition. The walls are constructed of exposed face brick infill between the concrete structures. Guardrails have been installed around all tanks. Existing original guardrails do not appear to meet current OSHA standards for height.

Slow Mix Room #3

Slow Mix Room #3

Suggested Repairs

- Clean and seal floors.
- Replace railings if space is going to continue being used.

Slow Mix Room #4

The Slow Mix Room #4 area was renovated over the non-used existing Slow Mix Tank #4 in 2001. The tanks are currently non-operational. The spaces include the following areas:

- Break Room/Workout Room.
- Control Room.
- Chemical/Biological/Operator's Lab

<u>Break Room/Workout Room</u>

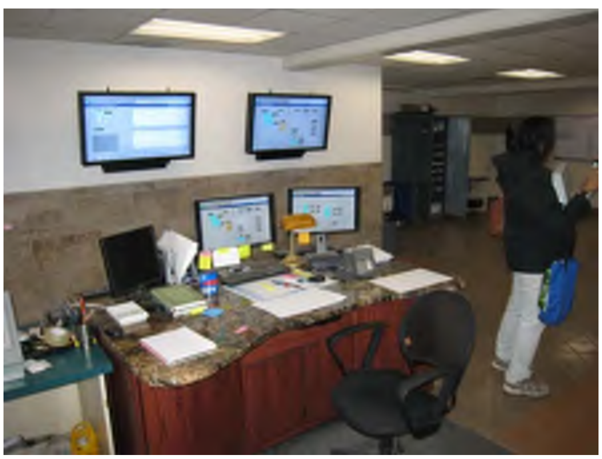
The Break Room and Workout Rooms are subdivided by a movable wall. It was constructed out of block walls, gypsum board walls, VCT floors, and hung acoustical ceiling. There is a kitchenette installed on the north wall. The overall condition is acceptable, though it lacks exterior views or natural light.

Break Room

Workout Room

Control Room

The Control Room was added at the same time as the break room. It was constructed out of block walls, VCT floors, and hung acoustical ceiling. Much of the floor space isn't currently being utilized. Its overall condition is acceptable and the location is preferred by the plant staff for its centralized location.



Control Room

Control Room

Chemical/Biological/Operator's Lab

The lab was added at the same time as the break room. It is constructed out of block walls, VCT floors, and hung acoustical ceiling. Its overall condition is acceptable and has been previously certified. It does lack storage space for files and equipment.

Chemical Lab

Biological Lab

Suggested Repairs

- Replace acoustical ceiling and lighting.
- Paint walls.
- Upgrade interior of control room finishes.

Lime Feed and Chemical Area Lower Floor

The Lime Feed and Chemical Area is centered between the slow mix tanks and acts as the primary softening and chemical storage area of the plant. The lower floor spaces are as follows:

- Lime slacker area.
- Men's and women's locker rooms.
- Chemical storage rooms.
- Delivery area.
- Freight elevator.

The Lime Feed area is constructed of a cast-in-place concrete wall, floor, and roof structure with face brick infill. All areas appear in good condition.

Lime Feed Area

Adjacent to Lime Feed Area

The Men's Locker Room was original to the plant. It has been upgraded in order to comply with ADA standards. The partitions have all been replaced and are in good, acceptable condition. Its overall appearance is dated and has the appearance of being retrofitted.

The Women's Locker Room was added as a retrofit. The space was previously the lab. Fixtures are new and one ADA shower is in place.

Men's Locker Room

Women's Locker Room

The Lunch Room is original to the building and is currently being used as a clock-in area for staff. Its walls are glazed block in good condition and has an acoustical tile ceiling, which is in aged condition.

The Janitor's Closet is adjacent to the Men's Locker Room; its walls are exposed brick, and are in good condition.

The Delivery Area was originally designed to have rail cars pull through in order to deliver chemicals. This has long been abandoned and is currently being used as a chemical storage area and storage of maintenance equipment. The side loading area is elevated and has access to the chemical storage areas. It has exposed brick walls with steel frame walls. The brick is in good condition and the structural steel columns and trusses need to be cleaned and painted.

Delivery Area

Delivery Area

The Chlorinator Room is used as a dosing area for chemicals, including chlorine. The walls are brick and the ceilings and floors are cast-in-place concrete. The windows have deteriorated due to chemical vapors.

The Chemical Storage Room is currently being used to store some chemical totes. The walls are brick and the ceilings and floors are cast-in-place concrete. The south storage room has a containment area with grating.


Chemical Area


Chlorine Storage Room


Chlorinator Room


Chorine Room

The Freight Elevator is a 4,000-lb. capacity traction power elevator. The interior cab is painted steel and the floors are wood. The elevator has been continuously upgraded and inspected throughout its life. To our knowledge, there have been no code violations noted by the inspector that indicate the elevator is not up to current code requirements.

Elevator Equipment Room

Elevator Plaque

Lime Feed Area Second Level

The Lime Feed Area is the second floor above the lime feed and chemical section of the building. The walls are brick and the ceilings and floors are cast-in-place concrete. These all appear to be in good condition. The original use of the space is currently not being utilized and there is some use of the area as storage of old file material. The following is a list of spaces on the floor:

- Carbon Storage Room.
- Chemical Storage Room.
- Electrical Service Room.

Lime Storage Area

Parts Storage

Suggested Repairs

- No major improvements are required in this area, other than cleaning.

Rapid Mix Areas #1 and #2

The secondary clarifier gallery is constructed of exposed concrete frame columns and beams with cast-in-place concrete roof structure and slab; all are in good condition. The walls are constructed out of exposed face brick infill between the concrete structures.

Operations Building

Operations Building

Primary Clarifiers

The primary clarifier addition was completed in 2001. It is constructed of precast concrete columns, beams, and roof slab. The walls are concrete masonry unit (CMU) infill and the floors are exposed concrete. All walls and concrete have been painted. The overall condition of the interior is good with no direct signs of deterioration. The rooms of the area consist of the following:

- Basin Room.
- Electrical Room.
- Control Room.
- Stairs.


Clarifier Room


Clarifier Room

Suggested Repairs

- Paint walls and structure.
- Seal concrete floors.

Doors and Hardware

As part of this condition assessment, a detailed door-to-door analysis has not been completed to-date. It was observed that there exist original doors from the original 1950s building and newer doors that were installed as part of the Slow Mix Room #4 improvements and the Primary Clarifier addition. There are no security access devices installed on any of the doors and there is no centralized key control system. Much of the existing hardware would not meet current code requirements in terms of egress requirements.

Suggested Repairs

- Replace all 1950s doors/frames and hardware.
- Replace all doors and hardware of Slow Mix Area.
- Replace locksets of Primary Clarifier addition.

This will allow for future access control devices to be installed and a common lockset to be institutionalized to make access, security, and maintenance more efficient.

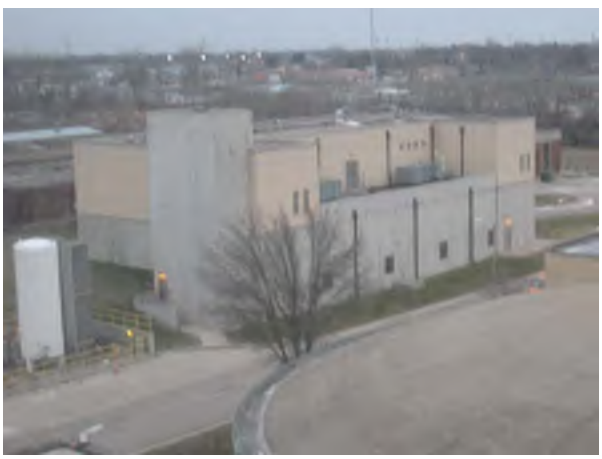
Ozone Building

The Ozone Building was constructed in 2001 as a new freestanding building. It is a 2-story building constructed out of reinforced concrete walls with cast-in-place structural frame above with masonry infill to match the color of the existing plant.

Exterior

Walls

The exterior walls are composed of solid cast-in-place concrete with concrete frame with infill composite wall masonry above. The overall condition of the walls is good but is suffering from some water infiltration at one of the downspouts. There currently is no parapet coping on the cast-in-place parapet walls. During rain events, there is noticeable moisture at the parapet top from dripping.



Ozone Building

Ozone Building East Wall

Suggested Repairs

- Install metal coping at top of precast wall.

Roofs

The roof system is a single-ply rubber roof with ballast. There are no direct signs of leakage. The roof is believed to be original to the building, which was constructed in 2001. The main issue related to the roof is the original scupper, which appears to be not wide enough to pick up all of the water that leaves through the scuppers. This has caused water to run down the side of the walls at all scuppers.

Roof

Typical Scupper

Windows

The windows are glass block and appear to be in good condition.

Suggested Repairs

- Install new, wider scuppers and rework flashing at these locations.
- Check all counterflashing.

Interior

Ground Floor

The ground floor walls, floors, and ceiling is exposed cast-in-place concrete and is all in good condition. The spaces on the ground floor are as follows:

- Ground Floor Galleries.
- Stairs
- Elevator.

Stairs are steel pan stairs with filled concrete and are in good condition and the hand and guardrails are galvanized steel and also in good condition.

The elevator is a hydraulic piston elevator with stainless steel interior. The elevator is in good condition and has passed inspection.

Gallery

Elevator

Second Floor

The rooms indicated below are all non-painted CMU block walls with concrete ceiling and floors. All rooms are in good condition. There has been some water staining on the west CMU wall, which is due to water running around the exterior scupper. The rooms of the second floor are as follows:

- Ozone Generator Room.
- Store Room.
- Mechanical Room.
- Electrical Room.
- Control Room.
- Utility Room.
- Janitor's Closet.

- Washroom.

Ozone Room

Ozone Room

Doors and Hardware

The doors and hardware are in good condition. If it is decided to revise the doors in the existing plant, cores may have to be switched out and re-keyed to a master key system. Access control may also be added, which may only be required at the entry doors.

Suggested Repairs

- Interior doors are in good condition and do not require any repair or replacement.

Substation Building

The Substation Building is one of the original buildings located on the northern end of the site. The building is where the main power feed enters the plant to a bank of switchgear inside the building.

Exterior

Walls

The Substation walls are a composite wall system composed of red brick on both the interior and exterior, similar in color to the original water treatment plant. The condition is fairly good for its age with no signs of significant deterioration.

South Elevation

Northwest Elevation

Suggested Repairs

- Tuckpoint and clean building (assume 20 percent needs joint repair).
- Clean and paint lintels.
- Remove and replace caulk at stone copings.

Roofs

The roofs are a built-up and ballasted system. There was not direct access to the roof, but it is believed that the roof is likely beyond its warranty period. There were some signs of leaking at the perimeter of the roof on the north elevation.

Suggested Repairs

- Remove and replace existing roof with new SBS Modified Bituminous roofing system over tapered insulation.
- Replace all counterflashing.

Interior

The interior is exposed face brick and the ceilings are precast panels. Both appear to be in good condition. The steel and precast panels have been painted.

Substation Interior

Ceiling and Roof Drain

Suggested Repairs

- Paint steel and precast.
- Clean masonry.

Windows, Doors, and Louvers

The windows are single-glazed steel windows, which appear to be original to the building. They are non-insulated and in worn condition. The existing exit door has been replaced and is in fair condition and has an exit device. The overhead coiling door is non-insulated and in a rusted condition. It currently has considerable air leakage. The louvers were retrofitted into an existing window opening with wood infill below that is not in good condition.

Suggested Repairs

- Replace windows with aluminum insulated windows.
- If access control is added, it would make sense to replace with new door and hardware.
- Replace overhead coiling door with insulated coiling door.
- Replace louvers with full height unit with insulated blank-off panels.

General Accessibility

Treatment Plant #2

The Flint Water Treatment Plant was constructed in the 1950s before the Americans with Disabilities Act (ADA) had been implemented. Like most facilities during this time, the plant was not designed to be accessible to people with disabilities. Even by today’s standards, not all spaces are required to be accessible due to their function and use classification, such as being regarded as a mechanical space.

In response to make the plant as accessible as possible, the City of Flint did a number of ADA upgrades to areas used specifically for general plant functions. An accessible route was added from the west door of the plant with ADA ramps so all employee areas are accessible. There is an existing ramp between the slow mix basins that is original to the building; however, it is steeper than allowed by the accessibility standards. It is also not able to be adapted to meet the standards, due to stop log drops at both the top and bottom of the ramp, preventing it from being lengthened.

Operations Building

Operations Building

The staff locker rooms have all been upgraded to have both women's and men's accessible toilets and showers.

The lower administration area, located in the filter area of the building, is accessible from the ground floor and has an accessible toilet.

The conference room located a floor above the administration area is not currently accessible with a stair being its only means of access. Installation of a ramp at this area is not practical because it would conflict with maintenance of the filters.

Ozone Building

The existing ozone building was constructed in 2001. This building was designed to be fully accessible. The building includes an accessible entrance, elevator to both levels, and an accessible toilet room on the second floor.

Substation Building

The Substation Building is a single-room building housing electrical equipment and is considered a mechanical space, making it exempt from being accessible.

General Programming Considerations

Staffing

As part of the condition assessment, a general review was made regarding current plant staffing and what was envisioned for the future plant. This was done at a very broad level and was done in order to understand if there may be required upgrades in the existing plant's administration and employee facilities in order to accommodate staff in future detailed design planning.

- Current Plant Staff – Total 25 (the current plant operates with 3 shifts per day, consisting primarily of operators on the 2 off-shifts).
  - Administration – 1.
  - Maintenance/Operations – 5.
  - Plant Operations – 14.
  - Laboratory – 3.
  - Electrical/SCADA – 2.

With the advent of new automation and modernization, the current plant staff is not projected to increase. For planning purposes, this will not require additional staff facilities.

Future Programming Needs

There are a number of functional needs that have been identified as potential improvements to the plant that can improve city accommodations and community outreach/education that should be considered in further development and planning for the improvements to the existing treatment plant.

Functional Spaces

- Multi-Functional Training – Conference Space.
- Plant Technical Library – File Storage.

Public Outreach Center

- Multi-Functional meeting room.
- Open space for flexible displays area.
- Fixed interpretive displays.
- Separated lobby area.
- Support spaces – restrooms, storage, electrical, mechanical.

END OF TECHNICAL MEMORANDUM

Appendix B

Structural Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *Michael Mitchell, CDM Smith*

Date: *January 13, 2017*

Subject: *Preliminary Structural Condition Evaluation Summary*

Introduction

From January 3, 2017 through January 6, 2017, a preliminary structural evaluation of the existing Flint Water Treatment Plant (WTP) was conducted. The purpose of this evaluation is to determine a baseline condition assessment of the existing facility. Structures evaluated include:

- Rapid Sand Filters.
- IPS Clarifier Building.
- Flocculation and Rapid Mixing.
- Chemical Feed Area.
- Boiler Building.
- Ozone Building.
- Dort Reservoir and Inlet/Outlet Buildings.
- Old Clarifiers #2 and #3.
- Old Slow Mix Tanks #2 and #3.
- Northeast Electrical Building.
- West Loading Building.

Rapid Sand Filters

Rapid Sand Filter Building, Operating Floor, Looking West

The Rapid Sand Filters were designed in 1952. The condition of the Rapid Sand Filter Building is fair to moderate. The superstructure appears to be in fair condition. The filter boxes also appear to be in fair to moderate condition. As observed from above, minimal cracking is visible in the filter boxes. However, signs of cracking and reinforcing steel corrosion are visible form the pipe gallery.

The west end of the pipe gallery shows signs of extensive rebar corrosion in the elevated slab, beams, and columns. Concrete deterioration is also visible in this area. Signs of leakage were observed on the influent water conduit, with plastic bags covering control panels and visible cracking at all filters. The underlying cause of the corrosion and concrete deterioration is currently unknown.

Further investigation and petrographic analysis of the concrete is recommended to determine the cause of the accelerated corrosion and concrete deterioration before a repair plan is implemented.

Delaminated concrete on the underside of the roof slab at the west end of the pipe gallery represents a safety hazard for falling debris. Hard hats and basic personal protective equipment (PPE) should be worn when working in this area.

Superstructure

The Filter Building superstructure appears to be in fair condition. White paint made it difficult to observe the concrete superstructure framing, although no movement or major cracks were observed. Some minor rebar chair corrosion is visible through the paint, but there does not appear to be any concrete deterioration, spalling, delamination, etc.

See West Pipe Gallery and Staircase sections for more information regarding the floor beam cracking in this area.

East Filters, Looking East

East Filter Gallery Roof Framing, Looking East

Rebar Chair Corrosion, Visible through Paint

Filter Building, Center Area Roof

Filter Boxes

The Filter Boxes, gullet walls, walkways, and trough supports all appeared to be in fair to moderate condition. The Filter Boxes were not entered, so assessment was made by visual observation from the operating floor and pipe gallery.

Wall cracking was observed in the filter box walls from the pipe gallery side. Crack injection repair is recommended.

