Comprehensive Waterworks Evaluation and Cost Estimate

City of Richmond, VA

Virginia Department of Health, Office of Drinking Water

VADOH 183662 | April 8, 2025

SEH

Building a Better World for All of Us®

Engineers | Architects | Planners | Scientists

For clarity, the following table of abbreviations is presented. This may not encompass the entirety of all abbreviations used throughout this report.

Table 1: Abbreviations and Description

Abbreviation	Description
CAO	Chief Administrative Officer
CIMS	Crisis Information Management System
CIP	Capital Improvements Plan
COR	City of Richmond
DCAO	Deputy Chief Administrative Officer
DECPR	Richmond Department of Emergency Communications, Preparedness and Response
DEQ	Department of Environmental Quality
DHRM	Department of Human Resource Management
DPU	Department of Public Utilities
EL	Elevation
EOM	Emergency Operations Manual
ERP	Emergency Response Plan
GPM	Gallons Per Minute
IC	Incident Commander
IMT	Incident Management Team
kV	Kilovolts
MGD	Million Gallons Per Day
MVA	Megavolt-amperes
NOAV	Notice of Alleged Violation
ODW	Office of Drinking Water
PLC	Programmable Logic Controllers
PS	Pump Station
PWSID	Public Water System ID
RRA	Risk and Resiliency Analysis
SCADA	Supervisory Control and Data Acquisition
SEH	Short Elliott and Hendrickson, Inc.
UPS	Uninterruptible Power Supply
VAC	Virginia Administrative Code
VDACS	Virginia Department of Agriculture and Consumer Services
VDEM	Virginia Department of Emergency Management
VDH	Virginia Department of Health
VFD	Variable Frequency Drive
VGS	Virginia Department of General Services
VRLA	Valve Regulated Lead Acid
WEBEOC	Web Emergency Operations Center
WTP	Water Treatment Plant

Executive Summary

At approximately 5:45 a.m. January 6, 2025, the City of Richmond (COR) Water Treatment Plant (WTP) experienced a power outage resulting from a winter weather event with snow and ice formation. The automatic power transfer switch, called a “bus tie,” intended to connect power from a backup feeder failed, leaving the facility without power for approximately 1 hour and 20 minutes. During the power outage, water flow continued in the WTP by gravity through the filtration system, into the subsurface clearwell and quickly flooded the underground equipment rooms. Backup systems intended to close water process valves and protect the underground equipment rooms during outages were not functional. The power outage and subsequent water inundation in equipment rooms caused an extended disruption in water production. Water storage volumes and system pressure throughout the COR water distribution system dropped below safe levels for consumption. A Boil Water Advisory was issued by the COR at approximately 4:30 p.m. on January 6, 2025. By January 8, 2025, production was partially restored, and normal production was restored on January 9, 2025. On January 11, 2025, after adequate pressure was restored to flush lines, disinfect, and test distribution sites to confirm that water was safe for human consumption the COR lifted the boil order.

This event, collectively known as the COR’s water crisis, prompted the Office of Drinking Water (ODW), Virginia Department of Health, at the direction of Governor Glenn Youngkin, to promptly investigate. Through an emergency contract process, ODW engaged Short Elliott Henderson, Inc. (SEH) to perform an independent, third-party, root cause evaluation to accurately describe what happened, what did not, effectiveness and timeliness of communication, and other analysis to be described in a report of findings, observations, and recommendations.

To accomplish these tasks, SEH mobilized a team of 10 licensed professional engineers and 10 additional engineering support staff delivering almost 1,500 hours of work in 60 days. The team consisted of senior level experts in the fields of water process engineering, electrical engineering, instrumentation and controls, hydraulic engineering, and water treatment plant design.

Working closely with the ODW and with the cooperation of the COR, SEH conducted a deep dive into the existing COR WTP design drawings, maintenance records, consultant reports, capital improvement program documents, COR Department of Public Utilities (DPU) communications, DPU organizational charts, notes from interviews with DPU staff, ODW and Environmental Protection Agency sanitary surveys, ODW incident writeups, and Supervisory Control and Data Acquisition (SCADA) data.

This initial data review preceded an intensive 3-day site visit conducting detailed process-by-process review. The investigation team split into groups based on engineering specialty. Separate groups toured process, electrical, and controls equipment at the WTP. Another group toured key facilities in the water distribution system, including water storage tanks and booster pump stations. The DPU provided operational and maintenance staff to explain the function and condition of the processes and associated electrical and controls equipment. During these site visits, SEH interacted with DPU staff and asked questions about the conditions at the WTP and water distribution system as well as the specific events surrounding January 6, 2025.

Executive Summary (continued)

Upon completion of the site visit, the SEH team continued its review and analysis into the existing records and decided to focus on two distinct parts. The focus for Part 1 is a Root Cause Analysis, which develops ideas and suggestions to identify the root causes of the water crisis. Part 2 is a Waterworks Needs Assessment, which advises ODW and COR as to recommended measures to prevent future occurrences of system failures increasing the waterworks reliability and resiliency.

Part 1: Richmond Water Crisis Root Cause Analysis

Analysis:

The SEH team, working in coordination with the ODW, and with the cooperation of the COR DPU staff, developed a detailed timeline of events beginning with the declaration of the state of emergency by the COR Mayor on January 5, 2025, to the lifting of the Boil Water Advisory on January 11, 2025. The timeline includes the date and time of the event including a description of the event, internal communication, external communication, and the source of the data. This timeline definitively represents the series of events immediately prior to the water crisis and through its conclusion. The timeline shows WTP staff diligently working on recovery operations while there were delays in communication between the WTP staff, DPU, neighboring jurisdictions, and external agencies, which hindered the response efforts.

Using the 6M Root Cause Analysis technique, SEH engineers assessed the six key factors contributing to the water crisis. These factors consist of Manpower, Machines, Materials, Methods, Mother Nature and Measurements. SEH determined the following failure modes as key factors to the water crisis.

- Emergency Preparation (Methods).
- Primary Power Failure (Machines).
- Electrical Switchgear Alarms No Longer Alarm to Control Room (Measurements).
- Winter Mode (Methods).
- Backup Power Failure – Switchgear Bus Tie Failure (Machines).
- Generator Requires Manual Startup (Machines).
- Lack of Qualified Electrical Staff on Night Shift (Manpower).
- Clearwells: Lack Overflow Pipes and Overflow to Filtered Pump Rooms and Filter Pipe Galleries (Materials).
- Location of Pumps: Does Not Provide Flooded Suction. Pumps Experience Issues with Suction Lift (Materials).
- Clearwell Volume and Operation Freeboard is Minimal (Materials).
- Clearwell Interconnection Reduces Redundancy of Parallel Plant Design to Clearwell Overflows (Materials).
- Poor Housekeeping Practices Created the Primary Pathway for Overflow into Plant 1 (Methods).
- UPS Value Controls Failed to Close Filter Effluent Valves (Measurements).
- UPS Batteries Not Included on PM Schedule (Methods).
- Filter Effluent Valve Manual Operation Not Feasible During Filter Gallery Flooding Event (Machines).

- Godwin Pump Flow Not Sized for Full WTP Flow (Machines).
- Plant Staff Immediate Response Focused on Ineffective Dewatering (Methods).
- Godwin Pumps Prime Slowly (Machines).
- Pump Motors and Electrical Equipment Located Below Hydraulic Grade of WTP (Machines).
- UPS for Various Programable Logic Controller Failed and Connectivity was Lost (Measurements).
- Incorrect SCADA data until midnight January 6, 2025 (Measurements).
- Network Switches Were Not Maintained with Up-to-Date Drivers (Methods).
- Some Plant 2 Filter Valves Require Hydraulic System Pressure to Operate (Machines).
- Byrd Park Reservoir had Reduced Capacity Due to Capital Project (Materials).

The critical failures were further analyzed using a cascading failure analysis. Critical failures leading to the water crisis occurred sequentially from top to bottom as follows:

- Severe Weather – State of Emergency.
- Primary Power Failure (Failure of Primary Winter Mode Feed).
- Summer vs Winter Mode (Practice of using Winter Mode).
- Switchgear Bus Tie Failure.
- UPS Valve Closure Failure.
- Clearwell: Lack of Gravity Overflow, Insufficient volume.
- Pumps and Electrical Equipment Located Below Hydraulic Grade Line.

Examination of each of the items above was performed utilizing a "why" analysis. The resulting analysis determined the failures were largely a result of a managerial environment where WTP staff works with known issues that increase risk of WTP failures. This environment fosters general acceptance and normalization of critical unacceptable issues, so the appropriate level of concern is not conveyed to leadership and DPU. Staff accept substandard conditions as normal, such as increased manual operation of the WTP, slow progress in replacing critical equipment, limited training and practice for power outages, and lack of standard operating procedures. WTP staff focuses on individual roles to keep the WTP operating and not the primary objective of delivering safe, reliable water to the community.

Conclusions & Recommendations:

Based on the Richmond Waterworks Root Cause Analysis, SEH arrived at the following conclusions:

- A loss of primary and backup power systems on January 6, 2025 stopped forward flow from the clearwell to chlorine contact tanks while gravity flow from filters to clearwell continued.
- Uninterruptible Power Supplies (UPS) intended to close the Effluent Valve system and stop flow into the clearwell failed leading to catastrophic flooding of pumps and equipment that led to extended water crisis.
- DPU's lack of testing and verification of the UPS system and functional testing of this failsafe was the cause of the water crisis.

- The underlying known issue of clearwell overflow and flooding of basement is a critical failure point that DPU staff worked around for decades. Valve operation is the critical last line of defense and the UPS did not work to close the valves to stop the flooding.
- DPU staff manages working through challenges such as flooding, manual operation, inoperative priming systems, and other problematic and fixable issues such that the working conditions became part of the culture. DPU staff deal with issues and inconveniences by just focusing on individual tasks at hand to keep the plant running.
- General acceptance and normalization of problematic issues at the WTP resulted in high risk for a water crisis. DPU staff accepted an inappropriate level of concern, such that problems were not assigned to fix or repair, or to communicate these issues. This normalized operations that needed to change. Neither consultants nor regulators raised red flags concerning the WTP design limitations over many years, which gave DPU staff the false impression that problematic issues were not urgent to address.
- Overall, the DPU team needed to focus on their individual tasks at hand to keep the plant running and did not focus on the primary objective of delivering safe reliable water to the community.

Given the conclusions above, SEH provides recommendations for capital improvements, operational procedures, maintenance procedures, and emergency preparedness. The following key recommendations as listed in the analysis:

1. Address the immediate causes of plant shutdown following the power failure through the following:
    a. Eliminate the use of “winter mode” as normal mode of power.
    b. Implement a UPS preventative maintenance schedule.
    c. Ensure that all relevant filter valves are closed by the control system upon loss of power, including valves that may be open during a backwashing cycle.
    d. Provide an automatic transfer system for the existing backup generators.
2. Address the underlying vulnerability that critical electrical equipment is not in spaces that are subject to clearwell overflows and flooding.
3. Improve automation at the plant.
4. Conduct a structural evaluation of the clearwell top slab for differential pressure conditions that result when the clearwell level rises. Some portions of the top slab are pressurized at design water surface elevations shown on the hydraulic profile and are further pressurized when the water level is elevated during disruptions in pumping capacity.

Part 2: Richmond Waterworks Needs Assessment

To improve the reliability and resiliency of the COR Waterworks, SEH conducted a Waterworks Needs Assessment identifying critical infrastructure and potential vulnerability, which may contribute to a future water crisis. This assessment makes recommendations for capital improvements, maintenance practices, and evaluates the existing condition of the waterworks, system by system. The major elements of the assessment include:

- Comprehensive on-site evaluation of the physical condition, capacity, reliability, performance, and operational and maintenance procedures of the City.

- Evaluation of compliance with current Virginia Administrative Code (VAC) Chapter 590 (12VAC5-590, eff. 06/2021), which regulates public waterworks and serves as the design standards for plant capacity by the Virginia Department of Health (VDH).
- Evaluation of general deficiencies and recommendations for potential improvements

Additionally, ODW should consider working with the Board of Health to improve and update certain regulatory requirements to better address grandfathered and legacy design issues. The Regulations, at 12VAC5-590-50, states that compliance with certain parts of the Waterworks Regulation (Part III. Manual of Practice for Waterworks Design) is not required for existing waterworks in operation before the effective date of the code, June 2021. This regulation allows legacy designs to exist, which should be changed when older water treatment plants make upgrades.

The report is separated into chapters consisting of an introduction, the water treatment plant, the distribution system, and recommending improvements and estimated costs. The WTP chapter include multiple elements of the water treatment process including: 1) Source Water Intakes (James River and Kanawha Canal), 2) Pre-sedimentation, North, and South Basins, 3) Raw Water Pump Station, 4) Water Treatment Plant 1 and Plant 2, and 5) Residuals Settling Lagoon. The distribution system chapter describes the condition of the 12 pump stations, which includes the 3 at the WTP in one section. Another section addresses the 10 water storage facilities and their related valves and piping.

Each section of both the WTP and the distribution system chapters are further detailed with descriptions, purpose, and element of each feature including dimensions, volume, and capacity. Operations and maintenance considerations are addressed for each element as well as heating, ventilation, air conditioning, and electrical conditions. Finally, a record of observations and recommendations are made for each feature. The final chapter consists of two comprehensive tables, one for the WTP and one for the distribution system. Each table describes the feature, area of concern (operations, safety, end of life, and notes), improvement items, estimated construction cost, contingency, total construction cost, engineering cost, and budget cost.

In summary, to increase long-term reliability and resiliency, SEH engineers identified and estimated $31.9 million of recommended improvements at the WTP and an estimated $32.0 million of recommended improvements to the distribution system. It is likely that some of these recommended improvements are currently included in the COR capital improvement plan, and timeframe for the needed improvements vary based on condition and age.

Conclusion:

The SEH team provided a thorough and professional review of the events leading to the Richmond water crisis as well as an assessment of the infrastructure needs contributing to the water crisis or required improvements to increase the reliability and resiliency of the waterworks. Observations and interviews with WTP staff demonstrate individual commitment and expertise, but they also highlight institutional complacency through the acceptance and normalization of known issues. While staff works diligently to keep the WTP running on a daily basis, the primary strategic objective of delivering safe, reliable, water is overlooked. The WTP needs to produce all the water demanded by the system every day with a reasonable allowance for predictable outages. The distribution system needs to distribute all the water demanded every day with enough volume in storage to handle WTP outages. SEH recommends focusing on these primary strategic objectives and prioritizing infrastructure projects and managerial practices to increase the WTP long-term reliability and resiliency.

Building a Better World for All of Us®

Sustainable buildings, sound infrastructure, safe transportation systems, clean water, renewable energy, and a balanced environment. Building a Better World for All of Us communicates a company-wide commitment to act in the best interests of our clients and the world around us.

We're confident in our ability to balance these requirements.

JOIN OUR SOCIAL COMMUNITIES

Part 1: Root Cause Analysis

Richmond Water Crisis

Virginia Department of Health - Office of Drinking Water

VADOH 183662 | April 8, 2025

Building a Better World for All of Us®

Engineers | Architects | Planners | Scientists

Richmond Water Crisis

Root Cause Analysis
Virginia Department of Health – Office of Drinking Water

SEH No. VADOH 183662

April 8, 2025

COMMONWEALTH OF VIRGINIA
EDGAR J.T. PERROW, JR.
No. 35820
4/7/2025
PROFESSIONAL ENGINEER

I hereby certify that this report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Virginia

Thad Webb, PE

Date: April 7, 2025 License No.: 0402035820

Reviewed By: Jeff Ledin Date: April 7, 2025

Short Elliott Hendrickson Inc.
400 Locust Avenue, Suite 2
Charlottesville, VA 22902-4858
434.202.3780

Contents

Contents (continued)

List of Figures

List of Appendices

Root Cause Analysis

Richmond Water Crisis

Prepared for Virginia Department of Health, Office of Drinking Water

1 Introduction

This report is compiled by Short Elliott Hendrickson (SEH) at the request of the Virginia Department of Health, Office of Drinking Water (VDH-ODW). The purpose of this report is for SEH to assist VDH-ODW in an investigation of the root cause analysis, timeline, and review of the City of Richmond (COR) Waterworks. SEH's role is providing professional engineering services and collaboration with VDH-ODW in aiding their investigation and support in the regulatory oversight duty of the City of Richmond waterworks.

1.1 Background

The City of Richmond Department of Public Utilities (DPU) Water Utility provides potable water to the City of Richmond (COR or City) and the neighboring counties of Hanover, Henrico, and Chesterfield. The Richmond Water Treatment Plant (WTP) is the primary Richmond water supply. The WTP operates under the permit Public Water System ID (PWSID) #4760100. The WTP is located on the banks of the James River, which is the primary water source.

The current WTP has a rated capacity of 132 million gallons per day (MGD). Typical production is reported to vary seasonally from 50 to 75 MGD and current summertime maximum day production is approximately 100 MGD.

At approximately 5:45 a.m. January 6, 2025, the WTP experienced a power outage resulting from a winter weather event with snow and ice formation. The WTP has redundant power supplies from two main feeders served by different electric utility substations. At the time of the power outage, the facility was operating in Winter Mode. In Winter Mode only one of the feeders provides power to the plant, with the second feeder available via a bus tie breaker should the first feeder go offline. Upon loss of this feeder, the automatic bus tie intended to switch power to the backup feeder failed. The facility was without power for approximately 1 hour and 20 minutes, until power was restored by electrical maintenance staff. Had the plant been operating in Summer Mode, the substation would have been fed by both feeders, and only the portion of the plant fed by feeder 1 would have gone offline. During the power outage, flow continued through the plant by gravity through the filtration system, into the subsurface clearwell and quickly flooded the underground equipment rooms. Plant staff were unable to manage the flows during power outage. Backup systems intended to close water process valves and protect the underground equipment rooms during outages did not function. Maintenance records indicate that these valves experienced power failure issues in 2021 and 2022, leading to similar but less severe plant basement flooding.

The power outage and subsequent water inundation in equipment rooms caused an extended disruption in WTP production. By January 8, 2025, production was partially restored to approximately 10 to 14 MGD and normal production was restored on January 9, 2025. Water storage volumes and system pressure throughout the Richmond water distribution system dropped below safe levels for consumption. A Boil Water Advisory was issued at approximately 4:30 p.m. on January 6, 2025, and remained in place until January 11, 2025, after adequate pressure was restored to flush lines, disinfect, and test distribution sites to confirm that water was safe for human consumption.

During the outage, customers experienced low water pressure followed by a disruption in service starting the evening of January 6, 2025, and continuing through January 9, 2025, when pressure was restored and January 11, 2025, when boil water advisory was lifted. The Virginia Department of Emergency Management, the local health department, the Virginia Emergency Support Team and Medical Reserve Corps enabled the community to receive bottled water.

1.2 Notice of Alleged Violation

In response to the water disruption event, VDH ODW issued a notice of alleged violation (NOAV) to the DPU. The NOAV asserts that the water outage was an avoidable event that the City of Richmond could have prevented through better preparation, verifying critical equipment was functional before the weather event, ensuring sufficient staffing, and making sure staff present at the WTP during the event had appropriate training to effectively respond to the temporary power outage. The ODW identified the following sections of the Virginia Waterworks Regulations which may have been violated:

1. Section 12VAC5-590-510.C of the Waterworks Regulations, states that *“All waterworks shall provide a minimum working pressure of 20 psi gauge (psig) at all service connections.”* A violation may have occurred in that pressures within the City of Richmond waterworks fell below 20 psig on January 6, 2025, when the water levels in distribution system storage tanks fell below normal operating levels and ultimately were emptied. Water pressure started to return by January 9, 2025, and the distribution system was fully pressurized by January 10, 2025.
2. Section 12VAC5-590-360.A of the Waterworks Regulations, states that *“The owner shall provide and maintain conditions throughout the entirety of the waterworks in a manner that will assure a high degree of capability and reliability to comply with Part II (12VAC5-590-340 et seq.) of this chapter. This requirement shall pertain to the source water, transmission, treatment, storage, and distribution system facilities and the operation thereof. The owner shall identify and evaluate factors with the potential for impairing the quality of the water delivered to the consumers. Preventative control measures identified in Part II of this chapter shall be promptly implemented to protect public health.”* A violation may have occurred in that multiple failures at the WTP resulted in the loss of water service to the City of Richmond and portions of the consecutive waterworks that the City of Richmond waterworks provides wholesale water to, resulting in a Boil Water Advisory that was in place from January 6, 2025, to January 11, 2025.

1.3 Scope

The scope of this report is to provide an overall review of the events, actions, failures, and causes associated with the inability of the City of Richmond to provide water to its customers starting on January 6, 2025. That includes, but is not limited to, the following specific tasks:

- Develop a timeline of events based on staff interviews, communication logs and available data;

- Review backup power systems, redundancy, and operation. Provide recommendations as applicable;
- Review plant staffing, operational procedures, and training on procedures;
- Review emergency response plans;
- Review available maintenance and capital improvement information;
- Evaluate modes of failure associated with the events of January 6. Perform Root Cause analysis and summarize results; and
- Recommend technical solutions as well as provide operational and logistical recommendations.

1.4 Documents Reviewed

Following a data request submitted by SEH, VDH-ODW and Richmond DPU provided the following relevant documents and SEH reviewed them. Refer to Appendix A for the list of the specific documents:

- Record drawings;
- Consultant reports including Master Plans, Emergency Response Plans, Cybersecurity Plans, Condition Assessments;
- Capital Improvement Program documents;
- Maintenance Records;
- DPU staff communications related to the January 6, 2025, events;
- DPU organizational charts;
- Interviews of DPU staff about the events of January 6, 2025, conducted by the City's consultant and VDH ODW staff;
- Sanitary surveys completed by the ODW and the EPA and DPU response;
- Incident writeups completed by the ODW; and
- Supervisory Control and Data Acquisition (SCADA) data, including filter flow and valve position for select time periods.

1.5 Site Visit

SEH completed a site visit to the Richmond WTP on February 6, 2025, followed by a 3-day site visit beginning February 18, 2025, for data collection. SEH was accompanied by VDH ODW staff on both site visits. The initial site visit included an overview plant tour. The subsequent site visit included detailed process-by-process tours. The investigation team split into several groups based on specialty. Separate groups toured process, electrical, and controls equipment at the WTP. Another group toured key facilities in the water distribution system, including water storage tanks and booster pump stations. The DPU provided operational and maintenance staff to explain the function and condition of the processes and associated electrical and controls equipment. During these site visits, SEH interacted with DPU staff and asked questions about the conditions at the WTP and water distribution system as well as the specific events surrounding January 6, 2025.

2 Existing Conditions

2.1 Water Treatment Plant Description

The WTP is a conventional surface water treatment plant located adjacent to the James River consisting of two interconnected water treatment plants (Plant #1 and Plant #2). Plant #1 was initially constructed in 1924, with the addition of a second plant in 1950. Numerous modifications to both plants over the years have increased the capacity of Plant #1 to 60 MGD and Plant #2 to 72 MGD, resulting in a total permitted capacity of 132 MGD.

The plant is permitted as a high-rate water treatment facility in accordance with 12VAC5-590-874 of the Waterworks Regulations which allows filter loading rates of 4.0 gpm/ft^2. Prior to around 1989, the plant was permitted as a rapid rate water treatment facility, which allows filter loading rates of 2.0 gpm/ft^2. Raw water obtained from the James River is first directed through a pre-sedimentation basin prior to low lift pumps sending the raw water to each plant to be treated. Chemical coagulant is added to the raw water and rapidly mixed prior to entering flocculation basins and additional sedimentation basins containing inclined plate clarifiers. Following this sedimentation, the water spills over into gravity filters. Low lift pumps send the filtered water to chlorine contact basins to provide adequate disinfection using chloramine. Fluoride, corrosion inhibitor, and pH adjustment chemicals are added before high lift pumps send the finished water to the distribution system and throughout the surrounding communities.

Refer to the following figures which show the general arrangement of the WTP:

- Figures 1 and 2 are aerial view plant flow diagrams.
- Figures 3 and 4 show the Plant 1 and Plant 2 hydraulic profiles.
- Figure 5 is a plant overview diagram.

2.2 Distribution System Description

The Richmond water distribution system includes twelve pump stations, ten storage facilities, nine pressure zones, and various pressure reducing valve (PRV) stations interconnecting the pressure zone, as well as a significant quantity of buried water main. These system components are shown with Maximum Day water demands in Figure 6.

Following treatment at the WTP, water is pumped to the distribution system from the three onsite pumps stations: Korah No. 1, Korah No. 2, and Korah No. 3. Korah No. 1 pumps directly to the City’s largest tank of Byrd Park Reservoir, Korah No. 2 pumps either to Byrd Park Reservoir or Zone 1 South pressure zone, and Korah No. 3 pumps to Henrico County’s Three Chopt Facilities but can pump to Zone 4 pressure zone when necessary. Additionally, a 54-inch reinforced concrete gravity fed conduit from the WTP’s chlorine contact basins provides water to Byrd Park Main and Byrd Park Reserve pump stations. Byrd Park Reserve pumps to Byrd Park Reservoir and Zone 2 South pressure zone and Byrd Park Main pumps to Byrd Park Reservoir. From Byrd Park Reservoir, Trafford and Columbus pump stations pump to the remaining pump stations and pressure zones.

2.3 Regional Bulk Water Sales

The City of Richmond sells bulk water to the three neighboring counties of Henrico, Chesterfield, and Hanover through wholesale contract arrangements. Wholesale contracts reviewed for this study largely outline costs and do not include any requirements for notifications, emergency response or coordination of operations.

> **SEH Recommendation:**
>
> Coordination on emergency notification and periodic testing (suggest monthly). Additionally, periodic coordination meeting to review operations, upcoming projects, emergency preparedness, etc. may be beneficial.

In review of staff interviews, as well as after action report from Henrico, communication was either delayed or did not occur in some instances due to incorrect contact information or staff turnover. Additionally, in discussion with DPU staff it was mentioned that periodic scheduled meetings between partner counties and cities for coordination used to occur but were discontinued around the time of COVID.

2.4 Operational Emergency Preparedness

On January 3rd, Governor Youngkin declared a state of emergency across the state of Virginia due to the impending winter weather event. Richmond Mayor Danny Avula issued a follow up state of emergency declaration for the City on January 5.

In preparation for the storm the following precautions were taken at the WTP:

- Serviced diesel-powered temporary pumps (referred to by staff as Godwin pumps). Pumps are used to connect to sump within filter gallery for dewatering of the area in the event of flooding within the area. Service of the pumps included checking all fluids, topping off fuel and starting pumps.
- Topped off fuel in generators.
- Plant staffing: Plant Operations staff remained at typical level with 3 operators on-site. Two maintenance staff remained onsite overnight for snow removal (one left at 5:00 a.m. due to illness) and an additional operator was staying at a hotel near the facility for quick response.

WEB Emergency Operations Center (WEBEOC) is a Crisis Information Management System (CIMS) used by the state of Virginia. Following declaration of the state of emergency, Richmond DPU updated WEBEOC the evening of January 5, 2025, indicating no issues to report at the WTP.

During the site visit, the WTP Maintenance group indicated that an enhanced severe weather preparedness Standard Operating Procedure has been developed and put into practice after the events of January 6, 2025.

2.4.1 Emergency Response Plans

SEH reviewed emergency response plans provided by Richmond DPU. There are two documents intended to be used together. The documents received included:

DPU Water Treatment Plant Emergency Response (ERP) – 2021 Update. The ERP is specific to the water plant itself and refers to the Emergency Operations Manual (EOM) for figures, charts, and checklists. Initially completed and sent to EPA (received September 25, 2020) and included in DPU Operations manual as Annex 1, this document includes the basic information related to emergencies specifically for the WTP including defining the emergency response team, how to alert staff to an emergency, evacuation of the site, chemical spills and first aid. It does not contain any specific procedures or guidance for failure of equipment at the WTP.

DPU Emergency Operations Manual (EOM) – 2021 Update. The EOM is intended to be applied across all DPU departments. This document defines plan activation triggers and level of emergency, defines the Incident Management Team, notifications, training and exercises and specific action plan checklists. Specific sections from the EOM relevant to this event includes but are not limited to below:

- 4.1 Triggers – DPU defines actions by emergency phase as outlined below with descriptions related to this event.
  - Routine Operations;
  - Increased Readiness – Declaration of Emergency ahead of storm;
  - Response Operations – Power Failure and flooding within the plant;
  - Recovery Operations – Removing Water from plant basement, drying out submerged equipment and restoring water service; and
  - Mitigation – Implement changes to reduce the probability of future outage.
- 4.1.5 Customer Notification – DPU Public Information Office (PIO) is responsible for public notifications per the Crisis Communication Plan (Appendix C).
- 4.1.4 VDH ODW should be notified if the water system has been compromised.
- Appendix C – Municipal and Sensitive Customers shall be notified by DPU PIO of changes to water quantity that may seriously affect their operations. This differs from checklists in Appendix B where Plant Superintendent is listed as responsible.
- 8.2 Exercises are recommended per EOM at the following intervals.
  - Tabletop exercise conducted annually:
  - Operational exercise conducted at least once every three years:
  - Full scale exercise conducted at least once every five years.
- Appendix A Incident Command Organization – This section outlines the Incident Management Team (IMT), see org chart below. The Incident Commander (IC) directs the actions of the IMT. IC responsibility can formally transfer during an event.

In discussion with facility staff, the ERP and EOM documents were not widely distributed and were available only in digital format. Additionally, a number of staff members were not aware of the existence of these documents. However, it is noted that actions taken by plant staff to dewater the basement (as will be described later in this report) were in line with the recommended procedure prescribed in the ERP.

SEH Recommendation:

Managers and operators acknowledge and provide written indication they reviewed the ERP.

- As stated above, the ERP main document presents general information while the issues and failures at the plant were very specific in nature. The portion of the documents that were more specific were incorporated into Appendix B Action Plan Checklists – Checklists that provided with some relevance to this particular event are noted below and included as Appendix B:

- 5. Extended Power Outage Rip and Run Flowchart – The flowchart is generic in nature and relates to not just the water treatment plant but all DPU facilities. It refers to generator power as a backup and not a second power feed and a generator. This chart did not consider this event's situation of switching between utility feeds manually or using generator power. As such it would not have been particularly useful for this event.

SEH Recommendation:

Update Action Plan Checklists and Flow Charts to reflect actual onsite conditions. Implement formal training program for all WTP staff and ensure they are distributed and readily available onsite.

Illustration 1: DPU Incident Management Organization Chart

- 11. Interior Flood Event – This checklist covers what to do in the event of an interior flood at the water treatment plant due to a power failure, which is what occurred on the day of January 6, 2025. This indicates that basement flooding at the facility due to power outage was a concern. However, the outlined procedure which the WTP staff followed exactly during the January 6th power outage, cannot keep up with flooding. The flow rate coming into the clearwells and overflowing to the filter gallery is approximately 42,000 gpm (gallons per minute) at 60 MGD (million gallons per day) typical flow when filter valves don't close. The specified Godwin portable pumps can only handle approximately 1,700 gpm, so they will have limited impact. The specific procedure listed in the Interior Flood Event checklist is as follows:

SEH Recommendation:

Update Interior Flood Event Action Plan Checklist to include verification that filter effluent valves are closed and filter flow has stopped. Stopping filter flow is the priority. Ensure Checklists are distributed and readily available to WTP staff.

  - Connect portable pumps.
  - Operate portable pumps.
  - Monitor pumps and basement water levels and if additional piping required to remove standing water.
  - If pumps cannot manage standing water levels, notify plant superintendent and plant maintenance manager.
  - Reassess needs to maintain system operations.
  - Call additional staff to assist.

- 20. Network Failure/Cyber Event – During the power failure the WTP lost network connectivity. This checklist covers what to do in the event of a network failure or cyber attack. Within the checklist the emphasis is on isolating the system, preserving programs, and methodically solving the issue. This relates to loss of network and general loss of controls. A loss of network or controls at the water plant would require quick action by the operations team to ensure that filter effluent was not entering the filter gallery and filtered water pump rooms prior to performing items on checklist.

  This checklist provides good practices in the event of a network failure to ensure security and to limit loss of data. Although the loss of SCADA network on January 6th was not a critical path failure, a similar loss of network or control system failure appears to have caused similar flooding in the past. Maintenance records reviewed by SEH from May 25, 2021, and May 9, 2022, seem to describe loss of water production and filter building basement flooding resulting from control failures in the Plant 2 SCADA and Uninterruptable Power Supply (UPS) systems.
- 35. Low Water Pressure Incident Action Checklist – This checklist covers what to do in the event of low water pressure in the distribution system. While much of the information is related to diagnosing the issue, there are relevant tasks to this event related to monitoring and adjusting system operation as well as notification of VDH and surrounding county bulk water users. Since the low water pressure occurred hours following the plant

failure and similar notifications are called out in checklist #36 below, this checklist would not have been particularly useful during event on January 6, 2025.

- 36. Destruction/Failure of any part of the Water System – This section includes tasks to notify internal leadership at DPU, VDH, wholesale customers and City Emergency Management in the event of process failure. It does not provide specific information about the threshold for notification. The pre-action checklist instructs staff to develop the Catastrophic Main Break SOP and review it annually.

> **SEH Recommendation:**
>
> Add thresholds and clear guidelines for notifications, develop SOP for a major failure at the water plant and set up a schedule for review and training.

The emergency response plan presents an overall framework to navigate an emergency response by setting up a support network and coordinating communication and response. It includes specific information provided in checklist form that pertains to the immediate problem, especially related to interior flooding; and these actions were followed by plant staff during the emergency. However, the recommended actions were inadequate.

Staff indicated that the ERP and EOM documents were not widely circulated and existed only as digital files. The events on January 6, 2025, created a chaotic emergency with operational phase of the response lasting around 2 hours and immediately starting the recovery phase of the emergency. The Incident Management Team was able to quickly mobilize and make internal notifications. Plant staff performed all tasks on the “interior flooding due to power outage” checklist within minutes of the event. Given the very technical nature of the issues experienced and short timeline, just having availability of the document onsite would not have been practical to review as the larger team was not already familiar with it.

> **SEH Recommendation:**
>
> Perform training and emergency exercises (per section 8.2 of EOM) to better prepare for any future emergencies and streamline operations including communication. Collect input from field staff during benchtop exercises and incorporate into the emergency planning documents.

2.4.2 Training

SEH staff discussed training and operations with facility operations and maintenance staff during the site walk through. In addition, SEH reviewed previous interviews with plant staff to understand training at the facility. These earlier interviews were conducted by HNTB Corporation, who were hired by the City of Richmond to perform an after-action review of the event.

The operations and maintenance staff includes personnel with a significant amount of experience in the industry. Additionally, a number of them have decades of service at this specific plant. According to facility staff, training is largely done through on-the-job-training. Junior staff shadow more senior staff and are given additional responsibilities as they become familiar with each specific task. There is no specific written training program for staff to follow. Senior staff at the plant indicated that they were trained in a similar non-formal apprenticeship manner and continued that practice. This style of training is commonly used within the industry, but can be enhanced using utility specific training manuals and Standard Operating Procedures (SOPs).

SEH reviewed SOPs provided by Richmond DPU. The SOPs were largely related to conducting repairs within the distribution system. SOPs for the water plant itself were limited. Plant operation relies on operator experience rather than written documentation. A transition in approach from individual knowledge to institutional knowledge through clear policies and procedures that are communicated through standardized training could increase efficiency, improve safety, and reduce the amount of time required to respond to an emergency.

Institutional knowledge is defined as the collective knowledge, expertise, and information unique to an organization, accumulated over time by employees, leaders, and stakeholders, encompassing insights, experiences, best practices, processes, and procedures.

Institutional knowledge involves standard procedures that are communicated and available to all employees without relying on any one specific individual. This can take the form of SOPs, standardized training, outlined policies and procedures, etc.

Post event note: Richmond DPU has indicated that enhancement of institutional knowledge is a focus moving forward. During our site visit we observed a new SOP being distributed to staff for standby generator use and staff training on that SOP.

SEH Recommendation:

We recommend DPU develops standard operating procedures, prioritizing those related to the most critical processes at the facility first and later developing procedures and standard training for all major processes onsite.

2.4.3 Staffing

The Richmond WTP is a Class 1 facility. 12VAC5-590-461 requires a minimum of 2 staff onsite for Class 1 facilities whenever the treatment plant is in operation. At least one must be an operator licensed at the Class 1 level. Additionally 12VAC5-590-450 states that consideration for staffing shall be given to such factors as the competency of personnel; water quality, including drinking water standards; water treatment plant maintenance and cleanliness; analytical laboratory control; and the operation and maintenance of the facilities, including water treatment plant equipment, distribution system equipment and piping. It further states that as the complexity of the waterworks increase, so does the expertise and skill required of the operations staff. This does not indicate a specific required staffing level but does indicate that facilities need to evaluate facility operational requirements to determine needs over and above the minimum required by 12VAC5-590-461.

Richmond DPU staffs the facility 24 hours per day, 7 days per week with operations staff working two 12 hour shifts. Maintenance is staffed during the day shift only and is on call after hours. Typical staffing levels prior to January 6 were shown below:

- Day Shift
  - 8 Operators, with 1 minimum with a Class 1 level license
  - Maintenance Staff all work day shift.
- Night Shift
  - 3 Operators, with 1 minimum with a Class 1 level license
  - After hours on call list posted to operator station weekly for Maintenance Staff.
- Typical Emergency: Emergency staffing determination was made on a case-by-case basis by DPU staff determined by expected storm and impact.

Operations and Maintenance have separate reporting structures. Plant operations staff report up to the Plant Superintendent. Maintenance staff report up to the Water Plant Program and Operations Supervisor who is overseen by Program and Operations Manager. Organizational structure charts are included as Appendix C. Staffing levels as of the date of the organizational charts are provided as a snapshot in time as of December 19, 2024. At that time, Operations group consisted of 22 positions with 2 vacancies. The Maintenance group consisted of 31 positions, with 5 vacancies.

> **SEH Recommendation:**
>
> Enhance coordination between Operations and Maintenance groups to ensure both groups work towards the same common goal.

Staff indicated some minor confusion with the separate Operations and Maintenance reporting structures. Some staff reported that it was unclear how Operations should request and direct assistance from the Maintenance group. Both Operations and Maintenance staff mentioned coordination meetings with both groups had been held to discuss this issue. Additional coordination and clarification between groups is recommended to ensure both groups work towards the same common goal. However, staff also indicated that throughout the event both operations and maintenance assisted each other and at times worked side by side to get the plant back online despite some a lack of coordination and communication.

On the day of power failure, there were 3 onsite operators, consisting of one Class 1 lead operator, one Class 3 operator and one Class 4 operator. Two maintenance staff (Mechanical Specialists) were onsite tasked with snow removal, but one left due to illness at 5:00 a.m. There was no electrician onsite. For additional analysis on staffing see section Failure Modes Section of this report under Staffing/Training.

2.5 Ongoing Capital Projects

The City of Richmond was constructing several capital projects relevant to the plant outage on January 6, 2025. Brief descriptions of the projects that SEH identified as relevant to the plant outage are provided below:

2.5.1 Substation No. 1 Replacement

This project includes replacement of Outdoor Substation SS-1 and new automatic controls at Switchgear SG-6. The project excludes replacement of the main bus tie at SG-6 which failed on January 6, 2025, and the other 4,160 voltage electrical gear that makes up the switchgear. The bus tie was replaced with new equipment as a maintenance activity after it failed, and the failed equipment was repaired to serve as a spare unit.

DPU verbally confirms the new controls include automatic transfer for the generator and generator circuit breaker. The proposed controls will enable the generator to start and feed the plant either through automatic or remote control.

This project had no known impact on the events leading to the water outage or the recovery effort. Some aspects of the project provide additional resiliency for future potential outages, including replacing aging equipment, automating the generator, and improving remote supervision of the outdoor substations and Switchgear SG-6.

2.5.2 Byrd Park Reservoir Roof Repairs

This project includes roof replacement of the Byrd Park Reservoir. The roof repair is phased such that half the reservoir is removed from service for roof repair and the other half remains in service. Due to the physical arrangement of the reservoir, the half that remains in service is necessarily operated at reduced maximum level of 19 feet, which limits the storage volume of the active side to three quarters of normal, however, this construction operating level varied based on phase of construction. Maximum normal water level is approximately 25 feet with overflow piping at an elevation of approximately 27 feet. The project reduces the capacity of the Byrd Park Reservoir from approximately 55 MG to approximately 20.6 MG.

Byrd Park Reservoir is the largest potable water storage tank in the Richmond water distribution system, and it normally comprises approximately 80 percent of the total storage in the system excluding storage in the bulk water customer systems. The construction impact reduced the usable storage volume available in the system, see section 4.4.2 for additional information and analysis.

Tank	Total Storage Volume (MG)	Usable Volume (MG)	Usable Volume During Byrd Park Reservoir Roof Repair (MG)	Comments
Byrd Park Reservoir	54.8	41.8	**20.6**	Main reservoir, under rehabilitation
Ginter Park Tank	1.0	1.0	1.0	
Church Hill Tank	4.9	2.2	2.2	
Cofer Road Tank 1	2.0	1.2	1.2	
Cofer Road Tank 2	2.1	1.2	1.2	
Woodside Tank	1.0	1.0	1.0	
Warwick Rd. Tank	2.0	2.0	2.0	
Stratford Hills	0.3	0.0	0.0	Not used for storage
Jahnke Rd. Tank	2.4	1.4	1.4	
Hioaks Tank	2.0	2.0	2.0	
Huguenot Road Tank	0.75	0.38	0.38	
Total Storage	**73.2**	**54.2**	**25.0**	

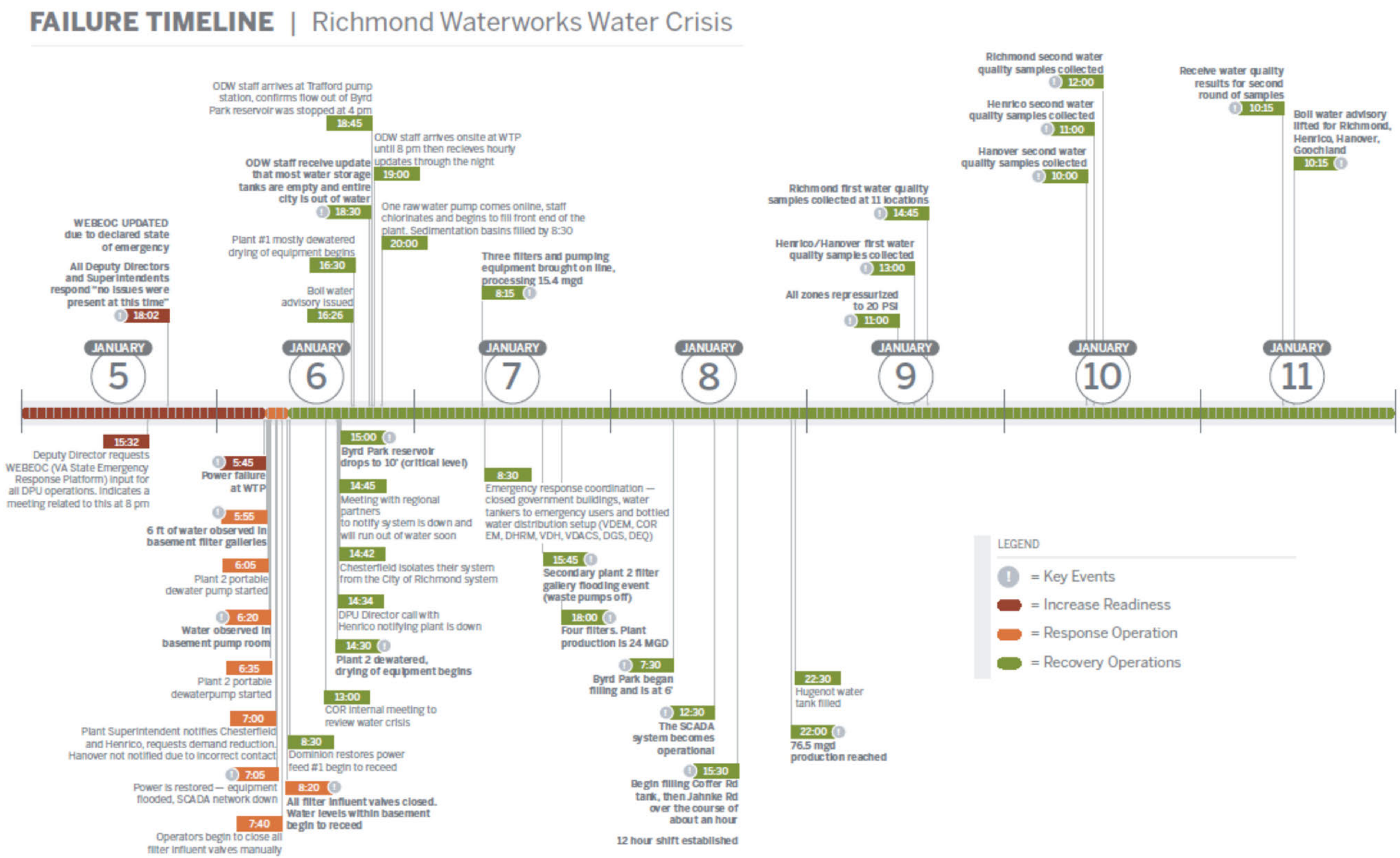
2.5.3 Raw Water Screening Facilities

This project includes raw water screen replacement and concrete work in the south pre-sedimentation basin, which removed the plant 2 raw water pumps from service during the project. During normal operation plant 2 is fed from plant 1 raw water channel, bypass pumps are installed to pump from the pre-sedimentation channel to the raw water channel 2 if additional capacity is needed. This project had no known adverse impacts on the plant during the production outage.

3 WTP Failure Sequence of Events

SEH developed the sequence of events timeline based on documents provided by ODW and DPU. Additional questions or discrepancies were resolved through questions provided to DPU and ODW. Many of the events listed on the timeline are based on interviews with DPU and ODW staff who were onsite during the initial failure and subsequent recovery process. For the purpose of our evaluation of the water crisis and in line with terminology used in Emergency Operations Manual, this event was broken into the following timelines: Readiness Phase (Pre-Failure), Response Operations Phase (Active Failure Response) and Recovery Phase (System Recovery Post Active Failure) prior to return to Routine Operations. These timelines were verified to the extent possible, but some items relied on the recollections of people during an emergency response situation and are presented as an estimate. Below is a graphical timeline of major events associated with the water crisis. A more detailed timeline in table format follows in subsequent sections.

Figure 1 – Overall Timeline of Water Crisis



3.1 Detailed Timeline of January 6, 2025

A detailed timeline of events is provided in table format below and is broken into three columns, which include description of actual physical event taking place, internal communication within the DPU/COR, and external communication to either the Public or Regional DPU partners. Each line item may incorporate one or more of these categories. An evaluation of the event timeline along with a summary is included in the subsequent section.

The timeline of events includes the source of information, which includes the COR, HNTB After-Action Report, VDH-ODW, and additional phone and text communication records.

Time	Description	Internal Communication	External Communication	Source
Sunday, January 5				
			Mayor Avula Declared State of Emergency for Richmond (following Governor Youngkin's declaration 1/3/2025)	HNTB
3:32 p.m.		Deputy Director requested WEBEOC (VA State Emergency Response Platform) input for all DPU operations. Indicated a meeting related to this at 8:00 p.m.		Text message from DPU Director to DPU Group
6:02 p.m.	WEBEOC UPDATED - due to declared state of emergency	All Deputy Directors and Superintendents responded "no issues were present at this time"		Text message from 804-219-7592 to DPU Group
Monday, January 6				
4:25 a.m.	WTP Experienced a short power interruption. Staff indicated this was a matter of seconds. One Filtered Water Pump (N3) stopped functioning because of the power interruption.			HNTB, COR
4:35 a.m.	Staff was unsuccessful in re-priming N3, so they primed Pump N1, previously not in service. Critical equipment check was completed at this time.			HNTB, COR
5:45 a.m.	Active power feed to WTP lost power. Main automatic bus tie failed to transfer power to alternate power feeder. SCADA network and phones were not on UPS backup and went down because of loss of power. All electrical systems stopped functioning, except for some systems with UPS backup, such as PLCs and emergency lights in select areas. Exterior and filter building basements lacked emergency lighting.			HNTB, COR
5:50 a.m.	Operators observed flooding in filter galleries and attempted to start a diesel engine driven pump (Godwin Pump) to dewater Plant 1 basement. Operators had difficulty priming the pump.	Operators called Electrical and I&C on call staff		HNTB, COR, ODW
5:55 a.m.	Operators observed 6' of water in both Plant 1 and 2 underground filter galleries. This water level corresponded to approximately 90.5 feet of elevation.			HNTB, COR, ODW
6:05 a.m.	Operators successfully primed the diesel engine driven pump (Godwin Pump) at Plant 2, and it began pumping water from the underground filter gallery. Electrical Specialist arrived early for shift at WTP and worked to try to open the entrance gate to the Plant, unaware of flooding issues.	Utility Plant Specialist Senior Called Program and Operations Supervisor		HNTB, COR
6:15 a.m.	Electrical Specialist went to electrical switchgear SG7 to investigate the loss of power.			COR
6:20 a.m.	Water Level reached bottom of stairs (pump room floor) observed in Plant 1 (approximately elevation 91.0 feet), N2 Check Valve lid observed to be loose with substantial overflow from filtered water clearwell. Valve was partially disassembled for ongoing maintenance. Valve was significantly above the hydraulic grade of the clearwell during normal operation.			HNTB, COR, ODW
6:30 a.m.	Electrical Supervisor arrived at WTP and went to Switchgear SG7, observed no power.			HNTB, COR, ODW
6:35 a.m.	Plant 1 Godwin Pump achieved prime and began discharging. Due to location of the discharge hose, portion of the discharge reentered Plant 1 basement.	Mechanical Specialist Called for backup for snow removal/deicing to facilitate additional staff arriving		HNTB, COR, ODW
6:40 a.m.	Electrical Supervisor arrived at SG6 and observed active main feed without power and bus tie that did not close. Attempted to manually close tie breaker with the control handle that activates tie breaker solenoid coil. Tie breaker did not close. Chest high water observed in Plant 1 Pump Room (approximately elevation 95.0 feet)			HNTB, COR
6:45 a.m.	Electrical Supervisor unsuccessfully attempted to close bus tie by opening the breaker for Main Feed 2.	Electrical Supervisor instructed Specialist to call Dominion. Electrical Supervisor called Operations Supervisor to discuss situation		HNTB, COR

Time	Description	Internal Communication	External Communication	Source
7:00 a.m.	Electrical Supervisor verified Main Feed 1 Phase to Phase Voltage was incorrect. Godwin Pump discharge redirected to inlet that drains to Douglasdale Wastewater Pumping Station instead of back into Plant 1.	Plant Superintendent notified DPU Director, all Deputy Directors, Public Information Manager. Program and Operations Supervisor notified Maintenance Program and operations Manager	Plant Superintendent notified Chesterfield and Henrico, requested demand reduction. Hanover not notified, Superintendent noted they had some turnover and didn't have current contact information.	HNTB, COR, Henrico. Text from Superintendent to DPU group on notifications. Interview with Superintendent
7:05 a.m.	Electrical Supervisor successfully closed the main bus tie by closing plunger on breaker manually. This attempt differed from the previous attempt at 6:40 because it did not rely on electro-mechanical solenoid to close bus tie. Power to the WTP was restored. The SCADA network had communication errors and failed to resume normal function. Plant 2 water level in pump room had reached MCC.	Confirmed Superintendent in route to WTP. Program and Operations Manager and Supervisor confirmed they were heading to plant.		HNTB, COR
7:09 a.m.		DPU Director directed team not to post to WEBEOC until 8:00 a.m. update meeting.		Text from DPU Director to COR group
7:10 a.m.		Electrical Supervisor notified Program and Operations Supervisor that power is back on.		COR
7:15 a.m.	Program and Operations Supervisor arrived at WTP.	Program and Operations Supervisor called plant staff to manually open gate		COR
7:20 a.m.	Program and Operations Supervisor entered basement and confirmed flooding.			COR
7:30 a.m.	Dominion arrived onsite to repair Main Feed 1.			HNTB, COR
7:35 a.m.		Maintenance Program and Operations Manager called WTP and was briefed over the phone.		COR
7:40 a.m.	Operators began to close all filter influent valves manually.			HNTB, COR, plant Superintendent Interview
7:45 a.m.	Plant Operations Supervisor Senior arrived onsite.	Maintenance Program and Operations Manager called WWTP maintenance staff to come to WTP and bring additional sump pumps for dewatering		COR, HNTB, Text from Program & Operations Manager to DPU Group at 8:00 a.m. confirming
8:00 a.m.	Dewatering Pumps and WWTP Maintenance Staff arrived onsite. Staff worked to hook up four 2" pumps.	Deputy Director (Whitehurst) headed to plant. Richmond Emergency Operations meeting indicated at 8:00 a.m. by DPU Director, unknown topics or attendees.		Communication log provided by ODW
8:10 a.m.	Floodwaters continued to rise. Staff rechecked all filter influent valves.			COR
8:11 a.m.	Chesterfield reverted to normal withdrawal of water.		DPU Director Notified Chesterfield that power was restored following communication related to demand reduction. No additional communication from DPU director to clarify WTP that plant was not operational. No additional communication with Chesterfield until 2:35 p.m.	HNTB, COR, Henrico, Text from DPU Director to George Hayes.
8:20 a.m.	Program and Operations Supervisor determined not all filter influent valves closed, once closed water began to recede. Max water level observed above bottom of stairs to basement (approximately elevation 97.0 feet).			COR
8:30 a.m.	Dominion restored power feed 1.			COR
8:45 a.m.	Deputy Director arrived at the WTP.			COR
9:00 a.m.			Henrico (Simunkonde) called contacts at Richmond DPU. Staff indicated they were having water production issues but indicated distribution system was looking ok.	Henrico
10:00 a.m.		Plant Superintendent notified DPU Director and Deputy Director that there may be a service interruption and to start considering service interruption.		HNTB, Interview with Plant Superintendent, Verified by Deputy Director

Time	Description	Internal Communication	External Communication	Source
11:00 a.m.	Electrical Specialist turned off washwater pumps to keep them from burning up from extended runtime underwater.			COR
12:00 p.m.			WEBEOC Situation Report 1 for winter weather as of 12:00 p.m. 1/6 indicated no issues in Region 1.	WEBEOC Situation Report #1
12:30 p.m.	Byrd Park Reservoir water level dropped to 12.7'. Max level at the time of the event was 19' due to an ongoing capital project. Minimum water level required to maintain system pressure is 10'.			Text from Superintendent to DPU Group
1:00 p.m.		Internal Meeting with DPU Director, DPU Deputy Director , Plant Superintendent , Mayor , DPU CAO Senior Policy Advisor, COR DECPR , COR DCAO , Public Information Officer		Communication log provided by ODW
2:18 p.m.			Richmond opened virtual EOC and updated WEBEOC. Actual EOC was not set up until later in the afternoon.	WEBEOC VA Local/Tribe Situation Report Library review
2:30 p.m.	Plant 2 mostly dewatered down to basement level, staff began to dry motors, actuators and other equipment. Work continued through the night. R1 Pump was shut off to preserve finished water tank level (pump is manual control and runs full time). Tank was 12' below operating level, essentially empty.			COR, HNTB
2:34 p.m.			Richmond DPU Director Called Henrico DPU Director and indicated WTP down and may not be able to restart that day. Requested Henrico Coordinate call with regional partners.	Henrico
2:42 p.m.	Chesterfield isolates their system from the City of Richmond System.			Henrico
2:45 p.m.			Virtual meeting with Richmond DPU and regional partners explaining that system was down and would run out of water soon.	Henrico
3:00 p.m.	Byrd Park Reservoir Dropped to 10' (critical level).			COR, Tank Level Log
3:49 p.m.			Richmond DPU Circulated draft Boil Water Advisory to Chesterfield, Henrico, and Hanover for review.	Henrico, Hanover
4:26 p.m.	Zone 7A remains pressurized above 20 PSI due to interconnect with Chesterfield County.		Boil Water Advisory issued, included information promoting water conservation and potential loss of service.	Henrico, Hanover
4:30 p.m.	Plant 1 mostly dewatered.		Regional Meeting included Henrico, Hanover, Chesterfield, VDH.	HNTB, COR, Henrico, Hanover
6:30 p.m.	ODW staff received update that most water storage tanks were empty, and entire City is out of water.			ODW Incident write up
6:45 p.m.	ODW staff arrived at Trafford Pump Station, confirmed flow out of Byrd Park reservoir was stopped at 4:00 p.m.			ODW Incident write up
7:00 p.m.	ODW staff arrived onsite at WTP until 8:00 p.m. then received hourly updates through the night.			ODW Incident write up
8:00 p.m.	One raw water pump came online, staff chlorinated and began to fill front end of the plant. Sedimentation Basins filled by 8:30.			ODW Incident write up
8:26 p.m.			DPU Director indicated they have 8 filters ready for service and 2 pumps but struggling with SCADA, requested any contacts for SCADA assistance from partner DPU's. DPU Director followed up with Heritage from recommendation and they mobilized to site.	Richmond DPU Director text to area DPU text group.
10:52 p.m.	Mayor was onsite with DPU Director.			Text from DPU Director to COR DCAO
Evening	Staff worked through night to dewater motors, valves, and electrical equipment to get filters online.			ODW Incident write up

Time	Description	Internal Communication	External Communication	Source
Tuesday, January 7				
12:05 a.m.			Public Announcement: Situation Update from Mayor	COR Press Release
4:59 a.m.			Richmond sent request for additional electricians to partner DPU's. Chesterfield provided on call number, DPU Director connected with them, and they mobilized at 6:50 a.m.	Hanover, Richmond DPU Director text to area DPU text group.
5:40 a.m.			Public Announcement: City Emergency Operations Center was up and running, Mayor will hold press conference at 8:00 a.m.	COR Press Release
6:00 a.m.			Richmond sent request for additional Operational Help; Hanover provided staff.	Hanover
8:00 a.m.	Hanover Operations Staff arrived onsite to assist.		Mayor Avula held a press conference to inform the public about the event.	Hanover, Communication log provided by ODW
8:15 a.m.	Plant 1: 3 filters rewashed and online along with S1 finished water pump, operators began filling finished water tank, approximately 15.4 mgd.			Texts between Mayor and DPU Director. Referenced in COR Timeline.
8:30 a.m.		Internal Meeting: Emergency Response coordination - closed government buildings, water tankers to emergency users and bottled water distribution setup (VDEM, COR EM, DHRM, VDH, VDACS, DGS, DEQ).		Meeting Write up e-mail from VDH at 9:14am.
9:20 a.m.			Public Announcement: Bottled water distribution site information provided.	COR Press Release
10:40 a.m.			Public Announcement: Bottled water distribution update.	COR Press Release
11:30 a.m.	ODW arrived onsite and maintained continuous presence at the WTP through 1/12.			HNTB, ODW
11:31 a.m.			Public Announcement: Bottled water distribution update.	COR Press Release
12:00 p.m.	Korah K3 turned on to send water to the distribution system and pressurize the water main line to Henrico. In-plant water main was tapped off this line, which provided house pressure to Plant 2 Filter Actuated valves.			COR
12:30 p.m.			Public Announcement: Water production has been restored, and system is filling prior to distribution. *Note: At this time, the actual flow being produced at the WTP was less than 15 MGD, well below the plant's rated production capacity and normal average demand. Water is not being sent to the distribution system at this time,*	COR Press Release
3:36 p.m.	Mayor arrived onsite			Text from Deputy Director to DPU Director
3:45 p.m.	Second inundation event began Plant 2 basement. Backwash pumps manually turned off without operator knowledge prior to initiating backwash. The backwash water overflowed from waste channel to gallery through the filter-to-waste air breaks. Operators managed water levels by turning on the washwater pumps; however, it quickly flooded to within 3-4' of walkway.			COR, Pictures from ODW
4:00 p.m.	Operators able to quickly start Godwin pumps to dewater area and manage water levels in the Filter Gallery to elevation below equipment. However, effluent valve actuator panels open for drying were impacted by water splashing and had to be dried out.		Public Announcement: Bottled water distribution update.	COR, COR Press Release
4:30 p.m.	Main plant electrical switchgear reconfigured such that the bus tie was energized between both main feeds for added redundancy (configuration known as "Summer Mode") and remains that way.			COR
6:00 p.m.	Four filters are online in Plant 1. Plant production is 24 MGD.			COR

Time	Description	Internal Communication	External Communication	Source
6:20 p.m.			Public Announcement: Progress at the facility delayed due to set back with electrical panel failure. NOTE: this is a reference to 3:45 p.m. event referenced above.	COR Press Release
9:00 p.m.			Public Announcement: Progress update - 6 filters and 1 pump running.	COR Press Release
Wednesday, January 8				
1:00 a.m.	Two 4 MGD bypass pumps arrived onsite, and crews began to establish a connection between the clearwell and finished water basin			COR
2:00 a.m.	Pump R1 was turned on to start filling Byrd Park Reservoir.			COR
2:30 a.m.	The SCADA system became operational.		DPU Director texted partner DPU directors that SCADA is operational, and they were attempting to backwash and start producing water.	COR
4:30 a.m.			Public Announcement: Progress update - 12 filters and 3 Pumps Running.	COR Press Release
5:30 a.m.			Public Announcement: Bypass Pumps Installed (arrived at 1:00 p.m.).	COR Press Release
6:00 a.m.	13 of 22 filters were rewashed manually and put online			COR
6:30 a.m.	Two 4 MGD bypass pump installations are completed and supplemented water pumping from clearwell into the finished water basins.			COR
7:30 a.m.	Byrd Park Reservoir level filled to 6'			COR
2:30 p.m.			Mayor Avula press conference.	COR Press Release
3:20 p.m.			Public Announcement: Status update and conservation reminder.	COR Press Release
3:30 p.m.	Begin filling Cofer Rd and Jahnke Rd Tanks	12-hour shift established.		COR
3:20 p.m.			Public Announcement: Status update and conservation reminder.	COR Press Release
7:00 p.m.	16 of 22 Filters washed and ready.		Public Announcement: Status update and conservation reminder.	COR, COR Press Release
10:00 p.m.	76.5 mgd production reached.		Public Announcement: Status update and conservation reminder. Four zones are now operational.	ODW Incident write up, COR Press Release
10:30 p.m.	Huguenot Water Tank filled.			COR
Thursday, January 9				
Morning	Bypass pumps frozen, staff thawed with heaters, N2 failed			
7:00 a.m.	18 of 22 filters washed and ready, continued pressurizing system, repaired air bleed valve at Coffer Rd tank. *Note: At the time of the event, only 19 filters were in service or available to produce water. Three filters were out of service for maintenance or repairs.*			
8:30 a.m.			Public Announcement: Status update and conservation reminder. Eight zones are now operational.	COR Press Release
11:00 a.m.	All zones repressurized to 20 PSI.			COR Press Release
1:00 p.m.	Henrico/Hanover First Water Quality samples collected.			ODW Incident write up
2:13 p.m.			Public Announcement: First Water Sampling Event is underway.	COR Press Release
2:37 p.m.			Public Announcement: Bottled water distribution site information provided.	COR Press Release
2:45 p.m.	Richmond First Water Quality samples collected at 11 locations.			ODW Incident Write Up, COR
6:12 p.m.			Public Announcement: Water Restoration Status Update.	COR Press Release

Time	Description	Internal Communication	External Communication	Source
Friday, January 10				
Morning	Finished water pump motor failed and needed to be sent for repair.			COR
10:00 a.m.	Hanover Second Water Quality samples collected.		Mayor Avula press conference.	ODW Incident write up
11:00 a.m.	Henrico Second Water Quality samples collected.			ODW Incident write up
12:00 p.m.	Richmond Second Water Quality samples collected.			ODW Incident write up, COR
Saturday, January 11				
10:15 a.m.	Received Water Quality Results for second round of samples.			ODW Incident write up
11:30 a.m.	Boil Water Advisory Lifted for Richmond, Henrico, Hanover, Goochland.			ODW Incident write up

3.2 Evaluation and Summary of Timeline

An evaluation of the timeline of events is broken into several phases as described below.