East Filters, Looking Southwest

Filter Box

Filter Box

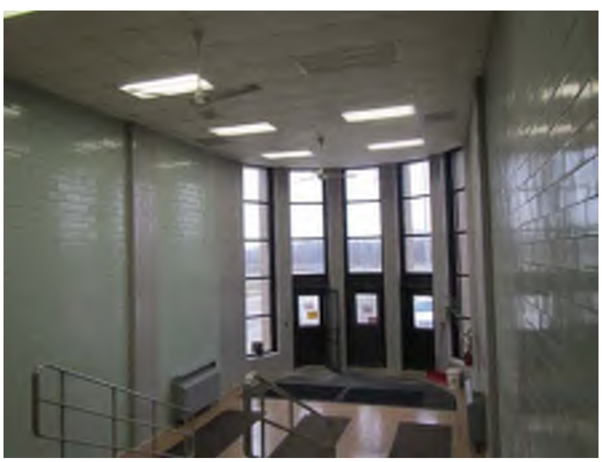
Filter Box, Minor Discoloration but no Visible Cracking

Filter Box Wall Cracking (as seen from Pipe Gallery)

Exposed Vertical Wall Reinforcing

Main Entrance

The main entrance exhibited concrete spalling from the underside of the elevated slab. Corroded rebar chairs and exposed/corroded reinforcing steel were observed. Further investigation into the cause of the corrosion is recommended prior to implementing a repair plan.



Main Entrance, Ground Floor Level, Looking South

Main Entrance, Underside of Elevated Slab, Exposed/Corroded Rebar, Visible Rebar Chair Corrosion

Main Entrance, Underside of Elevated Slab, Corroded Steel Insert Embedded in Beam

Pipe Gallery – Overall

The Pipe Gallery shows signs of past leaking due to cracks in the influent water conduit. Plastic bags were observed to have been placed over control panels. Localized minor spalls with exposed reinforcing steel was observed. The West Pipe Gallery, in particular, shows signs of extensive deterioration and rebar corrosion.

Further investigation is recommended to determine the underlying cause of the rebar corrosion prior to implementing a repair plan. Coring and petrographic analysis is recommended.

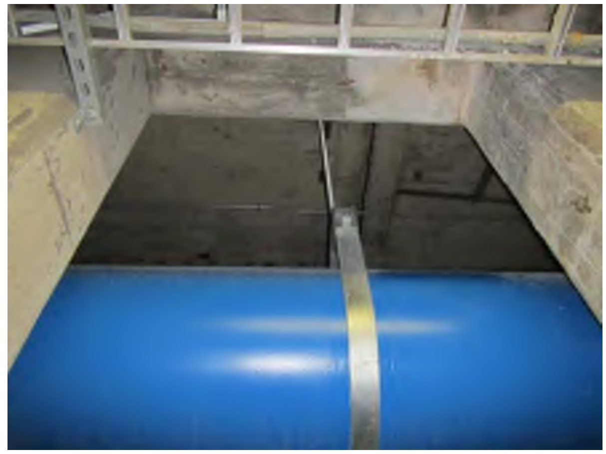
East Filters

Plastic Bag Placed Over Control Panel

Exposed Vertical Wall Reinforcing

Wall Cracking

Previously Repaired Slab Spall, with Further Exposed Reinforcing Steel



Corrosion Visible on Concrete Beam, Previously Completed Cementitious Repair

East Loading Area

The East Loading Area is generally in fair condition. However, localized spalls and corroded reinforcing steel are visible.

East Loading Area

East Loading Area

East Loading Area

East Loading Area Roof

East Loading Area Column and Beam Spall, Exposed Rebar

East Loading Area Slab Spall and Exposed Rebar

East Loading Area Concrete Beam Delamination

East Loading Area Joint Crack/Leak

West Pipe Gallery and Staircase

The West Pipe Gallery and Staircase showed signs of extensive rebar corrosion, concrete deterioration, spalling, and cracking. Further investigation and petrographic analysis are recommended.

Delaminate concrete on the underside of the roof slab at the west end of the pipe gallery represents a safety hazard for falling debris. Hard hats and basic personal protective equipment (PPE) should be worn when working in this area.

Staircase Down to West Pipe Gallery

Beam Cracking and Delamination at West Staircase

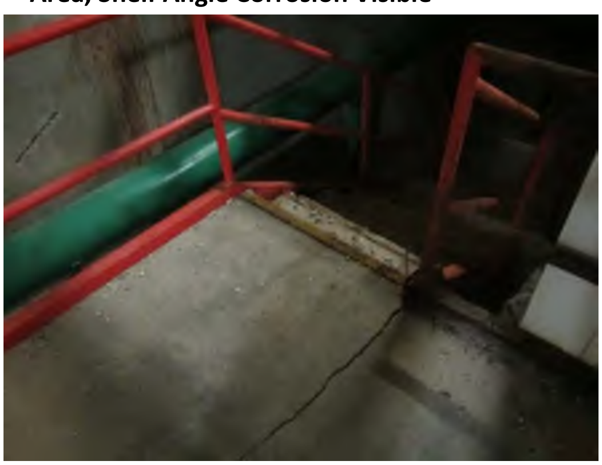
West Pipe Gallery Elevated Slab, Large Delamination about to Fall

Elevated Slab, Visible Delamination, Exposed/Corroded Rebar

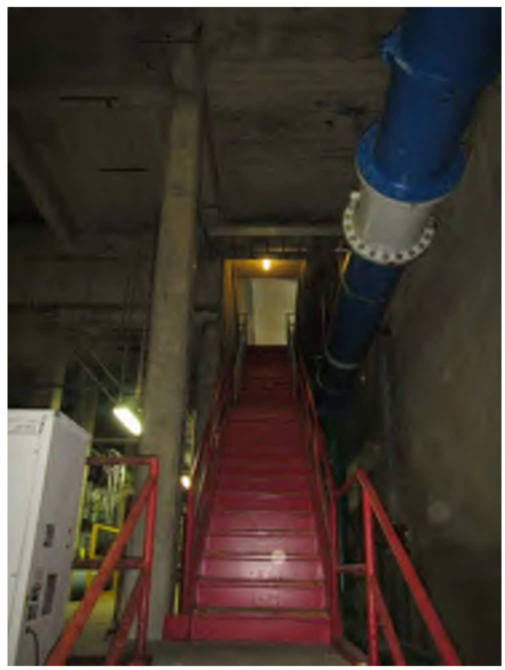
Underside of Elevated Slab, Concrete Deterioration, Spalling, Exposed/Corroded Rebar, Delamination

Underside of Elevated Slab, Beam Cracking/Delamination, Slab Spalling

Double-Leaf Floor Hatch into West Loading Area, Shelf Angle Corrosion Visible



Lower Staircase, Full-Depth Slab Crack, Concrete Debris from Spalling Above



Staircase, Looking East

Lower Staircase, Corrosion Visible

Lower Staircase Corrosion

Lower Staircase Corrosion

Column Cracking at Base

Column Cracking at Base

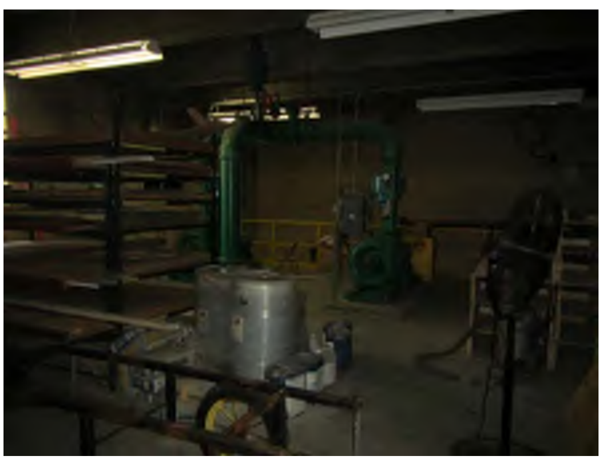
FRP Ladder Appears to be Missing Anchorage at Mid-Height

West Loading Area

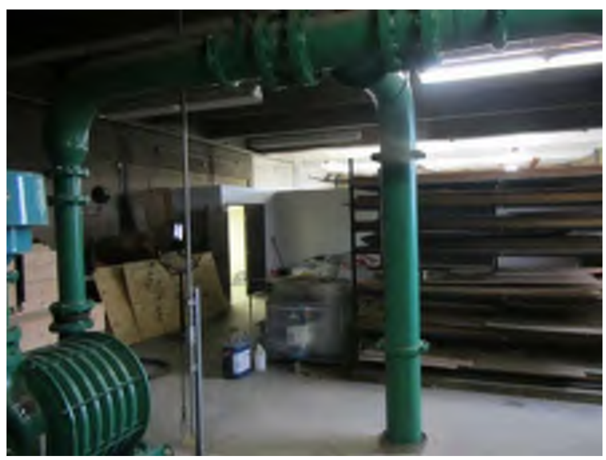
The West Loading Area superstructure appears to be in fair condition. However, significant concrete deterioration, spalling, and corroded rebar was observed from the underside of the West Loading Area. It appears that the deterioration is limited to the Pipe Gallery side of the slab (underside). Further investigation is recommended.

West Loading Area

West Loading Area, Double-Leaf Hatch to Pipe Gallery



West Loading Area, Blowers



West Loading Area

Major Observations and Recommendations

- Superstructure is in fair condition. Substructure and Pipe Gallery are in moderate condition.

- Spalled and delaminated concrete in slabs, beams, and columns, exposed and corroded rebar, especially at West End Pipe Gallery. This represents an occupational safety hazard. It is recommended to wear a hard hat and basic PPE at all times.
- Evidence of cracking and leaking of influent water conduit above Pipe Gallery. Repair is recommended.
- Cracking in Filter Box walls visible from Pipe Gallery. Repair is recommended.
- Staircase in West Gallery is heavily corroded at Lower Level. Repair is recommended.
- Recommend taking core samples of concrete for petrographic analysis to determine cause of concrete deterioration. Further investigation into the history and cause of the concrete deterioration and rebar corrosion is recommended.
- Recommend implementation of a concrete repair plan.

IPS Clarifier Building

The IPS Clarifiers were designed in June 2000. The condition of the IPS Clarifiers is generally good; however, significant cracking was observed in the clarifier walls. Injection crack repair is recommended.

Interior Upper Level

Wall Cracking

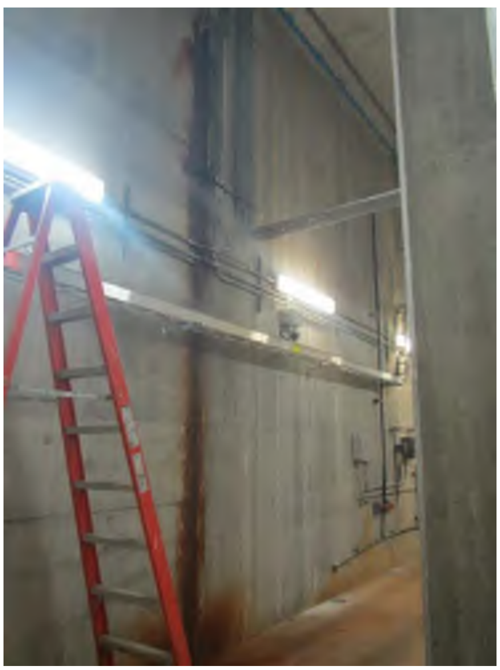
The walls of the IPS Clarifier Tanks show signs of cracking and past leaking. The tanks were dry at the time of observation, so it is unclear whether the cracks have 'self-healed' or are actively leaking cracks. These cracks do not appear to be structural cracks, and injection crack repair is recommended after determining whether the cracks are actively leaking.

Wall and Slab Cracking in Lower Level, South Corridor

West Wall, Visible Cracking, Looking East

West Wall, Visible Cracking, Looking Southeast

West Wall, Visible Cracking, Looking East



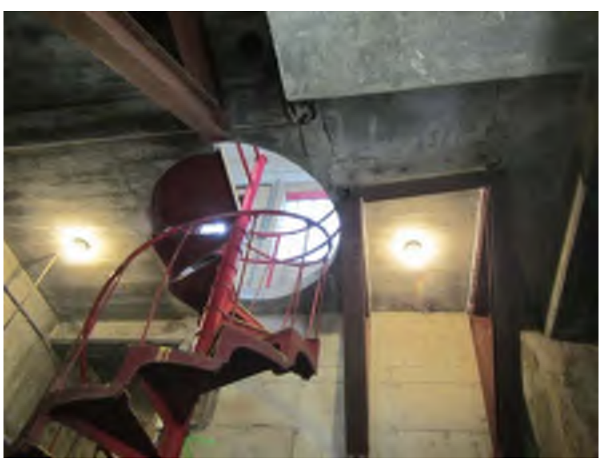
West Exterior Wall, Lower Level, Corroded Electrical Conduit

Connection to Flocculation Area

The previously completed demolition of the old Primary Clarifier #1 and subsequent construction of the IPS Clarifier resulted in a structural connection to the older existing facility. This connection is at the south end of the IPS Clarifier. The condition is generally fair, with local rebar corrosion at drain pipe penetrations and cracking at a cantilevered slab section adjacent to the spiral staircase. The west support of the south monorail shows signs of anchorage pullout and should be repaired prior to further use of the hoist.

IPS Connection, Ground Level, Looking South

IPS Connection, Lower Level, Looking West, Local Spalling/Corrosion in Cantilevered Slab to East of Water Conduit



Underside of Elevated Slab at Spiral Staircase

Slab Cracking Adjacent to Spiral Staircase

Monorail Anchorage Pullout

Major Observations and Recommendations

- Generally in good condition, but extensive cracking is visible from outside faces of the tank walls (accessible from inside the building).
- Injection repair of cracks is recommended.
- Crack on west wall in gallery shows signs of leakage directly over electrical conduit. Repair is recommended.
- Cracked cantilever slab to the east of the top of the spiral staircase at the 'connection' point to the rest of the facility. Repair is recommended.
- Monorail anchorage pullout; do not use until repaired.

Flocculation Tanks and Rapid Mixing

The condition of both East and West Flocculation Building was generally fair. The undersides of the roof beams in both Flocculation Buildings show signs of previous cementitious repair.

East Flocculation Room

West Flocculation Room

Roof Beam Spalling and Previously Completed Repairs

The roof beams have been previously repaired in both the East and West Flocculation Rooms with a cementitious repair mortar. The repairs appear to be in fair condition, though spalling and delamination were observed on the west-most N/S beam in the West Flocculation Room.

Beam Repair in West Flocculation Room

Beam Repair in West Flocculation Room

Beam Spalling

Beam Delamination, Visible Corroded Rebar Chairs

Elevated Walkways

The elevated walkways over the Flocculation Tanks are generally in good condition. There are minor cracks in some locations. Injection crack repair is recommended.

Cracked Elevated Walkway

Flocculation Tanks

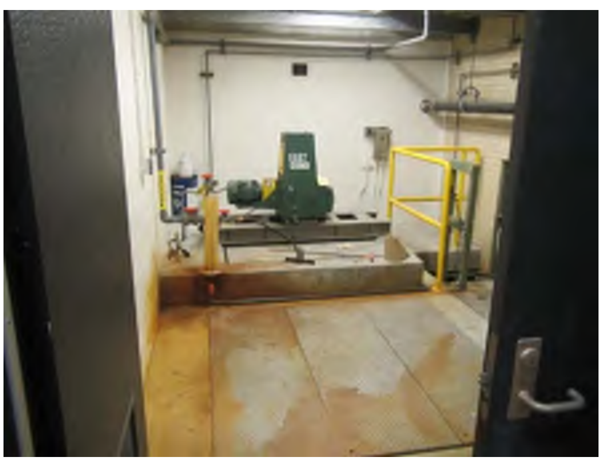
The Flocculation Tanks appear to be in good condition from visual observation.

Flocculation Tank Interior, typical

Flocculation Tank Interior, typical

Rapid Mixers

The condition of the Rapid Mixers appears to be good. Superficial rust from bollards and equipment is visible on the surface of the concrete, but does not appear to be structural. Structural cracking was observed at the anchorage of the East Rapid Mixer slide gate operating stand. Repair is recommended.



East Rapid Mixer

East Rapid Mixer Chamber

East Rapid Mixer Slide Gate, Cracked Operating Stand Anchorage

West Rapid Mixer

Major Observations and Recommendations for Old Slow Mix and Rapid Mixers

- Generally in fair condition.
- Previous cementitious roof beam repair.
- Beam delamination and spalling.
- East Mixing Chamber slide gate operating stand anchorage is cracked.
- Repair of cracks and anchorage is recommended.
- Further investigation of previously completed beam repair history is recommended.

Chemical Feed Area

The condition of the Chemical Feed Area superstructure is generally good. The substructure shows signs of local beam spalling and corroded reinforcing steel. It appears that structural columns were added in the lower level to support the ground level slab after the original construction.

Upper Level

Ground Floor Level, Looking Southwest

Upper Level Maintenance Storage Room

Upper Level Hoppers

Ground Floor Elevated Slab Beam Spalling and Corrosion

The reinforced concrete beams supporting the ground level elevated slab show signs of deterioration, spalling, and corroded reinforcing. Repair is recommended.

Beam Spalling and Exposed/Corroded Rebar in East Chemical Area

Ground Level East Chemical Area, Topside View of Previous Photo

Additional Steel Columns in West Chemical Area

It appears that galvanized steel structural columns were added at the midspan of reinforced concrete beams which support that ground floor elevated slab. The condition is good, though the history of why these columns were added should be investigated.

Additional Structural Columns in West Chemical Area Lower Level

Additional Steel Column, Previous Concrete Repair, Exposed/Corroded Reinforcing Steel, West Chemical Area Lower Level

Bypass Well Cracking

One corner of the Bypass Well (as-marked onsite) is cracked and should be investigated further. Repair is recommended.

Bypass Well Cracking, Chemical Area Lower Level

Major Observations and Recommendations

- Generally in fair condition.
- Local concrete beam spalling and corrosion. Further investigation and repair is recommended.
- Post-installed galvanized steel structural columns added to support ground floor elevated slab in West Chemical Area. Further investigation into history if recommended.
- Bypass Well cracking. Further investigation and repair is recommended.