Increased Readiness

Prior to the failure on January 6, 2025, a state of emergency was declared on January 5, 2025, by the Mayor of the City of Richmond (following prior state of emergency declaration by governor). Staffing was augmented as detailed in prior sections and DPU Director coordinated with the team to update WEBEOC.

Response Operations

Plant Operations: Failure of the primary electrical feed at 5:45 a.m. started the active response operations phase of the water crisis as backup systems did not activate as expected at the same time. Operators noticed flooding within 5 minutes of losing power, with water levels reaching 6' above the basement floor 5 minutes later (10 minutes from loss of power) While on call electrical staff were mobilizing to the facility, onsite staff focused on starting portable basement dewatering pumps. By the time electrical staff restored power to the WTP, 1 hour and 20 minutes later, pumping, and electrical equipment had already been submerged and damaged. Staff then shifted focus to shutting down inflow of water into filters, and by 8:20 a.m. water was receding in the filter gallery and pump rooms. Total duration of this phase was two hours and thirty-five minutes (5:45 a.m. to 8:20 a.m.).

Internal Communication: Within approximately one hour of initial power failure all sections impacted within DPU including the Director and Deputy Directors had been notified and the majority were mobilized to the site or on their way. Other City staff including Information Officer and DCAO were notified during this phase as well. Director provided specific guidance to not update WEBEOC until 8:00 a.m. meeting. Meeting details were unknown by current DPU staff but indicated this would have been with Richmond Emergency Operations. Additional information on internal communication for Response operations handled in the communication section.

External Communication: Plant superintendent initially contacted Chesterfield and Henrico at 7:00 a.m. to notify them of power failure and request reduction of flow into their systems within about an hour. Hanover was not contacted due to turnover with staff so new contact information was not known to superintendent, and no additional contact between superintendent to partner counties was documented during this phase. Communication between DPU Director and Chesterfield indicated that power loss had been resolved at 8:05 a.m. and Chesterfield returned to normal withdrawal.

Recovery Operations

Plant Operations: Once water level began to recede at 8:20 a.m. the timeline entered recovery phase of the water crisis. The immediate flood threat was over; however, equipment had been damaged, and staff shifted focus to recovery efforts until routine operations was restored. Following dewatering operations staff worked to dry out equipment and electrical gear and replace valve actuator internal parts. This was accomplished with a combination of in-house staff and subcontractors. Staff accomplished a large scope of work quickly with the WTP beginning to process limited amounts of water (15.4 MGD) within about 26 hours of initial failure. Processed water began to flow to Byrd Park Reservoir within about 50 hours, with full system flow leaving plant achieved at 66 hours and minimum pressure achieved within distribution system at about

75 hours. Boil water advisory was lifted 48 hours after minimum pressure was achieved. The facility accomplished a substantial amount of work in a short timeframe, mobilizing resources and people quickly in a challenging environment. DPU staff worked diligently throughout the event but very independently within various work groups. Overall coordination and communication to restore operation of the entire facility could have been improved. A few events indicated on the timeline illustrate the lack of coordinated direction.

1. The initial focus for plant operators was on getting Plant #2 back online. Staff worked diligently on their specific tasks before realizing that hydraulic pressure was required to operate Plant 2, resulting in a minor restoration delay.
2. Equipment was manually operated without overall coordination of completed and in-progress activities. Backwash waste pumps were manually shut off during the emergency flooding phase due to concerns of pump damage. This information was not communicated or coordinated. Plant operators were not aware of this change and subsequently attempted to backwash filters to restore normal operations, resulting in a secondary overflow event and minor delay to recovery efforts. Additional minor instances of lack of coordination and direction exist through the recovery process. While the cumulative effect of these actions was minor, it indicated that staff was used to putting their heads down and addressing the specific task at hand out of necessity. Standard procedures, training, and shared vision would have made the process more efficient and accelerated the recovery process.

Internal Communication: There was limited, documented internal communication during the recovery operations, with the exception of a meeting with DPU Director, Deputy Director, CAO, WTP Superintendent along with as COR DCAO, Mayor, and DECPR at 1:00 p.m. on January 6, 2025.

External Communication: The first external communication during the recovery phase occurred between the DPU Director and Henrico County at 2:34 p.m. and indicated that the WTP may not be able to restart that day (January 6, 2025). A meeting with Henrico, Chesterfield and Hanover Counties immediately followed. VDH was made aware of this issue at this time. Boil water advisory was issued to the public later that day at 4:26 p.m. External communication to the public following boil water advisory was largely handled by the City. According to verified timeline, at approximately 10:00 a.m. on January 6, 2025, Plant Superintendent made DPU Director and Deputy Director aware that failure to deliver water was something for which they needed to prepare. External communication to Henrico, Chesterfield and Hanover was handled by DPU Director during recovery phase.

4 Root Cause Analysis

At a basic level, the WTP production outage and resulting loss of water to the City of Richmond and bulk water customers was caused by a weather-related utility power outage and equipment failure of the main automated bus tie. However, the Richmond WTP is a sophisticated facility with multiple levels of redundancy intended to prevent a utility power loss event from transforming into a regional water shortage. The events surrounding the January 6, 2025, water outage had many contributing factors. The intent of this report section is to determine which of these factors are most critical.

4.1 Methods

A three-step process is used in this section of the report to evaluate which of the contributing factors are the underlying root causes of the water crisis. The first step is to develop a problem statement that will define the analysis. In this instance, that problem statement is "Loss of water to Richmond and surrounding area." The second step consists of identifying the individual modes of failure and the associated consequences. This section is organized into sections describing: 1) conditions leading to the shutdown, 2) conditions extending the WTP shutdown, and 3) conditions which limited the ability of the distribution system from sustaining water supply during the WTP shutdown. These encompass sections 4.2, 4.3 and 4.4 below. Key factors are identified in this section and a graphic representation is assigned to each factor. Each key factor is categorized according to the 6M's, Manpower, Machines, Materials, Methods, Mother Nature, and Measurements. These categories are merely a useful means of organizing ideas, and significant overlap may exist between them. A brief description of each category as it is used in this report is provided below:

- Manpower: The operational and/or functional labor of people engaged in operation of the WTP and delivery of water to customers.

KEY FACTOR
Manpower

- Machines: The equipment, facilities and tools used in the operation of the WTP and production of water. Examples include pumps, electrical equipment, and process equipment.

KEY FACTOR
Machines

- Materials (site constraints): This includes all the raw materials and physical site features that are part of the site used in production of water. Examples include consumables (i.e., bulk chemical) and raw water as well as site features/constraints like installed concrete tankage (i.e., clearwell)

KEY FACTOR
Materials

- Methods: Processes and procedures associated with operation of the WTP and production of water. Examples include standard operating procedures, training emergency response plan, etc...

KEY FACTOR
Methods

- Mother Nature: Environmental factors and events that are uncontrollable and/or unpredictable. Examples include storms, earthquakes, floods, etc...

KEY FACTOR
Mother Nature

- Measurements: Inspection and other physical measurements related to operation of the treatment plant whether manual or automatic. Examples include SCADA System, visual inspection, etc.

KEY FACTOR
Measurements

The third step is further evaluation of the modes of failure to determine main modes of failure and root causes for those modes of failure, covered in section 4.5 below.

4.2 Conditions leading to WTP Shutdown

4.2.1 Severe Weather Preparation

Prior to the event, the DPU lacked a formal severe weather preparation SOP. Staff report that standard practice included fueling vehicles and generators (see section 2.4 for additional information).

Emergency Preparation
Methods

Special staffing was limited to two additional maintenance personnel assigned for snow and ice removal.

On January 3, 2025 Governor Youngkin declared a state of emergency across the state of Virginia due to the impending winter weather event. Richmond Mayor Danny Avula issued a follow up state of emergency for the city on January 5, 2025.

SEH reviewed historical weather records collected at the Richmond Airport weather station, which were readily available from www.wunderground.com for January 5, 2025, and January 6, 2025. According to the data, approximately 0.8 inches of precipitation accumulated as snow on the evening of January 5, 2025 and an additional 0.2 inches of precipitation in the hour leading up to 5:45am. The prevalence of ice forming conditions was not included in the weather data although it is understood to have occurred.

Primary Power Failure
Machines

The snow and ice weather event caused a utility power outage on the main power Feeder #1, which was the catalyst that set the subsequent failures into motion. The primary power source was lost when utility power was disrupted at 5:45 a.m. Operators present during the event described observing a distant explosion that was believed to be a transformer. The underground main power Feeder #2 did not experience a disruption.

4.2.2 Main Power Feed

There are two feeders from Dominion Energy feeding the Richmond WTP at 34.5kV. Feeders are as follows:

3. Feeder 310 to substation #1, (SS1), is overhead from the Dominion Energy ACCA substation.
4. Feeder 399 to substation #2, (SS2), is underground from the Dominion Energy Carver substation.

Both feeders supply 7.5MVA outdoor 34.5kV-4.16/2.4kV transformers which feed 4.16kV switchgear SG6.

Switchgear SG6 receives 4160V power from SS1 and SS2 and distributes it throughout the water treatment plant. This includes:

1. Switchgear SG7, which distributes power to the Filter Plants, West Chemical Building and Douglasdale Wastewater Pumping Station.
2. Switchgear SG8, which distributes power to the Korah 2-3 pumping stations.

Feeder Substations and SG6

3. Switchgear SG6, and utility substations which distributes power to the Water Treatment Plant and Korah Pumping Stations.

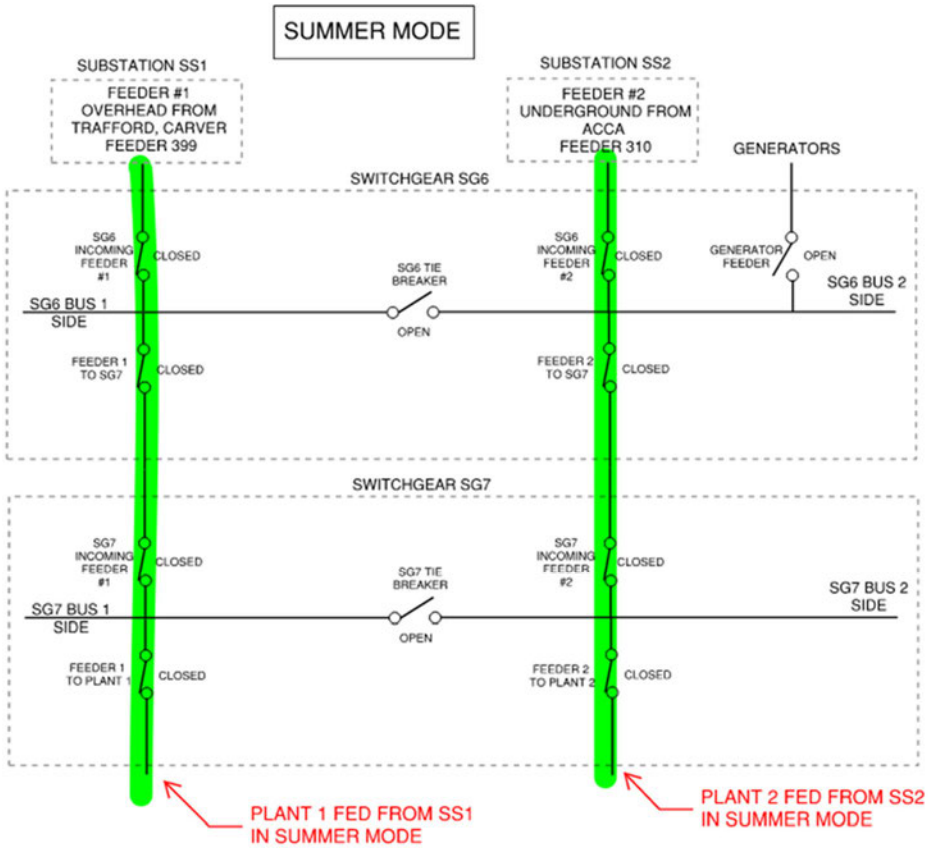
SG-6 has no status indication or alarms to main SCADA or at the Filter Plant control rooms. There is a Panalarm System that alarms in the Switchgear enclosure, which provides local indication of alarms through an alarm light grid. Electrical Maintenance staff indicated the Panalarm system used to be wired back to control room #2 and duplicated on the old control panel, but that was abandoned during one of the previous projects.

Electrical Switchgear Alarms No Longer Alarm to Control Room
Measurements

All switchgear equipment is tested every 3 years by a third-party testing entity. The last round of testing was performed in 2022 by Electric Power Systems, (EPS), and a test is scheduled for 2025.

Historically, there have been two operating modes utilized for feeding power to the plant from Substation SG6. These are referred to as Summer Mode and Winter Mode. In Summer Mode, both SG6 incoming feeder breakers are closed and the SG6 tie breaker between the busses is open. The feeder from SS1 to downstream switchgear SG7 is closed, and the feeder from SS2 to SG7 is closed. The tie breaker at SG7 is open. This results in each of the 4160V-480/277V transformers that provide power to the water treatment plants 1 & 2 being fed from a unique substation. See Summer Mode Diagram below for illustration of power flow using Summer Mode.

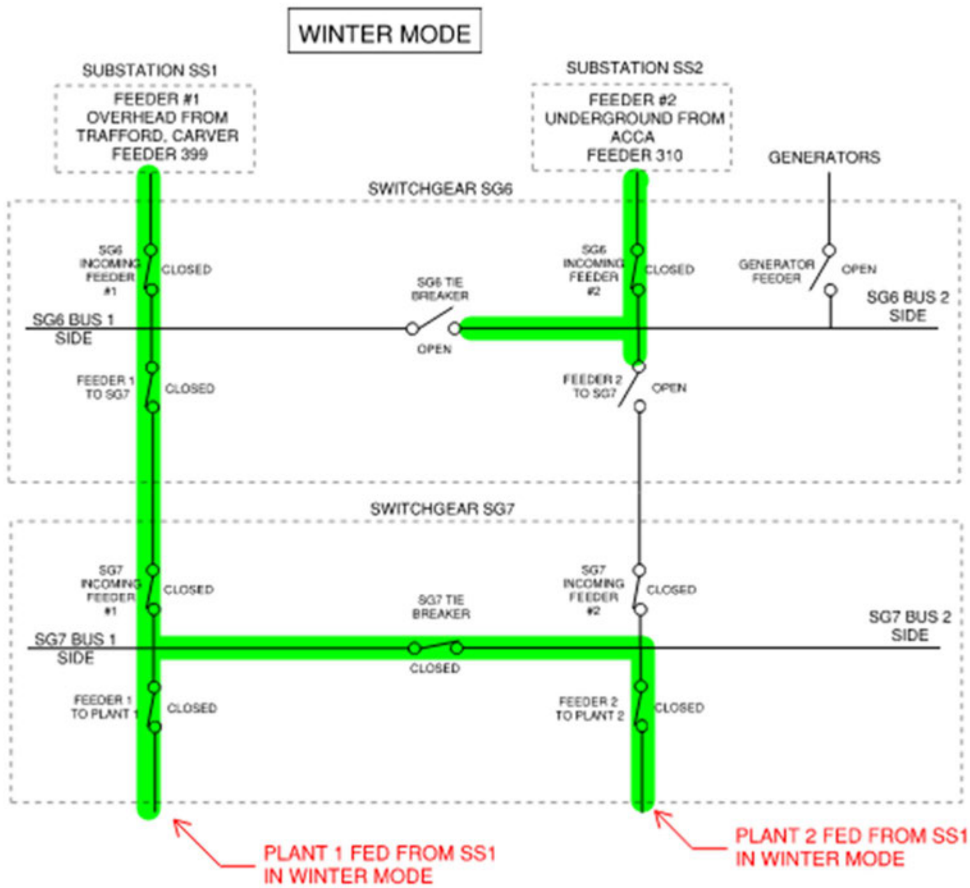
Diagram 1: Summer Mode Electrical Feed



Winter Mode
Methods

At the time of the power outage, the plant was operating in "Winter Mode." In Winter Mode, both incoming main feeder breakers from the substations are closed and the tie breaker between the busses is open. The feeder from SS1 to downstream switchgear SG7 is closed, while the feeder from SS2 to SG7 is open. The tie breaker at SG7 is closed. This results in both 4160V-480/277V transformers that provide power to the water treatment plants 1 & 2 being fed from Substation SS1. This mode has been in place for over 20 years as a cost saving measure. See Winter Mode Diagram below for illustration of power flow using Winter Mode.

Diagram 2: Winter Mode Electrical Feed



Backup Power Failure – Switchgear Bus Tie Failure
Machines

With the WTP operating in Winter Mode, the SG6 Tie Breaker would normally sense that power is still available on the SG6 Bus 2 upon failure of the feed from SS1 and automatically switch the power feed to the Bus 2 side of the Switchgear. A failure of the SG6 Tie Breaker resulted in the breaker not automatically switching over. This resulted in a loss of power to the entire plant. See Diagram below for an illustration of power flow during the power outage of January 6, 2025. Investigation after the event determined that coil was burned out and the associated fuse was blown.

During the initial attempts to investigate and address the power failure during the event, Electrical Maintenance staff attempted to manually transfer power using the control handle. The burned-out coil and fuse prevented this attempt to transfer power.

Although this piece of equipment is over 30 years old, equipment of this age is common in older plants and although approaching the end of its expected life it was regularly maintained and tested on a 3-year cycle. With regular maintenance, this equipment could reasonably be expected to remain serviceable for the foreseeable future. The 2020 Water Treatment Plant Condition Assessment reviewed the switchgear and gave it a condition rating of 2 out of 5 (with 1 being best condition and 5 worst condition). Switchgear replacement was not listed in the 10-year asset replacement schedule.

Section 730 of the Virginia Waterworks Regulations requires that "Alternative power sources at all waterworks shall be considered in the design to maintain a minimum level of service during an electrical power outage." Operation in Winter Mode with a device for automatic transfer of power to an alternate power feeder from a different utility substation is generally considered to satisfy this requirement, even though a more reliable method of operating was available.

4.2.3 Back-up Generators Require Manual Startup and Switching

Generator Requires Manual Startup
Machines

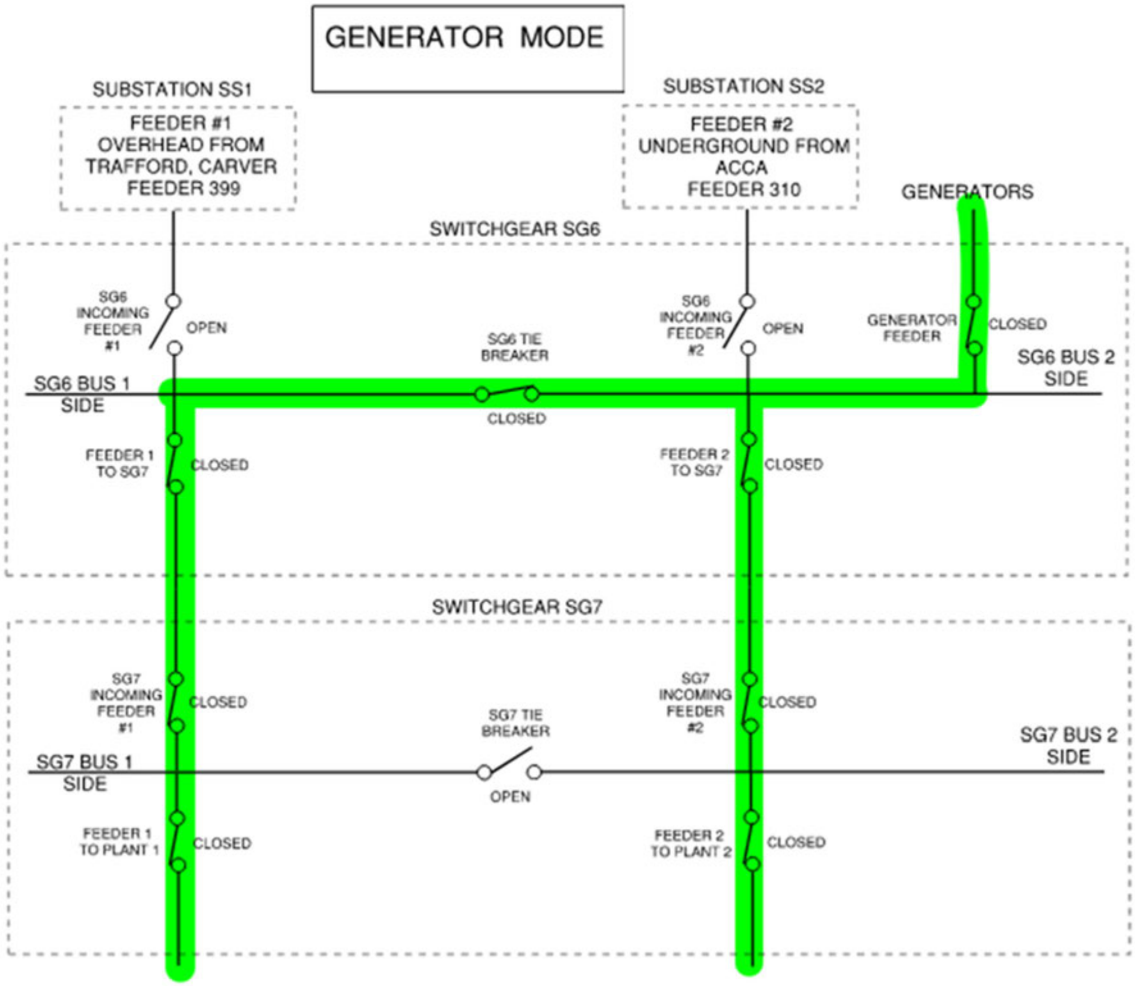
Two trailer-mounted generators operate in parallel and are permanently wired to the SS-1 side of Switchgear SG6. The generators can provide power to the WTP to support reduced capacity operation if both utility feeders are offline. To provide power to SG6, the generators must be started and switched manually by qualified electrical maintenance staff. Specifically, the SG6 incoming feeders 1 and 2 must be opened, the Generator Feeder breaker closed, and either the SG6 or SG7 tie breaker closed. See Diagram below for an illustration of power flow using the generators.

Lack of Qualified Electrical Staff on Night Shift
Manpower

No qualified electrical maintenance staff were on site at the beginning of the power outage. Therefore, the generator could not be started immediately upon loss of utility power. The duration of time required to start and connect the generators to SG6 that were reported by various personnel and documents varied from approximately 15 minutes to 45 minutes. As described in the following sections, following a power outage at normal operating conditions it is estimated that the clearwell would overflow into the filter pipe gallery in less than 3 minutes.

When the Maintenance Supervisor confirmed lack of power at the main feed on January 6, 2025, he had to decide whether to start the generator or diagnose and fix the bus tie. During the SEH site visit, the Maintenance Supervisor explained that it was necessary to diagnose the bus tie equipment failure before starting and connecting the generators to the main power feed to avoid further damage to the electrical equipment.

Diagram 3: Backup Generator Electrical Feed



4.2.4 Vulnerability of Filter Galleries and Filtered Water Pump Rooms to Clearwell Overflows

Clearwells Lack Overflow Pipes and Overflow to Filtered Pump Rooms and Filter Pipe Galleries
Materials

The underground filter pipe galleries and filtered water pump rooms in Plant 1 and Plant 2 are susceptible to process water infiltration overflowing from the filter clearwell. This is a known problem that has occurred for decades. Portable engine driven pumps with permanently installed suction piping were installed in the early 2000's to address the symptoms of these overflows. On January 6, 2025, this overflow occurred and damaged electrical equipment including pump motors and motorized valve controllers, which turned a brief power outage into a plant shutdown lasting several days while the equipment was repaired and dried out, and plant equilibrium was restored.

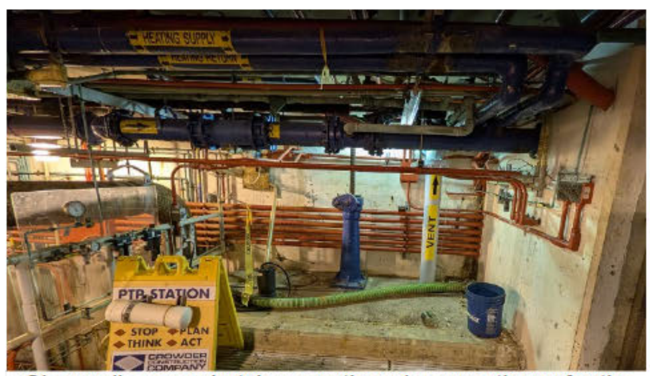
Examples of the physical arrangement and elevations of the underground filter building spaces in Plant 2 are shown in Figure 7 and Figure 8. The following description also explains the susceptibility to overflows. In each filter plant, the normal filter water surface elevation is slightly below grade. The ground surface elevation for the WTP is around EL 104 feet (feet above sea level). The normal filter water surface level is at EL 102.0 feet in Plant 1 and EL 102.3 feet in Plant 2. Each plant is equipped with suction lift-style filtered water pumps in a basement pump room that "lift" water from a lower water surface up to the pump inlet; Plant 1 finished floor elevation (FFE) is at EL 89.0 feet, Plant 2 FFE EL 90.0 feet. Each plant has a filter clearwell under the filters, which primarily serves as a pumping reservoir for the filtered water pumps, as well as a portion of the chlorine contact time. Water is conveyed from the clearwells to the pumps via concrete channels. The floor elevation of both clearwells is approximately EL 84.5 feet, the operating water level depicted on the most recent hydraulic profile is EL 92.13 in Plant 1 and EL 92.41 in Plant 2, and the clearwell ceiling elevation is EL 92.3 feet in each plant. According to these elevations, the clearwell has minimal freeboard available at design conditions. In order for the centrifugal style filtered water pumps to begin and continue to operate, they must be primed, in which air is removed from the pump body and inlet piping and filled with water. During normal conditions, the operators report that they are required to operate the clearwell level no lower than EL 89 feet. When the clearwell level is lower than 89 feet, the filtered water pumps begin to lose prime, which causes them to lose pumping capacity. As a result, the usable clearwell volume is significantly reduced.

Location of Pumps Does Not Provide Flooded Suction. Pumps Experience Issues with Suction Lift
Materials

Flow into the filter clearwell consists of filtered effluent water. Each filter effluent line is equipped with a modulating valve controlled by a rate of flow controller. As noted, flow out of the clearwell is conveyed by the Variable Frequency Drive (VFD) controlled filtered water pumps. These flow rates must match precisely. If the pumped flowrate exceeds the filtered flowrate, the clearwell level drops and the pumps risk losing prime. If the filtered flowrate exceeds the pumped flowrate, there is risk of overfilling the clearwell and spilling into the pump rooms and filter galleries. SEH estimates that at a typical plant flow of 60 MGD, a complete loss of pumping capacity such as occurred during the power outage on January 6, 2025, would cause the clearwell to overflow in approximately 3 minutes from a starting water level of 89.0 feet.