Boiler Building

The structural condition of the Boiler Building is generally fair. Corrosion of miscellaneous steel members is visible, but minor. Cleaning and painting is recommended to extend the service life of these structural elements.

Boiler Building

Boiler Building

Boiler Building, Looking West

Boiler Building Staircase

Steel Member Corrosion

Column baseplates and roof plank shelf angles show signs of typical maintenance-related corrosion. Cleaning and painting is recommended to extend the service life of these structural elements.

Column Baseplate

Roof Plank Shelf Angles

Major Observations and Recommendations

- Generally in fair condition.
- Minor corrosion of miscellaneous structural steel elements.
- Cleaning and painting is recommended to extend the service life of these structural elements.

Ozone Building

The structural condition of the Ozone Building is generally very good. The elevated floor slab on the upper level shows signs of extensive shrinkage cracking that has been previously repaired. There is some minor wall cracking visible on the interior tank walls, although the tank was empty at the time of assessment and it is uncertain whether the cracks are actively leaking or self-healed. Crack injection repair is recommended, as required. Perimeter beams show minor cracking that appears to be shrinkage-related and not structural. Further investigation is recommended.

Ozone Building

Ozone Building, Lower Level Gallery

Floor Slab Cracking

The floor slab of the elevated slab in the upper level does not appear to have any control joints and shows signs of extensive shrinkage cracking. These cracks have been repaired in most places. These cracks do not represent a structural problem.

The lower level also shows signs of minor cracking at re-entrant corners of penetrations, such as trench drain grating.

Elevated Floor Slab Cracking on Upper Level

Upper Level, Looking South

Termination of Crack Repair in Floor, Upper Level Laboratory Area

Trench Drain Cracking at Re-Entrant Corners

Wall Cracking

The interior walls show signs of previously-leaking cracks. Crack injection repair is recommended.

Cracking at Pipe Penetrations

Tank Cracking

Interior Tank Wall

Concrete Beam Cracking

The upper level floor beams show signs of cracking. This appears to be shrinkage-related and not structural. Repair is recommended.

West Perimeter Upper Level Beam Cracking

West Perimeter Upper Level Beam Cracking

Masonry Wall Discoloration

The west exterior masonry wall on the upper level has discoloration in a vertical line. This appears to be moisture intrusion due to a crack in the masonry wall. The location of the wall discoloration is in line with a crack in the concrete beam below and adjacent floor slab, and appears to be a continuous crack. Repair is recommended.

West Exterior Masonry Wall Discoloration, Upper Level

West Exterior Masonry Wall Discoloration, Upper Level

Major Observations and Recommendations

- Generally in good condition.
- Elevated slab cracking and previously completed crack repair.
- Interior tank wall cracking.
- Masonry wall discoloration likely due to moisture intrusion from cracking.
- Repair of cracks is recommended as required.

Dort Reservoir

The Dort Reservoir was evaluated by a confined space entry team. Visual observations were made, with occasional hammer sounding, as warranted. The structure was designed in 1966 and appears to be in good condition. There does not appear to be any critical structural issues that would require immediate remediation. Previous crack injection repairs to the exterior walls are in good condition. Some groundwater infiltration was observed, primarily at roof slab expansion joints.

Entry Manhole, Looking East

Interior of Dort Reservoir

Expansion Joints

Expansion joints in the structure are deteriorated and leaking. Premolded joint filler has fallen onto the base slab of the reservoir in many locations and surface groundwater on the roof slab was actively infiltrating the reservoir during the evaluation. Record drawings show that the expansion joint is "Type E3" detailed with a 9-inch center bulb natural rubber waterstop and 1-inch premolded joint filler. Repair is recommended.

Deteriorated Premolded Joint Filler at Type E3 Expansion Joint

Deteriorated Expansion Joint

Masonry Baffle Wall Joint Filler

The joint filler at the joints on the interior masonry baffle walls has fallen out in most locations. This is not a critical structural item, but replacement is recommended.

Masonry Baffle Wall Joint Filler Displacement

Column Delamination, Spalling, and Corroded Reinforcing Steel

A number of columns (roughly 10 to 20 percent) show signs of rebar corrosion and surface deterioration. Columns were not observed to have structural cracks, and deterioration seems to be primarily related to durability. Repair of these columns should be considered after further investigation to determine cause of rebar corrosion and concrete deterioration. Carbonation and/or alkali silica reaction may be present, and coring for petrographic analysis is recommended.

Column Deterioration and Corrosion

Column Deterioration and Corrosion

Column Deterioration and Corrosion, with Active Roof Leak at Expansion Joint

Column Deterioration and Corrosion

Column Bulging at Base with Circumferential Crack

A number of columns (roughly 20+ percent) showed a noticeable consistent circumferential crack about 4 to 6 inches above the top of the column pedestal, which also showed signs of outward bulging. The concrete was softer in this area, which may be the result of carbonation. Expansive alkali silica reaction (ASR) is also a possibility. Concrete core sampling for petrographic analysis is recommended to determine the underlying cause of concrete deterioration prior to repair.

Circumferential Crack and Bulging near Column Pedestal

Corroded Rebar Chairs

Early signs of corrosion in the roof slab is exhibited by corroded rebar chairs visible on the underside of the slab. Further corrosion of the roof slab reinforcing was observed in just one location. Further investigation is required to determine the extent of preventative repair required to mitigate corrosion propagation in the roof slab. Partial-depth concrete core sampling is recommended to determine the extent of primary reinforcing steel corrosion in the slabs.

Corroded Rebar Chair Tips Visible on Roof Slab

Spalled Concrete and Rebar Corrosion at Construction Joint in Roof Slab

In “Area #1” on the record drawings from 1966, approximately 90 feet east and 50 feet south of the extreme northwest corner of the reservoir, concrete spalling and exposed, corroded rebar are visible on a construction joint in the roof slab. The size of the area is approximately 12 inches wide by 30 feet long in the direction of the joint. Large pieces of delaminated concrete are on the verge of falling and it is recommended to wear a hard hat at all times during future entry into the reservoir, with careful consideration given to this particular area. Further investigation is required to determine the extent of preventative repair required to mitigate corrosion propagation in the roof slab. Repair is recommended

Exposed Reinforcing and Spalled Concrete on Roof Slab

Roof Slab Cracks

The roof slab shows signs of cracking at re-entrant corners of manhole penetrations. Local cracks are also visible occasionally throughout the chamber, with a higher frequency of cracks running from column drop panels outward to the exterior wall on the west side of “Area #6.” Crack injection repair is recommended.

Roof Slab Crack at Re-Entrant Corner

Roof Slab Crack from Column Drop Panel to West Exterior Wall of Area #6

Corroded Wall Reinforcing

The east wall of "Area 5" shows visible corrosion of the inside face vertical reinforcing steel. Observations indicate that reduced concrete cover has decreased the corrosion protection of the reinforcing steel at this location. This was the only location that primary reinforcing steel in a wall was observed to show signs of corrosion. Repair of this area is recommended.

Corrosion of Vertical Wall Reinforcing

Corrosion of Vertical Wall Reinforcing

Inlet and Outlet Buildings

The inlet and outlet buildings are generally in good condition. Minor cracking was observed and crack injection repair is recommended.

Outlet Structure Exterior

Outlet Structure Slab Cracking

Inlet Structure Exterior

Inlet Structure Exterior Wall Cracking

Major Observations and Recommendations

- Generally in fair condition.
- Previous crack injection repair in good condition.
- Local corroded vertical wall reinforcing. Repair is recommended.
- Deteriorated and leaking expansion joints in slabs and walls. Repair of all expansion joints is recommended.
- Minor roof cracking requires injection repair.
- Column concrete deterioration requires petrographic analysis to determine cause.
- Column spalling and rebar corrosion visible on approximately 20 percent of columns. Repair is recommended.
- Inlet/Outlet structures are in generally fair condition; minor crack injection repair is recommended.

Old Clarifiers #2 and #3

The Old Clarifiers #2 and #3 are not currently part of the water treatment process at the WTP, but may be used in the future. The structural condition was fair to moderate.

The tension ring beams on the domes show signs of rebar corrosion and delamination. The dome shows signs of rebar corrosion and delamination. The dome roofs are in fair condition, but show signs of past leakage. One concrete corbel in the lower level was observed to have a vertical shear crack through the full depth of the corbel, and its adjacent elevated slab has what appears to be a circular punching shear crack. Repair of these structural elements is required, regardless of the future use of these structures.

Exterior of East Clarifier

Old West Clarifier

Old East Clarifier

Roof Domes

The roof domes do not show any signs of structural damage. There is evidence of past leakage at circumferential cold joints, but it is unclear whether there is active roof leakage. Further investigation is recommended.

Old East Clarifier Dome

Old West Clarifier Dome

Cracked Column Corbel and Slab Punching Shear

One of the column corbels on the west clarifier, as accessed from the center gallery lower level, has a full-depth structural shear crack. At the same location, the corner of the adjacent slab (supported directly by the column, not the corbel) shows what appears to be a punching shear crack. This represents a major structural problem and repair is required.

Cracked Column Corbel

Shear Crack on Corbel with Slab Punching Shear Crack Visible

Punching Shear Crack

Ring Beams

The tension ring beams show signs of rebar corrosion and minor, localized delamination. Further investigation and repair is recommended.

Ring Beam Corrosion and Delamination, Corroded Rebar Chairs Visible

Previously Completed Repairs

Interior columns on the lower level show signs of previously completed cementitious repair. Further investigation is required into the history of these repairs.

Ring Beam

Cementitious Repair at Top Column, Lower Level, Corroded Rebar Chairs in Slab

Major Observations and Recommendations

- Domes show signs of previous leaking, but generally in good condition. Further investigation is recommended.
- Cracked corbel and punching shear in adjacent slab at lower level column. This is a structural problem and repair is required regardless of future use of this structure, unless demolished.
- Ring beam corroded rebar and delamination. Further investigation and repair is recommended.
- Previously completed cementitious repairs to lower level columns. Further investigation and repair is recommended.

Old Slow Mix Tanks #2 and #3

The structural condition of the Old Slow Mixers #2 and #3 is fair to moderate.

West Old Slow Mix Tank

East Old Slow Mix Tank, Additional Steel Columns

Wall Penetration into East Old Slow Mix Tanks at Lower Level

The rectangular penetration into the East Old Slow Mix Tank appears to be recently completed. The penetration edges were smoothly saw cut, but the cut rebar is exposed and not patched. While not currently a structural problem, the exposed rebar represents a durability problem which should be addressed. Patching is recommended.

East Old Slow Mix Chamber, Square Penetration

Exposed Rebar Ends from Saw Cutting

Cracking at Weir Wall End Support

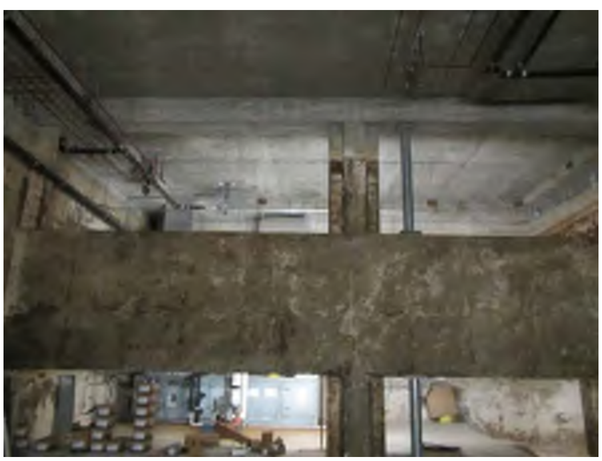
Cracking is visible at the east end of the interior wall in the East Old Slow Mix Tank. Further investigation is recommended.

East Old Slow Mix, Crack at Weir Wall Support

East Old Slow Mix, Crack at Weir Wall Support

Modification Beams and Slabs for Ground Level

The modification work to install an elevated structural slab for the ground floor level appears to be in good condition.



Modification to Original Structure, New Column, Beams, and Slab

Modification to Original Structure, New Beams and Slab

Major Observations and Recommendations

- Generally in fair condition.

- Cracking at edge of old weir wall in East Tank. Repair is recommended.
- New steel columns, footings, elevated concrete beams, and elevated concrete slab. Further investigation into the history of the modifications is recommended.
- Patching at exposed rebar ends at penetration into East Tank is recommended.

Northeast Electrical Building

The structural condition of the Electrical Building Northeast is generally fair. The lintel on the west rollup door is deflected at midspan and mildly corroded. The floor slab has minor shrinkage cracking but does not appear to be spreading or widening. Step cracking adjacent to the east window of the south exterior wall shows signs of moisture discoloration. Repair is recommended.

Northeast Electrical Building

Northeast Electrical Building

Northeast Electrical Building, Looking East

Floor Crack at Penetration

Step Cracking at Window on South Exterior Wall

Northeast Electrical Building, West Rollup Door Lintel Deflection

Major Observations and Recommendations

- Generally in fair condition.
- West rollup door lintel deflection and minor corrosion. Repair is recommended.
- Step cracking and minor moisture intrusion on south wall at window. Repair is recommended.
- Minor north/south floor cracking, located at approximately the center of the 2:1 building plan aspect ratio. Repair is recommended.

West Loading Building

The structural condition of the West Loading Building is generally fair. The north rollup door shows signs of corrosion and appears to have been damaged by vehicular impact from the outside.

West Loading Building, Looking Northeast

West Loading Building, Looking South

West Loading Building, Looking North

Corroded North Rollup Door Framing

Major Observations and Recommendations

- Generally in fair condition.
- North rollup door corrosion and impact damage. Replacement is recommended.

END OF TECHNICAL MEMORANDUM

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Appendix C

Process Mechanical Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *John Bergsma, CDM Smith*

Date: *January 13, 2017*

Subject: *Process Mechanical Assessment*

Introduction

CDM Smith performed a condition assessment of the City of Flint Water Treatment Plant (WTP) to establish work scoping needs related to the improvement of the various process mechanical systems within the facility. City of Flint maintenance staff accompanied CDM Smith during this assessment to assist with establishing which components require further evaluation or improvement.

The purpose of this report is to summarize the existing process mechanical components and to provide recommended improvements to supplement preliminary developed concepts to upgrade the facility.

The inspected process mechanical components are summarized below.

Existing Conditions

The existing process mechanical systems at the WTP consist of the following elements:

- Ozone.
- Rapid Mixing for Coagulation.
- Flocculation.
- Sedimentation.
- Filtration.

Upon inspection, the condition of several components were evaluated to define the concern related to remaining service life and performance of the process mechanical and ancillary support systems.

The following is a summary of the existing condition of these process systems and related concerns as identified through inspection with WTP staff on January 6, 2016.

Ozone System

The existing ozone generation system consists of 2 ozone generators and 3 ozone contact basins and was designed to provide ozone to facilitate disinfection of flows up to 36 million gallons per day.

- Maintenance staff noted that they have observed spalling and flaking from the inner coating of the 36-inch effluent pipe which conveys flows to the WTP from the ozone contact basins. Material from this pipe has been found in the plate settlers inside the facility during routine maintenance activities.
- Maintenance staff confirmed that the automatic air inlet valve to the ozone destruct unit does not function properly.
- The preliminary recommendation is to modify the existing ozone system to utilize one existing ozone contact chamber. This change will allow for future operation as a low-dose preoxidation process to reduce ozone concentration at low dose and low plant flow conditions while still providing adequate disinfection and turbidity removal. Access is restricted to most of the main process mechanical components within the ozone contact basins and will need to be evaluated by the ozone manufacturer during detailed design for a more detailed assessment.

Rapid Mixing

Two rapid mixing chambers are currently utilized to facilitate coagulation prior to flows entering the flocculation basins. Ferric Chloride is currently mixed in each chamber with a 5 HP mechanical mixer.

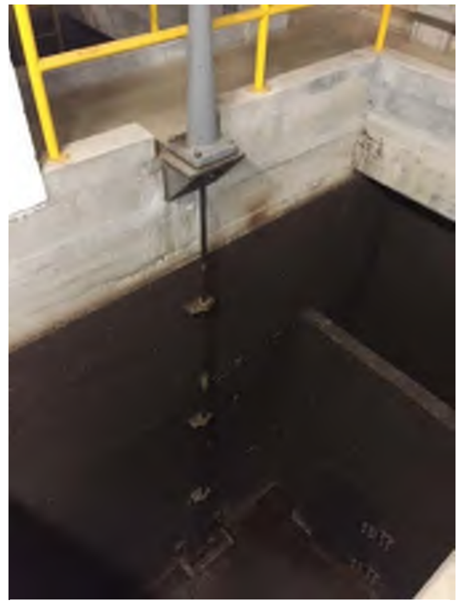
Existing Rapid Mixer Equipment

- Maintenance staff reported these mixers to be working properly, but noted that the mechanical components are aging, causing a concern related to remaining service life and mixing performance.
- The mechanical mixers at the rapid mix process are recommended be replaced with pumped injection rapid mixers to improve mixing efficiency for mixing of chemicals for coagulation.

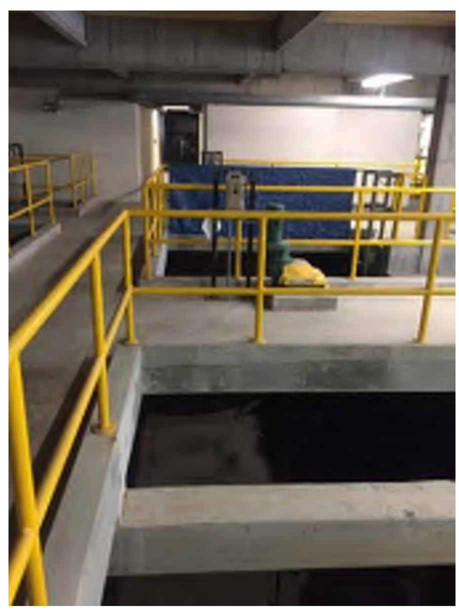
Flocculation

Two flocculation basins are used in conjunction with variable speed mixers to control mixing speed and optimize formation of floc.

- The inlet valves for both the West and East flocculation basins are reported to be working properly.
- Each flocculation basin is equipped with fifteen 2 HP mechanical mixers, all of which are working properly.
- Maintenance staff noted that they have observed spalling and flaking from the inner coating of the 36-inch effluent pipe which conveys flows from the flocculation basins to the plate settlers.
- Maintenance staff noted that the pumping system for the flocculation drainage vault is undersized. The flocculation drainage vault is currently equipped with 2-inch submersible Flygt pumps that reportedly do not provide the needed drainage capacity.
- The inlet gate to the drainage vault reportedly leaks and needs to be evaluated.
- The drainage valves from the flocculation basins are reported to be in acceptable working condition, but aged.
- The preliminary recommended modification to the existing flocculation basins include changes to compartmentalize four 3-stage flocculation trains. This proposed modification will require the construction of new inlet pipelines and pipe laterals. In addition, new baffle walls are needed in the flocculation basins to streamline flow patterns for flocculation.
- The existing mixers will need to be rearranged to provide variable mixing intensity and optimal formation of floc solids.
- A new slide gate will be installed in a common outlet channel to the plate settlers.



Inlet Gate to Flocculation Drain Basin



Existing Flocculation Basins and Mixers

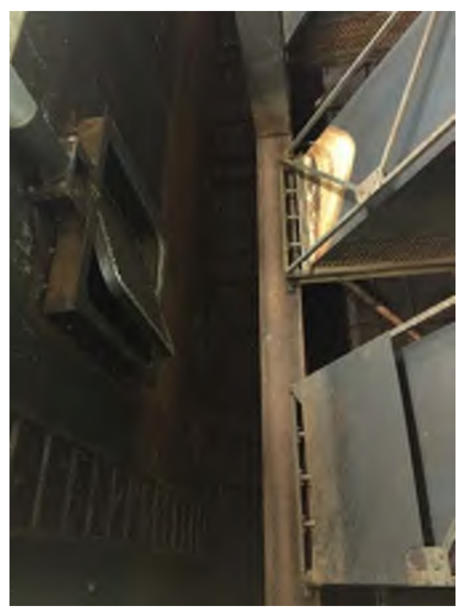
Inclined Plate Settling Basins

Three basins are currently used in conjunction with plate settlers to facilitate primary clarification following flocculation. Each basin is equipped with a fixed grid sludge collection system to remove solids.

- Maintenance staff confirmed operational issues with the existing sludge collection system. The fixed piping system routinely plugs, which is a cause for concern regarding the operational capability of the plate settlers.

Existing Plate Settlers and Sludge Collection System

- Maintenance staff noted that the process drain for the influent channel to the settlers is undersized. This requires operational staff to manually pump built up flow when the level becomes too high.
- Flows into the settling basins are controlled by large butterfly valves. The existing butterfly valves and associated actuators are reported to be in good working condition. Routine maintenance is sometimes needed to adjust and lubricate the valve seats.
- The plates settlers are damaged at the location of the inlet valves due to high flows where the water enters the basin from the influent channel. Stainless steel covers have been added by maintenance staff where flow enters the basin to prevent further damage to the plates.



Inlet Valve to Plate Settling Basins

- The recommended upgrades to the settling system include utilizing IPS basins 1 and 2 for water treatment and designating IPS basin 3 for wash-water recycle treatment.
- The existing fixed pipe sludge collection system for all 3 IPS basins is recommended to be replaced with a new hose-less system.
- The 4-inch and 6-inch sludge piping and fittings will need to be replaced in the west sludge gallery, and a new sludge holding tank is recommended.

- The addition of two isolation slide gates in the IPS basin inlet and outlet channels is recommended to provide better flow control in this area of the system.
- Maintenance staff has indicated that the isolation valves and check valves for the sludge pumps are not working properly and need to be replaced.
- The sludge dewatering pumps are reported to be in good working condition.

Isolation and Check Valves for Sludge Pumping System

Filtration

The existing filtration system consists of twelve filters consisting of sand and granulated activated carbon (GAC) media.

- Maintenance staff noted that pinholes are forming within some of the filter troughs, and that overall deterioration of the troughs should be further evaluated.
- The vibration detection system associated with the air scour system does not work properly. The sensors are outdated and upgrades are needed.
- The influent flow control valves into the filters are reported to leak at the valve seats.
- The 24-inch filter drains are also reported to leak at the valve seats.

Existing Troughs for Media Filtration

- Two pipe headers from the East and West side of the WTP are currently used to convey pressurized backwash water to the filters. Only 1 side of the system currently provides adequate pressure to facilitate this process. Recommended facility upgrades include configuring a new source for backwash water.
- Future recommended improvements include removing granulated activated carbon (GAC) and replacing with anthracite and sand media. This media will produce the same low turbidity filtered water and provide longer filter runs when source water has higher turbidity and requires higher coagulant doses.

- Two blowers are utilized as the source for the air scouring system to the filters. Maintenance staff reported that the pressure release valves for these blowers are not working properly, which allows unwanted pressure to build up in the system.

Inlet Flow Control Valve to Filters

Additional Items

- Maintenance staff noted that the altitude valve to the elevated finished water tank does not work and needs to be replaced.

Recommended Improvements

The following is a tabulation of the process mechanical components assessed during site visits by CDM Smith, and recommended future improvements where applicable.

Item No.	Finding	Area	Component	Recommendation
1	Spalling and flaking observed from the inner coating of the 36-inch effluent pipe which conveys flows to the WTP from the ozone contact basins.	Ozone Building	36-inch Pipe	Perform detailed condition assessment of pipe and coating and repair or replace as required.
2	Not working properly.	Ozone Building	Air Inlet Valve	Replace.
3	Inaccessible.	Ozone Building	Ozone Contactors	Obtain detailed mechanical condition assessment from manufacturer.
4	Mechanical mixers are functional, but outdated and not optimally efficient.	Rapid Mix	Mechanical Mixers	Replace mechanical mixers with pumped injection rapid mixers to improve mixing efficiency for mixing.
5	Spalling and flaking observed from the inner coating of the 36-inch effluent pipe which conveys flows to the pate settling basins from the flocculation basins.	Flocculation Basin	36-inch Pipe	Perform detailed condition assessment of pipe and coating and repair or replace as required.
6	Valves are functional, but very old.	Flocculation Basin	Flocculation Drainage Valves	Perform detailed condition assessment and either rehabilitate or replace.
7	Gate leaks.	Flocculation Basin	Inlet Gate to Drainage Vault	Perform detailed condition assessment and either rehabilitate or replace.
8	Pumping system for flocculation drainage vault is undersized.	Flocculation Basin	Drainage Vault Pumps	Remove existing 2-inch pumps and replace with new 4-inch submersible pumps to provide needed capacity.

Item No.	Finding	Area	Component	Recommendation
9	System to be modified to six 3-stage flocculation trains.	Flocculation Basin	Inlet Pipe	Remove and replace existing inlet pipe and pipe laterals.
10	System to be modified to six 3-stage flocculation trains.	Flocculation Basin	Mixers	Relocate existing mechanical mixers to provide variable mixing intensity and optimal flocculation.
11	System to be modified to six 3-state flocculation trains.	Flocculation Basin	Outlet Gate	Install new slide gate in common outlet channel.
12	Existing fixed pipe system routinely plugs.	Inclined Plate Settling Basins	Sludge Collection System	Replace the existing fixed pipe sludge collection system for all three IPS basins with a new hose-less system.
13	Drain for influent channel is undersized and needs to be manually pumped when level gets too high.	Inclined Plate Settling Basins	Influent Channel	Replace existing 4-inch drain.
14	Plates are damaged and corroded at inlet valves.	Inclined Plate Settling Basins	Plate Settlers	Install baffle wall to redirect flow.
15	Sludge collection system is in need of replacement.	Inclined Plate Settling Basins	Sludge Piping and Fittings	Replace the 4-inch and 6-inch sludge piping and fittings to accommodate new sludge collection system.
16	Isolation valves and check valves for the sludge pumps are not functioning properly.	Inclined Plate Settling Basins	Sludge Pumping System	Replace isolation valves and check valves for sludge pumps.
17	Maintenance cited possible degradation to trough components.	Filtration	Filter Troughs	Perform detailed evaluation, replace trough components as required.
18	Air scour system not working properly due to outdated vibration sensors.	Filtration	Vibration Detection System	Replace vibration sensor throughout system.
19	Leakage occurs at the valve seats.	Filtration	Influent Process Valves	Rehabilitate or replace valves as required.
20	Leakage occurs at the valve seats.	Filtration	Filter Drain Valves	Rehabilitate or replace valves as required.
21	Only one side of dual system currently provides adequate pressure for backwashing.	Filtration	Backwash System	Configure a new source for backwash water.
22	Pressure builds up in air scouring system due to faulty pressure release valves.	Filtration	Blower System for Air Scouring	Replace pressure release valves for both duty and redundant blower.
23	Altitude valve to the elevated finish water tank is not functional.	Finished Water Storage	Elevated Finish Water Tank	Replace altitude valve to the elevated finished water tank.

END OF TECHNICAL MEMORANDUM

Appendix D

Building Mechanical Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *April Ricketts, CDM Smith*

Date: *January 13, 2017*

Subject: *Building Mechanical Assessment*

Introduction

The purpose of this technical memorandum is to assess the existing Building Mechanical system at the 1954 Flint Water Treatment Plant (WTP) building (Treatment Plant #2) and newer Ozone Treatment building, which includes plumbing, natural gas piping, laboratory services, heating, ventilation, and cooling systems. Where issues have been identified, this technical memorandum will also make recommendations to remedy them.

Existing Conditions

The existing plumbing systems at the WTP building consist of sanitary drain and vent, roof drain piping, natural gas, cold water (for potable and protected uses), hot water, tempered water (for emergency fixtures), laboratory deionized water system, and various plumbing fixtures (for restrooms, breakrooms, laboratories, and janitor rooms).

- The original sanitary drain, vent, and roof drain piping appears to have been hub-and-spigot cast iron. During many building renovations, portions of this service have been replaced with either no-hub cast iron or PVC plastic pipe and fittings.

- It is not clear from observation what the original water piping in the building was made from, but branch piping was used for the various plumbing renovations used copper tubing with either soldered or brazed fittings. Reduced pressure backflow preventers are at various locations to provide protected water. For the most part, potable water to fixtures and emergency showers are fed from the same protected water lines that provides water to process equipment and wash hose stations.

- Electrical water heaters are scattered around the building, providing hot water to restrooms, showers, laboratory sinks, and related fixtures.

Janitor Supply Closet

- Natural gas piping running inside of the building appears to be schedule 40 black steel with either threaded or welded fittings (depending on the location). Natural gas serves the steam boilers and is also piped to counter mounted turrets at the laboratories.
- The laboratories (which include chemical and wet labs) utilize copper piping for hot and cold water service, as well as for tempered water for emergency fixtures. Lab sinks are built into the lab counters and have cast iron p-traps and drains, connecting directly to the building's sanitary drain system. The laboratories have specialized services, including compressed air, vacuum, natural gas, and deionized reagent water. The deionized water system includes plastic piping routed in a loop, pumps, filters, UV disinfection unit, and accessories. Laboratory fume hoods include water and gas outlets, and an autoclave looks to be manually fed using deionized water.

Restroom near Filter Gallery

- Restroom fixtures appear to have vitreous china fixtures, including water closets, urinals, and lavatories. Additionally, some of the restrooms include showers. Except where renovations have occurred (such as in one of the front office restrooms and the women's locker room), many of the restroom fixtures appear to be original to the building.
- A kitchen and cafeteria/break room looks to have been added at a later time during one of the building's renovations. The kitchen includes an electric range and a stainless steel two-compartment sink. Hot water is piped from the water heater serving the laboratories. Exposed water supply and drain piping appear to be both brass and chrome plated brass.
- Emergency showers and/or eyewash units are located at various locations in the building. Some are provided with tempered water and some are piped directly to cold water.
- Cast iron floor drains are located in various locations throughout the plant.

The existing HVAC systems at the WTP building include steam radiators, steam unit heaters, electric unit heaters, air handling units, makeup air units, exhaust fans, and split system air conditioning units.

Heating and Ventilation System Serving Filter Gallery

- Heating throughout the building is primarily with steam, using fin-tube radiators or unit heaters. Electric unit heaters have been added in some areas (such as restrooms) to provide heating when the steam system is seasonally off. Many of the steam radiators and unit heaters appear to be original to the building, but new units have been installed where building renovations have occurred.
- Many areas of the building do not have air handling units. The areas that do include the Filter Gallery (heating and ventilation unit), the main Conference Room (packaged rooftop air handling unit), the Laboratories (makeup air handling unit and exhaust fans), the Operators/SCADA room (split system air handling unit), and the Front Offices (ductless split system air conditioning units). Some process areas have exhaust fans only, but no means to provide makeup air (other than what is transferred from other adjacent spaces or infiltrated into the building through gaps in the windows/doors/walls).
  - The Filter Gallery is served by two vertical heating and ventilation units (located in the old clarifier rooms behind the Filter Gallery). Each Heating and Ventilation unit includes a fan section, heating coil section, filter section, and mixing box section. These units designed to supply a mixture of return air and outside air (ventilation air) into the space. At present, these units do not supply any ventilation air into the building.
  - The large Conference Room (located near the Filter Gallery) has a rooftop packaged air handling unit, which provides ducted heating and cooling to the conference room and adjacent spaces (which include a small kitchenette, file storage, and office). The rooftop unit also supplies a portion of ventilation air into the building. Supplementing this unit are steam fin-

Laboratory Fans

tube radiators located at the exterior walls.

Front Office Split System Units

- The Laboratories are served by a central makeup air unit (located in the basement level). This unit provides 100 percent outside air to the labs and includes steam heating direct expansion (DX) refrigerant cooling coil. There is a general laboratory exhaust, as well as two independently operated chemical fume hoods. The fume hood fans are only turned on when needed, rather than operating continuously. Once fume hood has ducted exhaust only and the other has ducted exhaust and makeup air (the makeup air is supplied by a rooftop supply fan with electric duct coil).

- The Control Room, which includes an operator area and a SCADA server room, is served conditioned air ducted from vertical split system air handling unit (located in a mechanical room near the laboratories). This unit has steam heating, DX cooling, and had a small portion of outside air ducted to it.

Steam Boiler

- The Front Office rooms (located on the lower level near the Filter Gallery) use ductless split system for heating and cooling of the spaces. No ventilation air is provided with these units.

- Some of the process spaces use central exhaust fans to remove contaminants and heat, but not all process spaces have exhaust fans. Some process equipment appears to have built-in exhaust systems, which are ducted to the outdoors. Except for the newer renovated areas, no means of providing makeup air mechanically to the process spaces is installed. Newer areas utilize outside air inlet louvers for makeup air.

- The restrooms have exhaust fans but no makeup air is provided. The spaces adjacent to the restrooms also do not have makeup air supplied to them.

- A cafeteria and kitchen were added in an unused process space during one of the building's renovations. The existing process exhaust fan (currently located above a new lay-in ceiling) is still active and does provide exhaust for the space, but there is no other HVAC system that serves these spaces.

- Steam is generated with two 200 PSI fire-tube boilers, which were installed in a recent building renovation. The 200 PSI steam pressure is reduced to 15 PSI with a PRV station (located in the lower level of the building), and is distributed throughout the building. Condensate is collected and pumped back to the boiler room through multiple condensate receiver pumps. The boiler room includes chemical treatment and water softeners, as well as blowdown tank and feedwater system. Combustion air is provided by two large louvers; one located low and one located high on the exterior wall.

- The Pipe Gallery (located under the Filter Gallery) does not have air fans serving it, but does have multiple plus-in style vapor compression style dehumidification units. Many of these units do not appear operational and some show signs of rusting.

Portable Dehumidification Units in Pipe Gallery

- Controls for HVAC equipment appears to be manual values for steam radiators and thermostats for air handling units (and some of the unit heaters). Boilers and associated motorized combustion air dampers appear to be controlled at each boiler's control panel. Steam to the radiators steam heating coils appears to be fully open (no modulating). Fume hood fans, as well as most of the general exhaust fans, are manually turned on and off.

Ozone Building

The plumbing systems at the Ozone Building includes sanitary drain and vent systems, roof drain conductors, natural gas piping and regulators, and protected water. The limited amount of plumbing in this building serves a unisex restroom, Utility Room, Janitor Room, and various floor and roof drains.