Clearwell Volume and Operating Freeboard is Minimal
Materials

The James River water surface elevations at the intake shown on the plant hydraulic profile vary from approximately EL 101 feet to 105 feet and are capable of gravity flow through the plant to the filter clearwell. Therefore, there is an effectively unlimited volume of water available to flood the clearwell in the event of a pump failure, until the flowrate into the facility is stopped by closing valves.



Clearwell access hatches are the primary pathway for the clearwell to overflow into the filter gallery in Plant 2.

Section 1081 of the Virginia Waterworks Regulations requires new finished water tanks to be equipped with an overflow pipe to convey overflows to a drainage system. The legacy design of the filter plants, which were originally constructed in 1924 and 1950, lacks overflow pipes. This predates the Virginia Waterworks Regulations 12VAC5-590 which were codified and adopted in their current form in 1974.

The filter clearwells are approximately 15 feet below grade in an area enclosed by a flood wall, which limits the feasibility of adding new overflow piping because disposal options are limited.

In both plants, the clearwell is interconnected to the pump rooms and filter galleries. Water surcharging the clearwell is allowed to spill into the dry spaces. These interconnections primarily consist of access hatches and vent pipes.

Although it is tempting to consider sealing up the various interconnections to maintain the filter galleries as dry spaces even when the clearwell level equalizes with the filters, this scenario could result in up to 13 feet of head differential. The 8” thick concrete slab is likely not designed to resist high differential pressures that could develop in this condition and could result in a major structural failure of the building.

To address the potential for flooding in the pump rooms and dry spaces, the Richmond WTP has implemented protective measures including an automated filter effluent valve closing sequence and the portable engine driven dewatering pumps. These measures are described in more detail in the following sections.

Clearwell Interconnection Reduces Redundancy of Parallel Plant Design to Clearwell Overflows
Materials

The two filter clearwells (Plant 1 and Plant 2) are interconnected by buried piping. A valve exists to isolate the clearwells, but it was reported that it has not been closed within the tenure of current staff. This factor was inconsequential in this event because the valve closure mechanism apparently failed in both plants independently. However, it is worth noting that upon loss of power, had the filter effluent valve closure sequence worked as intended in one filter building and still failed in the other, the interconnection would have caused excessive levels in the clearwell with the failed valve closure to propagate to the other filter plant. In this hypothetical scenario, both clearwells would overflow and damage equipment.

4.2.5 Check Valve Lid Unsecured

Poor Housekeeping Practices Created the Primary Pathway for Overflow into Plant 1
Methods

The primary pathway in Plant 1 for water to overflow from the filter clearwell into the filtered water pump room consisted of a check valve with an unsecured bonnet flange. Prior to the event, Pump N-2 was undergoing maintenance. Plant staff report that the check valve bonnet flange was partially secured in place with two loose bolts. During normal conditions, this method of fastening seems to be adequate because the check valve is “dry”. The check valve is isolated from the active pressurized piping on the downstream side and is above the clearwell level so there is no water from the supply side. However, during the event the water level rose out of the clearwell and flowed through the check valve and out of the piping system, into the pumping room. Alternate pathways for the clearwell to overflow into the pump room include two clearwell atmospheric vents that discharge into the pump room. However, the higher elevation of these alternate pathways meant the unsecured check valve lid was the path of least resistance during the event.

During the SEH site visits, numerous examples of poor house-keeping practices were observed, including poor standards of cleanliness, abandoned equipment and piping remaining in place, tool storage on access hatches, chemical totes draining to the process, plastic sheeting wrapping sample pumps to protect from spraying water that prevented air cooling, unsecured and dangerously unsupported grating which was not marked as safety hazard, and many others. The unsecured check valve lid is an result of the poor housekeeping factor affecting the water plant outage.

4.2.6 Failure to Close Filter Effluent Valves

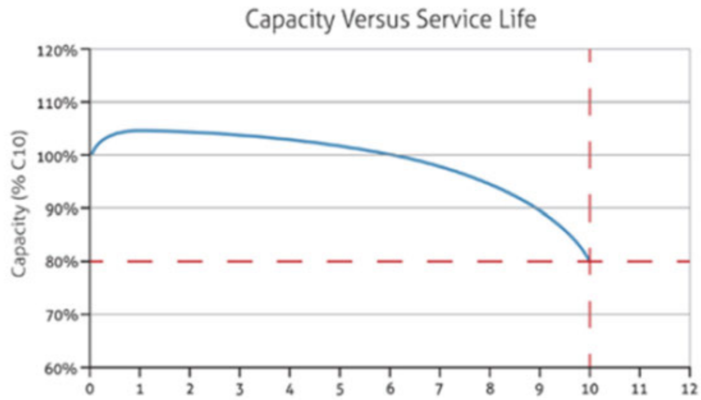
UPS Valve Controls Failed to Close Filter Effluent Valves
Measurements

The design of the WTP control system anticipated the need to close the filter effluent valves in the event of a prolonged power outage to avoid flooding the below-grade filter pipe galleries and pump equipment rooms. The relevant filter effluent valves had electric actuators along with adequately sized uninterruptible power supplies (UPSs) to provide emergency power to close the valves. The control system was designed to automatically close the filter effluent valves when the UPSs signaled that line power had failed and that the valves were running on battery power.

UPS Batteries Not Included on PM Schedule
Methods

UPS batteries, like all batteries, deteriorate over time. In the case of the valve-regulated lead-acid (VRLA) batteries typically used in UPSs, this deterioration begins the moment dioxide paste is applied to its lead grids in the factory. The deterioration reduces the ability of the batteries to store energy. VRLA batteries typically have a useful service life of 5 years. There are, however, numerous factors that affect the useful service life of a VRLA battery including temperature, frequency, and depth of discharge, charging system effects (operational voltages and ripple current), and storage conditions prior to being placed in service. To further complicate matters, there are no universal standards for UPS batteries, only guidelines, so each manufacturer has wide latitude to design their batteries as they best see fit. According to Riello, the manufacturer of the new 30 kVA UPS installed after the critical event to provide power to close the filter effluent flow control valves in Plant 2 in the event of a power failure, “UPS batteries tend to have either a 5 or 10-year design life.” Riello goes on to state: “Even though battery manufacturers will state their battery has a design life of 5 or 10 years, under EUROBAT (Association of European Automotive and Industrial Battery Manufacturers) international guidelines, a battery is considered at the end of its service life when its capacity falls below 80% of its original.” Riello then provides the following graphic to illustrate that batteries with a nominal 10-year service life fall below 100% capacity after just 6 years.

Diagram 3: Batter Life Decay



In any case, after their useful service life, the storage capacity of VRLA batteries declines to the point that the UPSs containing the batteries can maintain output power for only a few seconds instead of the many minutes of output power they can provide when the batteries are new. Consequently, UPS manufacturers recommend that the batteries in UPSs in critical applications be tested every 6 months to ensure that they can maintain UPS output power for at least the minimum required duration in the event of an incoming line power failure and so that the batteries can be replaced when needed.

New batteries would have allowed the UPSs to have provided sufficient backup power to close the filter effluent valves, but the batteries in the UPSs could not as they were past their useful service life when line power failed on the morning of January 6, 2025. Although the old UPS batteries had been replaced and taken offsite before the SEH site visit, this behavior was deduced from reviewing the SCADA data. SEH reviewed SCADA data of the filter effluent flow meters and valve positions. Following the loss of power, the SCADA data began recording “Bad” data in less than one minute. This shows that the PLCs that were powered by the same UPSs as the filter effluent valve actuators went offline virtually immediately, whereas more than a minute of backup power is required for the filter effluent valves to close.

The loss of valve monitoring on SCADA limited the ability of the operators to recognize that the valves failed to close. In-person inspection or operation of filter effluent valve position requires going to the lowest level of the filter gallery (shown in the picture to the right), which is the first area to fill with water when the clearwell overflows. Manual verification and operation of these valves was not feasible during the event due to safety concerns.

Filter Effluent Valve Manual Operation Not Feasible During Filter Gallery Flooding Event.
Machines

SEH discussed UPS maintenance with the Utility Plant Specialist Supervisor for I&C and the Program and Operations Manager (leader of plant maintenance). It was reported that prior to the event the UPS batteries were not on a preventative maintenance schedule. UPS maintenance was limited to informal visual observation of the built-in battery health monitoring system. Batteries were replaced when the battery health monitor identified them to be bad and sounded an alarm. In SEH’s experience, on board battery health monitors are not always sufficient to determine when batteries need to be replaced.

SEH reviewed maintenance work orders provided by the DPU. These work orders appear to confirm this strategy. The formatting and lack of asset tags on the UPS units did not allow SEH to determine when the specific units that failed were last replaced.

Filter Gallery Effluent Valves

SEH notes that historical work orders from 2021 and 2022 describe previous failures of the Plant 2 SCADA and UPS systems. These previous failures seem to indicate a known electrical issue with the UPS system that was never addressed.

- On May 25, 2021, a work order describes the UPS in Plant #2 electrical room “failed again”. Water production was lost for 4 hours. The immediate issue was resolved by resetting a breaker switch. The work order notes that the Maintenance group “will investigate why the breaker and switch was tripping to the UPS system.” No follow-up information was in the work order system.
- On May 9, 2022, two work orders describe a 5-hour SCADA failure in Plant 1 and Plant 2, due to Virtual Machines not running because of a faulted UPS. These work orders are believed to coincide with an event known to plant staff as the “Mother’s Day Flood.” One work order describes the I&C technician discovering a large quantity of water overflowing from the Plant 2 clearwell hatches into the filter gallery and submerging actuators and instruments. The other work order notes the UPS is inadequately sized and “NOT to be dependable to back up Plant 2 PLC or Filter cabinets.” The work order notes that the circuit needs to be analyzed because it is overloaded. No follow-up information was in the work order system.

The outcome of the UPS’s non-functional state was that the filter effluent valves in both filter buildings remained open, and filter flow continued into the basement clearwells overflowing into the filter pipe galleries and submerging key electrical equipment. As stated, additional resolution of this concern was not found or able to be determined; however, this demonstrates the overall poor maintenance strategy pertaining to UPS systems at the facility.

4.2.7 Maintenance / Asset Management

The WTP has a large amount of equipment that is at or nearing the end of its useful life. Historically, maintenance has been completed based on calendar year preventative maintenance and work orders submitted by operations management staff. Plant staff reported to SEH that due to the large amount of maintenance required to fix the aging equipment and keep it in operation, maintenance was often performed reactively instead of proactively.

The Maintenance group reported that, in recent years, they are working towards a more proactive approach. They are just beginning to look at the costs of ongoing maintenance of old equipment compared to equipment replacement. They are also moving to a prescriptive maintenance program. Examples of this approach includes taking oil samples and sending in for analysis and basing maintenance activities off of run time instead of the calendar year.

The DPU has an existing computerized maintenance management system that includes the WTP and distribution system. The City and its third-party consultant completed a comprehensive Water Treatment Plant Condition Assessment in 2020. This report states that it was intended to address all assets at the WTP and update the City's maintenance management system. SEH completed a brief review of the Water Treatment Plant Condition Assessment, work order history for 2020-2024, and the Preventative Maintenance Complete Report.

SEH reviewed the Capital Improvement Plan (CIP) document provided by DPU. Upgrades indicated on the CIP and related to critical systems identified during this root cause analysis include the following.

- Substation #1 Replacement includes installation of new substation #1 as well as generator automatic transfer switches and associated programming to allow backup generators to start and run without manual intervention. If this project was completed and operational on January 6, 2025 it could provide backup power to the plant when primary power source failed, and the extent of flooding would not have occurred.
- Waste Pumping and Control System Improvements. SEH did not receive any details of this project, which is only described as being to replace the four existing waste pumps and associated vacuum priming system. Waste pumping equipment is shared between Plants #1 and #2. This presents a common failure point when equipment and controls are beyond their usable life and in poor condition. Criticality of this equipment was illustrated with secondary flooding incident outlined within timeline of events. This upgrade is unlikely to have influenced the events on January 6 although it is a critical piece of equipment and its replacement will ensure that it is not the cause of future flooding events. The wastewater pumps also represent a current bottleneck in backwashing flow capacity to clean the filters, which is noted in greater detail in the Condition Needs Assessment Report.
  - As mentioned previously, a lack of coordination and communication with the wastewater pump status during the recovery efforts resulted in a delay in restoring production at the WTP. A new waste pumping system may have included controls programming to warn or prevent operators from backwashing filters when the waste pumping system is offline. This may have prevented the recovery delay but not the cause of the flooding.
- WTP Filtration System Actuators Replacement and Filter Media Replacement. SEH did not receive details of this project, which is only described replacing the four way and drain valve actuators in Plants 1 and filtration systems. It is not clear the exact scope, but the planned replacement does not appear to cover the filter effluent valve actuators. These actuators are a critical component that close the effluent valves to effectively stop the flow of water into the clearwells in the event of power loss or failure of finished water pumps. Actuators were working at the time of January 6th event and themselves did not originally fail. Rather, the UPS system did not have sufficient power to operate the valve actuators due to age and deterioration. New actuators, however, will ensure safe and reliable operation in the future.

The CIP plan provided for review was not very granular in detail, however, it did provide expenditures through 2030.

In addition, the CIP Operations Superintendent, Program and Operations Manager and Engineering meet every two weeks to review outstanding projects list to prioritize work and coordinate accordingly. This list incorporates all projects currently underway or major maintenance items required in the short term. SEH was provided a current copy of the list for review. The majority of items indicated on the list are in line with typical maintenance with one item related to the events of January 6, being SCADA repairs and service:

- A lengthy line item related to ongoing SCADA repairs and service with some recent network switch issues experienced in the months prior to January 6. SCADA network switches lost connectivity following loss of power and needed to be reset by DPU's third-party contractor to come back online. Restoration of the network did not end up being a critical failure during this specific event, but loss of SCADA network itself could have caused an extended outage at the facility and has led to more minor flooding in the past accordingly to site staff.

Godwin Pump Flow Not Sized for Full WTP Flow
Machines

4.2.8 Temporary Dewatering Pumps

As noted above, minor water infiltration from the filter clearwell into the pump rooms and filter pipe galleries is reported to be a known occurrence when the suction lift filtered water pumps fault out and/or lose prime, which results in a temporary partial loss of filtered water pumping until a different pump can be started. Typical procedures to address the water infiltration include utilizing a set of engine-driven, 6-inch Godwin pumps to remove excessive water from the basement areas. On January 6, 2025, plant staff responded to the water infiltration in the basement pump rooms by starting the Godwin pumps per normal operating procedure. However, this response was inadequate because conditions were substantially different. Instead of attempting to counteract a normal overflow from a temporary partial loss in pumping capacity, during this event, the operators were attempting to overcome a sustained complete loss of pumping capacity.

Plant Staff Immediate Response Focused on Ineffective Dewatering Methods
Methods

Godwin Pump Suction Piping

Operators report that the capacity of each Godwin pump is approximately 1,767 gpm (approximately 2.5 MGD) for a total pumping capacity of 5 MGD. At the time of the power failure, the filtered flow rate of the plant into the clearwell was approximately 60 MGD. Therefore, it was not feasible to manage water in the basement areas with these pumps until forward flow into the clearwell was stopped by closing valves.

Godwin Pumps Prime Slowly
Machines

These Godwin pumps have permanently installed suction piping from the sump in each filter gallery to the pump suction. A length of flexible tubing is used for the final connection at each pump. Suction lift on each pump is approximately 20 feet, and the length of the 6" suction line for each pump is approximately 100 feet. These suction conditions increase the time needed to prime the pump.

Pump Motors and Electrical Equipment Located Below Hydraulic Grade of WTP
Machines

Although these dewatering pumps were inadequate to prevent the submergence of critical electrical equipment, they did enable the subsequent dewatering effort to restore the basement areas to service.

4.2.9 Location of Critical Electrical Equipment Below the Plant Hydraulic Grade Line

Critical electrical equipment was located below the WTP hydraulic grade line in the filtered pump rooms and filter pipe galleries. Key equipment included the electric motors, variable frequency drives (pictured), valve actuators, sample pumps, and various sensors. As shown in the picture, the electrical gear is on a very short housekeeping pad so any appreciable amount of water in this area will innundate electrical equipment.

4160V MCC and Variable Frequency Drive – South Filter Plant

After water was removed from these spaces, the electrical equipment had to be dried, repaired, and/or replaced before being placed into service.

4.2.10 Staffing/Training

This section reviews staffing and training of staff on the overall WTP failure on January 6, 2025. That morning there were 3 onsite operators, consisting of one Class 1 lead operator, one Class 3 operator and one Class 4 operator. Two maintenance staff (Mechanical Specialists) were onsite tasked with snow removal. One left due to illness at 5:00 a.m.

As the timeline of events indicates it took approximately 45 minutes for the Electrical Supervisor to arrive onsite following the loss of power. Diagnosing and addressing the repair once he was onsite took an additional 35 minutes, and power was restored at 7:05 for a total time from failure to restoration of 1 hour, 20 minutes. By this time flooding within the facility had submerged key equipment. The two critical path roles for this specific event were restoration of power and reducing flooding, and each is described in more detail below.

The electrical failure could only be addressed by a staff member trained as an electrician. As described in prior sections the electrical failure was not something that could easily be corrected and required additional diagnostics to address. The 35 minute time frame to diagnose the issue and get electricity swapped over only applies to someone very familiar with the system. If an electrician was onsite, electricity could likely have been restored in less than 1 hour and 20 minutes. The electrical supervisor had a head start addressing the issue, as he was notified of the event with some additional information about it and was able to travel directly to the equipment in question. An electrician staffed at the maintenance office would have some perception/reaction time associated with identifying the issue and preparing tools and supplies, so a safe assumption would dictate a minimum of 15 minutes to arrive at the failed electrical equipment. Combined with 35 minutes to diagnose and resolve the issue would yield a minimum power restoration time of 50 minutes or in this event, restoration of power at 6:35 a.m. The timeline indicates that at 6:20 a.m. water was already rising on pump room floor, automated valves were flooded and damaged, and the electrical switchgear and pumps submergence would have been starting. Additionally, the SCADA system network was not functioning following electrical restoration, so additional time likely would have been required for operators to identify further issues and work around it. If an electrician was onsite on the morning of January 6 it is unlikely that the flooding of key equipment would have been prevented.

Reducing flooding within the facility was accomplished by turning on the portable Godwin pumps and shutting off flow to the clearwell. As indicated above, filter effluent valves cannot be safely accessed to manually shut off flow once flooding begins in the basement, which occurs within 3-5 minutes of power failure so is not a realistic option. Shutting flow off to the inlet of the filters from the sedimentation basins reduces the volume available for forward flow. However, a significant amount of water is already within the filters themselves, which will continue to flow into the clearwell and cause flooding, but at lower flow rates as the volume of water within the filters is reduced. Starting the Godwin pumps removes flooding water from the filter gallery sump pit, but flow rate for pumps as indicated in this report is insufficient in comparison to the full plant flow into basement. Staff focused first on starting Godwin pumps in accordance with Emergency Operations Manual and then later focused on shutting filter influent valves. Influent gates are long threaded gates that take significant amounts of time and effort to close manually. With the SCADA system inoperable, 19 filter gates needed to be closed manually (3 filters were already out of service prior to the event). The timeline of events notes that staff took at least 30 minutes to close most valves. Even if the facility had additional staff present and immediately began to close all the valves, the volume of water present within the large sand filters would have continued to flow into the clearwell and submerged equipment.

The above analysis is based on the conditions in place on the day of January 6, and it indicates that additional staffing and training in this instance would likely not have had an effect on the outcome of events due to the multiple cascading failures that occurred that day. As mentioned previously in this report, standards, procedures and training are recommended. This training coupled with benchtop exercises should be used to evaluate proper staffing for all scenarios.

4.2.11 Historical Facility Studies, Reports and Plans

SEH was provided with available facility studies, sanitary surveys, reports and plans from DPU related to this facility, past upgrades, and evaluations. Given the extensive age and history of upgrades at the facility, it is assumed that only a portion of documents were provided.

The "Vulnerability of Filter Galleries and Filtered Water Pump Rooms to Clearwell Overflows" section above lays out the critical failure point related to the gravity flow of water to a physically low point on site. This low point contains critical electrical and pumping equipment, which is vulnerable to flooding in the event of any failure of forward water flow, such as loss of power or pump failure. Plant staff know well that if pumps don't operate the basement begins to experience flooding within 3-5 minutes. Automatic closure of all 22 filter effluent valves immediately is the only line of defense.

Basement flooding is a commonly known problem for plant staff and management. Temporary pumps to help address this problem have been in place for around 20 years or more according to plant staff. Despite this being a commonly known issue, it is not mentioned as an issue in available reports, studies, and plans.

- 2001 Master Plan – document does not mention vulnerability of clearwell overflow and filter gallery flooding despite showing clearwell operating level with limited freeboard and indicating that clearwell may be surcharged significantly for priming of finished water pumps.

- 1996 WTP Capacity Evaluation Phase 2 – Hydraulic Evaluation Report – this report details increasing the flow significantly through the plant including through the filters into clearwell. This report also indicates running clearwell with the same limited freeboard but increasing flow without any mention of vulnerability of clearwell overflow and flooding of basement.
- 2021 DPU Emergency Operations Manual (EOM) - As described in previous sections this is a fairly generic document related to emergency procedures; however, it includes Incident Action Checklist for the emergency condition of “Internal Flood Event (Water Treatment Plant)” with a specific section titled “Water Treatment Plant Power Failure”. The only procedure called out is to start portable pumps to dewater. As indicated previously portable pumps are approximately 1,700 gpm. Effluent forward flow is approximately 42,000 gpm. This checklist is insufficient guidance to address the concern that occurred and gives staff impression that portable pump would be sufficient. It also does not address any other reasons basement would flood besides power failure which have occurred repeatedly according to staff.
- 2022 Sanitary Survey EPA/ODW - Sanitary survey did not indicate lack of overflow from clearwell (requirement for any new plant, grandfathered here) or vulnerability of basement are to flooding due to lack of overflow.

Reports, studies, plans, and surveys generated by trusted advisors and regulators that continually do not mention or address identified vulnerabilities can be discouraging to plant staff. This can have the effect of normalizing the vulnerability and lead to acceptance and indifference by operations and maintenance staff.

4.3 Conditions Extending the WTP Shutdown Duration

4.3.1 SCADA and Controls

4.3.1.1 Network Switches and Connectivity

UPS for Various PLCs Failed and Connectivity was Lost.
Measurements

The Richmond WTP uses a Supervisory Control and Data Acquisition (SCADA) system to collect information from the numerous sensors, equipment signals, and Programmable Logic Controllers (PLCs) throughout the plant, perform process calculations, and control equipment. The SCADA system is critical tool in the operation of large treatment plants such as the Richmond WTP, as it allows the operators to monitor the various plant processes from the control rooms and enables automatic operation.

No SCADA Visibility for 18 Hours While Restarting WTP
Measurements

Although the network switches in the WTP SCADA system were powered by the SCADA system’s UPS and remained operational throughout the nearly 2-hour power outage, they were unable to reestablish connectivity with the various remote PLCs throughout the plant whose UPSs could not keep the PLCs powered throughout the outage. Manual intervention by the plant’s SCADA contractor, E-Merge Systems, was required to restore connectivity. E-Merge Systems was mobilized to assist the DPU. Response time and delay in getting SCADA online did not directly affect the critical path for restoration of service; however, visibility to instrumentation and control would have been helpful during the event.

Out-of-date firmware in the network switches in the WTP SCADA system may have been the cause of the network switches being unable to reestablish connectivity with the PLCs when power to the PLCs was restored.

Network Switches were not Maintained with Up-to-Date Drivers
Methods

4.3.1.2 Limited Reliance on Automatic Controls

Despite a PLC-based control system infrastructure that has the potential to significantly automate WTP operations, the plant operation is largely manual, relying heavily upon the expertise of the operators, who must balance flows, levels, and chemical additions to the demand of the distribution system. The operators report that this mode of operation is required because key sensors and control sequences do not perform as intended and are not corrected when identified. Several examples are described as follows:

- Operators report that the raw flow meters have not been accurate for several years and are observed to differ from other measures of plant flow by up to 50 percent. SEH was not provided with sufficient data to confirm this observation. We understand that the influent flowmeter is planned to be addressed through a capital project, rather than as a maintenance activity, which extends the time the plant must operate without this critical piece of equipment. The influent flow meter is needed to flow pace certain chemicals, such as alum to the process. The lack of a trusted raw water flowmeter leads the operators to flow pace the chemicals manually.
- Normal practice at WTPs with similar capacity to the Richmond WTP includes controlling large pumps using a process variable such as flowrate, tank level, or system pressure. Computer programs adjust the pump speed to control the process variable to setpoint. The main process pumps at the Richmond WTP, including the raw water pumps, filtered water pumps, and some distribution system pumps, are controlled manually by the operators inputting pump speed into SCADA and watching the corresponding flowrates and tank levels to make further adjustments. This manual mode of operation requires a much higher level of operator vigilance and intervention to maintain consistent operation at the plant than when automatic operation is used. This is particularly true when the margin for variability is small, such as the operation of the filtered water pumps. As described above, the filtered water clearwells are operated with minimal freeboard. Even small drops in water level can cause hydraulic issues with the suction lift pumps and small increases in water level can cause overflows into the filter galleries.
- Priming the Filtered Water Pumps is a straightforward process to automate when equipment works properly. The lack of a robust priming system at the Richmond WTP requires manual priming by two operators. One operator controls the pump from SCADA, and one must operate the priming system from the pump room.
- A remote pump station (Byrd Park Main) is not on the SCADA system and runs unattended at a constant speed. This requires in-person visits to start and stop the pumps. The pumps apparently do not have adequate built in safety shutoffs, because it continued to pump down and empty the chlorine contact tanks when it was left running after the WTP was shut down on January 6 without plant staff becoming aware.

When plant operation is seriously disrupted, as it was during the prolonged power outage on the morning of January 6, 2025, it is very challenging to manually restore equilibrium throughout the plant. Operators must ensure optimal clearwell operating levels, flow rates, and chemical additions to maintain sufficient tank levels in the distribution system.

Adding and maintaining automation is by no means simple, but an investment in automation could be helpful in simplifying the training of new operators and restoring plant operations after disruptions caused by weather events and equipment failures.

4.3.2 Hydraulic Control Valves

Some Plant 2 Filter Valves Require Hydraulic System Pressure to Operate *Machines*

Some of the valves associated with the Plant 2 filters have hydraulic actuators that operate on house water pressure. These include the filter to waste valves, filter drain valves and backwash waste valves. Plant 2 effluent valves, however, use electric actuators. The house water pressure is provided from the distribution system, off the City's Korah 3 Pump Station transmission line. When the facility lost all plant production on January 6 and the Byrd Park Main pump station drained the chlorine contact tanks as noted in Section 4.3.1, the Korah 3 Pump Station could not operate and transmission line pressure was lost. When there is no pressure in this line, the hydraulic actuated valves cannot be operated. Following the facility failure on January 6, filters had to go through backwash cleaning cycle prior to being put back in service and begin producing water.

Due to the initial success in removing water from the Plant 2 filter pipe gallery, staff initially focused efforts on restarting Plant 2 to resume production of water. Staff later recognized the Korah 3 transmission line pressure needed to be restored before the valves could be operated using the hydraulic actuators. The recovery efforts were subsequently shifted to restarting Plant 1, which is equipped with electric actuators and therefore does not have the same constraint. It does not appear that this resulted in a significant loss of time related to recovery although it is difficult to determine given the number of staff working in all areas of the plant (estimated to be 1 to 2 hours total delay in restoration of water). This oversight is understandable given the unprecedented nature of the loss of system pressure and chaotic nature of the emergency environment. However, proper emergency planning including SOP's, training, and periodic benchtop exercises could have eliminated this setback.

This is not a high-priority issue to be addressed, but as the hydraulic actuators reach the end of their useful life, consideration should be given to replacing them with electric actuators. Alternatively, a pump could be provided to locally boost pressure to the valves so that they can operate when system pressure is reduced.

4.3.3 Washwater Pumps Not Operational

To restore the filters back into service after the flooding, each filter had to go through a full backwash cycle to clean the filters. This cycle entails first draining the filter to a lower level (drain water is sent to waste) and then initiating a backwash sequence, which includes aeration of the filter bed, and then reversing flow through the filter to remove accumulated particles, overflowing the backwash water to waste. The waste collection system is a channel that runs through the center of each filter gallery and is pumped to the residuals lagoon by a set of waste pumps. The waste pumps are located adjacent to the filter gallery in the lower level of Plant 2 near the James River flood wall. There is no physical tank volume for the pumps, just the waste channel. Pumps are operated on level set points, and if the pumps are not in service, the volume of the channel is quickly filled, and it surcharges.

During the recovery effort on January 7, 2025, a maintenance technician was working on valves in Plant #2 filter gallery, noticed an overflow coming out of Plant #2 waste air gaps and quickly ran to the operator station to alert them to the situation and to stop backwash. It was determined that the waste pumps had been shut off manually. While it is unclear why the pumps were shut off, it is likely related to recovery efforts to dry out submerged electrical and process equipment. Water within the filter gallery rose to within 4 feet of the elevated walkway during this event. Staff had to dewater the area once again and valves that had been opened for service during the event required additional time and attention to dry out once more. It does not appear that this resulted in a significant loss of time related to recovery although it is difficult to determine given the number of staff working in all areas of the plant (estimated to be 1 to 2 hours total delay in restoration of water).

This did, however, illuminate a vulnerability within the plant that it is heavily reliant on the shared waste pumps being functional, unlike the rest of the plant which is split into two largely separate plants (Plants #1 and #2). There is no significant storage volume within the waste channel so if pumps are out of service while either filter drain valve or filter to waste valve is open, a significant overflow will happen quickly. Currently, the backwash sequence is initiated manually by operators so there is an awareness of when backwash is happening. However, if backwash waste or filter to waste valves are open when pumps are not functioning for any reason, an overflow will quickly occur. Some possible scenarios include but are not limited to the following:

- Control Malfunction of Waste Pumps: Causes them not to operate.
  - Control Panel is older relay logic panel that appears in poor to fair condition. A panel failure is not expected but is possible. It does not appear to have any true feedback to main SCADA on if flow is leaving the waste channel;
  - Controlling level sensor is ultrasonic level sensor that uses relay level set points. There is no backup level switch. In the event of sensor failure, pumps will not run;
  - Pump Failure;
  - The waste pumps and associated priming equipment are beyond their useful life. A pump failure may reduce the pumping capacity and result in flooding.

Having a standard operating procedure and associated training and exercises for bringing the plant back online from a shutdown would highlight the need for this pump station to be online and could prevent and delays in return to service in the future.

4.4 Conditions which limited the ability of the distribution system from sustaining water supply during the WTP shutdown

4.4.1 Communication

Overview of internal and external communication during this event was provided in the Timeline section of this report. This section is related to internal communication during the initial response operation phase of failure and how DPU staff responded to the issue.

Since the event occurred towards the end of a nightshift, limited staff with and no senior leadership was onsite. Immediately following the power failure, the Operations Supervisor enlisted the help of one of his shift operators to follow on call protocol for maintenance help and to notify plant operations senior leadership.

Plant Operations Supervisor took the following steps related to on call staffing directly following power failure at the plant:

- Instruct Class 4 Operator to make the following calls.
  - Electrical Supervisor – reached and headed to Plant.

- I&C Supervisor – was not able to reach, previously had called in sick.
  - I&C Utility Specialist – reached and headed to Plant.
- Reached out to the following staff directly.
  - Plant Operations Supervisor Senior
    - Initially left message, followed back up quickly
    - Supervisor Senior reached out to Maintenance Supervisor – reached and headed in.
      - Maintenance Supervisor reached out to Program and Operations Manager.
  - Plant Operations Superintendent
    - Initially left message, followed back up quickly
    - Superintendent reached out to DPU Director, All DPU Deputy Directors, and Public Information Manager to notify them of event. City of Richmond Director of Emergency communication and DCAO (Deputy Chief Administrative Officer) were included on follow up communication.

Mechanical Specialist onsite during power outage took the following steps related to on call staffing directly following power failure at the plant:

- Reached out to the following staff directly.
  - Mechanical Specialist – reached and headed to plant.
  - Program and Operations Supervisor – left message, followed back up.

Within about an hour of the event the entire DPU had been notified and a good portion of it had already mobilized. Senior DPU leadership as well as city leadership and emergency personal were notified as well. Given that no formal procedures had been issued widely to the team, they very effectively followed the on-call list and methodically notified everyone quickly.

Initial external communication to VDH-ODW and Partner DPU customers was limited to initial contact with Henrico and Chesterfield Plant Superintendents to request demand reduction. No follow up to Hanover or VDH-ODW occurred until they were in immediate danger of dropping below 20 psi. EOM indicates that partner DPU customers need to be notified if pressure drops below 20 psi, however, in this event staff had communicated to leadership earlier in the day that this needed to be considered and was a likely outcome. While it is not anticipated that advanced warning would had a significant impact on this event, it would have given partners more than a couple hours warning to plan for this event.

4.4.2 Capital Improvements Project Impacts

Byrd Park Reservoir had Reduced Capacity Due to Capital Project *Materials*

The volume of water stored in finished water tanks in the distribution system backs up the WTP in the event of an outage. Typically, the minimum available distribution storage volume maintained is either one Average Day or half of the Maximum Day. On January 6, the distribution system maintained usable storage throughout the system for less than 12 hours on a typical demand day.

As noted above, the Byrd Park Reservoir re-roofing project reduced the finished water storage capacity in the system by approximately 34 million gallons. Byrd Park Reservoir provides approximately 75% of the total storage volume within the entire City of Richmond distribution system during typical operation. The reduction in storage volume limited the duration that water could be delivered to customers during the plant outage. Typical water usage for the system is 50 – 60 MGD so the additional storage capacity that was not in service equates to approximately 13-14 hours of additional supply. This additional volume would have reduced the outage duration but would not have eliminated it entirely. The plant started producing 15.4 MGD starting at 8:15 a.m. and did not increase significantly until the following day. The figure below illustrates water levels within the distribution system including Byrd Park Reservoir on January 6, 2025.

Richmond Tank Level Readings January 6, 2025										
	RES. ELEV (BYRD)	HUG. ROAD TANK	JANK. ROAD TANK	GIN. PARK TANK	WOOD SIDE TANK	WAR ROAD TANK	COF. ROAD TANK	CHUR HILL TANK	HIOAKS TANK	CHEST. POC TANK
	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0:00	12.6	16.5	38.7	11.3	20.1	27.8	46.4	37.0	25.2	65.9
1:00	12.5	16.1	35.4	12.5	22.4	28.5	48.9	39.1	26.0	64.8
2:00	12.3	15.6	31.4	13.9	27.3	31.2	56.8	40.6	26.5	64.2
3:00	13.2	15.2	36.9	11.5	23.0	26.7	56.7	41.4	26.8	63.0
4:00	13.7	14.8	37.7	13.3	24.4	29.4	56.6	41.7	27.2	62.2
5:00	14.1	14.2	35.0	14.1	26.8	30.8	56.1	42.2	27.2	60.7
6:00	14.3	14.2	34.1	13.8	26.9	31.0	56.0	42.3	27.5	60.1
7:00	14.0	14.9	31.9	15.7	27.6	31.6	56.2	42.1	26.4	59.1
8:00	12.9	19.0	37.5	14.0	24.0	30.1	51.7	40.1	23.8	57.1
9:00	12.7	20.2	35.5	13.6	23.2	28.6	50.9	40.3	22.9	60.9
10:00	11.9	20.3	30.3	11.6	25.8	29.8	49.1	40.0	20.5	65.9
11:00	10.8	21.9	30.7	9.1	24.5	28.9	46.6	37.8	19.0	64.8
12:00	10.2	20.8	31.3	8.2	25.6	28.1	44.8	36.0	18.2	62.7
13:00	9.1	18.9	32.4	12.4	26.1	11.3	40.6	34.4	17.8	61.0
14:00	6.6	16.7	31.4	13.1	25.3	30.1	38.3	30.9	17.6	57.7
15:00	4.8	12.3	27.2	0.0	15.6	25.6	19.6	25.9	17.5	55.4
16:00	3.8	7.0	26.4	0.0	8.8	21.2	13.5	21.5	17.4	64.3
17:00	3.3	1.4	27.9	0.0	5.5	19.0	9.5	20.6	17.4	64.0
18:00	2.9	0.4	28.9	0.0	2.1	16.7	6.1	17.5	17.4	64.0
19:00	2.7	0.1	28.0	0.0	1.2	5.3	6.8	15.3	17.4	64.6
Normal Range (FT)	13-23	15-25	28-37	9-18	21-27	28-34	30-55	25-48	20-30	40-65

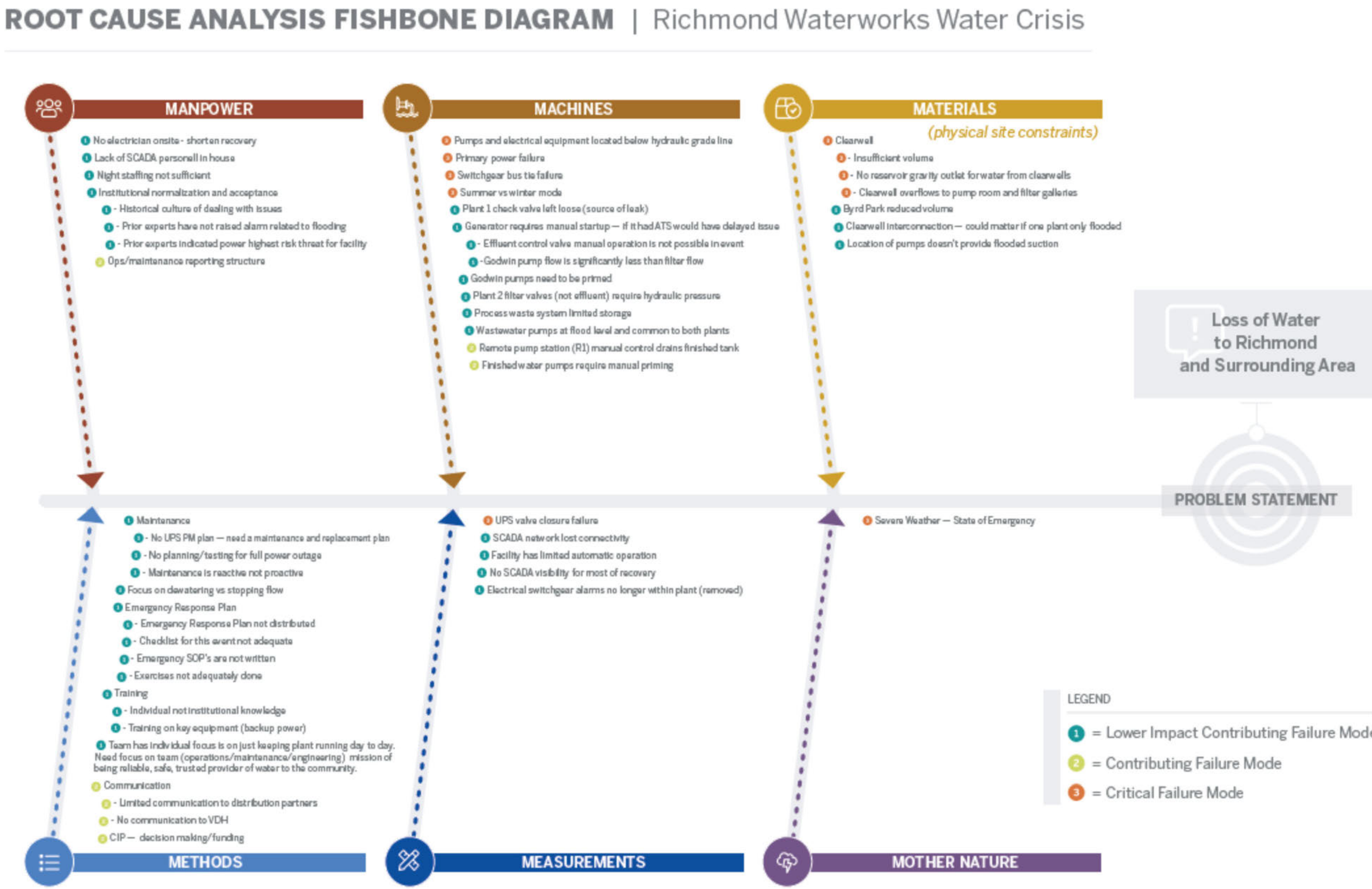
	- Normal Range (level)

Distribution System Tank Levels January 6, 2025

4.5 Failure Mode Analysis and Root Cause Determination

Failure mode analysis was performed by evaluating each failure mode against our problem statement “to determine if it was a critical failure associated with the problem statement “Loss of Water to Richmond and Surrounding Area” for the specific event of January 6. A critical failure is defined as an item that if it did exist failure would not have occurred. Contributing or Supporting Failures are defined as items that may have contributed to or supported the critical failure in some way or caused additional delay/concern but by itself could not have prevented overall failure if it didn’t happen. The figure below, referred to as an Ishakwa (or Fishbone) Diagram, is a graphical representation of 6 M’s previously described above, with failure modes listed under each category. Failure modes were categorized as critical failure modes meaning without this event water crisis would have been avoided and contributing failure modes meaning they contributed to the severity of the failure but were not directly responsible. Lower Impact contributing failure modes had minimal impact on the overall event.

Figure 2 – Root Cause Analysis Fishbone Diagram



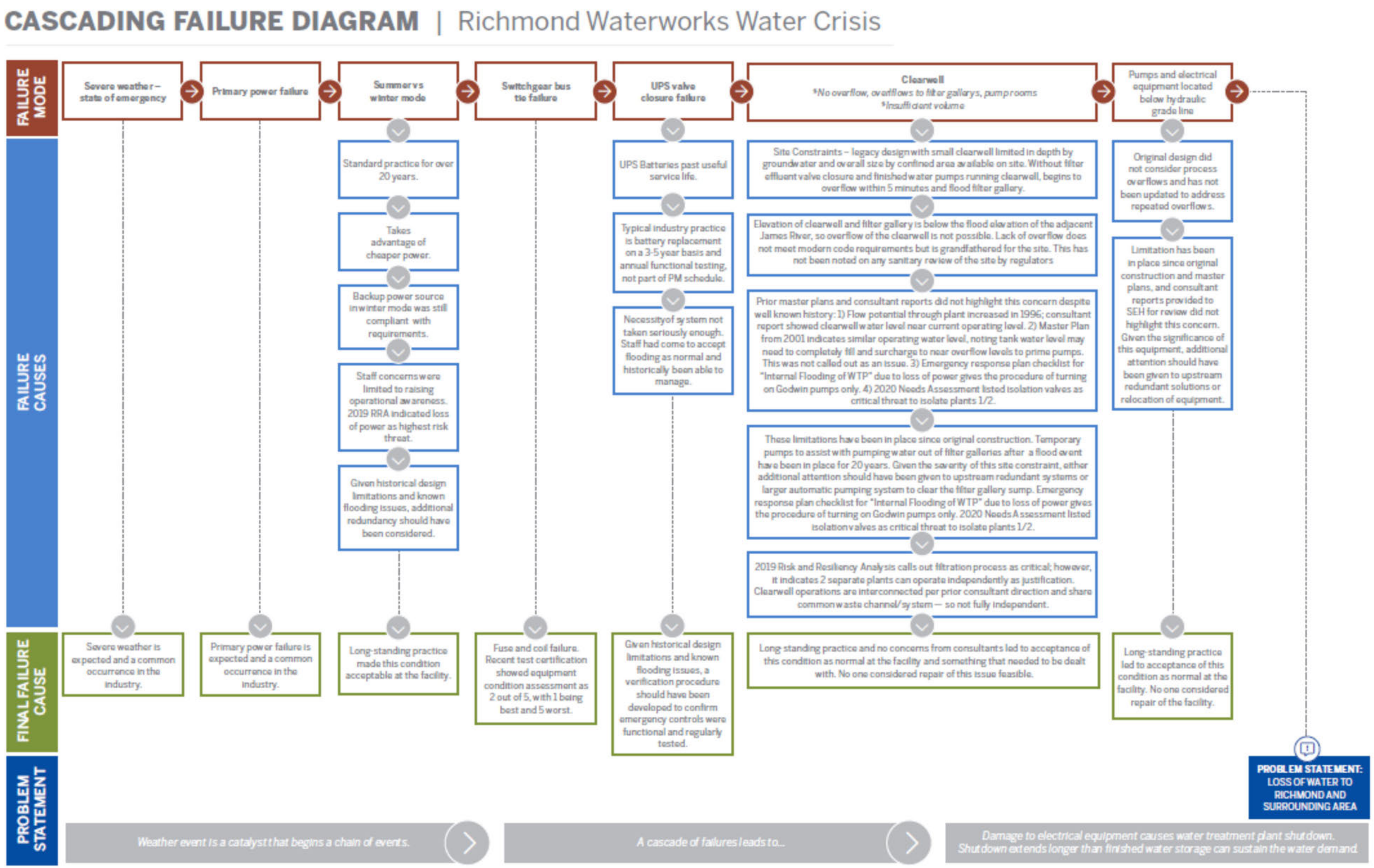
Critical Failures were further analyzed using a cascading failure analysis. Critical Failures for the “Loss of Water to Richmond and Surrounding Area” occurred sequentially from top to bottom as follows:

- Severe Weather – State of Emergency;
- Primary Power Failure (Failure of Primary Winter Mode Feed);
- Summer vs Winter Mode (Practice of using Winter Mode);
- Switchgear Bus Tie Failure;
- UPS Valve Closure Failure;
- Clearwell: Lack of Gravity Overflow, Insufficient volume; and
- Pumps and Electrical Equipment Located Below Hydraulic Grade Line (HGL).

Analysis of each of the items above was performed utilizing a “why” analysis. This methodology takes each failure mode and essentially asks “why did this occur” repeatedly until a final answer is determined, or no additional answers can be generated.

The following figure is a cascade diagram with failure modes arranged sequentially left to right in a cascading manner with results of “why” analysis under each failure mode arranged sequentially top to bottom.

Figure 3 – Root Cause Analysis Cascading Failure Diagram



To summarize the overall failure and Root Cause Analysis, “Loss of water to Richmond and surrounding area” was caused by a production outage at the City’s main water supply, the Richmond Water Treatment Plant. The WTP outage occurred because key electrical equipment was submerged by a process water overflow. The production outage lasted 66 hours before full production flow was leaving plant, which was longer than the capacity of the distribution system to maintain adequate pressure in the system.

The plant contains a vulnerablity built into the filter buildings dating to the original construction 100-years ago. At the time, the plant was built to allow gravity flow from the James River intake through the plant to the filters, although pumps were provided to supplement and control the plant flowrate. Furthermore, the plant was constructed with small clearwell volumes and suction lift filtered water pumps located underground in the filter building basement. This configuration, placed critical electrical equipment below the hydraulic grade of the plant. The water level in the clearwell must constantly be controlled by balancing the amount of water flowing in through the filters with the amount of water being pumped out. If the pumps are stopped for any reason, the filter effluent valves must be closed within minutes or the filter gallery and subsequenty the pump rooms will be innundated. This vulnerability was well known, howerver, studies, reports, surveys and plans by consultants and regulators did not acknowledge or address this vulnerability. With no external flags and historical frequency of flooding staff came to accept this as standard practice at the WTP, staff indicated they didn’t consider repair of this issue feasible.

Modern design standards require similar clearwells to be equipped with overflow piping to avoid this issue. However, plant construction likely occurred before this provision was in place, and the Virginia Waterworks Regulations do not require processes to be brought up to modern standards unless the process is part of an upgrade project (code reference 12VAC5-590-50.B). The Richmond WTP site is highly congested. It is constrained by location between railroad tracks, a flood wall, and a canal. Over the plant’s history upgrade projects have utilized nearly the entire available footprint with buildings, tanks, and yard piping. Overflow piping would need to be in excess of 15 feet below grade to protect the pump room which is well below flood level of the James River and any adjacent grade.

The plant design anticipates the vulnerability to equipment room flooding and provides a layered defensive system. Multiple failures had to occur to result in the plant outage. The key failures are described as follows:

- The first defensive layer is to maintain filtered water pumping at all times when the plant is operational. The clearwell does not surcharge during normal operations when the filtered water pumps are online and their operation is in harmony with the filtered flowrate. Significant disruptions in the filtered flowrate for any reason result in clearwell overflows into the filter gallery. Disruptions due to power loss were the most common historical reason reported by plant staff, however, other issues such as pump mechanical failure, control failure, level sensor failure, operator error, etc. could have similar effect. This layer of defense failed on January 6, 2025, because the plant lost power.
- Multiple redundancies existed within the power system, including redundant power feeds from different utility substations, automatic switching equipment, and generators with manual transfer. The power failure occurred primarily for two reasons. First, a historical decision was made by prior management to operate during winter months in a less reliable manner (Winter Mode) to save money on electricity. This decision was maintained by current management. An inherently reliable mode with both power feeds connected to various portions of the plant, Summer Mode was available and was used

for part of the year. Winter Mode, the less reliable mode, with Summer Mode, the more reliable underground power feed in standby, was used at the time of the event. Winter Mode relied on an automated bus tie to transfer power in the event of a utility power outage. Staff had brought up the concern with running in Winter Mode as an operational consideration but it was not taken as a serious condition due to long term historical practice. This decision made the bus tie a critical piece of equipment. Therefore, when the utility power outage occurred and bus tie failed to close, the other feed, which still had power, could not supply the plant until electrical maintenance staff diagnosed the failure and closed it manually. The bus tie was an aging piece of equipment, and although approaching its expected end of life, it is regularly maintained, tested on a three year interval and it was not selected for replacement in an ongoing capital improvement project at the switchgear and adjacent substation. Testing on a three year cycle is a reasonable schedule and equipment of this vintage is common in older installations. It is reasonable to expect it to function as designed given its condition and regular testing

- The final layer of defense was the UPS and associated controls logic to close filter effluent valves in the event of a power outage. Thereby, the filter flow is intended to be stopped and the clearwell overlow avoided. This system failed because UPS batteries were past their useful life and failed before the filter effluent valves closed. UPS batteries require replacement when they reach the end of useful life. However, no replacement schedule was developed, and no testing was performed to confirm battery health and overal system function. This aspect of the failure could have been avoided with adequate preventative maintenance and testing.

The only document SEH reviewed that indicated risk of basement flooding due to power outage is the 2021 Emergency Operations Manual (EOM), but its recommended action is to connect the portable dewatering pumps and to dewater. As described above, if effluent valves don’t close this is completely inadequate. The operators acted according to the recommendations of the EOM, although they may not have been aware of this specific documentation.

As described in the preceding sections, after power was lost and the filter effluent valves failed to close, the operations and maintenance staff performed a variety of actions to prevent, limit, and recover from the damage that was sustained by inundation of the filter galleries and pump rooms. However, it is SEH’s opinion that no actions were available that would have prevented the clearwell overflowing and damage to the basement electrical equipment and filtered water pump motors. Once this occurred the plant production outage and subsequent water shortage were inevitable.

The Root Cause of “Loss of water to Richmond and surrounding area” is the failure of UPS due to lack of maintenance and testing which led to effluent valves not being able to close which flooded key equipment and caused outage.

This root cause issue was largely a result of an environment where WTP staff manages working through adversity and learning to work with known issues. This resulted in general acceptance and normalization of critical issues so appropriate level of concern was not conveyed to leadership. WTP staff had to focus on individual roles to keep the WTP operating and not the primary objective of delivering safe, reliable water to the community.

5 Conclusions and Recommendations

5.1 Conclusions

Based on the Root Cause Analysis and descriptions provided above, SEH arrived at the following conclusions:

- A loss of primary and backup power systems on January 6, 2025, stopped forward flow from the clearwell to chlorine contact tanks while gravity flow from filters to clearwell continued.
- UPS systems intended to close the effluent valve system and stop flow into the clearwell failed leading to catastrophic flooding of pumps and equipment that led to extended outage.
- Lack of testing and verification of the UPS system and functional testing of this failsafe was determined to be the cause.
- Underlying known issue of clearwell overflow and flooding of basement is a critical failure point that staff worked around for decades. Valve operation is the critical last line of defense.
- Staff manage to work through challenges such as flooding, manual operation, inoperative priming systems, etc. and it has become part of the culture to be able to deal with issues and inconveniences by just focusing on individual tasks at hand that moment to keep the plant running.
- General acceptance and normalization of issues at the WTP resulted, appropriate level of concern was not assigned to these issues or conveyed. This was supported when neither consultants nor regulators raised red flags concerning the WTP design limitations.
- Overall DPU team needed to focus on their individual tasks at hand to keep the plant running and was not able to focus on the primary objective of delivering safe reliable water to the community.

This conclusion is based on a thorough review of information provided by VDH-ODW, as well as the City of Richmond DPU. Summary of key information in support of this conclusion is below.

- The Richmond WTP was vulnerable to clearwell overflows into basement equipment rooms containing critical electrical equipment. The location of the electrical equipment and pump motors in these spaces may have been reasonable at the time of original plant construction. However, in the current context of the plant this is a persistent vulnerability to future clearwell overflows. Studies, reports surveys and plans from consultants and regulators reviewed by SEH did not flag this vulnerability.
- An overflow occurred because of a power outage. The power outage resulted from the following combination of failures:
  - Weather related utility failure;
  - Operating in Winter Mode, creating a situation where the bus tie was a single point of failure;
  - An equipment failure of the Main Bus Tie. The main Bus Tie was regularly maintained and was found to be acceptable for continued use in a recent Condition Assessment Report (WRA 2020);
  - A UPS in a non-functional state. The data reviewed appears to indicate that the UPS batteries were beyond useful life and failed immediately. Additionally, historical UPS

power issues caused SCADA and plant production outages in 2021 and 2022, with resulting flooding of the basement areas. It does not appear that follow through was completed after these past events to address the underlying issue.

- Attempting to avoid future clearwell overflows by sealing up penetrations into the filter galleries and pump rooms could result in an excessive differential pressure scenario, if the water level were allowed to rise to the filter water surface elevation (elevation 102.3) while the pump room floor (elevation 90.0) and top of the clearwell remained dry (elevation 93.0). It's unlikely that this condition was anticipated in the original structural design of the filter buildings.
- Plant design anticipates the vulnerability to flooding basements and provides means of resilient power and valve automation to stop flooding in the event of a power outage. However, it appears that the risk was not properly identified by DPU prior to January 6, 2025. DPU inadvertently amplified the risk of clearwell overflows through the following means:
  - Management decisions made, such as operating in the less reliable Winter Mode power feed configuration;
  - Lack of adequate maintenance, such the failure to replace critical UPS batteries at the end of useful life, and the apparent lack of adequate follow through to correct previous failures of the UPS system;
  - Lack of adequate emergency planning, such as including inadequate emergency response procedures to basement flooding in the Emergency Operations Manual and failing to mention the critical filter effluent valves in place to prevent flooding.
- Based on SEH discussions with staff, the utility historically practiced maintenance in a reactive manner. Current management reports that they have been moving towards a more proactive maintenance approach in recent years. However, this requires replacing less reliable assets until manpower can be freed up to complete preventative maintenance. This process may take several years at a large utility. The critical UPS batteries were not included in key documentation such as the 2020 Condition Assessment Report or the Preventative Maintenance Plan. Oversight of this asset may be a remaining symptom of the reactive approach to maintenance.
- The plant operates with mostly manual operation. Plants with similar capacity typically operate with much higher levels of automation. Manual operation is time consuming and makes optimization more difficult.
- The WTP at the time of the event on January 6th was staffed at near the minimum level required by Virginia code. The plant was staffed during the night shift by three operators, with one being a Class 1 operator. Additional staffing is warranted (12VAC5-590-450) due to the critical nature and complexity of the facility with a limited reliance on automation, which increases the level of effort to operate the plant and prevents operators from completing all the required tasks. DPU has increased staffing following this event.
- Poor housekeeping is normal and is likely symptomatic of staffing limitations along with widespread normalization and indifference of longstanding conditions. A previous evaluation by the EPA in 2020 noted poor housekeeping as an issue, which has persisted and not been addressed.

5.2 Recommendations

SEH offers the following recommendations intended to prevent the recurrence of a future water crisis similar to the events surrounding January 6, 2025.

5.2.1 Key Recommendations

1. SEH recommends addressing the immediate causes of plant shutdown following the power failure through the following:
    a. Eliminate the use of Winter Mode as normal mode of power. We understand that the DPU has already implemented this recommendation, and that Summer Mode is the standard year-round power feed configuration moving forward;
    b. Implement a UPS preventative maintenance schedule. We understand that the DPU has already replaced the UPSs and plans to add additional battery capacity. We recommend implementing functional testing every six months to confirm battery capacity;
    c. Ensure that all relevant filter valves are closed by the control system upon loss of power, including valves that may be open during a backwashing cycle; and
    d. Provide an automatic transfer system for the existing backup generators. We understand that this was already planned to be included in the ongoing Substation Replacement Capital Project.
2. Furthermore, we recommend addressing the underlying vulnerability that critical electrical equipment has in spaces that are subject to clearwell overflows. We understand that DPU has proposed relocating certain electrical equipment up to the ground level, but current plans leave the pumps and motors in the basement. The pumps and motors are not immersion rated and will still be at risk. Relocating the motors to the ground level is recommended to ensure that no active intervention is required either by the operators or control system to protect them from clearwell overflows. Relocating the motors will require replacing the pumps with a different style and will be a costly project. Refer to the concurrent Richmond WTP Condition Assessment Report (SEH, 2025) for more detail and opinion of cost.
3. We recommend investing in improving automation at the plant. Although automation exists at the WTP, it is not used for many processes. Manual operation is often less precise and requires significantly more operator attention. Additional automation enables optimization and frees the operators up to complete more tasks. Successfully automating systems requires the operators to trust the computer systems and equipment. Critical equipment deficiencies like the inaccurate influent flowmeters require prompt resolution through maintenance activities or emergency procurement. Otherwise, the plant staff will become disengaged and develop less efficient and less reliable manual workarounds.
4. Conduct a structural evaluation of the clearwell top slab for differential pressure conditions that result when the clearwell level rises. We note that some portions of the top slab are pressurized at design water surface elevations shown on the hydraulic profile and are further pressurized when the water level is elevated during disruptions in pumping capacity.

5.2.2 Capital Improvements Recommendations

1. Where hydraulic valves are used, provide a local means of supplying hydraulic pressure through booster pumps and/or stored in pressure tanks.

2. Consider replacing hydraulic actuators with electric actuators rated for submergence as protection for clearwell floods as they reach their end of life.

5.2.3 Operational Procedures Recommendations

1. Review staffing levels during normal operations. DPU increased staffing following this event.
2. We recommend DPU develops additional SOPs prioritizing those related to the most critical processes at the facility with a goal of generating SOPs for all standard and emergency procedures. Generating SOPs allows for the transfer of individual knowledge to institutional knowledge and assists with training and standardization. Include the following SOPs as a start:
   a. Managing clearwell level;
   b. Restarting the plant from shutdown, including restarting/operating on emergency generator power; and
   c. Note: DPU is in the process of generating SOPs for number of processes at the date of writing of this report, revised SOPs related to backup generator operation were shared with SEH, additional SOPs are expected to follow shortly.

5.2.4 Maintenance Procedures Recommendations

1. Continue transition to proactive maintenance program for all plant assets. Develop a formal asset management plan. Re-evaluate current work order system to identify if other key assets are missing from the system. Solicit input from experienced operations and maintenance field personnel.
2. Implement preventative maintenance schedule for network switches (either by DPU staff or third-party contractor). Activities to include annual driver updates, review of existing equipment for the need to replace based on obsolete models.

5.2.5 Emergency Preparedness Recommendations

1. Conduct regular coordination meetings with bulk water customers to review emergency notification and capital projects which affect customers. Regularly test emergency notification channels. Additionally, periodic coordination meeting to review operations, upcoming projects, emergency preparedness, etc. may be beneficial.
2. Maintain hard copies of emergency plans and manuals in areas accessible to the control rooms.
3. Review Emergency Response Plans and Operations Manuals and make plans more site specific. Solicit input from experienced operations and maintenance field personnel.
4. Conduct emergency response training and exercises in accordance with the Emergency Response Plan recommendations.
5. Develop plans for various power failure scenarios, including the loss of each main feeder and loss of the Bus Tie. Train electrical staff on the plans.
6. Review staffing levels during declared States of Emergency. Review whether a qualified electrician should be on site during declared States of Emergency.

7. Update the Emergency Operations Manual Checklist *36. Destruction/Failure of any part of the Water System.* Add thresholds and clear guidelines for notifications, develop an SOP for a major failure at the water plant. Include a schedule for review and training with plant staff.