Janitor Room in Ozone Building

- Sanitary drain and vent and roof drain piping appeared to be no-hub cast iron piping and fittings, using no-hub couplings.
- The water service is protected with a reduced pressure backflow preventer and appears to use copper tubing, with either soldered or brazed fittings, to service plumbing fixtures. This protected water serves process equipment and wash hose stations, but is also piped to plumbing fixtures and the emergency shower/eyewash. All of the water piping appears to be insulated.
- A small electric water heater provides hot water to the restroom Janitor's room, and a lab and Utility room.
- Natural gas service includes a pressure regulating valve (located outside of the building) and is piped to various gas appliances. The piping appears to be schedule 40 black steel with either threaded or welded fittings (depending on the location). Equipment served includes infrared radiant heaters, dehumidification air handling units, a rooftop air handling unit, and makeup air handling units.
- Restroom fixtures appear to be vitreous china and include a water closet with flush valve and wall-mounted lavatory.
- An emergency shower/eyewash is located on the first floor, and appears to be served with protected water. The water does not appear to be tepid.

Emergency Shower/Eyewash in Ozone Building

- Various process pipes are also located in the building, including lines carrying oxygen and nitrogen from outdoor liquid oxygen and nitrogen tanks.

The HVAC at the Ozone Building includes electric unit heaters, gas-fired infrared radiant heaters, rooftop air handling unit, makeup air units, dehumidification air handling units, exhaust fans, and split system air conditioning units.

- The first floor is heated primarily using gas-fired infrared radiant heaters. Combustion air is piped to each of these units and the

Rooftop Makeup Air Units

flue outlets are combined together and piped to wall-mounted flue vent fans. The second floor uses gas-fired makeup air units, but smaller rooms are provided with electric unit heaters.

- Dehumidification air handling units are located on both the first and second floors. When operated, these units use solid desiccant wheels with natural gas regenerators to provide dehumidified air to the process spaces.

Dehumidification Air Handling Units at Ozone Building

- Ventilation is also achieved using ducted propeller-style exhaust fans and multiple outside air inlet louvers with motorized dampers.
- The second-floor Control Room, Restroom, and Utility Room are served with a rooftop air handling unit with gas heat and DX cooling.
- There is a large electrical room on the second floor, which is served by a thermostatically controlled exhaust fan and outside air inlet louver.
- Except for unit heaters and smaller systems, the major HVAC equipment is controlled with a building automation system. Modes of controls ventilation methods are available for unoccupied, occupied, and emergency operations.
- The elevator machine room uses a ductless split system air conditioning unit.

Building Mechanical List of Findings and Recommendations

The following identifies HVAC and Plumbing items found during the assessment site visits by CDM Smith, as well as recommendations to remedy them.

Item No.	Finding	Building	Area in Plant	Recommendation
1	HVAC equipment, including air handling units, makeup air units, supply air fan, exhaust fans, etc., do not look to have been maintained.	Water Treatment Plant	Throughout	Where reusing HVAC equipment, replace belts, change filters, and perform other manufacturer recommended procedures
2	Many process areas and chemical rooms do not include ventilation air, exhaust air, or both	Water Treatment Plant	Throughout	Provide ventilation makeup air handling units and exhaust fans to provide minimum code and/or industry recommended required air changes.

Item No.	Finding	Building	Area in Plant	Recommendation
3	While some of the steam and condensate piping has been replaced, much of the piping (especially on the upper floors) look to be old. In a few areas, insulation is missing from steam and/or condensate piping.	Water Treatment Plant	Throughout	Have an integrity test performed on older steam and condensate and replace pipe sections where needed. Insulation steam and condensate piping, where needed.
4	The Emergency fixtures (showers and eyewashes) are currently supplied from the same water that also serves process equipment and wash hose stations (protected water).	Water Treatment Plant	Throughout	Re-pipe emergency fixtures to be fed from potable water, separated from water service process equipment, and wash hose stations.
5	Other building upgrades have been done, the HVAC equipment appears to have aged and is in need of replacement.	Water Treatment Plant	Throughout	Where equipment age is beyond industry accepted equipment life, consider replacing.
6	HVAC sensor and gauges do not look to have been maintained or calibrated in some time.	Water Treatment Plant	Throughout	Calibrate sensors and replace defective sensors/gauges.
7	HVAC equipment throughout the plant appears to be on individual control thermostats/sensors.	Water Treatment Plant	Throughout	Consider adding an HVAC building automation system to control all of the HVAC equipment.
8	Horizontal sanitary storm drain piping (4-inch and larger) does not appear to have restraint support as required by Plumbing Code.	Water Treatment Plant	Throughout	Provide restraints at changes in directions on sanitary and storm drain piping 4-inch and larger.
9	Much of the drain, waste, and vent (DWV) and Storm Drawing piping looks to have been replaced in recent history with cast iron no-hub piping with no-hub couplings and PVC piping. For the most part, the CI piping looks to be in good shape. Couplings look to be stainless steel. Hangers and rods look to be galvanized steel. When plant is operational, consider chlorine corrosion effects on couplings and hangers.	Water Treatment Plant	Throughout	Consider coating hangers and couplings.
10	Restrooms are exhaust only. No supply air. Since the bulk of the plant does not have supply air, it is unclear where the makeup air is being transferred from.	Water Treatment Plant	Throughout	Provide air handling unit to provide makeup air to restrooms (or at least to adjacent areas).

Item No.	Finding	Building	Area in Plant	Recommendation
11	Air handling units (AHUs) that serve the Filter Gallery have ducted outside air and return air that are supposed to mix at the AHU, but observations of the rooftop air inlets suggest no outside air is being introduced (i.e., the AHUs are 100 percent return air).	Water Treatment Plant	Filter Gallery	Fix missing dampers to allow for minimum outside air to be mixed with return air going to the air handling unit.
12	Maintenance staff report leakage at some roof drains located above Filter Gallery	Water Treatment Plant	Filter Gallery	Repair or replace roof drain.
13	AHUs serving the Filter Gallery appear to be original to the building and are in need of replacement. AHUs may be undersized once water is reintroduced into the filters.	Water Treatment Plant	Behind the Filter Gallery	Replace AHUs.
14	Outside air intake hoods associated with filter gallery air handling units are showing signs of corrosion.	Water Treatment Plant	Roof above Filter Galleries	Replace outside air intake hoods.
15	Steam condensate pump drain pump/vent pipe in Filter Pipe gallery hot drainage in close proximity to a plastic chlorine pipe. The discharging of hot steam near the wall of the chemical pipe could affect the pipe integrity over time.	Water Treatment Plant	Pipe Gallery under Filter Gallery	Reroute hot discharge from steam condensate pump away from chlorine pipe, if chlorine piping is maintained.
16	No air changes are provided in filter pipe gallery.	Water Treatment Plant	Pipe Gallery under Filter Gallery	Provide fans to move air around.
17	Portable dehumidification units (DHUs) appear to not have been maintained. Many are rusting and appear to not have had filters changed in quite some time. It is questionable if the quantity of DHUs will be sufficient once water is reintroduced into the filter beds.	Water Treatment Plant	Pipe Gallery under Filter Gallery	Replace filters and perform required maintenance. Replace broken units with new units. Provide additional units to meet expected humidity levels.
18	The main corridor leading from the Filter Gallery to the rest of the plant has steam fin-tube radiators on both walls of the corridor, but one side of the radiators has been disconnected from the steam service.	Water Treatment Plant	Corridor near Filter Gallery	If additional heating is needed, consider reconnecting the steam service back to the radiators. Otherwise, consider removing the abandoned radiators.
19	The Polymer Pumping Room does not have any space heaters.	Water Treatment Plant	Polymer Pumping Room	If this room will continue to be used, consider providing unit heaters.
20	None of the water piping serving the laboratory (both in the lab and in the level below the lab) is insulated.	Water Treatment Plant	Laboratory	Insulate all water piping throughout (piping in room as well as runs in basement level).

Item No.	Finding	Building	Area in Plant	Recommendation
21	The deionized water system does not look to have been maintained in quite a while.	Water Treatment Plant	Laboratory	Replace water filters and other manufacturer required maintenance.
22	The roof drain in storage room where deionized water equipment is stored looks like it may have been leaking.	Water Treatment Plant	Laboratory	Repair or replace roof drain.
23	The floor drain located in the deionized water equipment room leaks to the lower level/basement below.	Water Treatment Plant	Laboratory	Fix/replace floor drain and seal pipe connections properly.
24	One of the chemical labs has a pipette washer that is connected to a laboratory faucet that only has a vacuum breaker. However, vacuum breakers are not adequate to provide backflow protection for the current connection configuration (AVBs are required to be installed a minimum of 6 inches above the fixture, but in this case the pipette washer inlet is much higher than the height of the AVB).	Water Treatment Plant	Laboratory	Consider providing greater backflow protection, such as using hose bib backflow preventers at the lab sink or provide a reduced pressure backflow preventer for the entire lab.
25	Acid storage cabinet does not appear to be properly vented/exhausted as required by Code.	Water Treatment Plant	Laboratory	Consider providing local exhaust in the vicinity of acid storage cabinet.
26	The drainage, waste, and vent (DWV) piping is cast iron. The p-traps at the lab sinks are showing signs of rusting. The lab waste connects directly to the sanitary waste (there are no acid neutralization tanks to treat the lab wasted first).	Water Treatment Plant	Laboratory	Consider replacing lab waste and vent piping with acid resistant piping. Consider providing under-counter and neutralization basins.
27	The water heater serving the laboratory (and kitchen) does not have a thermal expansion tank. The hot water piping is not insulated. The system is designed with a hot water recirculation system, but could not locate the recirculation pump. Dielectric union at the water heater is showing signs of corrosion.	Water Treatment Plant	Laboratory	Install thermal expansion tank. Insulate hot water piping. Provide hot water recirculation pump (if none exist). Change out dielectric fitting with new.
28	The starter for the laboratory general exhaust fan is in the “off” position. The design drawings indicate the general exhaust fan is to be on, so it is unclear why the fan is turned off.	Water Treatment Plant	Laboratory	If laboratory general exhaust fan is operational, turn it on (confirm if belts need to be changed). If it is not operational, repair or replace fan.

Item No.	Finding	Building	Area in Plant	Recommendation
29	The door at the Wet Lab is always opened and a portable fan is being used. Suspect low air flow is being provided to the lab.	Water Treatment Plant	Laboratory	Rebalance air flows to the wet lab to provide design air flow rates.
30	Rooftop supply air fan serving the fume hood does not have an air filter, which could allow outdoor contaminants and duct to enter the laboratory/fume hood.	Water Treatment Plant	Lower Roof above Labs	Modify the ductwork associated with the supply fan at the roof to allow for an air filter to be installed.
31	Laboratory fume hood stacks appear to be too close to operable windows than what is permitted in Code.	Water Treatment Plant	Lower Roof above Labs	Consider extending the heights of the fume hood exhaust stacks or use an engineered air fume exhaust system (such as is made by Strobic Air) to discharge the fume hood exhaust high above the operable windows.
32	Laboratory fume hood makeup air intake is located closer to sanitary vent stack than what is permitted in Code.	Water Treatment Plant	Lower Roof above Labs	Relocate sanitary vent termination through the roof.
33	The emergency eyewash is served off of the same protected water branch water piping that also serves the wash hose stations. Code requires emergency fixtures to be served from potable water, which on the current installation is questionable (as a backflow condition on the wash hose stations allows contaminants to be discharged at the emergency fixture outlet).	Water Treatment Plant	Boiler Room	Provide separate potable water (tempered) for emergency eyewash.
34	It appears that maintenance on the boilers and accessories has not been kept up.	Water Treatment Plant	Boiler Room	Provide manufacturer required maintenance on boiler, chemical feeder, water softener, and other accessories.
35	Lower combustion air louver at boiler room is blocked off with cardboard. Suspect it was done to prevent cold air from entering the boiler room and freezing pipes.	Water Treatment Plant	Boiler Room	Either relocate the combustion air louver to a better location or provide a unit heater in the vicinity of the louver to temper the air coming in.
36	Steam boiler has discharge going to a funnel drain on the condensate pipe (located near the side of the boiler) in the immediate vicinity of the natural gas piping. The hot condensate steam cloud, which is near the gas pipe, could overtime affect the pipe integrity.	Water Treatment Plant	Boiler Room	Reroute discharge pipe and funnel drain to not discharge near gas piping.

Item No.	Finding	Building	Area in Plant	Recommendation
37	No HVAC system serves the Cafeteria/Kitchen. There is an old exhaust fan located above the drop down ceiling (from when this space served a different function), but this is only effective in drawing in tempered air from the adjacent corridor and only if the ceiling tiles are removed.	Water Treatment Plant	Cafeteria and Kitchen	Provide an air handling unit to serve the Cafeteria and Kitchen. Remove the exhaust fan.
38	Kitchen sink does not appear to have a plumbing vent.	Water Treatment Plant	Kitchen	Provide a plumbing vent.
39	No ventilation or exhaust air provided to the Janitor Supply Closet.	Water Treatment Plant	Janitor Supply Closet	Provide exhaust fan.
40	Hot water piping at the water heater and to areas served (janitor sink, restrooms, and showers) is not insulated. No thermal expansion tank provided for water heater.	Water Treatment Plant	Janitor Supply Closet	Insulate all water piping. Provide thermal expansion tank.
41	The janitor sink has a hose connected to the faucet, but the faucet does not have a backflow preventer.	Water Treatment Plant	Janitor Supply Closet	Provide a backflow preventer at the janitor sink faucet.
42	Electric water cooler (located near janitor room) appears to be aged beyond expected equipment life.	Water Treatment Plant	Outside of Janitor Room	Replace water cooler and associated water filter.
43	P-traps at restrooms improperly installed. Current installation is essentially an 'S-Trap' which is not allowed in the Plumbing Code.	Water Treatment Plant	Women's Restroom / Lockers	Re-pipe the restroom p-traps.
44	Hot water piping is not insulated.	Water Treatment Plant	Women's Restroom / Lockers	Insulate all water piping.
45	Exhaust fan serving restroom was not operating during this visit.	Water Treatment Plant	Women's Restroom / Lockers	If fan is operational, replace belts and turn on. If not, replace the fan.
46	Sanitary waste pipe is running above electrical switchgear, which is an Electrical Code violation.	Water Treatment Plant	Electrical Room below Men's Lockers	Reroute sanitary drain piping.
47	Water heater serving Women's Restroom / Lockers does not have thermal expansion tank. Hot water piping is not insulated.	Water Treatment Plant	Electrical Room below Women's Lockers	Provide thermal expansion tank. Insulate all water piping.
48	Water heater (located below Women's Restroom at Filter Gallery) does not have thermal expansion tank. Likewise, hot water piping is not insulated.	Water Treatment Plant	Below Women's Restroom	Provide thermal expansion tank. Insulate all water piping.

Item No.	Finding	Building	Area in Plant	Recommendation
49	The Emergency Eyewash is served off of the same protected water branch piping that also serves the wash hose stations. Code requires emergency fixtures to be served from potable water, which on this current installation is questionable (as a backflow condition on the wash hose stations could allow contaminants to be discharged at the emergency fixture outlet). Additionally, this water does not appear to be tepid.	Water Treatment Plant	Primary Clarifiers	Provide separate potable water (tempered) for emergency eyewash.
50	The front office spaces are served with ductless split system air conditioning units, but these units do not provide ventilation air. The room does appear to have operable windows.	Water Treatment Plant	Front Office	Consider replacing the ductless split system units with air handling units that can provide ventilation air.
51	The split system air handling unit originally designed to serve a large SCADA room now serves as an Operator Room and SCADA server room. Temperature requirements for the SCADA server room may be different than the operator's room. Steam and condensate piping to AHU not insulated.	Water Treatment Plant	Operator and SCADA Rooms	Consider providing a separate air conditioning unit to the SCADA room. Insulate steam piping.
52	Kiosk/office in Slow Mix area does not have ventilation air.	Water Treatment Plant	Slow Mix Area	Provide tempered ventilation air.
53	Outside air intake damper is missing motorized damper actuator.	Electrical Substation	Electrical Substation	Provide motorized damper actuator.
54	HVAC air handling units, makeup air units, supply air fans, exhaust fans, etc., do not look to have been maintained.	Ozone Building	Throughout	Where reusing HVAC equipment, replace belts, change filters, and perform other manufacturer recommended procedures.
55	According to maintenance, the building automation system controls for this building (which controls the operation of the dehumidification air handling units, makeup air units, exhaust fans, and emergency ventilation) has never worked as designed.	Ozone Building	Throughout	Either fix the existing controls to operate as originally designed or replace with new robust controls system.
56	HVAC sensors and gauges do not look to have been maintained.	Ozone Building	Throughout	Calibrate sensors and replace defective sensors/gauges.

Item No.	Finding	Building	Area in Plant	Recommendation
57	Outside air intake louvers have no means to provide filters, which could allow outdoor dust to enter the building when the louvers are opened.	Ozone Building	1st Floor	Modify louver outlet to allow for changeable air filters.
58	Proximity of outside air intake louvers is close to process piping. According to maintenance, this has caused freezing in the winter when the louver is opened.	Ozone Building	1st Floor	Consider relocating outside air louver directing the air away from the process piping.
59	Because of large process pipes in the vicinity, not all exhaust fans are accessible for maintenance.	Ozone Building	1st Floor	Relocate exhaust fans or provide means to make the fans accessible.
60	The Emergency Shower/Eyewash is served off of the same protected water branch water piping that also serves the wash hose stations and process equipment. Code requires emergency fixtures to be served from potable water, which on the current installation is questionable (as a backflow condition on the wash hose stations or process equipment could allow contaminants to be discharged at the emergency fixture outlet). Also, this water does not appear to be tepid, as required by Code.	Ozone Building	1st Floor	Re-pipe emergency fixture to be fed from potable water. Provide tempered water.
61	Water heater in Janitor Room does not have a thermal expansion tank.	Ozone Building	2nd Floor Janitor Room	Install thermal expansion tank.
62	Motorized damper at makeup air unit supply outlet is not operating (it is currently stuck in the opened position).	Ozone Building	2nd Floor	Replace motorized damper actuator.

END OF TECHNICAL MEMORANDUM

Appendix E

Electrical Conditions Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *Robert Magsipoc, CDM Smith*

Date: *January 13, 2017*

Subject: *Electrical Conditions Assessment*

Introduction

This section summarizes the existing conditions of the electrical system for the Flint Water Treatment Plant (WTP) as observed in January 2017. This section also documents any code violations associated with the National Electric Code (NEC), National Fire Alarm Signaling Code (NFPA 72), Life Safety Code (NFPA 101), with recommended upgrades and improvements to the electrical system.

Note: This report does not include assessment of the Raw Water Pump Station (PS4), Control Stations CS2, CS3& CS5 and the Electrical/Maintenance Facility (EMF).

Existing Conditions

Overall Electrical System

Existing Overall Electrical System

Electrical power to the Flint WTP is currently provided by Consumers Electric Power (CEP) via two 46kV overhead lines from two independent Utility substations. The 46kV lines terminate at two Plant-owned 3500kVA, 46kV-2400V transformers located outdoors adjacent to the WTP main electrical room called "Electrical Substation". The transformers feed a 1200A, 2400V double-ended Main Switchgear with an electric-interlocked main-tie-tie-main configuration located within the Substation. Feeders from the Main Switchgear are distributed radially from the Substation to 2400V-480V transformers located throughout the WTP and one 2400V PS4 Switchgear in the Raw Water Pump Station (PS4). The Plant overall electrical distribution system is shown on Figure 1.

The highest power usage peak demand for the WTP while in full operation over the past 24 months is 1,714kVA, which was recorded on February 27, 2015. This data was provided by CEP on January 6, 2017.

Reliability and Conditions of Existing Electrical System

The reliability of the electrical distribution system is of paramount importance. For that reason, redundant electrical services, service transformers and double-ended distribution switchgears installed at the WTP.

As indicated above, the WTP is fed from two independent utility substations to a double-ended Switchgear. The Main Switchgear is constructed in a main-tie-tie-main configuration with each side normally supplying power to approximately half the facility loads. In the event a feeder or substation transformer is out of service, all the loads serviced by the Main Switchgear will be powered via one transformer and the Utility feeder. The Main Switchgear main circuit breakers are normally closed and the tie circuit breakers are normally open. Additionally, the downstream switchgears feeding the critical loads are main-tie main configured and dual fed. This redundancy in the main electrical distribution system for the WTP provides reliability to maintain plant operations.

Although the switchgears are dual fed, the MCCs throughout the WTP are single fed, which leaves them susceptible to a common mode failure. The term “common mode failure” is an industry term used to identify a point in the electrical distribution system where a single failure will result in the disruption of the electrical power to that load.

For critical equipment, it is highly recommended for MCCs to be dual fed and power panelboards to be fed from an automatic transfer switch (ATS) to lower the risk of losing power for plant operations. Each MCC or power panelboard feeding a large section of the WTP is evaluated individually in the body of this report. The proposed overall electrical distribution system is shown on Figure 2.

The average useful life of the electrical equipment including cables is approximately 25-30 years. All MCCs, switchgears, and outdoor 2400-480V transformers for the WTP were installed between 1999-2002 or a part of the 2014 upgrade and are all within their average useful life and are in good condition.

Electrical Substation

Existing Electrical System

Existing electrical service to the Electrical Substation is suppled from two Consumer Electric Power 46kV overhead lines via two separate and independent utility-owned substations. The 46kV lines drop down to two outdoor Plant-owned 3500kVA, 46kV-2400V, FR3 oil-filled transformers. The secondary lines (2400V) form the transformers are routed underground to the adjacent Electrical Substation building to a 1200A, 2400V Main Switchgear. The Main Switchgear feeds the Plant 2, Pump Station PS 4 (Raw Water Building), Old Building and Grounds (B&G) Room, Electrical/ Maintenance Facility (EMF), Ozone Building and Substation/Control Station (CS2, CS3 &CS5) Buildings.

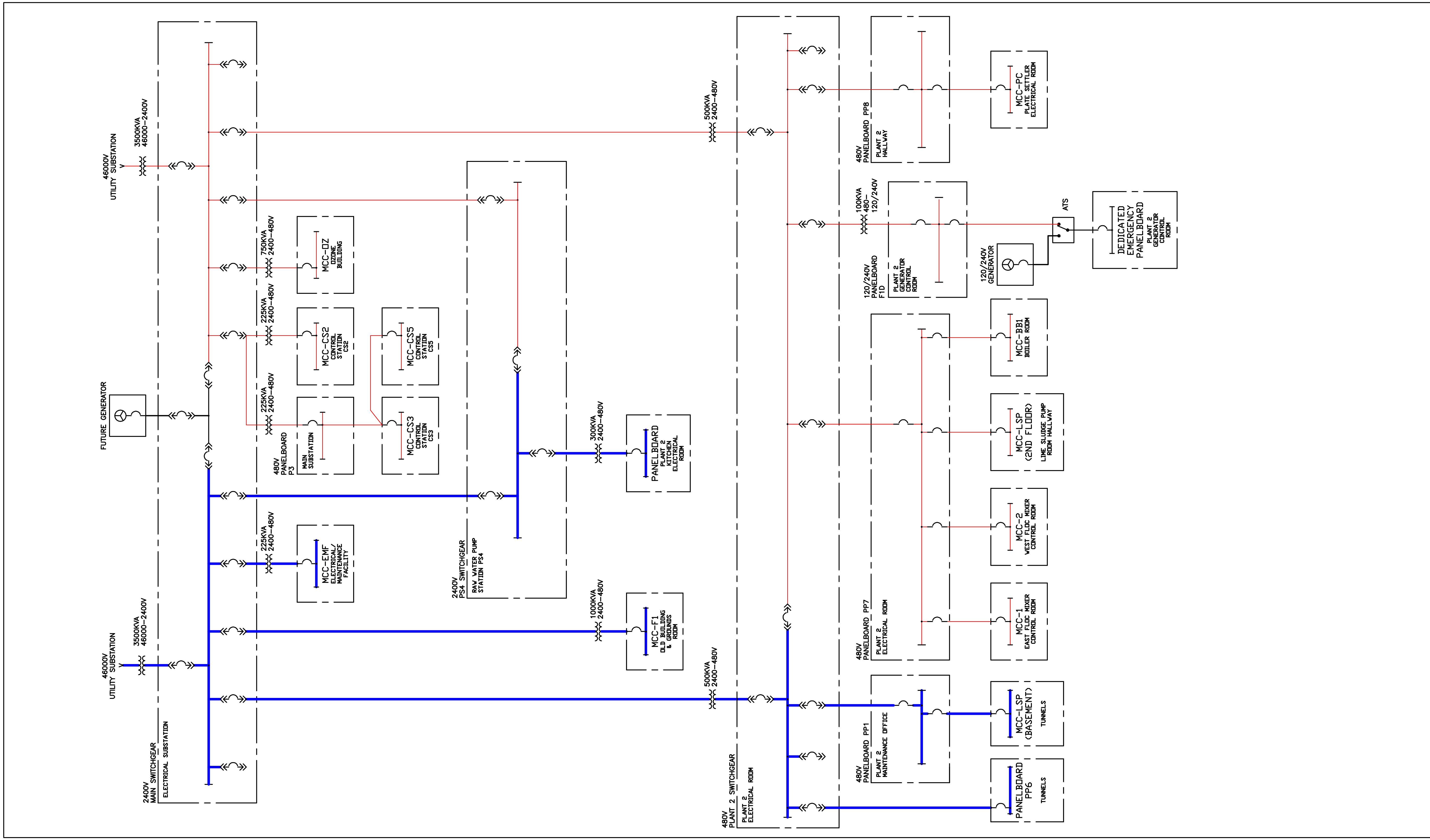


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FIGURE NO. 1
EXISTING ELECTRICAL DISTRIBUTION ONE-LINE DIAGRAM
01/27/17

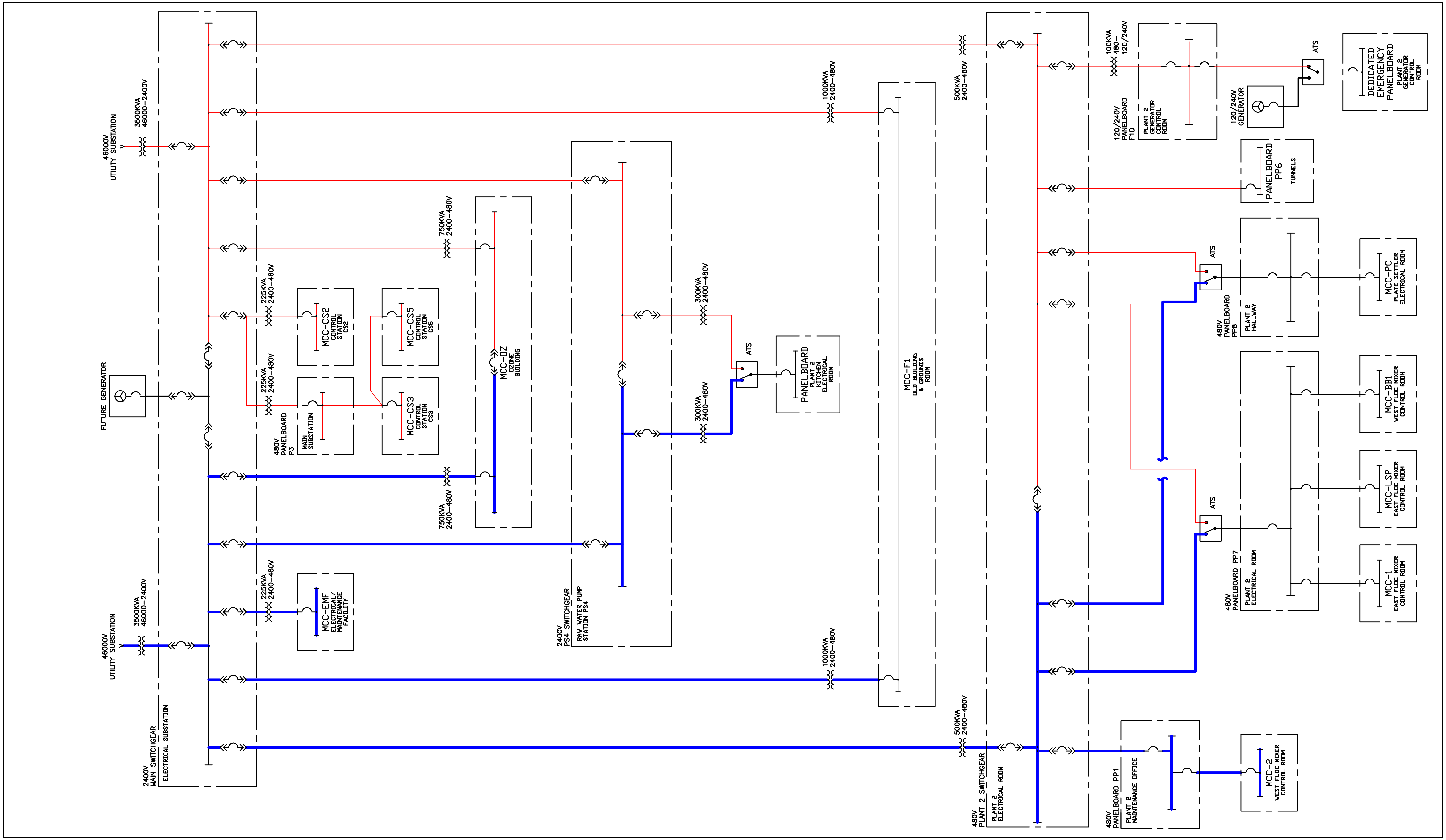


FIGURE NO. 2
PROPOSED ELECTRICAL DISTRIBUTION ONE-LINE DIAGRAM
01/27/17

The Main Switchgear is made by Eaton and has an EATON PXM 2000 power quality meter in each circuit breaker bucket compartment.

Miscellaneous loads within the Electrical Substation are fed from a 225kVA, 2400-480V transformer located within the Electrical Substation for Control Station CS3 and CS5, and one 15kVA 480-208/120V transformer and panelboard for lighting, general receptacles, and other miscellaneous loads.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for the Electrical Substation is dual fed from the electric utility. The existing Main Switchgear is retrofitted with a future generator connection between the tie circuit breakers. Since the two Utility feeds are supplied from independent Utility Substations, the redundancy and reliability of the WTP main electrical distribution is satisfactory. In the event a feeder or substation transformer is out of service, all the loads serviced will be powered via one transformer and Utility feeder; this provides a reliable electrical system and minimizes the need for a future standby generator.

The Electrical Substation was installed as part of an electric upgrade in 2014 with an EATON VacClad-W Metal-Clad Switchgear. The two existing 225kVA, 2400V-480V transformers for Control Stations CS2, CS3, and CS5 were installed as part of a facility upgrade in 2000. Overall, the electrical equipment within the Electrical Substation is in good condition. However, it is worth mentioning that the electrical equipment not labeled with arc flash hazard category and appropriate personal protection equipment (PPE) to be used as required by NEC.

NFPA 70 (NEC) and NFPA 70E require arc flash labels on all electrical equipment to assure personnel working on or in close proximity of the electrical equipment are aware of potential arc flash hazards. Arc flash labels define the arc flash hazard category and appropriate personal protection equipment (PPE) to be used when maintaining or interacting with the electrical equipment.

Recommended Upgrades

- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.

Plant-Owned 3500kVA, 46-k-2400V Transformers

Main Switchgear

225kVA Transformer across the Main Switchgear

Main Switchgear Bucket Missing Arc Flash Label

Ozone Building

Existing Electrical System

The existing electrical service to Ozone Building is supplied from underground lines running from the Main Substation to an outdoor oil-filled 2400-480V, 3-phase pad-mounted transformer on the east side of the Ozone Building. The secondary feeders from the transformer to the building are routed underground to 1200A standalone main circuit breaker then to a single ended 1200, 480V, 3-phase motor control center (MCC-OZ).

Low voltage process loads and miscellaneous loads are fed from the motor control center. One 480V-208/120V transformer, one 208/120V panelboard, one 480-240/120V transformer, and one 240/120V panelboard provide power for additional miscellaneous loads including lighting, HVAC and general receptacles. The 208/120V panelboard feeds a UPS for the Ozone and LOX control panels and monitoring.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for the Ozone Building is provided via a single feed from the 2400V Main Switchgear routed underground with no alternate power source. This leaves the electrical system susceptible to common mode failures, where a single failure in the incoming power lines will result in the complete loss of power to the facility. Additionally, the MCC is single ended and a failure in this MCC will disrupt power to the entire facility.

The electrical equipment in the Ozone Building was not included during the 2014 electrical upgrade and the existing equipment for the building was installed in 2002. The MCC is by Square D Model 6 and is provided with a surge protective device and power quality meter that can only be monitored locally. The MCC and panelboards are located in dedicated electrical rooms, are in good condition and the electrical system for the Ozone Building has the capacity for future expansion physically and electrically.

The following concerns were observed during the January 2017 site visit:

- The Ozone Building is fed from a single feeder from the Main Switchgear.
- The existing MCC does not match the MCCs replaced during the electrical renovation in 2014 and does not have the IntelliCENTER communicating capabilities for when the WTP will be upgraded.
- Lack of emergency egress lighting and exit signs within the Ozone Building hallways and stairwells.
- Electrical equipment not labeled with arc flash hazard category and appropriate personal protection equipment (PPE) to be used as required by NEC.

Recommended Upgrades

- Install a second transformer and feeder from the Main Switchgear.
- Replace the existing Square D MCC with a dual-fed main-tie-main MCC.
  - It is recommended that the new MCC to be Allen-Bradley IntelliCENTER MCC with power quality metering, surge protection, and fiber optic communicating capabilities to match the MCCs from the 2014 upgrade.
- Provide emergency egress lighting and exit signs in compliance with NFPA 101.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.

MCC-OZ External Main Circuit Breaker

MCC-OZ Power Quality Monitor

Single Transformer Feeding the Ozone Building

Panelboards and UPS

Plant #2 – Switchgear Room and Generator Controls Room

Existing Electrical System

The existing electrical service to Plant #2 – Electrical Room is supplied from two underground lines routed from the Main Substation to two outdoor 500kVA, 2400-480V, 3-phase, oil-filled pad-mounted transformer on the east side of the Plant #2. The secondary feeds from the transformer to the building are routed underground to a double-ended 800A, 480V, 3-phase electrically-interlocked main-tie-main EATON Magnum DS Metal-Enclosed LV Switchgear. Feeders from the switchgear feed multiple panelboards located throughout the Plant 2. The switchgear contains EATON PXM 2000 Power Quality Meters, and surge protective devices for both busses on either side of the tie circuit breaker. The two transformers and the switchgear were part of the 2014 electrical upgrade of the WTP and are in good condition.

Additionally, a small natural gas emergency generator is located outdoors serving the building emergency egress lighting and the operator's SCADA workstation via an Automatic Transfer Switch and dedicated emergency panelboards. Plant staff have indicated that due to the redundancy of the upstream power supply, the generator for Plant #2 hasn't been used for its intended purpose since its installation in 2002. The staff exercises the generator once per year for four hours and have not had any issues with starting the generator, however plant staff have not verified that the lights on the emergency panelboard circuits are working properly. The generator, automatic transfer switch, and one emergency lighting panelboard were part of the 2002 upgrade and are in good condition.