Figures

[redacted]

PLANT FLOW DIAGRAM

50 0 50 100
scale 25 feet

SEH Project	VADOH 183662	Rev.#	Plan Revision Issue Description	Date	Rev.#	Sheet Revision Issue Description	Date
Drawn By	WSW						
Designed By							
Checked By	MTN						

SEH

CITY OF RICHMOND, VIRGINIA
WATERWORKS

PLANT FLOW DIAGRAM

Appendix A

Information Provided by DPU and ODW

Information Provided By DPU & ODW				
Proviided By	Category	Subcategories		Name
DPU	As- Builts	Distribution System	Gis Mapping	8th and Canal Water.pdf
				Byrd Park Pump House.pdf
				Byrd Park Pump Station.pdf
				Byrd Park Water 2.pdf
				Byrd Park Water.pdf
				Trafford Pump Station.pdf
			Pipelines	12 inch Bells Road Waterline.pdf
				12 inch gas main West Broad Street Road Route 250 Phase 1.pdf
				16 inch High Pressure Gas Main.pdf
				31st Street 12inch Waterline 2009.pdf
				6 inch gas Main Huguenot Farms.pdf
				6 inch gas main Meadowbrook Farms.pdf
				78-1, 78-2 36-30 inch Water Transmission main zone 4.pdf
				8 inch gas main Woodman Road.pdf
				81-1 48-36 inch Water Transmission Main Zone 1 (1981).pdf
				81-1 48-36 inch Water Transmission Main Zone 1 (1982).pdf
				92-1 Water Transmission Mains Zone 1 South and Zone 2 South.pdf
				93-1 Janke Road Transmission Main.pdf
				Cowardin Pipeline.pdf
				Cross section of R.F. and P.R.R. - 15' North of Rothesay Road Overpass.pdf
				Demand Metering Improvements Hermatige Road.pdf
				East Grace and 8th Street WL 2010.pdf
				Green Acres Phase II 2010.pdf
				Green Acres Phase III 2010.pdf
				Hermitage Road Meter Vault Backpressure Control.pdf
				Hioaks Water Storage Tank 2008.pdf
				Hioaks Water Storage Tank As-Built 2011.pdf
				Korah Interconnection to Zone 4 - 2002.pdf
				Korah Interconnection to Zone 4 Record.pdf
				Rothsay Circle and Loch Lomond 2010.pdf
				Water Transmission Mains Zone 1 South and Zone 2 South.pdf
				West 7th Street 2010.pdf
				Zone 5 Distribution System Improvements Phase 1 - Forest Hill Avenue 16-inch Water Main.pdf
				25th Street (Folder)
				31ST Street (Folder)
				Brandon Road (Folder)
				Broadrock (Folder)
				Chippenham Parkway Phase 1 (Forest Hill) (Folder)
				Chippenham Parkway Phase II (Folder)
				Marcy Place (Folder)
				Price Street (Folder)
				Rock Falls Drive (Folder)
			Pumping Stations	1923 Byrd Park Main PS.pdf

Proviided By	Category	Subcategories		Name
DPU	As- Builts	Distribution System	Pumping Stations	79-2 Trafford Pumping Station.pdf
				91-4 Church Hill Pumping Station Miscellaneous Improvements (1991).pdf
				91-4 Church Hill Pumping Station Miscellaneous Improvements (1994).pdf
				91-6 Cofer Road Pumping Station.pdf
				Byrd Park Reservoir and Supply Schematic.pdf
				Church Hill Pumping Station.pdf
				Map of all Pumping Stations.pdf
		Misc		(1975) WTP Soil Borings.pdf
				90-2 Douglasdale Road Ductback and Feeders (1993).pdf
				90-2 Douglasdale Road Ductback and Feeders.pdf
				Belle Isle Access Bridge.pdf
				Browns Island Dam Gates Site Plan and Details.pdf
				Division S Rothesay Circle Intercepting Sewer.pdf
				Douglasdale Road between Walpole St. and Booster Station.pdf
				Douglasdale Road Ductbank and Feeders Boring Location Plans.pdf
				Douglasdale Road.pdf
				Easement for a 36 inch Pumping Main through the Right of Way of the James River Branch of R.F. and P.R.R..pdf
				Forest Hill Park Lake Restoration.pdf
				Fulton Area Redevelopment.pdf
				12-2020 Condition Assessment Tech Memo - Compiled Final.pdf
				COR_SCADA_Upg_Submittal_DWG_FINAL_PCN_20200626.pdf
				COR_SCADA_Upg_Submittal_DWG_FINAL_SCADA_06262020.pdf
				Filters_Data 20250218.xlsx
				Final Filter Evaluation Report.pdf
				FINAL_MOA_VDH-25-103-0091_2.3.25_signed.pdf
				Water CIP Summary.xlsx
				WATER TREATMENT HIGH PRIORITY PROJECTS_13-FEB-25.xlsx
				WTP OM Projects_12.19.24.xlsx
				WTR_Chesterfield.PDF
				WTR_Hanover.PDF
				WTR_Henrico.PDF
		Reports		1946 Report on Richmond WTP (003).pdf
				2018-10-02 James River-Kanawha Canal Feasibility Study - March 1990.pdf
				BoshersDam_InspectionMemo_8-29-14 Draft.pdf
				Hazard Classification Report Final 20140902.pdf
				Time and the River.pdf
		SewerRecord Drawings		22nd Street Sewer Interceptor Part 1
				Hull Street Interceptor Sewer
		Tanks		Cofer Road Tank II Plans.pdf
				Forest Hill Tank.pdf
				Ginter Park Tank.pdf
				Hiokas Water Storage Tank
				Jahnke Road Tank.pdf

Proviided By	Category	Subcategories		Name
DPU	As- Builts	Tanks		Woodside Tank.pdf
		WTP		(1924) Mechanical Filter Plant Waste Water Basin Sections.pdf
				(1924) Mechanical Filter Plant.pdf
				(1938) Filter Plant Road from South End of Filter Plant to R.F. and P. Belt Line Rail Road.pdf
				(1938) Korah Pumping Station Electric Wiring and Pump Starter Template.pdf
				(1938) Korah Pumping Station Plan - Section and Elevation of North Wall.pdf
				(1938) Korah Pumping Station.pdf
				(1938) Map of the Lower End of the Filtration Plant.pdf
				(1939) Plan Showing Shifted Position of the Thirty Inch Pumping Main at the Juncture.PDF
				(1947) Water Purification Plant NO.2.pdf
				(1949) Low Lift Pump.pdf
				(1949) Water Purification Plant NO.2.pdf
				(1957) Enlargement of Intake From Canal at Filter Plant.PDF
				(1968) Water Purification Plant NO.2 General Plan.pdf
				(1970) Byrd Park Reservior Cover - West Basin Cover Framing Plan Phase 2.pdf
				(1972) Basin 3 and 4 Phase 1 Restoration.pdf
				(1973) Basin 1 and 2 Phase 2 Restoration.pdf
				(1973) Purification Plant and Byrd Park and Korah Pumping Stations.pdf
				(1973) Sewage Disposal Project.pdf
				(1975) 84-1 Division Wall Stabilization and Prechlorine Relocation_GeotecReport_1975.pdf
				(1975) Water Purification Plant NO.1 Proposed Covering for Wastewater STG Tank.PDF
				(1976) 76-1 Plants NO. 1 and 2 Wastewater Treatment Facilities.pdf
				(1976) 76-2 North and South Access Wells.pdf
				(1977) 75-1 Plant NO.1 Flash Mixers and Venturi Vaults.pdf
				(1977) 76-3 Plant NO.1 Filters, Flocculators and Effluent Pipes.pdf
				(1977) 77-1 Korah Pumping Stations NO.2 and NO.3 (2).pdf
				(1977) Plant NO.1 Raw Water Venturi Meter.pdf
				(1978) 77-2 Bridge over Kanawha Canal and Access Roadway.pdf
				(1979) 77-2 Bridge over Kanawha Canal and Access Roadway.pdf
				(1979) 78-3 Lime Feed Improvements - Korah Pumping Station NO.1 Raw Water.pdf
				(1979) 78-3 Water Purification Plant Lime Feed Improvements.pdf
				(1979) 78-4 North and South Aeration Basins.pdf
				(1979) 79-1 Wastewater Pumping.pdf
				(1981) 77-1 Korah Pumping Stations NO.2 and NO.3.pdf
				(1981) 80-1 Plant NO.1 Filter Water Pumping.pdf
				(1982) Byrd Park Reserve Pumping Station Improvements (1982).pdf
				(1983) Water Purification Plant Wastewater Lagoon Cleaning.pdf
				(1984) 84-1 Division Wall Stabilization and Prechlorine Relocation.pdf
				(1984) 84-2 Filter Media - Plant NO.1.pdf
				(1984) 84-3 Replacement of Transformers.pdf
				(1985) 83-1 Byrd Park Reserve Pumping Station Improvements.pdf
				(1985) Lagoon Survey Sept. .pdf
				(1986) 83-2 Bulk Ammonia Storage.pdf
				(1986) 86-1 Post Lime Improvements.pdf

Proviided By	Category	Subcategories		Name
DPU	As- Builts	WTP		(1987) Raw Water Pump NO.1 Gear Reducer Support.PDF
				(1988) 87-1 Water Purification Plant NO.2 Filter Improvements.pdf
				(1989) 85-1 Raw Water Low Lift Pumping.PDF
				(1989) 89-1 Raw Water Intake and Sludge Pumping.pdf
				(1990) 85-1 Raw Water Low Lift Pumping.pdf
				(1990) 90-1 Electrical Distribution.pdf
				(1990) 91-1 Korah Pumping Station NO.3 Additional Pumping Unit.pdf
				(1991) 91-2 Pretreatment Facility and Plant No. 1 Filter Controls - Reduced.pdf
				(1991) 91-2 Pretreatment Facility and Plant NO.1 Filter Controls.pdf
				(1991) Water Purification Plant Master Plan (Plant Schematic).PDF
				(1991) Water Purification Plant Master Plan.pdf
				(1992) Flood Protection Richmond Water Filtration Plant .pdf
				(1992) Plant NO.2 Filter Water and Aeration Basin Piping - Storage Improvemements.pdf
				(1994) 94-1 Water Purification Plant NO.1 Filter Upgrades.pdf
				(1994) Conformed Dwg - Miscellaneous Upgrades.pdf
				(1994) Misc WTP Upgrades.pdf
				(1994) Spec Vol. 1 - Water Purification Plant No. 2 Filter Pumps & Adj. Freq. Drive.pdf
				(1994) Water Purification Plant No. 2 Filter Pump & Adj. Freq. Drive Prepurchase.pdf
				(1994) Water Purification Plant No.2 Filter Pump & Adj. Freq. Drive PrePurchased (Sheet E-1).pdf
				(1994) Water Purification Plant NO.2 Filter Pump and Adj Drive Prepurchase.pdf
				(1995) Floodwall - Record Drawings.pdf
				(1996) Korah Pumping Stations NO.2 and NO.3 and Solids Handling Improvements Project.pdf
				(1996) WTP Capacity Evaluation Phase II - Hydraulic Analysis Report.pdf
				(1997) Water Purification Plant Miscellaneous Upgrades Project.pdf
				(1998) Misc. Upgrades (CH2MHILL) Copy.pdf
				(1998) Misc. Upgrades (CH2MHILL).pdf
				(1999) Flood Protection Richmond Water Filtration Plant .pdf
				(2000) Floor and Reflected Ceiling Plans.pdf
				(2000) Flouride Storage Tank System.pdf
				(2000) Lab Floor Plan.pdf
				(2000) Lime Storage Floor Plan.pdf
				(2000) Misc. Improvements Details.pdf
				(2000) Misc. Improvements Elec. Plan.pdf
				(2000) Misc. Improvements Notes.pdf
				(2000) Raw Water Pump Replacement.pdf
				(2000) Storage and Feed Sections.pdf
				(2000) Storage and Feed Systems.pdf
				(2000) Yard Piping Plan.pdf
				(2001) Water Purification Plant Master Plan.pdf
				(2002) Raw Water Pump Replacement - Raw Water Recovery Unit - P.S. Skylights.pdf
				(2003) Raw Water Screening Facilities.pdf
				(2004) Electrical Reliability Project.pdf
				(2004) Elevator Upgrade Plant 1.pdf
				(2004) Raw Water Pump Replacement.pdf

Proviided By	Category	Subcategories		Name
DPU	As- Builts	WTP		(2004) Survey Control Korah Pump Station.pdf
				(2004) West Chemical Facility.pdf
				(2004) WTP Filtration Upgrades Project Vol. 2.pdf
				(2009) Feeder Channel Dredging.pdf
				(2009) Korah NO.1 Pump Station Upgrades.pdf
				(2011) Finished Water Basin Cover.pdf
				(2011) North Basin Cover AsBuilt by CST.pdf.pdf
				(2011) South Basin Cover AsBuilt by CST.pdf
				(2012) Berm Repair Phase 1B.pdf
				(2013) FWBC Electrical Permit Plan Additions - CH2M.pdf
				(2014) Floodwall Repairs Phase II.pdf
				(2014) S-2 S-3 Pump Motor One Line Diagrams_new Multilins.pdf
				(2014) S-4 Pump motor Benshaw One Line Diagram_new Multilin.pdf
				(2004) Elevator Upgrade Plant 1 - CH2M
				(2004) West Chemical Facility - CH2M
				(2011) Chemical System Upgrades - CH2M
				(2014) Lime Feed Pilot System
				(2015) Electrical Reliability Project - CH2M
				(2016) Aerial Photos
				(2018) Aerial Photos
				2025 FEBRUARY - PROJECTS UNDER CONSTRUCTION
				June 2013 Existing Conditions - Richmond SCCS Report
				June 2013 Existing Conditions - Richmond SCCS Report
				ETAP
				Raw Water PS Control Panel Asbuilts
			Reports	(1994) RIC Lead and Copper CCT Study.pdf
				(1994) RIC WTP Corrosion Control Treatment with Info.pdf
				(1994) RIC WTP Filter Pumps and Adjustable Frequency Drives.pdf
				(2001) RIC WTP Infrastructure Repairs Study.pdf
				(2001) RIC WTP Master Plan.pdf
				(2004) RIC WTP Filtered Water Pumping Upgrades PER.pdf
				(2008) RIC WTP Basin Removal System Replacement Eval.pdf
				(2008) RIC WTP Basin Removal System Replacement Eval_Optimized.pdf
				(2008) RIC WTP Tube Settler vs. Plate Settler Eval.pdf
				(2008) RIC WTP Tube Settler vs. Plate Settler Eval_Optimized.pdf
				(2009) RIC WTP SCADA Master Plan.pdf
				(2012) RIC WTP Sed. Basin Improvements PER.pdf
				WTP Flood Wall O&M.doc
				SCADA References
				SCADA Upgrade Project - CH2M
				Soil Borings
	Cyber Secuirity			Appendix C Cyber Security
	Emergency Response Plans	ERP		Emergency response plan certification receipt
				Water Treatment Plant Emergency Response Plan

Proviided By	Category	Subcategories		Name
DPU	Emergency Response Plans	Risk Assessment		Appendix A1_ Risks Sorted High to Low.pdf
				Appendix A2_ Risks Sorted by Asset.pdf
				Appendix B Asset Summary Sheets.pdf
				Appendix C Cyber Security.pdf
	Emergency Response Plans	Risk Assessment		Implementation Plan Richmond RRA 4.1.2020.pdf
				Richmond RRA Report 3.11.20.pdf
				Richmond DPU Emergency Operations Manual 2021
	Master Plans			Richmond Master Plan-Copies_WRA_May_2001
				Water Distribution System MP 2001 Reduced
	Org Charts			Engineer Org Chart 8.20.24
				Water Treatment Plant Maintenance Org Chart 12.13.24
				Water Treatment Plant Operations Org Chart 2024-12-19
				WD Org Chart
	SCADA Data			Filters_Data 1-10.xlsx
				Filters_Data 11-22.xlsx
				Plant1 Data_20250106.xlsx
				Plant1 Data_20250131.xlsx
				Plant2 Data_20250106.xlsx
				Plant2 Data_20250131.xlsx
	SOP For Maintenance Repairs			3.0-Main-Break-Types-Responses-chlorination
				W-05 Water Main Repair
	System Diagram			46526036 Water Diagram-8.5x11
	UPS Specifications			Liebert GTX5 6KVA UPS
				Sentryum Reillo 30KVA UPS
	Work Order History From 2020-2024			WO History (052) 01012020 - 12312024
	WTP Maintenance Plan			WTP PM Complete Report
ODW	Letters			1976_08_RI15_ENLARGED_FILTER_INFLUENT_GATES.pdf
				1981_09_RI15_FLOOD_PROTECTION.pdf
				1982_11_RI15_RICHMOND_WTP_Water Purification Certificant Test No.1 Plant.pdf
				1983_04_RI15_RICHMOND_WTP_Water Purification Certification Test No.1 Plant.pdf
				1985_03_RI15_RICHMOND_WTP_SLUDGE_ Wastewater Discharge Requirements.pdf
				1989_02_RI15_PROJECT.pdf
				1990_08_RI15_RAW_WATER.pdf
				2004_06_RI15_4760100_RICHMOND_WTP_PROJECTS_7_03-6_04.pdf
				20200730091327330_RI15_RICHMOND_4760100_WTP_10_89-2_91.pdf
				20200820103709178_RI15_4760100_RICHMOND_WTP_SYSTEM_PROJECTS_2011-.pdf
				20200820121039829_RI15_4760100_RICHMOND_WTP_SYSTEM_PROJECTS_2009-2010.pdf
				20200820132951849_RI15_4760100_RICHMOND_WTP_SYSTEM_PROJECTS_7_04-5_05 (1).pdf
				20200820132951849_RI15_4760100_RICHMOND_WTP_SYSTEM_PROJECTS_7_04-5_05.pdf
				20200824115914990_RI15_4760100_RICHMOND_WTP_SYSTEM_PROJECTS_JAN_2000-JUNE_2003.pdf
				20200824132427333_RI15_KORAH_PUMP_STATION.pdf
				20200826082312654_RI15_CITY_OF_RICHMOND_WATER_36IN_TRANSMISSION_LINE.pdf
	Site Plans			1969_10_Byrd Park Reservoir Cover.pdf
				1970_05_Byrd Park Reservoir Cover.pdf

Proviided By	Category	Subcategories		Name
ODW	Site Plans			1971_4_Proposed Water Mains & Related Facilities.pdf
				1972_06_Jahnke Road 2.5 Million Gallon Ground Level Water Storage Tank.pdf
				1972_11_Water Improvements Jahnke Road Water Pumping Station.pdf
				1973_2_Water Improvements Forest Hill Avenue Water Pumping Station.pdf
				1974_06_Water Improvements Water Filtration Plant.pdf
				1975_11_Water Plant Improvements Plant No.1.pdf
				1977_09_Water Plant Improvements Plant No.1.pdf
				1978_07_Renovation of 5 MG Church Hill Water Storage Tank.pdf
				1979_08_Project No.77-1 Korah Pumping Stations No.2 & No.3.pdf
				1979_12_Water Plant Improvements Wastewater Pumping.pdf
				1980_7_Water Plant Improvements Filtered Water Pumping.pdf
				1986_05_Byrd Park reserve Pumping Station Improvements.pdf
				1993_08_Jahnke Road Transmission Main From Jahnke Road Pumping Station To Boulders Parkway.pdf
				1994_09_Clearwell Modification For The Water Purification Plant No. 2.pdf
				1994_10_Water Purification No.2 Filter pump and Adjustable Frequency Drice Prepurchase.pdf
				1995_3_Water Purification Plant No. 2 Filter Water Pump and Adjustable Frequency Drive Instillation.pdf
				1996_05_Jahnke Road Pumping Station Phase 2 Improvement Project_.pdf
				1996_05_Jahnke Road Pumping Station Phase 2 Improvements Project.pdf
				1996_06_Zone 3 Mains Church Hill Carlisle Water Main.pdf
				1996_09_Water System Improvements korah Pumping Stations No.2 and No.3 And Solids Handling Improvements Project.pdf
				1996_7_Water System Improvements Church Hill Pumping Station Improvements Phase 2.pdf
				1997_03_Water Purification Plant Miscellaneous Upgrades Project.pdf
				1997_12_Zone 2 North Transmission Maing Phase 1.pdf
				1998_04_Zone 2 North Transmission Main Phase 2.pdf
				2000_12_Water Purification Plant Raw Water Pump Replacement.pdf
				2002_12_Byrd Park Reserve Pumping Station Improvements.pdf
				2002_12_Water Purification Plant Raw Water Screening Facilities.pdf
				2005_02_Water System Improvements Church Hill Pumping Station Improvements Phase 3.pdf
				CITY OF RICHMOND-BYRD PARK-WATER_119-26C-4859A.1-1.pdf
				CITY OF RICHMOND_298-4867.1.pdf
				RICHMOND, DEPARMENT OF PUBLIC UTILITIES WATER PLANT IMPROV.NORTH AND SOUTH ACCESS WELLS_131-760-4865.1-1.pdf

Appendix B

Emergency Response Plan Sections

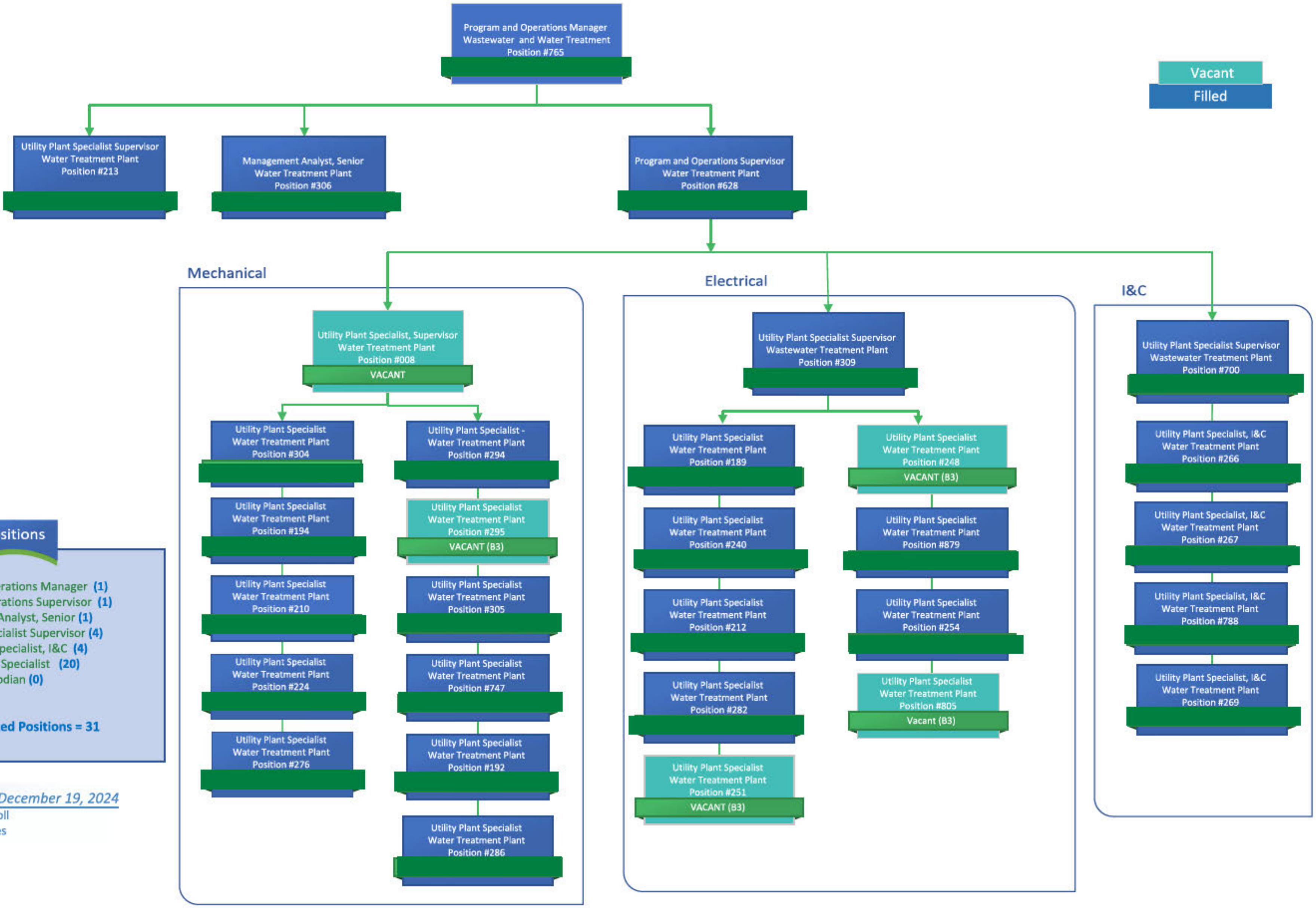
[redacted]

Appendix C

Organization Charts

Water Treatment Plant Operations- 12/19/24

Water Treatment Plant-Maintenance



Positions

Program and Operations Manager (1)
Program and Operations Supervisor (1)
Management Analyst, Senior (1)
Utility Plant Specialist Supervisor (4)
Utility Plant Specialist, I&C (4)
Utility Plant Specialist (20)
Custodian (0)

Total Authorized Positions = 31

Total as of December 19, 2024

- 26 On Payroll
- 5 Vacancies

Building a Better World for All of Us®

Sustainable buildings, sound infrastructure, safe transportation systems, clean water, renewable energy, and a balanced environment. Building a Better World for All of Us communicates a company-wide commitment to act in the best interests of our clients and the world around us.

We're confident in our ability to balance these requirements.

Part 2: Needs Assessment

Richmond Waterworks

Virginia Department of Health - Office of Drinking Water

VADOH 183662 | April 7, 2025

Building a Better World
for All of Us®

Engineers | Architects | Planners | Scientists

Office of Drinking Water, Virginia Department of Health

Richmond Waterworks Needs Assessment
Richmond, Virginia

SEH No. VADOH 183662

April 8, 2025

I hereby certify that this report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Virginia

Brad Weiss, PE

Date: April 8, 2025 License No.: 0402063557

Reviewed By: Jeff Ledin, PE Date: April 8, 2025

Short Elliott Hendrickson Inc.
400 Locust Avenue, Suite 2
Charlottesville, VA 22902-4858
434.202.3780

SEH

Contents

List of Figures

Office of Drinking Water, Virginia Department of Health

1 Introduction

1.1 General

This report is broken down into four chapters. Chapter 1 – Introduction, provides a basic description of the City of Richmond Water Treatment Plant layouts and treatment process as well as a brief description of the distribution system. Chapter 2 – City of Richmond Water Treatment Plant, provides a greater detail and evaluation of the plant and associated pumping and storage facilities to identify their condition, capacity, and needs for improvements. The chapter begins with an evaluation of general building facilities and supporting equipment, followed by an evaluation of each treatment process in the facility. Chapter 3 – Distribution System, provides a similar detailed evaluation of the pumping and storage facilities within the City owned distribution system. Chapter 4 provides a summary of recommended improvements and their associated opinion of probable costs for both the City of Richmond Water Treatment Plant and Distribution System.

The major elements of this assessment include:

- Comprehensive on-site evaluation of the physical condition, capacity, reliability, performance, and operational and maintenance procedures of the City.
- Evaluation of compliance with current Virginia Administrative Code (VAC) Chapter 590 (12VAC5-590, eff. 06/2021) which regulates public waterworks and serves as the design standards for plant capacity by the Virginia Department of Health (VDH).
- Evaluation of general deficiencies and recommendations for potential improvements
  - Some recommendations for improvement are made to address current code. It should be noted that **12VAC5-590-50** states that compliance with certain parts of the Waterworks Regulation (Part III. Manual of Practice for Waterworks Design) is not required for existing waterworks in operation before the effective date (eff 06/2021).
  - Some recommendations may already be included to some extent in the City's current projects list in design or construction phases.

Throughout the on-site evaluation, SEH staff observed that numerous treatment process units were identified by multiple names. City staff acknowledged that process units have been renamed throughout the years and that there were inconsistencies and a lack of standardization on process nomenclature.

For clarity, the following table provides a list of terms that will be used through this report, as well as other frequently referenced names. The report nomenclature seeks to match the terminology used in the plant's SCADA system to the greatest extent possible. The terms are defined for reference following the summary table.

Table 1 – Report Nomenclature Table

REPORT NOMENCLATURE	OTHER NOMENCLATURE	HNTB NOMENCLATURE
Feeder Channel	Intake Channel, Feeder Canal, Raw Water Channel	Raw Water Channel
Pre-sedimentation Basin	North Subsiding Basin, Presettling Basin, WTP Sedimentation Basin	
Raw Water Pumps	Raw Low Lift Pumps, Low Service Pumps	Low Service Pumps
Raw Water Channel	Raw Water Channel	
North Intake Basin	North Subsiding Basin, East Gravity Settling Basin	
South Intake Basin	South Subsiding Basin, West Gravity Settling Basin	
Applied Water (Channel)	Settled Water, Coagulated Water	
Filters (Plant #1 & 2)	Filters	Filters
Filtered Water Pumps	Finished Water Pumps, Filter Effluent Pumps	Filter Effluent Pumps
Clearwell (1 & 2)	Filtered Water Vault/Well	Clearwell
Chlorine Contact Basin (1 & 2)	Aeration Basins, Finished Water Basins	Finished Water Basin
Wastewater Pumps	Backwash Pumps	
Residuals Settling Lagoon	Residuals Basin, WTP Waste Basin	
Filter Effluent Valves	Filter Effluent Valves	Filter Effluent Valves
Filter Influent Gates	Filter Influent Gates	Filter Influent Gates

- Feeder channel: channel with concrete walls that runs from the Williams Island Dam that supplies water to the head of the pre-sedimentation basin
- Pre-sedimentation basin: large basin at the head of the plant used to remove gravel, sand, and other particulate material from the raw water before entering primary treatment processes in a water treatment plant.
- Raw water pumps: pumps water from raw water intake basins to raw water channels that flow to the start of the treatment processes
- Raw water channels: concrete channels which convey raw water to the start of the conventional water treatment processes
- Intake basins (north & south): basins that accept raw water from the James River and/or Kanawha Canal and supply water to the raw water pumps
- Applied water: settled water that has passed through the sedimentation basins
- Filters: tanks with filter media that removes particulates from the water

- Filtered water pumps: pumps water having passed through the plant gravity filters to the chlorine contact basins
- Clearwells: water storage structure below the filters that holds water that is either pumped to the chlorine contact basins or used to backwash the filters for cleaning
- Chlorine contact basins: storage basin with long channels to provide sufficient contact time for disinfection
- Wastewater pumps: pumps collected plant backwash water and drainage to the residuals settling lagoon. Does not include sanitary waste.
- Residuals settling lagoon: large earthen storage lagoon that collects the facility's backwash water and drainage, allowing solids to settle and decanted water to recycle to the front the plant.
- Filter Effluent Valve: device used to stop and control the flow of water leaving the filters.
- Filter Influent Gate: type of valve used to primarily stop the flow of water entering the filters.