The LV Switchgear feeds the following electrical distribution equipment:

- Panelboard PP7 – 400A, 480V, 3 Phase.
- Panelboard PP1 – 400A, 480V/277V, 4 Phase.

- Panelboard PP8 – 400A, 480V, 3 Phase.
- Panelboard PP6 – 225A, 480V, 3 Phase.
- 100kVA, 480-120/240V, Single Phase Transformer to power Main Lighting Distribution Panelboard F1D, 600A, 120/240V, Single Phase.

Panelboard PP-7 feeds the East Flocculation Mixers (MCC-1), West Flocculation Mixers (MCC-2), Lime Sludge Pump System (MCC-LSP 2ND FLOOR), and Boiler Room (MCC-BB1). Panelboard PP-1 feeds Lime Sludge Pump System (MCC-LSP BASEMENT), the elevator, panelboards, and miscellaneous HVAC loads. Panelboard PP8 feeds the Plate Settlers (MCC-PC) and miscellaneous loads. Panelboard PP6 feeds Sump Pumps and miscellaneous loads in the tunnels. Main Lighting Distribution Panelboard F1D feeds the site lighting and lighting panelboards.

Reliability and Conditions of Existing Electrical System

The LV Switchgear is dual fed from the Main Switchgear located in the Electrical Substation Building and has a main-tie-main configuration to provide redundancy. The feeder circuit breakers to the panelboards and MCCs located throughout the WTP contain a single feeder from this LV Switchgear with no alternate power source. This leaves the downstream electrical system susceptible to common mode failures, where a single failure in the incoming power to any of these panelboards and MCCs will result in the complete loss of power to the that equipment. Additionally, the panelboards and MCCs are single ended and a failure in the panelboards and MCCs will disrupt power to the area they are feeding.

The following concerns were observed during the January 2017 site visit:

- Panelboard PP7 feeds four MCCs located throughout Plant 2 and has only one feed from the LV Switchgear.
- Generator does not have a weatherproof enclosure to protect it from the weather.
- Equipment are not labeled with stickers indicating the last time they have been maintained or serviced.
- Panelboard Schedules within the panelboard doors are blank, handwritten, or not kept up-to-date.
- Dedicated emergency panelboards are not properly labeled to indicate that only emergency loads may be fed from the panelboards.
- LV Switchgear has handles for rear access however the working distance to the wall is insufficient at 21 inches.
- Lack of emergency lighting and exit signs within the Plant 2 hallways and stairwells.

- It is not clear of the emergency lights are functional or properly light the path of egress.
- Electrical equipment not labeled with arc flash hazard category and appropriate personal protection equipment (PPE) to be used as required by NEC.
- There is a sanitary waste pipe from the locker rooms located directly above the Electrical Room that travel across the top of the LV Switchgear. The sanitation line violates the NEC for dedicated electrical space above equipment and is also a hazard if the line leaks, breaks, or creates condensation.

Recommended Upgrades

- Provide a second circuit breaker feeder and an ATS in the Plant #2 Electrical Room to feed Panelboard PP7.
- Provide a weatherproof enclosure for the emergency generator.
- Place maintenance and service stickers on all electrical equipment to indicate the month and year of when it was completed and the name of the person who completed the maintenance.
- Update all panelboard schedules with typewritten loads that are fed from the panelboards.
- Label the panelboards that are fed from the emergency generator as dedicated emergency only loads.
- Provide emergency lighting and exit signs in compliance with NFPA 101.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.
- Relocate the sanitary waste pipe from being above the sanitation line to the walkway.
    - An alternative is to concrete-encase the sanitation lines to convert the room into a dedicated electrical room.

Plant #2 – 2400-480V Transformers

Plant #2 Switchgear

Locker Room Sanitation Line Directly Above Switchgear

Generator Automatic Transfer Switch and Unlabeled Emergency Lighting Panelboard

Improper Exit Sign

Blank Panelboard Schedule

Plant #2 – Old Building & Grounds (B&G) Room and Filter Tunnels

Existing Electrical System

The existing electrical service Old B&G Room, located in the southwest corner of Plant 2, is supplied via a single underground feeder from the Main Substation to an indoor 1000kVA, 2400-480/277V dry-type Transformer and 1200A, 480V, 3-phase single-ended motor control center (MCC-F1) located within the Old B&G Room. The Old B&G MCC feeds the filter valves, filter drain pit pumps, and backwash blowers.

The 2400-480/277V transformer is an insulated dry-type transformer manufactured by Square D, was a part of the 2002 upgrade, and is in good condition. The MCC is an Allen-Bradley IntelliCENTER Centerline 2100 provided with power quality meter PowerMonitor 5000, was a part of the 2014 upgrade, and is in good condition, however it does not have surge protection.

Miscellaneous loads within the Old B&G Room, the Blower Room, and the Filters are fed from a 75kVA, 480-208/120V transformer and panelboard for lighting, general receptacles, and other miscellaneous loads.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for the Old B&G Room is provided via a single feed from the 2400V Main Switchgear routed underground with no alternate power source. This leaves the electrical system susceptible to common mode failures, where a single failure in the incoming power lines will result in the complete loss of power to the filters and backwash blowers. Additionally, the MCC is single ended and a failure in this MCC will disrupt power to the entire area.

The conduits and valves in the Filter Valve tunnel are in fair condition; however, several process pipes show signs of leakage onto the filter instruments.

The following concerns were observed during the January 2017 site visit:

- The Old B&G Room is fed from a single feeder from the Main Switchgear.
- Equipment are not labeled with stickers indicating the last time they have been maintained or serviced.
- Electrical equipment not labeled with arc flash hazard category and appropriate PPE to be used as required by NEC.
- Backwash Air Valve Control Panels and Drain Valve Control Panels are located at the valves. To operate the valves manually (locally) would involve entering the pipe gallery.

Recommended Upgrades

- Provide a second transformer to feed MCC-F1 and provide a second feed from Main Switchgear.

- Upgrade MCC-F1 to include a second main to provide redundancy.
- Place maintenance and service stickers on all electrical equipment to indicate the month and year of when it was completed and the name of the person who completed the maintenance.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.
- Relocate Backwash Air Valve and Drain Valve Control Panels remotely along the walkway to ease of access.

Single Transformer Feeding MCC-F1

Old B&G Motor Control Center (MCC-F1)

Instruments in Filter Pipe Gallery Below Leaking Process Pipes

Valve Control Panel Located in Pipe Gallery without Ease of Access for Manual Controls

Plant #2 – Office, Conference Room, Kitchen, Operations Room, and Associated Feeders

Existing Electrical System

The existing electrical service to Plant #2 – Offices and Conference Room is located on the southeast side of Plant #2 and is supplied via a single underground service from the Raw Water Pump Station (PS4) Switchgear to a disconnect switch located in the Filter Tunnels in the basement. Feeders from the disconnect switch are routed to an indoor 300kVA, 2400-480/277V dry-type Transformer, that feeds a 400A, 480V, 3-phase panelboard. A 100kVA, 480V-120/240V transformer powers a lighting panelboard for miscellaneous loads, all located in the Kitchen Electrical Room.

The electrical equipment in the Kitchen Electrical Room was installed in 1989 and appears to be in good condition.

The 2400-480/277V Transformer Disconnect Switch located in the Filter Tunnels is part of the installation in 1989 and was last serviced in April 2011. The Disconnect Switch is in a wet area and the footings and top of the enclosures are corroded. The telephone backboards, associated conduit, and junction boxes are also wet and corroded. All equipment in this area are in poor condition.

Reliability and Conditions of Existing Electrical System

The Raw Water Pump Station (PS4) is dual fed from the Main Switchgear located in the Substation Building and has a Main-Tie-Main configuration to provide redundancy. A single feeder is routed underground to the Kitchen Electrical Room transformer with no alternate power source. This leaves the downstream electrical system susceptible to common mode failures, where a single failure in the incoming power lines will result in the complete loss of power to the office, conference room, and kitchen.

The following concerns were observed during the January 2017 site visit:

- The disconnect switch is highly corroded and is not in an environment suitable for that type of equipment or enclosure type.
- The telecom equipment in the basement is not in an environment suitable for that type of equipment.
- The Kitchen Electrical Room is fed from a single feeder from PS4 Switchgear.
- Equipment are not labeled with stickers indicating the last time they have been maintained or serviced.
- Panelboard Schedules within the panelboard doors are blank, handwritten, or not kept up-to-date.
- Proper exit signs for correct path of egress are missing from the Office, Conference Room, and Kitchen.
- Electrical equipment not labeled with arc flash hazard category and appropriate PPE to be used as required by NEC.
- Dedicated electrical room is improperly being used as storage.

Recommended Upgrades

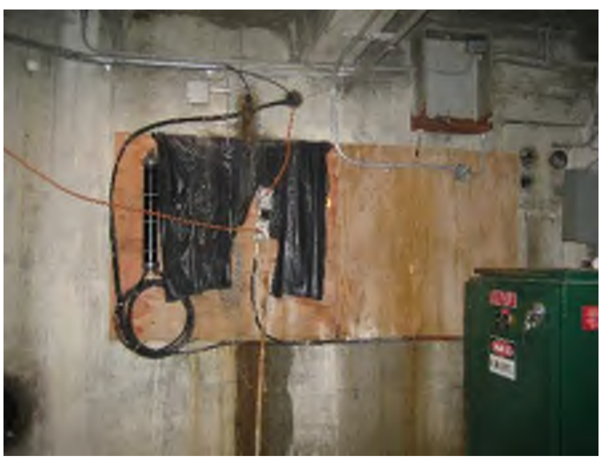
- Replace and relocate the disconnect switch to a dedicated electrical room that is environmentally controlled. This will reduce the amount of corrosion and extend the life expectancy for the electrical equipment.
- Replace and relocate the telecom equipment to a dedicated electrical room that is environmentally controlled.
- Install a second transformer and an ATS to feed the panelboards in the Kitchen Electrical Room.
- Place maintenance and service stickers on all electrical equipment to indicate the month and year of when it was completed and the name of the person who completed the maintenance.

- Update all panelboard schedules with typewritten loads that are fed from the panelboards.
- Provide exit signs in compliance with NFPA 101.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.
- Remove items being stored in the electrical room and place label on the door indicated that only authorized personnel shall be permitted in the room.

Single Transformer Feeding the Kitchen Electrical Room

Kitchen Electrical Room 2400-480V/277V Transformer Disconnect Switch in Basement – Corroded Footings

Kitchen Electrical Room 2400-480V/277V Transformer Disconnect Switch in Basement – Corroded Top of Enclosure



Wet and Corroded Telephone Backboard in Basement Below Kitchen Electrical Room

Telephone Backboard in Basement Below Kitchen Electrical Room

Plant #2 – Flocculation Mixer and Clarifier System

Existing Electrical System

The existing electrical service to Plant #2 – Flocculation Mixer Systems is supplied by two Allen-Bradley IntelliCENTER 2100 motor control centers (MCC-1 and MCC-2) located on the first floor. The 200A, 480V, MCC-1 is located in the West Floc Mixer Control Room and the 200A, 480V, MCC-2 located in the East Floc Mixer Control Room. The motor control centers are each supplied via a single underground service from the Plant #2 Switchgear and Panelboard PP7 in the Plant 2 Electrical Room. The MCCs feed the mixers and the clarifiers and 480-208/120V transformers & 208/120 panelboards lighting, general receptacles, and other miscellaneous loads.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for both MCCs for the flocculation mixer systems are provided via a single feed from the Plant #2 Switchgear routed underground. The flocculation mixer systems are redundant with half the mixers and clarifiers fed from MCC-1 and half of the mixers and clarifiers fed from MCC-2. The MCCs were a part of the upgrade in 2014 and are in good condition.

The following concerns were observed during the January 2017 site visit:

- Equipment are not labeled with stickers indicating the last time they have been maintained or serviced.
- Although loads for this area are distributed over two MCCs, the MCC are fed from a common source with a single feed from LV Switchgear.
- Electrical equipment not labeled with arc flash hazard category and appropriate personal protection equipment (PPE) to be used as required by NEC.
- No surge protection for the motor control centers.
- Power System Study for the WTP was performed prior to the 2014 upgrades. An updated Study has not been completed since the installation.

Recommended Upgrades

- Place maintenance and service stickers on all electrical equipment to indicate the month and year of when it was completed and the name of the person who completed the maintenance.
- Relocate the feeds for MCC-2 from PP7 to PP1 to provide redundancy from a separate source.
- Provide surge protective devices for the motor control centers.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.

MCC-1 (West Floc Mixer Control Room)

Floc Mixer/Clarifier Hallway with Inadequate Emergency Lighting & Exit Signs

Plant #2 – Boiler System

Existing Electrical System

The existing electrical service to Plant #2 – Boiler System is supplied by a Square D Model 6 motor control centers (MCC-BB1) located in the Boiler Room on the first floor. The 200A, 480V, MCC-BB1 is fed from a single underground service from the Plant 2 LV Switchgear via Panelboard PP7 in the Plant 2 Electrical Room. The MCC feeds the boilers and 480-208/120V transformers & 208/120 panelboards for lighting, general receptacles, and other miscellaneous loads.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for MCC-BB1 for the boiler system is provided via a single feed from the Plant #2 Switchgear routed underground with no alternate power source. This leaves the electrical system susceptible to common mode failures, where a single failure in the incoming power lines will result in the complete loss of power to the lime system. Additionally, the MCC is single ended and a failure in this MCC will disrupt power to the entire area. The operational staff at the WTP have indicated that the boiler system does not feed any critical equipment that will require any additional redundancy than what is already installed at the Plant.

The MCC-BB1 was installed as a part of the upgrade in 2002 and is in good condition.

The following concerns were observed during the January 2017 site visit:

- The existing MCC does not match the MCCs replaced during the electrical renovation in 2014 and does not have the IntelliCENTER communicating capabilities for when the WTP will be upgraded.
- Electrical equipment not labeled with arc flash hazard category and appropriate PPE to be used as required by NEC.

- The luminaries in the basement area are not easily accessible due to the mechanical equipment and height of the luminaries.
- Equipment are not labeled with stickers indicating the last time they have been maintained or serviced.
- No surge protection for the motor control centers.

Recommended Upgrades

- Replace the existing Square D MCC with an Allen-Bradley IntelliCENTER MCC with power quality metering, surge protection, and fiber optic communicating capabilities to match the MCCs from the 2014 upgrade.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.
- Provide surge protection devices for the motor control centers.

Square D MCC-BB1 that was not Updated with Allen-Bradley in 2014

Luminaries that are not Easily Accessible Due to Height and Process Equipment

Plant #2 – Plate Settler System

Existing Electrical System

The existing electrical service to Plant #2 – Plate Settler System is supplied by an Allen-Bradley IntelliCENTER Centerline 2100 motor control center (MCC-PC) with AB PowerMonitor 5000 located in the Plate Settler Room on the first floor. The 600A, 480V, MCC-BB1 is fed from a single underground service from the Plant #2 LV Switchgear in the Plant #2 Electrical Room via Panelboard PP8 in the Plant #2 Hallway. The MCC feeds the plate settlers and 480-208/120V transformers & 208/120 panelboards for lighting, general receptacles, and other miscellaneous loads.

Reliability and Conditions of Existing Electrical System

As described above, electrical power for MCC-PC for the plate settler system is provided via a single feed from the Plant #2 LV Switchgear routed underground with no alternate power source. This leaves the electrical system susceptible to common mode failures, where a single failure in the incoming power lines will result in the complete loss of power to the lime system. Additionally, the MCC is single ended and a failure in this MCC will disrupt power to the entire area.

The electrical equipment in this area was installed as a part of the upgrade in 2014 and is in good condition.

The following concerns were observed during the January 2017 site visit:

- Panelboard PP8 feeds MCC-PC and has only one feed from the LV Switchgear.
- MCC bucket labels are blank.
- Electrical equipment not labeled with arc flash hazard category and appropriate PPE to be used as required by NEC.
- Equipment not labeled with stickers indicating the last time they have been maintained or serviced.
- No surge protection for the motor control centers.

Recommended Upgrades

- Provide a secondary feeder from LV Switchgear and provide an ATS to feed Panelboard PP8.
- Update MCC labels to indicate the equipment that the buckets are feeding.
- Perform power system study, including short circuit, coordination, protective device, and arc flash studies. Provide arc flash labeling in accordance with the latest version of NFPA 70E, Electrical Safety in the Workplace.

- Place maintenance and service stickers on all electrical equipment to indicate the month and year of when it was completed and the name of the person who completed the maintenance.
- Provide surge protective devices for the motor control center.

MCC-PC with Blank Labels

END OF TECHNICAL MEMORANDUM

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Appendix F

SCADA and Instruments Assessment Technical Memorandum

Technical Memorandum

To: *File*

From: *Saed Hussain, CDM Smith*

Date: *January 13, 2017*

Subject: *SCADA and Instruments Assessment*

Introduction

This technical memorandum provides an overview of the existing SCADA system and instruments at the Flint Water Treatment Plant (WTP), summarizes the existing conditions, and provides recommendations for future improvements.

Existing Conditions

The WTP is currently monitored and controlled by a Supervisory Control and Data Acquisition (SCADA) system consisting of three main components, along with the communication medium that passes data between them:

- Human Machine Interface (HMI).
- Programmable Logic Controllers (PLC) located in 18 control panels at the plant and five control panels at remote sites.
- AT&T Cellular Modem connecting the remote sites to the plant SCADA system.

An overview of each of these subsystems is provided hereunder along with a description of any deficiencies that have been identified in each area during site inspections conducted with operational staff on January 4, 2017.

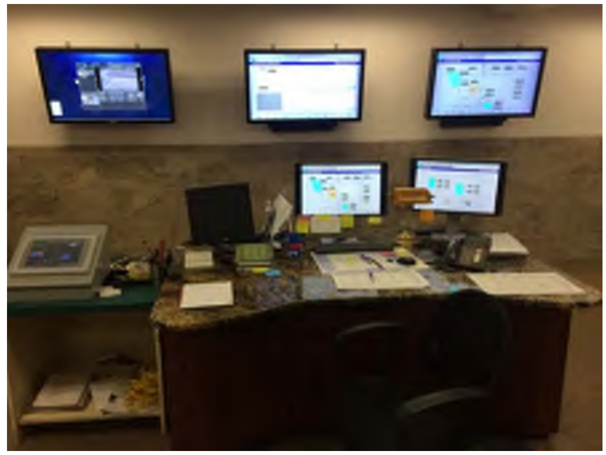
Human Machine Interface (HMI)

The WTP SCADA system uses Rockwell Automation FactoryTalk View SE Human Machine Interface (HMI) software version 8.00.00 (CPR 9 SR 7) with unlimited displays license installed on two redundant HMI Dell PowerEdge 4720 rack servers purchased in a previous upgrade in 2014. The WTP HMI system is licensed for 10 FactoryTalk SE Clients, the servers are currently connected via rack mounted Hirschmann Mach 4002 Layer 2 Ethernet switch to five clients in the control room, three Dell Optiplex 9020 workstations running Windows 7 Professional SP1 and two Dynics industrial computers mounted on the wall of the control room, as shown below, leaving five additional client licenses for future expansion.

An additional Dell PowerEdge 4720 rack server is used for historical data archiving and is running FactoryTalk Historian SE including OSI PI Server release 2012.

There is currently no reporting or alarming notification software as part of the plant SCADA system.

The Ozone system is currently isolated from the WTP SCADA system and is controlled and monitored separately at the Ozone Master Control Room (OMCP) PanelView 1000 or at the PanelView Plus 1250, located at the control room console.



Control Room Console

Programmable Logic Controllers (PLC)

The SCADA PLC system was upgraded in 2014 to standardize on using Allen Bradley CompactLogix L33ER PLCs in the plant control panels at the following plant locations:

- Filter 1 through Filter 12, each with PanelView Plus 600.
- Master PLC at Operations Center, used for polling remote sites.
- Elevated Tank and Control House (TCH).
- Dort Reservoir Inlet Control Station No. 3 (CS3).
- Dort Reservoir Inlet Control Station No. 5 (CS5).
- Control Station No. 2 (CS2).
- Pump Station No. 4 (PS4).

The following remote sites control panels were also upgraded in 2014 to use Allen Bradley CompactLogix L33ER PLCs:

- Cedar Street Reservoir and Pump Station No. 3 (CSR).
- Torrey Road Booster Station (TRB).
- West Side Reservoir and Pump Station No. 5 (WSR).

- Kearsley Dam Control (KS).
- Brown Street and Bradley Street – Pressure Monitoring Station (BB).

The above remote sites communicate to the master polling PLC at the Operation Center via AT&T cellular modem.

The only two control panels at the plant that do not use CompactLogix 33ER are the following:

- The Ozone Master Control Panel (OMCP) has CompactLogix Remote I/O cards but uses a ControlLogix 5572 with Ethernet and DH+ adapter and Allen Bradley PanelView 1000 for local monitoring and control.
- Desludge System Control Panel, which is isolated from the plant SCADA network, uses Allen Bradley Micro830 processor with PanelView C600.

The power supplied to the above control panels is not backed up by an uninterruptable power supply (UPS), which can result in PLC fault or PLC memory loss during power outages or damage to the operator interface terminals (OIT) due to voltage surge or sag, which would be prevented by the power conditioning provided by a UPS.

During visual inspection, it was noted that Filter 1 through Filter 10 control panel enclosures were severely damaged from corrosive exposure to sodium hypochlorite vapors.

Filter Control Panel Enclosures

Communication Media

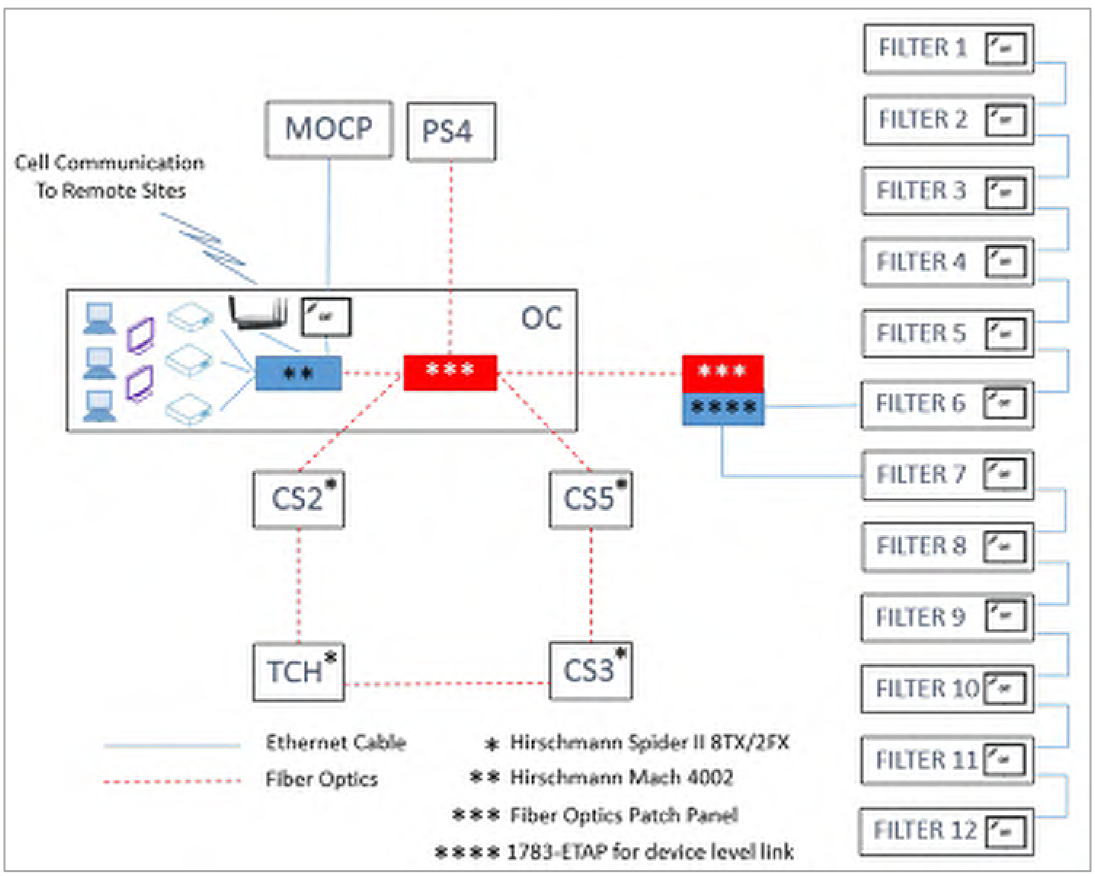
The plant control panels are connected via 6-strand fiber optic ring, with the exception of the following:

- The Master Ozone Control Panel (MOCP), which is connected via Ethernet CAT6 copper cable to a 4-port Ethernet switch located in the Operations Center console.

- Filter 1 through Filter 12 are connected via Allen Bradley 1783-ETAP over Ethernet CAT6 cable to create a linear device network. The embedded switch links the filters to the Operations Center through a fiber optic branch, separate from the fiber optic ring.
- Pump Station No. 4 is connected to the Operations Center through a fiber optic branch, separate from the fiber optic ring.

The five remote sites (CSR, TRB, WSR, KS, and BB) communicate to a master CompactLogix L33ER, connected to AT&T cellular service provided by Cradlepoint WiPipe modem located inside the server room at the Operations Center. Currently, there is no backup communication method to these remote sites in case of modem failure or cellular service interruption.

The diagram below represents the current plant SCADA network.



Existing SCADA Network Architecture

The fiber optic network and patch panel, as well as most of the Ethernet CAT6 network connections, have been performed internally by City staff. Due to labor limitations, time constraints, and equipment availability, some of the network installation is performed ad-hoc without labeling cables, creating record drawings, or securing equipment. For example:

- The server room at the Operations Center has a master CompactLogix L33ER PLC polling the remote sites laying on a desktop without proper panel or rack mounting installation.
- The plant fiber optic patch panel at the server room is not secured or labeled, making it difficult to troubleshoot communication problems or maintain vulnerable fiber optic cables from damage.
- TCH, CS2, CS3, and CS5 do not have a patch panel to terminate the 6-strand of the SCADA fiber optic network. Instead, a metal board connected to the side panel is used to terminate the fiber optics.

Server Room, Cellular Modem, and Fiber Optics Patch Panel

The WTP has recently installed new Allen Bradley CENTERLINE 2100 motor control centers (MCCs) with IntelliCENTER technology using DeviceNET at several locations (West Flocculation, East Flocculation, Plate Settlers, and Lime/Sludge Electrical rooms) with Allen Bradley power monitor 5000. The plant has future plans to connect these MCCs and power monitors to the plant SCADA network for monitoring and control to improve their data analytics capabilities.

Process Instruments

The following instrument deficiencies were identified during the site inspection on January 4, 2017:

Filter Areas

- Filter 1 through Filter 12 Rosemount 3051 differential pressure transmitters for head loss measurement are damaged due to leaks from the filters influent channel.
- Filter 6 ABB MAG-XM Magnetic meter coils are damaged.
- The filters influent channel located above the turbidity analyzer and flow transmitter of each filter leaks over the filter instruments, which caused severe damage to some of the flow transmitters and turbidity meters. In addition, the turbidity analyzers for Filter 1 through Filter 4, as well as the combined filter effluent uses the old Hach Model 1720D.
- None of the filters have level measuring instruments.

Filter No. 3 Damaged Flow Transmitter

- The majority of the instruments have not been calibrated since installation. The most recent calibration for some instruments goes back to 2013.

Plate Settlers Area

- Clarifiers ultrasonic level transmitters have been uninstalled to be used in other areas.
- Hach GLI Accu4 Turbidity meter is not functional. The installation has air binding problems; a new analyzer installed at more suitable location is preferable.
- Ametek Drexelbrook sludge blanket detector does not report accurate level.

Filters Influent Flow Meter

- ADS Environmental Accusonic transit-time flow meter measuring the influent flow in an open channel from the Ozone Building is inaccurate and unreliable.

Ozone Area

- Sodium Bisulfite Leak Detection has been damaged in previous leaks.
- Dissolved Oxygen meters on the inlet and outlet of Ozone Contact Chambers No. 1 through No. 3 have not been calibrated since 2014 and the readings are not reliable.
- Ozone Inlet Gas flow meter for Ozone Contact Chamber No. 2 is not operational.
- Sodium Bisulfite flow meters are not operational.
- Pre-sedimentation chamber pressure level transmitter is not operational.
- None of the showers/eyewash stations have flow switches tied to SCADA or local annunciators to activate the alarm when in use.

Needs and Drivers

The WTP staff SCADA needs and drivers to improve and expand the control system were discussed with the plant supervisor, SCADA technician, and multiple plant operators during the January 4, 2017 site visit. The following needs and drivers were identified when discussing the current SCADA system:

- Integrated SCADA HMI system including all plants processes in one, up-to-date, secure, easy to maintain and control application.
- Expand the control and monitoring capabilities beyond the Operations Center to the filters gallery, plate settlers, ozone building, and chemical systems area.
- Automated reporting software the utilize historical and laboratory data.
- Alarming Notification System for annunciating events and alarms.
- Self-healing fiber optic ring at all plant locations.
- Redundant communication media for remote sites to eliminate single point of failure.
- Mobile accessibility to SCADA inside the plant and remote accessibility from outside the plant.
- Computerized Maintenance Management System (CMMS) and Laboratory Information Management System (LIMS) capable of interfacing with the SCADA system.
- New dashboards and plant overview graphics with Key Performance Indicators (KPIs) and critical trends to provide single snapshot, easy to read, real-time displays that enable early identification of negative trends.

- Plant overview and process summary displayed for visitors in the conference room using high resolution TV screens.

Recommendations

Human Machine Interface (HMI)

The following improvements are recommended for the WTP SCADA HMI system:

- Microsoft has announced end of mainstream support for Windows 7 running on all current plant clients. In addition, SCADA hardware needs to be expanded to improve network security and provide flexibility for future expansion. It is recommended to replace the existing SCADA HMI hardware with the following:
    - Primary Domain Server.
    - Secondary Domain Server.
    - Primary SCADA Server.
    - Secondary SCADA Server.
    - Historian and Reporting Server.
    - Network Attached Storage (NAS) server for automated backup of the system.
    - Three dual monitors for Client Workstations.
    - Two Dashboard TVs for the Control Room, with two client workstations.
    - Two Dashboard TVs for the Conference Room, with two client workstations.
    - Six PanelView Plus 1500 to be distributed at the following locations: Ozone Building, new High Service Pump Station, new Chemical Building, Filters Gallery, Plate Settlers, and proposed Low Service Pump Station.
    - Development Workstation including FactoryTalk View Studio and RSLogix 5000 Studio software. The development workstation will contain a virtual machine for changes and patch testing prior to deployment to the operation environment.
    - Two iPads with cellular data for remote SCADA access.
    - Fifteen Wireless Access Points devices to create SCADA WiFi network inside the plant.
    - VPN Router to extend the SCADA network securely to onsite mobile SCADA users.

  - Firewall Layer 3 Ethernet Switch for secure connection to the future CMMS and LIMS systems to the SCADA network.
  - Demilitarized Zone (DMZ) firewall to provide a buffer zone between the WTP SCADA network and outside remote users where all incoming traffic is restricted into the DMZ, protecting the plant network components.
- Upgrade the current HMI software to the latest version of FactoryTalk View SE Version 9.00.00.
- Acquire ten additional FactoryTalk View SE client licenses.
- Furnish and install alarms notification software, such as WIN911.
- Provide a plant-wide annunciating system via horns and speakers.
- Furnish and install automated reporting software with open database connectivity capabilities, such as WIMS by Hach.

Programmable Logic Controllers (PLCs)

The WTP standard PLC (CompactLogix L33ER) is a medium-sized processor that can accommodate a 2 MB program and a maximum of 3 I/O banks. This PLC is suitable for the different plant areas, including the future high service pump station, the new chemical building, and the proposed low service pump station.

The following recommendations are applicable for the PLC and their control panels:

- Replace the desludge system panel and provide a new control panel using the standard plant CompactLogix L33ER PLC.
- Provide a rack-mounted UPS (15 minute panel backup minimum) and 6-strand fiber optic patch panel to the following panels:
  - Elevated Tank and Control House (TCH).
  - Dort Reservoir Inlet Control Station No. 3 (CS3).
  - Dort Reservoir Inlet Control Station No. 5 (CS5).
  - Control Station No. 2 (CS2).
- Replace Filter 1 through Filter 12 enclosures only; re-use PLC and back panel components.
- Provide a small control panel in the server room to house the cellular modem and the master PLC polling the remote sites.

- Subcontract Ozonia to upgrade Ozone Generators, Sodium Bisulfite, Ozone Off-Gas Destructs, and Main Ozone Control Panels. Upgrade will include programming modifications, panels modifications, and integration of the Ozone system into the plant SCADA system.

Communication Media

The WTP uses a 6-strand fiber optic network as the backbone of the SCADA network. The original network was built as a ring, but the filters and PS4 were added as a fiber optic branch and are not part of the fiber optic ring. In addition, the Master Ozone Control Panel is currently connected via Ethernet CAT6 cable to the plant SCADA system at the Operations Center. The following is recommended to improve the SCADA network and its communications:

- Revise the plant fiber optic network to provide a self-healing fiber optic ring that includes all current and future plant locations: Filters, Ozone Building, CS2, CS3, CS5, TCH, new Chemical Building, new High Service Pump Station, and proposed Low Service Pump Station. Include Smart MCCs and power monitors at all locations in the fiber optic network. Use existing conduits to the extent possible.

- Provide redundant communications media between the master PLC at the server room and the five remote sites: CSR, TRB, WSR, KS, and BB to ensure continuous monitoring without interruption. A redundant communication can be established via radio, cable, or another cellular modem supplied by a service provider other than AT&T. Radio is economical (no continuing contract costs); the drawbacks include building and maintaining towers, lightning damage, terrain obstructions, and interference by other users of the same frequency. Cable internet is fast and has virtually unlimited data usage to support both SCADA data and real-time full-rate video camera data, if video monitoring of the remote sites is desired.

Process Instruments

- Replace all non-operational instruments listed under the existing conditions section in this technical memorandum, with the exception of the sludge blanket sensors, which will not be required in the new modified process.

- Re-calibrate all existing plants instruments that will not be replaced. Put in place a standard operating procedure (SOP) for regular inspection and calibration of plant instruments.

- Research the possibility of replacing the transit-time flow meter to measure the plant influent from the Ozone Building with a magnetic meter to provide more measurement accuracy.

END OF TECHNICAL MEMORANDUM

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