For clarity, the following table of abbreviations is presented. This may not encompass the entirety of all abbreviations used throughout this report.

Table 2 – Abbreviations and Descriptions

COR	City of Richmond
WTP	Water Treatment Plant
GPM	Gallons Per Minute
MGD	Million Gallons Per Day
VDH	Virginia Department of Health
ODW	Office of Drinking Water
VAC	Virginia Administrative Code
DPU	Department of Public Utilities
SCADA	Supervisory Control and Data Acquisition
SEH	Short Elliott and Hendrickson, Inc.
UPS	Uninterruptible Power Supply
kV	Kilovolts
MVA	Megavolt-amperes
PS	Pump Station
EL	Elevation
VFD	Variable Frequency Drive
CIP	Capital Improvements Plan
PLC	Programmable Logic Controllers

1.2 Water Treatment Facility Overview

The City of Richmond Water Treatment Plant is a conventional surface water treatment plant (WTP) located adjacent to the James River consisting of two interconnected water treatment plants (Plant #1 and Plant #2). Plant #1 is located to the north of the facility and was initially constructed in 1924, with the addition of Plant #2 1950. Numerous modifications to both plants over the years have increased the capacity of Plant #1 to 60 MGD and Plant #2 to 72 MGD, resulting in a total permitted capacity of 132 MGD. The WTP is permitted as a high-rate treatment facility in accordance with VDH standards 12VAC5-590 to produce high quality drinking water utilizing treatment processes including pre-sedimentation, high-rate clarification, high-rate gravity filtration, and chloramination disinfection.

The WTP currently serves over 250,000 consumers, providing water to the City of Richmond service area along with wholesale water to serve portions of water demand for nearby Henrico County, Chesterfield County, and Hanover County. Henrico County wholesales water to Goochland County, which also wholesales water along with Hanover County to smaller subdivision water systems. Typical production varies seasonally from 50 to 75 MGD, with current summertime maximum day production reported to be approximately 100 MGD.

The WTP receives its primary water supply from the James River which runs along the south of the plant. Raw water is normally diverted from the river by the Williams Island Dam, through a feeder channel, and into the head of the plant. When needed, the plant has the ability to receive raw water from the Kanawha Canal, which runs north of the plant and receives water from both the James River and Tuckahoe Creek.

Water from the James River flows into a single pre-sedimentation basin that runs north and south parallel to the James River. Water then flows by gravity into raw water basins at the start of each plant (Plant #1 and #2), which can be operated independently or in parallel. The raw water is then screened before raw water pumps lift the raw water into raw water channels located between Plants #1 and #2 where some treatment chemicals are added prior to a rapid mixer in each coagulation channel. The water then continues to flow by gravity through flocculation basins and then to sedimentation basins which contain inclined plate settlers. After passing through the sedimentation basins, the water is conveyed through one of four “applied water” (settled water) channels to gravity filters. The filtered water flow to each WTP’s separate clearwells, where it is then pumped by filtered water pumps (commonly referred to by the plant as “finished water pumps”) to separate chlorine contact basins (commonly referred to by the plant as “Finished Water Basins/Storage”) where the water is disinfected, and additional treatment chemicals are added for pH adjustment, corrosion control, and fluoride. Once the water travels through the chlorine contact basins, it is pumped to the distribution system.

Figures A and B provide an aerial view of the water intake and WTP that illustrates the flow of water as it moves through the COR Waterworks. Figure C shows an overall process flow diagram of the WTP.

1.3 Distribution System

The Richmond distribution system consists of 12 pump stations, ten storage facilities, nine pressure zones, and various pressure reducing valve (PRV) stations interconnecting the pressure zones. Figure D provides a schematic of the distribution system, including system flows on a maximum day demand.

2 City of Richmond Water Treatment Plant

2.1 General Building Facilities and Grounds

This section describes the overall building facilities and general operations. Subsequent sections in this chapter focus on each individual treatment process at the WTP.

2.1.1 Description/Purpose/Elements

The WTP is located between the bank of the James River and Kanawha Canal and consists of several major building units:

1. Source Water Intakes (James River and Kanawha Canal)
2. Pre-sedimentation, North, and South Basins
3. Raw Water Pump Station
4. Water Treatment Plants
    a. Plant #1
    b. Plant #2
5. Residuals Settling Lagoon

The WTP site also contains the Korah Pumping Stations, which will be covered in further detail in the distribution section of this report.

The WTP is protected by a flood wall constructed in 1999 that runs around the west, south, and east sides of the WTP along with US Army Corps of Engineers (USACE) owned canal locks on the Kanawha Canal. The flood wall was designed with a top of wall elevation of 117'.

Access to the facility is secured by a locked gate with badge access and security guard present 24/7.

2.1.2 Dimensions/Volumes/Capacity

The facility is currently permitted to produce a combined 132 MGD of finished drinking water, with Plants #1 and #2 rated at 60 MGD and 72 MGD respectively. Typical average day flows for the facility are reported to vary seasonally from 50 to 75 MGD with current summertime maximum day production of approximately 100 MGD. The WTP is generally located on a single parcel. The parcel size is 77 acres as identified on the City of Richmond's GIS platform. The feeder channel is not located within the WTP parcel boundaries.

2.1.3 Operations/Maintenance

The WTP staff is organized with separate groups, Operations and Maintenance with separate leadership. The Operations group has twenty-two (22) authorized positions, with one current vacancy. The WTP is staffed 24/7 with a minimum of three licensed operators (one supervisor) working 12-hour shifts. Typically, one operator is designated as the primary chief operator that is stationed within Plant #2 at the main SCADA control center. The primary operator's duties are to continuously monitor and control both Plants #1 and #2. Due to the heavy amount of manual operation at the facility, this operator is generally constrained to the SCADA control center and not able to physically assist within the WTP except for urgent issues, and does not perform operator rounds The second operator on shift generally resides at the Plant #1 control room and provides assistance in monitoring the WTP levels and flows. This operator is designed to be mobile and performs rounds every two hours. The plant does not utilize a check list or log sheet to document consistent routine checks, observations, and data collected during rounds. . The third operator (shift supervisor) provides overall assistance throughout the WTP as required. The operations group also staffs an operator at the nearby Trafford Pump Station, who is responsible for monitoring and controlling the City's pump stations and distribution storage tank levels.

While the staffing level meets 12VAC5-590-461 requirements for a Class 1 facility, the Plant Operations Superintendent that heads the operations group expressed that given the complex nature of the plant, the plant would benefit from having a total of twenty-four (24) authorized positions. The Superintendent noted that the facility previously benefited from a process engineer within the operations group that was assigned to the plant and whose responsibilities included minor plant improvements along with developing standard operating procedures (SOPs) and training programs.

The Maintenance group has thirty-one (31) authorized positions with five current vacancies. The maintenance group is only physically staffed during business hours Mondays through Fridays and on-call for emergencies after hours. The maintenance group is responsible for the WTP process equipment and general building & grounds maintenance along with the City's pump stations and storage tanks, and is divided into mechanical, electrical, and instrumentation and controls (I&C) groups. A separate public works maintenance group is responsible for maintaining the distribution system piping and valves.

Several years ago, the maintenance group performed a comprehensive asset inventory, installing asset tags with QR codes on major and key equipment. However, the majority of locations within the plant do not have cellular service or Wi-Fi to enable the tags to be read.

2.1.4 HVAC/Electrical/Controls

<u>HVAC</u>

- The general areas of Plants #1 and #2 are served by central HVAC systems. The condition of the HVAC system varies greatly, as improvements have been made throughout the years.
- Some equipment in the lower level of Plant #1 and Plant #2 appears to have been damaged in the recent flooding even ton Junary 6, 2025.
- There are significant amounts of old and abandoned HVAC equipment throughout the plant including an old boiler and associated pumps and electrical panels in the lower level of Plant #2. There are multiple old water heaters, with some that are disconnected.

<u>4160V Electrical Power Distribution</u>

There are two feeders from Dominion Energy feeding the plant at 34.5kV. Feeders are as follows:

- Feeder 310 to substation #1, (SS1), is overhead from the Dominion Energy ACCA substation.
- Feeder 399 to substation #2, (SS2), is underground from the Dominion Energy Carver substation.

Both feeders supply 7.5MVA outdoor 34.5kV-4.16/2.4kV transformers which feed 4.16kV substation SG6. SS2 was installed circa 1992 and is in fair condition. SS1 is older and shows signs of significant corrosion. SS1 is being replaced, with work expected to be completed Fall 2025.

Switchgear SG6 receives 4160V power from SS1 and SS2 and distributes it throughout the WTP. This includes:

- Switchgear SG7, which distributes power to the Filter Plants, West Chemical Building and Douglasdale Wastewater Pumping Station.
- Switchgear SG8, which distributes power to the Korah 2-3 pumping stations.
- Switchgear SG9, which distributes power to the Korah 1 pumping station.

All switchgear dates from the early 1990s and is over 30 years old. Overall the equipment is well maintained and is in good condition. Immediate replacement is not required. rRplacement within 5-10 years is recommended due to the age of the equipment and its critical role in the operation of the WTP. The following routine maintenance items are recommended to ensure that the equipment is functioning properly and to extend its lifespan:

- The equipment is currently tested and maintained every three years. Maintenance was last performed in 2022 and is expected in 2025. Continue with routine maintenance schedule.
- Clean any dirt or dust accumulation from the equipment.

Transformers T1A and T2A are fed from SG7 and provide 480V to the Filter Plants.   Each Substation contains a 2500kVA oil filled 4.16kV-480/277V transformer and 4000A fused switch to feed the downstream Main Switchboards for each plant.

Summary:

- Perform annual routing maintenance on electrical distribution equipment
- Replace 4160V Switchgear SG-6 within 5-10 years.
- Replace 4160V Switchgear SG-7 within 5-10 years.
- Replace 4160V Switchgear SG-8 within 5-10 years.
- Replace 4160V Switchgear SG-9 within 5-10 years.

<u>Supervisory Control and Data Acquisition (SCADA) System</u>

- A plant-wide SCADA system allows plant operation to be monitored and controlled from a central location. The SCADA system was updated in 2016 and generally serves its purpose well.
- Some SCADA system components, such as network switches and routers are obsolescent (no longer in production but supported by the manufacturer) and would benefit from annual maintenance to ensure hardware health and up-to-date firmware.
- Programmable Logic Controllers (PLCs) provide the physical connections to sensors and actuators that allow instrumentation data to be displayed by the SCADA system and SCADA system commands to control pumps, valves, and similar equipment. The PLCs are in generally good condition and function reliably. The newer Schneider Electric / Modicon M340 PLCs are current, but consideration should be given to phasing out the remaining Quantum PLCs with Schneider Electric / Modicon 580 PLCs since the Quantum PLCs are no longer supported by the Schneider Electric.

2.1.5 General Plant Observations & Recommendations

1. Housekeeping is a significant concern throughout the plant and in nearly every structure. SEH staff observed significant amounts of clutter, abandoned equipment with and without power, storage containers, standing water, and other general debris in violation of **12VAC5-590-470. Waterworks condition.** The waterworks shall be maintained in a clean and orderly condition.
2. SEH and ODW staff observed significant amounts of equipment and supplies stored in various locations that are not appropriate, such as filter plant hallways, underground flocculator hallways, and chemical rooms. It is recommended that the WTP staff identify and designate proper storage facilities within the WTP, and organize and consolidate materials.
3. Operations, maintenance, and engineering groups are not always aligned on responsibilities and priorities. City personnel noted frustration with the organizational structure and noted difficulty in reporting and addressing issues.
    a. Several operations staff expressed a lack of clarity and frustration with reporting maintenance issues and ensuring they were completed.
    b. Operations and maintenance staff had very limited knowledge of planned and on-going improvement projects.
    c. It is recommended that the City's engineering department work to be more closely integrated with the on-site operations and maintenance departments. The operations department would benefit from hiring a staff member whose primary responsibility would be operational improvements to the facility.
4. Maintenance throughout the facility is largely performed in a reactive manner. Ongoing efforts are being made to move to a more proactive maintenance approach, which should be prioritized.
    a. Maintenance staff perform office work in spaces that were not intended for that purpose but have been converted in a makeshift fashion to offices. SEH staff observed multiple rooms throughout the buildings that appeared to be largely unused or for storage. With proper housekeeping work including organizing and consolidating storage of equipment and supplies at the facility, there appears to be adequate room for additional office space for the Maintenance group. The facility appears to prioritize repair of equipment after it fails. Due to the age of the facility and equipment, it is recommended that the facility implement a proactive replacement schedule to replace critical equipment at the end of its useful life, prior to an equipment failure.
5. The WTP operation heavily relies on institutional knowledge, with manual observation and control by operations staff rather than automated systems. At the WTP, chemical feed pump rates are typically manually calculated and input into the SCADA system to operate the plant. As a result, staff generally have a good working knowledge of the WTP.
6. Manual operation of the water treatment facility requires heavy operational staff involvement. This appears to limit staff ability to identify and work on operational improvements. The WTP frequently experiences minor process flooding within Plants #1 and #2, which the staff appear to be well adept at handling. However, the WTP did not appear to be prepared to handle major flooding such as occurred during the January 6, 2025 water crisis. Efforts could be better focused on preventing issues from occurring rather than addressing them.

a. It is recommended that the City assign or hire a specific engineer to the WTP whose primary responsibilities include focusing on plant projects and operational improvements.

7. One of the critical issues repeatedly noted throughout multiple discussions with plant staff is with flow metering instrumentation. Some flow meter transmitters were upgraded in 2016 but newer flow metering instrumentation was reported to be unreliable and the equipment that was not replaced is past its useful life. Plant staff reported that in-channel raw and applied water flowmeters struggle with flow variations, with large discrepancies reported between the channel and venturi meters in Plant #1. The online raw water flow meter for Plant #2 is an insertion style meter and was noted to be largely unreliable. Operations and maintenance staff repeatedly noted that flow monitoring has been a known and on-going issue for several years that has not been properly resolved. As a result, there is a general mistrust in the SCADA data. The lack of reliable flow instrumentation is a major issue in reliably operating the plant and ensuring accurate chemical dosage to produce high quality drinking water.

   a. As an example, the image below was captured on February 6, 2025 which shows flow rates displayed on the WTP SCADA. The partial screenshot shows a discrepancy between the raw water flows, finished water flows, and filtered water flows.

8. The facility is slow to address issues and implement improvement projects. For example, staff reported that the Plant #2 raw magnetic flow meter failed around 2020. A replacement insertion style meter was not installed until 2022 and was reported to not be reliable to this day. The facility has also been using an interim, rented lime silo and feed equipment for approximately 10 years and has not completed a project to replace the original lime feed equipment.

9. Due to the age and location of the facility, legacy designs constrain and challenges the plant operations and future design considerations.

   a. The facility was originally designed so most of the tankage tends to be just above the ground surface and allows for gravity flow of water. However, as a result filter galleries, pump rooms and other facilities are located below the plant hydraulic grade line, including critical electrical equipment.

   b. The filtered water clearwells and chlorine contact basins are likely below the groundwater table. A geotechnical report prepared by CH2M Hill in 2003 noted that at the north end of the facility near the intake basins, groundwater was encountered 15-18 feet below the surface (EL 90'-94') in 1989. In 2003, additional soil borings for the West Chemical Facility project noted groundwater levels at depths of 1.2-2.5 feet below the surface (EL 105.5' to 106.5'). The 2003 geotechnical report recommends a design groundwater elevation for both short term and long term conditions to be 107'.

   c. Minor to significant flooding of the Plant #1 and Plant #2 filter galleries is a longstanding common occurrence and identified problem at the plant. The facility has installed large portable trailer mounted, diesel powered de-watering pumps to manage flooding in the plant, along with permanent suction piping. Staff on-site could not definitively identify when they were installed, but data review noted the first pump was installed in 2006.

d. There is a significant lack of designed overflows throughout the plant. The facility relies on critical pumping equipment and filter effluent valves to prevent the natural flow from the hydraulic gradeline from continuing into the plant and flooding the facility. The style of installed pumps depends on heavily outdated and unreliable priming equipment to start pumping.

e. As the facility was expanded and capacity increased throughout the years, the size of the filtered water wells has not increased. The small volume combined with limited suction lift capabilities and unreliable priming equipment requires a very high level of operator attention and control. At the maximum permitted flow rate of 132 MGD, the filter wells have an effective buffer time (from empty to overflowing) of approximately 8 minutes. At normal operating levels and flow rates, this time may be reduced to as little as 3 minutes or less. This provides minimal time for the plant to react to a loss of pumping capacity.

10. Given the age of the facility and number of past and ongoing improvements, there are areas of the plant (such as below grade structures) that are not well understood by all plant staff, particularly newer staff without institutional knowledge. In addition, it is difficult to understand all the limitations and potential site issues that exist or have been resolved.

    a. It is recommended that old equipment be designated and labelled as abandoned and scheduled for demo and replacement.

    b. While WTP staff are adept at addressing minor flooding within the plant, staff were generally unaware of what level/elevation of river flood protection was present at the facility, and specific procedures to take during high river levels. It is recommended that the plant evaluates and trains staff on current flood protection systems, levels of current protection, and limitations of the system.

    c. It is recommended that the facility implement a strong, on-going training program for both newer and experienced staff. An understanding of historical changes throughout the plant would help staff better understand plant limitations.

11. The exterior of Plants 1 and 2 are in fair condition. There are areas with apparent damage to the wooden fascia/soffits. Recommend further roof assessment and general exterior repairs, including selective roof repairs, exterior tuckpointing, weather stripping, and roof drain/leader selective replacement.

It was noted that the roof decking and roof is in critical disrepair, with replacement options currently underway for Plant #1 and Plant #2.

Plant #1 Exterior

12. There is a significant and noticeable amount of standing water throughout the WTP, caused by both weather events and process leaks. While some efforts are made to remove larger amounts of water, it is inadequate and the presence of standing water appears to be normalized. WTP staff do not appear to be concerned with minor pooling inside the buildings, especially in areas that are less trafficked or abandoned. This can lead to increased corrosion, damaging assets and affecting the asset management plant.Recommend facility weatherproofing to address sources of water intrusion, along with identifying and fixing process leaks.
13. The HVAC system in the lower levels of both plants appears to be insufficient. Limited airflow was observed, with high levels of humidity. The condition of the HVAC system in both plants varies greatly. It is recommended that a separate detailed HVAC study be completed.
    a. Review of the City's current project list notes that an HVAC study and improvements project is currently on-going.
14. The WTP is bordered by a railroad track, which also crosses over the WTP's intake channel. The City's emergency planning does not include scenarios for a possible train derailment. Given the critical nature of the WTP and intake channel, it is recommended that the City prepares special planning for a potential derailment event.

2.2 Source Water Intakes (James River and Kanawha Canal)

2.2.1 Description/Purpose/Elements

The WTP is situated between the James River to the south and the Kanawha Canal to the north and can receive raw water from both sources. In normal operation, water from the James River is diverted by the Williams Island Dam through four (4) manually operated intake gates.

Williams Island Dam and Intake

Diverted water flows through a feeder channel approximately 1,600 feet in length. The feeder channel is approximately 50’ wide, with a cast-in-place concrete wall on the south side of the channel. Water in the channel flows south and underneath railroad tracks, where it then enters the pre-sedimentation basin through the Pre-sedimentation head wall, which is a cast-in-place concrete structure with three (3) manually operated intake gates. The head wall separates the raw water in the channel from both the pre-sedimentation basin and the residuals settling lagoon. Immediately upstream of the Pre-sedimentation head wall is an additional manual gate valve that connects the James River to the downstream end of the feeder channel.

James River to Intake Channel Connection

During dry periods when the James River level is low, the WTP can also receive additional raw water from the Kanawha Canal. The Kanawha Canal receives water from the James River at Bosher's Dam as well as Tuckahoe Creek. Water in the Kanawha Canal flows through the 5-Mile Lock Dam, which is a cast-in-place concrete structure containing four (4) manually operated intake gates with bar screens and a floating debris boom.

5-Mile Lock Dam - Upstream

The structure also contains a vault at the northern end that contains transmission piping from the Korah 3 Pump Station located at the WTP. The discharge piping is prestressed concrete cylinder pipe (PCCP) that runs through the Kanawha Canal below the water surface before rising above the water level and passing through the intake.

The discharge piping in the vault was submerged at the time of inspection and appeared to contain air blowoff piping.

Discharge Piping

5-Mile Lock Dam (Downstream) and Korah 3 Discharge Piping

The supplemental water from the Kanawha Canal is diverted into the head of the pre-sedimentation basin directly downstream of the Pre-sedimentation head wall, through two (2) manually operated head gate valves.

Kanawha Canal to Pre-sedimentation Basin Gate Valves

Kanawha Canal to Pre-sedimentation Basin Inlet

2.2.2 Dimensions/Volumes/Capacity

N/A

2.2.3 Operations/Maintenance

The Williams Island Dam, Feeder Channel, and 5-Mile Lock Dam are not routinely inspected. DPU staff noted that the dams and flood wall are owned by the City of Richmond, with inspections by the US Army Corps of Engineers (USACE) completed annually. The feeder channel has not been dredged in at least 10 years, but the City noted that a 3rd party engineering project is underway to establish a dredging schedule.

During dry summer periods when the James River level is low and operators visually notice the pre-sedimentation basin level to drop, operators manually open the Kanawha Canal intake gates to supplement the James River.

The gates on the intake structures are not regularly operated or exercised with the exception of the Kanawha Canal to the Pre-sedimentation basin inlet which is operated on an as needed basis.

2.2.4 HVAC/Electrical

There are solar powered surveillance cameras located at the head of the pre-sedimentation basin that allow plant staff to monitor the intake areas as well as the locked gate that provides access to the 5-Mile Intake and Williams Island Dam Intake.

2.2.5 Observations & Recommendations

1. To access the 5-Mile Intake, DPU staff must cross a locked gate and then walk on the side of two active railroad tracks for approximately 300 feet. To access the Williams Island Dam Intake, DPU staff must additionally cross the railroad tracks and walk through private property for several hundred feet. DPU staff indicated that the City of Richmond does not have a right-of-way nor an easement to allow them to legally inspect or maintain the feeder channel and Williams Island Dam.
    a. Recommend the City acquire an easement and add visual inspection to operator rounds (weekly/monthly). It is recommended the City explore the potential to add additional security cameras around the intake structures and private property.
    b. There is no at-grade, approved pedestrian railroad crossing. It is illegal to cross railroad tracks and poses significant safety risks to City personnel. Recommend that the City acquire ROW/easements to allow them to legally access and inspect the feeder channel, 5-Mile Intake, and Williams Island Dam. It is recommended to add visual inspection of these facilities to operator rounds at least weekly.
2. Due to high river levels, SEH staff were not able to visually inspect the feeder channel walls. The feeder channel is not regularly inspected nor dredged, and DPU staff noted the walls have significant deficiencies including a visible hole. It is recommended to perform a structural inspection of the feeder channel walls and necessary repairs as required.
3. It is recommended that the City improves security and limits access to the intake structures, such as posting additional signage at 5-Mile Lock Dam as well as additional security cameras.
4. Air relief/blowoff valve piping at 5-Mile Intake shows sign of heavy corrosion, likely due to being submerged. It is recommended that the access cover is repaired and sealed to try to limit water intrusion. It is unclear if the structure was designed to be watertight, so preventing the piping from being submerged may be difficult without additional inspections and repairs.
5. Air relief/blowoff valves at 5-Mile Intake are not screened as required by **12VAC5-590-1160E.1**. It is recommended that screens are installed. .
6. Korah K3 discharge piping is exposed in the Kanawha Canal and shows visual signs of damage and repairs. The piping also does not meet **12VAC5-590-1140. Installation and testing of water mains.** A. Adequate supports and restraints shall be provided for all pipes. There is potential for damage due to riverbed movement. DPU staff noted that a previous break in the prestressed concrete cylinder pipe (PCCP) line buried in the Kanawha Canal was extremely difficult and costly to repair and required a third-party contractor and extensive excavation work. Recommend further inspection and evaluation of the transmission piping along with repairs as required.
7. As the Kanawha Canal also receives water from the James River, the City of Richmond WTP does not have a secondary source of water that is independent from the James River. DPU staff noted that in 2014 an oil spill occurred upstream of the plant, which prompted the plant to temporarily shut the raw water intakes and later install floating oil booms.
8. The James River Regional Flow Management Plan (JRRFMP) stipulates a max withdrawal rate of 150 MGD from James River for City of Richmond WTP. There is currently no flow monitoring infrastructure associated with any of the intakes from the James River or Kanawha Canal. As the water quality differs between the James River and Kanawha Canal,

this requires adjustment to the treatment process. There is no prescribed procedure to adjust for treatment, nor any way to determine the amount of supplemental Kanawha Canal flow. The 2022 EPA inspection report noted:

> *"Recommended Standards for Water Works" (2018 Edition) Part 2.13 states that "[a]ll water supplies shall have an acceptable means of measuring the flow from each source, the wash water, the recycled water, any blended water of different quality, and the finished water."*
>
> *Part 2.19.h. states that "[r]eal time water quality monitoring with continuous recording and alarms should be considered at key locations to provide early warning of possible contamination events."*
>
> *System risks exceeding turbidity standards described in 40 CFR §141.173(a)(1)*

9. The WTP currently collects raw water turbidity, pH, alkalinity, and temperature data every four hours at the inlet of the raw water pump station. The WTP does not conduct any other periodic monitoring of raw water for potential contaminants or locations further upstream (James River or Kanawha intakes). Staff noted that use of the Kanawha Canal creates differences in water quality which requires adjustment to treatment. The 2022 EPA inspection report noted:

   > *"Recommended Standards for Water Works" (2018) Edition 2.21.h – "Real time water quality monitoring with continuous recording and alarms should be considered at key locations to provide early warning of possible contamination events.*

   a. It is recommended that continuous water quality monitoring be installed at the head of the pre-sedimentation basin.

10. The feeder channel has not been dredged/cleaned in staff memory. It is understood that the City is currently working with an engineering consultant to establish a cleaning schedule.

2.3 Pre-Sedimentation Basin

2.3.1 Description/Purpose/Elements

Water from the James River and Kanawha Canal flows by gravity to a pre-sedimentation basin, which provides hydraulic retention time to settle and remove gravel, sand, and other larger particulate material from the source water. According to VDH permit data, the basin has an earthen bottom and sloping sides lined with stone. The pre-sedimentation basin helps to reduce the high turbidity and improve the treatability of the raw water. DPU staff noted that the pre-sedimentation basin is effective at reducing typical turbidity levels in the raw river water from 300-400 NTU down to 5-10 NTU. In addition, decanted water at the end of the residuals settling lagoon is recycled to the head of the pre-sedimentation basin. The decant structure is a cast-in-place concrete structure with two (2) 4' x 4' slide gates.

Recycled Water Inlet to Pre-sedimentation Basin

The facility does not continuously add coagulation to the pre-sedimentation basin, so is not eligible to receive a 0.5-log Cryptosporidium treatment credit.

2.3.2 Dimensions/Volumes/Capacity

The VDH permit notes the basin is approximately 10' deep and 300' wide, with a capacity of approximately 42.5 million gallons. The basin provides a retention time of approximately 0.32 days at the maximum combined plant capacity of 132 MGD.

2.3.3 Operations/Maintenance

Currently, operators visually inspect the pre-sedimentation Intake at least daily. During the summer months, operators periodically add bags of copper sulfate for algae control at the head of the pre-sedimentation basin when the water temperature exceeds 60°F.

When the pre-sedimentation basin appears visually full, the basin is dredged by a contractor. DPU staff noted that dredging should be performed annually, but has not been performed recently or routinely.

2.3.4 HVAC/Electrical

There are buried power lines running along the earthen berm separating the pre-sedimentation and residuals settling basin. Power was previously run to support early dredging efforts prior to the City utilizing contractors. It is unclear whether the power distribution equipment is still functional.

2.3.5 Observations & Recommendations

1. The pre-sedimentation intake wall shows signs of damage with significant cracking present. Copper sulfate addition appears to be broadcast over the wall, with significant staining present. Recommend additional structural inspection and repairs.

2. There is no flow measurement and control of the recycled supernatant from the residuals settling lagoon to the pre-sedimentation basin. While backwash wastewater flows are metered and make up the majority of water sent to the residuals lagoon, **12VAC590-550** requires waterworks to collect recycle flow information.

3. It is unknown when the pre-sedimentation basin was last drained down and the condition inspected. It is recommended that the City perform an inspection of the pre-sedimentation basin.

2.4 Raw Intake Basins – North & South

2.4.1 Description/Purpose/Elements

Water from the pre-sedimentation basin passes below a flood wall that protects the WTP, and can be diverted independently to two intake basins: North Intake Basin and South Intake Basin. Water flows into each basin through two (2) manually operated intake gates at the north end of each basin and are equipped with mechanically cleaned bar screens.

North Basin Intake Screen

North Basin Intake Gates – From Pre-sedimentation

Raw water from the Kanawha Canal can bypass the pre-sedimentation basin if needed and directly enter the North Intake Basin through two (2) manually operated intake gates located at the northern end of the basin.

Kanawha Canal to North Intake Basin

The North and South Intake Basins are interconnected by two sluice gates.

Water from each intake basin flows by gravity through travelling water screens to enter the suction wells of the Raw Water Pump Station. Water from the North Intake Basin enters Raw Water Pump 1 through four (4) manually operated 3’ x 4’ influent gates, and Raw Water Pump 3 through one (1) 3’ x 5’ influent gate. Water from the South Intake Basin enters Raw Water Pump 2 through four (4) manually operated 3’ x 4’ influent gates, and Raw Water Pump 4 through one (1) motorized 3’ x 5’ influent gate.

The plant is currently undergoing a project to upgrade the raw water screening facilities with four (4) new travelling screens. In addition, the upgrade includes concrete modifications, bar screens, and additional motorized influent gates that provides operational redundancy in the event a travelling screen is offline. Level transmitters are being relocated and added to allow the plant to monitor the level in each intake basin as well as raw water pump well.

2.4.2 Dimensions/Volumes/Capacity

The North and South Intake Basins have been modified throughout the years as the WTP has been expanded and modifications made to the raw water and sludge pumping facilities. The North Intake Basin is approximately 300’W x 100’L while the South Intake Basin is significantly smaller and triangular in shape, estimated to be about 50’W x 100’L.

2.4.3 Operations/Maintenance

In normal plant operations, raw water from the pre-sedimentation basin enters both the North and South Intake Basins, with the interconnection gates opened. The Plant Superintendent noted that the mechanical bar screens at the inlet of the North and South Intake Basins no longer automatically function. Instead, operations staff is supposed to manually initiate a cleaning at least once a day but is not routinely performed. Operations staff performs a raw water grab sample at the North Intake Basin for water quality analysis every 4 hours.

The Plant Superintendent noted that the facility has not bypassed the pre-sedimentation through the Kanawha to North Intake Basin gate in over 10 years.

2.4.4 HVAC/Electrical

None.

2.4.5 Observations and Recommendations

1. As the raw water screening project was under construction, the South Intake Basin was currently offline and drained. One of the interconnecting sluice gates between the North and South Intake Basin was observed to be leaking water. Flow was not measured but appeared to be close to the standard acceptable leak rate for the style of gate.
2. Recommend repair or replacement of bar screens to automatically perform cleaning function.
3. The intake basins (North and South) are not currently cleaned and it is unknown when they were last drained and inspected. It is understood that the City is currently working with an engineering consultant to establish a cleaning schedule. It is recommended that the City include an inspection of the basins as soon as possible.

2.5 Raw Water Pump Station

2.5.1 Description/Purpose/Elements

There are four (4) raw water pump stations located adjacent to the North and South Intake Basins. The pumps are used to lift water from the intake basins up to two separate concrete conduits to the downstream treatment processes. The pumps are used to supplement gravity flow to the treatment plant.

Pumps No 1. and No. 2 are housed in a common building and are vertical turbine type pumps with the motors for each located on the main operating floor of the pump station. Water from the intake basins passes through a travelling water screen prior to entering the pump suction wet wells through four (4) manually operated 3’ x 4’ influent gates. A manually operated 5’ x 5’ sluice gate allows the suction wetwells of Pumps No. 1 and No. 2 to be isolated.

Typical Raw Water Intake. Fixed Bar Rack (Left) and
Pump No. 1 Traveling Screen (Center)

Pump No. 3 and Pump No. 4 are housed in their own buildings are each connected to the North and South Intake Basins respectively. Once the screening project is complete, water will flow through a fixed bar rack and then through independent travelling water screens before entering the pump suctions.

Both pumps are vertical turbine type pumps that discharge directly into the raw water conduit downstream of Pumps No. 1 and No 2. through two (2) manually operated 3’ x 5’ slide gates. During higher river levels, some water can flow by gravity around Pumps No. 3 and No. 4 and directly into the raw water conduits through motorized 3’ x 5’ sluice gates located adjacent to the pump discharge sluice gates.

The two raw water conduits flow south before turning back to the north and entering the rapid mix basins. A manual 5' x 5' sluice gate located at the head of the raw water conduit allows the two conduits to be interconnected if needed.

Pump No. 4 Discharge Sluice Gates and Gravity Sluice Gate

Pump stations No. 3 and No. 4 each contain two spray wash pumps used to clean the travelling screens. At the time of inspection, spray wash pump 3B (located in Pump Station No. 3) was missing. Due to current construction, only spray wash pump 3A was operational and in service. Pump stations No.3 and No. 4 each also house an on-line turbidimeter to continually monitor the raw turbidity levels of the North and South Intake Basins.

There are not individual flow meters on each pump discharge. The facility measures the total combined gravity and pumped raw water flow to the Plants with several flow instruments. Historically the plant has measured the total raw flow to Plant #1 with two (2) venturi flow meters, and raw flow to Plant #2 with one (1) magnetic flow meter. The magnetic flow meter failed within the last 5 years at which point the facility abandoned the meter in place and installed an insertion type flowmeter within the same metering vault. In 2022, Accusonics 8510 series open channel flow meters were installed within the concrete conduits to measure flow. Currently, the plant operators utilize a combination of the venturi flow meters,insertion flow meter, channel flow meters, and filter effluent meters to manually calculate and dose treatment chemicals at the raw water channel.

2.5.2 Dimensions/Volumes/Capacity

Pumps No.1 and No. 2 each have capacity of 60 MGD at 13 feet TDH. Pumps No. 3 and No. 4 were installed in 1990 and each have a design capacity of 50 MGD at 7.5 feet TDH, with 150 HP motors.

2.5.3 Operations/Maintenance

The WTP is operated 24/7, with starting and stopping of the raw water pumps manually by operators. The raw water pumps are controlled by operators, who manually set and adjust pump speeds to maintain raw water flow rates. Operators reported that level sensors located in the North Intake Basin and individual pump wetwells are not used to control the raw water pumping speeds. Operations staff manually set the desired plant production flow rate by adjusting the filtered water pumps, and then adjusting the raw water pump speeds as required to accomplish a steady-state operation.

Maintenance of the pumps is reportedly performed on an as-needed basis.

2.5.4 HVAC/Electrical

A Schneider Electric / Modicon M340 PLC provides on/off and speed control of the raw water pumps in accordance with operator commands received via the SCADA system. The PLC also provides the SCADA system with the status of the raw water pumps and the associated instrumentation.

Raw Water Pump Electrical Systems

Raw Water pump #1 and #2 VFDs are fed from 400A circuit breakers in switchboard MSB-HDP2 in Filter Plant #2. The VFDs were recently replaced in 2024 and are in good condition. Other electrical equipment, including panelboards in the Raw Water Pump #1 and #2 building are currently being replaced and no further action is recommended currently.

Raw water pump #3 is fed from MSB-HDP-1 in Plant #1. PPA-3 is a 400A General Electric Panelboard and distributes power to the RWP-3 VFD, associated spray wash pumps and 120/240V panel LPA-3. All electrical equipment and is over 30 years old and past its expected life. Replacement is recommended within 5 years.

RWP 3 Electrical Equipment

Raw water pump #4 is fed from MSB-HDP-2 in Plant #2. PPA-4 is a 400A General Electric Panelboard and distributes power to the RWP-4 VFD, associated spray wash pumps and 120/240V panel LPA-4. All electrical equipment and is over 30 years old and past its expected life. Replacement is recommended within 5 years.

Summary:

- Perform annual routing maintenance on electrical distribution equipment
- Replace Panelboard PPA-3 within 5 years.
- Replace Panelboard LPA-3 within 5 years.
- Replace RWP-3 VFD within 5 years.
- Replace Panelboard PPA-4 within 5 years.
- Replace Panelboard LPA-4 within 5 years.
- Replace RWP-4 VFD within 5 years.

2.5.5 Observations and Recommendations

1. Through conversations with multiple DPU operations and maintenance staff, the facility currently struggles with flow measurement instrumentation. Flow meter issues were identified as an on-going problem. The general plant consensus is that the venturi flow meters in Plant #1 are the only reliable raw water meter. When the Plant #2 magnetic meter failed around 4 years ago, staff reported that the replacement insertion type meter took 2 years to be installed and claims to not be reliable today. Staff also reported that in-channel flow meters installed in 2022 were also not reliable. Numerous staff indicated that they generally did not trust the readings and instead relied on monitoring various water levels throughout the plant (raw conduit, applied water conduits, basins) and the filtered water effluent flow meters to reliably operate the plant at steady-states. It is recommended that the facility prioritize flow meter improvements:
    a. Solicit manufacturer support to resolve the in-channel transducer issues. Replace with alternative technology as required.
    b. Replace the non-functional Plant #2 raw water magnetic flowmeter. It was noted by the City that this replacement is
2. Operation of the raw water pumps is currently performed manually by selecting a pump and setting a pump speed through the VFD. It appears that a lack of trust in the flow metering capabilities prevents the operators from allowing the SCADA system to automatically control and operate the raw water pumps. Operators must constantly monitor plant flows and frequently adjust pump speeds as needed.
3. The static bar racks immediately upstream of the traveling screens do not appear to have cleaning capabilities. Operations staff was uncertain how these racks would be cleaned if they become clogged in the future.
4. Based on river elevation, the James River can flow by gravity through the raw water pumping station to downstream processes and the WTP buildings. The first location of actuated valves at the WTP is at Pumps No. 3 and No. 4., which are currently being upgraded with motorized sluice gates that can stop flow into the pump stations. Flow into Pumps No. 1 and No 2. require closing four manual influent gates on each side (8 total). In an emergency event such as flooding or contamination, it would take considerable time and effort to close all eight gates and stop all flow into the plant. It is recommended that the plant SOP's include preparation for river flood events.
5. Raw Water Pump No. 3 was observed to be leaking water through the shaft packing/seal. It is recommended that the pump is repaired.

2.6 Coagulation and Flocculation

2.6.1 Description/Purpose/Elements

Gravity and pumped flow from the intake basins travel down the two separate raw water conduits for approximately 400 feet. From May to October, the facility periodically feeds potassium permanganate at the discharge of the raw water pumps. The facility also has the ability to feed powdered activated carbon (PAC) at the discharge of the raw water pumps when it receives taste and odor complaints, as well as sodium hypochlorite.

Approximately two-thirds of the way down each raw water conduit is an in-line Water Champ flash mixer which aggressively blends alum (aluminum sulfate, for coagulation) into the raw water. At the end of the channels, a manually operated 4’ x 5’ sluice gate connects the two channels when needed. Raw water on the Plant #1 side is directed to a flow straightening structure before passing through venturi flow meters. Raw water on the Plant #2 side flows directly into a meter vault containing an insertion flow meter and a non-functional magnetic flow meter.

Plant #1 – Flow Straightening Structure

Plant #1 – Venturi Flow Meter

Raw water in each plant then flows through an influent sluice gate and within a “triple conduit”. The triple conduit is a cast-in-place concrete structure running between the rapid mixing basins and the WTP buildings, and contains concrete channels for raw water, applied water, and plant wastewater.

Plant #1 and 2 each consist of four (4) flocculation basins for a total of eight (8) basins.

Flocculation Basins – Plant #1

At the head of each flocculation basin is a mixing chamber that contains two rapid mixers that are not currently used.

Rapid Mixers

Each of the eight flocculation basins are split into four individual chambers with winged-wall baffles and a vertically-mounted, motor driven mechanical flocculator. This arrangement provides a 4-stage tapered flocculation process, with coagulant polymer added in the first stage of each flocculation basin to aid in floc production. The rotating paddles of the flocculators provide a gentle stirring or mixing action that increases the contact opportunities for particles in the water, destabilized by the coagulation process, to grow into larger settleable floc. From the flocculation basins, the agglomerated particles flow by gravity into the sedimentation basins.

The facility has streaming current monitors (SCM) located at the inlet of each flocculation basin (8 total) that provide data to the SCADA system.

2.6.2 Dimensions/Volumes/Capacity

The total rapid mix basin capacity is approximately 107,000 gallons. Details on the mixing basins are provided in the table below, taken from the VDH's Engineering Description Sheet (1996).

Rapid Mixing Basin #	Dimensions (ft) L=Length W=Width H=Water Depth	Detention Time (minutes)*	Volume (gallons)	Velocity Gradient (sec^{-1})
1A	L=31, W=6, H=11	1.26	15,304	847
1B	L=32, W=6, H=11	1.30	15,798	833
2A	L=28.5, W=6, H=11	1.16	14.070	883
2B	L=29, W=6, H=11	1.18	14,317	875
3A	L=24, W=6, H=11	0.97	11,848	962
3B	L=24, W=6, H=11	0.97	11,848	962
4A	L=24, W=6, H=11	0.97	11,848	962
4B	L=24, W=6, H=11	0.97	11,848	962

* ***Evaluated at 16.5 MGD per mixing basin.***

At the permitted max flow rate of 132 MGD, the average detention time is approximately 70 seconds assuming a design flow of approximately 16.5 MGD through each basin. Each of the sixteen (16) top-mounted 10-HP rapid mixers are speed adjustable with a variable frequency drive.

The total flocculation basin capacity is approximately 2.34 million gallons. Details on the flocculation basins are provided in the table below, taken from the VDH's Engineering Description Sheet (1996).

Flocculation Basin #	Volume (gallons)	Detention Time (minutes) @ 16.5 MGD	GT Value
1A	292,879	25.56	153,285
1B	298,781	26.07	154,913
2A	285,332	24.90	151,433
2B	283,492	24.74	150,631
3A	298,407	26.04	154,380
3B	299,866	26.17	154,632
4A	284,659	24.84	150,967
4B	296,066	25.84	153,724

Evaluated at 16.5 MGD per mixing basin.

At the permitted max flow rate of 132 MGD, the average detention time is approximately 25.5 minutes, which meets 12VAC5-590 requirements for plants operating with high rate filters (> 20 minutes).

2.6.3 Operations/Maintenance

The inline Water Champ channel mixers are operated continuously. DPU staff noted that the rapid mixers have not been as effective as the rapid channel mixers and as such have not been utilized for several years. Staff noted that the rapid mixers were believed to be functional, but that modifications to the raw piping and chemical feed equipment would be necessary prior to resuming their use.

The flocculator speed is controlled by the VFDs which were all observed to be in local speed control. The VFDs are in electrical control buildings situated between sedimentation basins in each plant. The actual flocculator speed is adjusted by the plant operator on duty.

There is no overflow for these basins. The operating water surface elevation is controlled by the downstream level of the sedimentation basins, which is ultimately controlled by the water level in the filter cells.

Solids that accumulate on the floor of the flocculation basins are periodically cleaned along with the sedimentation basins which are drained and a full clanout performed annually. The accumulated sludge is discharged to the Basin Sludge Pump Station.

2.6.4 HVAC/Electrical

All rapid mixer and flocculator motors were recently replaced in 2022 and are operated with VFDs. The MCCs were replaced in 2022 and are in good condition.

Schneider Electric / Modicon M340 PLCs (one for Plant #1 and another for Plant #2) provide monitoring and control of the sensors and actuators associated with coagulation and flocculation.

2.6.5 Observations and Recommendations

1. SEH staff observed an abandoned raw water mixer panel at the front of the raw water channel. City staff were unaware when the previous mixer was removed. Recommend removal.
2. SEH staff observed that alum feed hose was installed in a semi-permanent fashion using flexible chemical hoses that were run above the walkway between the raw water channels before discharging into each raw water channel. SEH staff observed the chemical hoses to be routed below the grass before terminating within Plant #2. SEH staff could not locate where the chemical hose transitioned to rigid piping within the building. **12VAC5-590-860** requires that chemical feed lines be protected against freezing and specifically requires that liquid alum does not mix with water before the point of application. Recommend permanently installing feed lines in such a manner to protect them from freezing and damage minimizing trip hazards.

Alum chemical hoes run above ground and along walkway to channel mixers.
Extension cords and heat tracing run along hoses.

3. Between the sedimentation basin control building for Plant #1 and 2, there is a below grade structure that previously housed the motors for horizontal style flocculators. The area appears to be abandoned, with multiple birds observed along with debris, hoses, stagnant water, and an old propane cylinder. The concrete walls show signs of efflorescence. Recommend removal of debris and periodic visual inspection of the area for further signs of deterioration.



Old flocculation motor areas

2.7 Sedimentation

2.7.1 Description/Purpose/Elements

The COR WTP has four sedimentation basins that provide a quiescent environment for the particles created in the flocculation basins to settle. Water from two flocculation chambers combine in a concrete flocculation dispersion channel measuring approximately 8'W x 60'L, where it then flows into the beginning of each sedimentation basin through a ported distribution baffle wall to evenly distribute the flocculated water. The quiescent environment in the sedimentation basins reduces the solids loading applied to the filters located downstream. Due to short detention times within the basin, inclined plate settlers are installed at the effluent end of each basin to enhance sedimentation by increasing the surface area while decreasing the vertical settling distance. Water enters the plates through side inlet ports and rise between inclined stainless steel plates. As water travels up the plates, solids settle out onto the plate surface. The clarified or settled water flows through orifices into top tubes and then over a weir into troughs where it flows out of the basin in a concrete channel. The plant refers to the settled water in the channels as “applied” water”. Sodium hypochlorite for disinfection is dosed at the inlet of the applied water channels which run along either side of the sedimentation basins before entering the downstream filters.

Sedimentation Basins and Plate Settlers

Each sedimentation basin is equipped with nine (9) hoseless suction sludge (Cable-Vac) systems to provide automated, mechanical removal of the solids that accumulate in the basins. The sludge removal system consists of a suction header that traverse across each basin, withdrawing settled sludge through orifices. The header is connected to an actuated 4” plug valve to control discharge into a larger 8” collection header located in each basin. The sludge is then conveyed by gravity to the Basin Sludge Pump station, with a 6” magnetic flow meter at the outlet of each basin. The system allows routine sludge removal without having to take a basin offline.

There is no overflow for these sedimentation basins. The operating water surface elevation is controlled by the water level in the filter cells downstream.

2.7.2 Dimensions/Volumes/Capacity

As the sedimentations were built within the confines of the original 1909 water plant between the James River and Kanawha Canal, the four basins are all irregular in shape and size. Basins 3 and 4 were historically much larger than Basins 1 and 2. The latest sedimentation improvement project in 2022 replaced existing tube settlers with new plate settlers and reduced the length of of Basins 3 and 4 to reduce capital and operational costs. Plan dimensions show the basins to be approximately 140’W x 220’L with a working water level of approximately 10’-9”. The total basin capacity is approximately 9.9 MG, which results in a detention time of approximately 1.7 hours at 140 MGD.

Virginia Waterworks Regulations normally requires a minimum detention time of 3 hours and a maximum surface overflow rate of 0.5 gpm/ft^2 for plants employing high-rate gravity filters. With the use of the inclined plate settlers 12VAC590-872 allows a maximum loading of 0.5 gpm/ft^2 based upon the effective settling area (80% of the projected horizontal plate area).

The VDH has approved the stainless-steel plate settlers in all four basins that are designed for 35 MGD per basin, with an overflow rate of 0.5 gpm/ft^2, permitting a total capacity of 140 MGD. The plate settler troughs and support structures were designed with future expansion in mind to allow the installation of additional modules to handle flows up to 47 MGD per basin (188 MGD total).

The hoseless sludge removal system is rated for 35 MGD in each sedimentation basin, and was also installed with future expansion in mind.

2.7.3 Operations/Maintenance

The hoseless sludge collection system is automatically operated based on operator set frequency to routinely remove accumulated solids in the sedimentation basins. The plant sets the collectors closest to the flocculators to operate more frequently as it is the area with the highest solids accumulation. Operations staff noted that the collection system is generally reliable, but noted that staff occasionally uses air operated diaphragm valves and hoses to manually clear clogs with the collection headers.

The sedimentation basins and plate settlers are drained for cleaning and inspection twice a year. To aid in cleaning, the facility utilizes raw water from the South Intake Basin. A 3'x5" sluice gate allows water to drain by gravity into a 16" flushing header and then into two (2) 12-inch butterfly valves per sedimentation basin. The flushing water flows down the sloped floor to four (4) 12-inch mud valves located near the flocculation basins which drain into the waste conduit in the triple conduit.

South Basin Raw Water Drain Gate

There are several smaller flushing connections located around the sedimentation along with a yard hydrant above the plate settlers that utilize filtered water effluent to assist in cleaning. The facility periodically cleans the top of the plate settlers using the yard hydrant in between the twice annual basin cleanings.

2.7.4 HVAC/Electrical

A Schneider Electric / Modicon Quantum PLC provides monitoring and control of sedimentation basins 1 and 2, and a second Schneider Electric / Modicon Quantum PLC provides monitoring and control of sedimentation basins 3 and 4.

2.7.5 Observations and Recommendations

1. There is no overflow in the sedimentation basin.

2. The sedimentation basins appear to be in good conditions, with adequate means for sludge removal and cleaning. The recent upgrades appear to include provisions for future expansion if needed.

2.8 Filtration

2.8.1 Description/Purpose/Elements

The COR WTP has a total of twenty-two (22) high-rate gravity filters, with ten filters at Plant # 1 and 12 filters at Plant #2. The filters receive water from the applied water channels which enter each filter cell through motorized influent sluice gates. The water in the cells flows by gravity down through the filter media, into the underdrain system, through a filtered water conduit, and then into a clearwell. During filtration, the settled water passes through the filter media to assist in the removal of particulate matter, bacteria, and viruses.

Plant #1 filters (Filters No. 1-10) are covered within a finished building space while Plant #2 filters (Filters 11-22) are uncovered. All filter control panels are located within finished building spaces adjacent to the filter cells.

The filter media within each filter cell contains approximately 18 inches of anthracite (top), followed by 8 inches of silica sand (middle), and 4 inches of garnet sand (bottom) for a total filter media depth of approximately 30 inches. The filter media in Plant #1 sits on top of several inches of support garnet and support gravel. In Plant #2, the filters have an integral media support (IMS) cap below the support garnet in lieu of the support gravel.

The filtration system in both plants utilize an air scour step utilizing two blowers for improved cleaning performance.

There are no designed gravity overflows in the filters.

2.8.2 Dimensions/Volumes/Capacity

Each filter cell is noted to have a surface area of 1,078 ft^2, based on VDH ODW permit sheets and previous filter studies. Plan dimensions indicate cells to be approximately 44’ x 24.5’. With ten filters in Plant #1, the maximum rated capacity based on 4.0 gpm/ft^2 limit set by 12VAC5-590-874 is 62 MGD. The twelve filters in Plant have a maximum rated capacity of 74.5 MGD, resulting in a total filtration throughput of 136.5 MGD.

There are two air scour blower systems, each equipped with inlet and outlet air silencers. Both blowers are powered by 125 HP motors. The blowers are rated at 2,700 SCFM @ 6 PSI discharge pressure. The total capacity of 5,400 SCFM provides the filters with an air scour rate of 5 $SCFM/ft^2$.

2.8.3 Operations/Maintenance

The filters at the COR WTP are operated in a continuously cyclical manner, where solids are removed until the media becomes clogged and then the media is flushed clean to that another filtration cycle can occur.

The following describes the operation of the filters in more detail:

Filtration Mode

Water enters the filter cells by gravity through the filter media and into the filtered water well. The rate of flow is set by the effluent rate of flow control valve which the plant operators set manually.

During the filtration cycle, online turbidimeters continuously measure the turbidity of the filtered water. As more solids are removed from the water, the turbidity of the filter effluent will start to rise. As the turbidity values rise close to 0.1 Nephelometric Turbidity Units (NTU), the plant operators will terminate the filtration cycle and wash the filter media in preparation for another filtration cycle.

As the filters remove solids from the flowing water, the depth of water above the filter media needed to maintain the same rate of flow through the filter media increases. Left to continue operating in this manner, a terminal headloss condition will eventually occur where the depth of water over the filter media approaches the sedimentation basin overflow level and water will no longer readily pass through the filters. Filtration cycles at the WTP are terminated when any of the following conditions occur: headloss above 5 feet, turbidities reaching 0.1 NTU, or after 80 hours of filtration.

Backwash Mode

Once the filtration cycle is terminated for the conditions stated above, the filter is put through an air scour and backwash cycle to flush the captured solids from the media. Air is introduced into the bottom of the filter bed with two blowers, which helps to break up and loosen accumulated particles. Once air scour is completing, backwash water supplied from the filtered water pumps flows upwards to flush the solids from the media. The backwash is first performed at a low rate for 2 minutes (at 5 gpm/ft^2) before increasing to a high rate backwash for 10 minutes (at 13.5 to 15.5 gpm/ft^2). The up flowing water is collected in the washwater troughs positioned within the filter cell and then is discharged into the filter cell gullet where gravity flow drains the spent backwash into a concrete drain conduit, which is then pumped out to the residuals lagoon. Once the backwash is complete, the filter cells are put into a filter-to-waste step. Settled water is introduced to the top of filter cell and filtered water is directed to the drain conduit to flush out any remaining suspended solids and turbidity. After a preset time, the backwashing process is complete and the filter can return to service. Plant operators also monitor the effluent turbidities to ensure that effluent water is below 0.1 NTU before returning to service.

Operators reported that the facility typically backwashes 2-3 filters in each plant per day (4-6 total filters per day), and is limited to backwashing one filter at a time based on wastewater pumping capacity.

2.8.4 HVAC/Electrical

There is no dehumidification equipment in the lower level filter gallery of Plant #2. Plant #1 has a central dehumidification unit that was installed in 1993 but is non-operational..

Each of the 22 filters is monitored and controlled by its own Schneider Electric / Modicon M340 PLC with commands from the SCADA system relayed though the Plant #1 and Plant #2 main PLCs (via TCP/IP messaging), both of which are Schneider Electric / Modicon Quantum PLCs.

Filter Plants #1 & #2 Electrical Systems

Main Switchboards MSBH-1A and MSBH-2A distribute power in Plant #1 and Plant #2 respectively and were manufactured in 2013. This equipment is in good condition and is tested every three years. Other than continuing with routine maintenance, no further recommendations are made at this time for the switchboards.

On the Filter Plant #1 side, Switchboard MSBH-1A which is a 4000A, 480V switchboard with the following feeder breakers:

- 2000A feeder for MSB-HDP-1.
- 800A feeder for 500kVA 480-120/208V transformer T1B.
- 2000A tie breaker to MSBH-2A.

MSB-HDP-1 is manufactured by Siemens and is over 30 years old. This equipment is past its expected life and has signs of corrosion. Replacement of this equipment is recommended within 5 years.

HDP-1

Transformer T1B feeds 1600A 120/208V switchboard MSBL-1B. MSBL-1B was manufactured in 2013 and is in good condition. MSBL-1B is tested every three years and other than continued regular maintenance, no further recommendations are made at this time.

MSBL-1B feeds Panels LP1 and PP2 via a 400A breaker and has a 1000A tie breaker connection to Plant #2 MSBL-2B Switchboard.

On the Filter Plant #2 side, Switchboard MSBH-2A which is a 4000A, 480V switchboard with the following feeder breakers:

- 2000A feeder for MSB-HDP-2.
- 800A feeder for 500kVA 480-120/208V transformer T2B.
- 2000A tie breaker to MSBH-1A.

MSB-HDP-2 is manufactured by General Electric and is over 30 years old. This equipment is past its expected life and has signs of corrosion. Replacement of this equipment is recommended within 5 years.

HDP-2

Transformer T2B feeds 1600A 120/208V switchboard MSBL-2B. MSBL-2B was manufactured in 2013 and is in good condition. MSBL-2B is tested every three years and other than continued regular maintenance, no further recommendations are made at this time.

MSBL-2B has a 1000A tie breaker connection to Plant #2 MSBL-1B Switchboard.

In addition to any capital improvements recommended, the following routine maintenance items are recommended for electrical distribution equipment, (panelboards, switchboards and motor control centers). This maintenance should be performed annually to ensure that the equipment is functioning properly and to extend its lifespan:

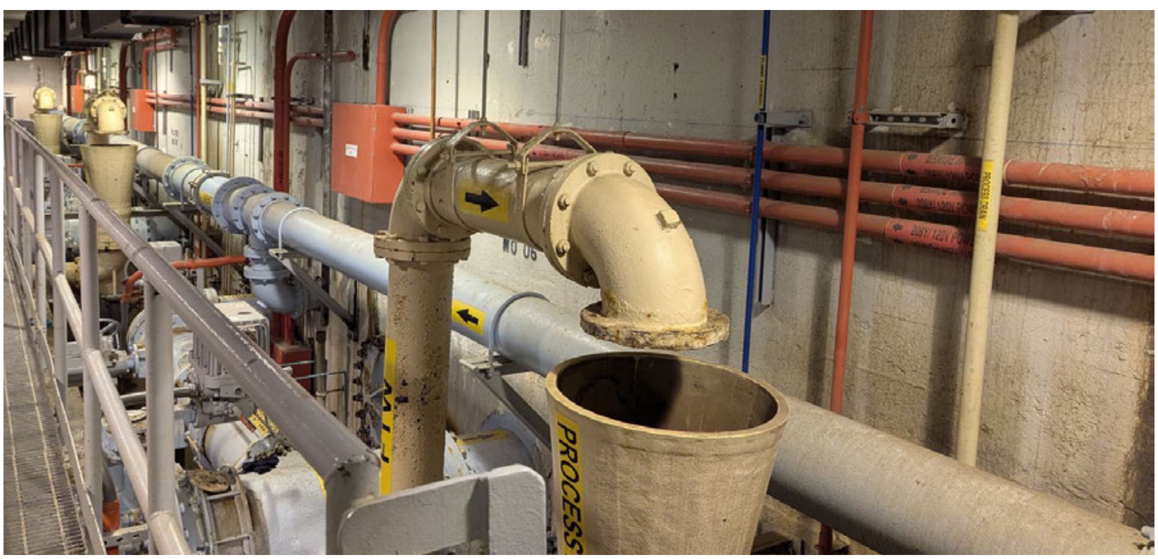
- Operate (exercise) the breakers. Check for proper functioning and freedom of movement. Replace any damaged or worn parts.
- Check all terminals for tightness and tighten any loose connections.
- Verify all grounded conductors, equipment grounding conductors and grounding electrode conductors are tightened properly.
- Check contacts for excessive wear and dirt accumulation.
- Check coils for evidence of overheating (cracking, melting or discoloration).
- Clean any dirt or dust accumulation from the equipment.

Summary:

- Perform annual routing maintenance on electrical distribution equipment
- Replace 480V, 2000A switchboard MSB-HDP1 within 10 years.
- Replace 480V, 2000A switchboard MSB-HDP2 within 10 years.

2.8.5 Observations and Recommendations

1. The filter piping, bolts, and lower-level structures of Plants 1 and 2 show signs of severe corrosion and damage and are in very poor condition. The stainless-steel air scour piping show signs of severe chlorine induced corrosion and pitting. The facility previously used chlorine gas for disinfection which would have accelerated the damage. The piping gallery in Plant #2 is in noticeably worse condition than Plant #1. Due to the age of piping and severe damage, SEH recommends rehabilitation of filter piping in both Plants 1 and 2. The piping should be blasted, thickness verified, and recoated. All corroded bolts should be replaced. The walkway in Plant #2 should be replaced as the supports are severely corroded with minimal material remaining.



Plant #1 – Filter Piping Gallery

Plant #1 – Filter Piping Gallery

Plant #1 – Stainless Steel Air Scour Piping

Backwash Waste Water Piping in Plant #2

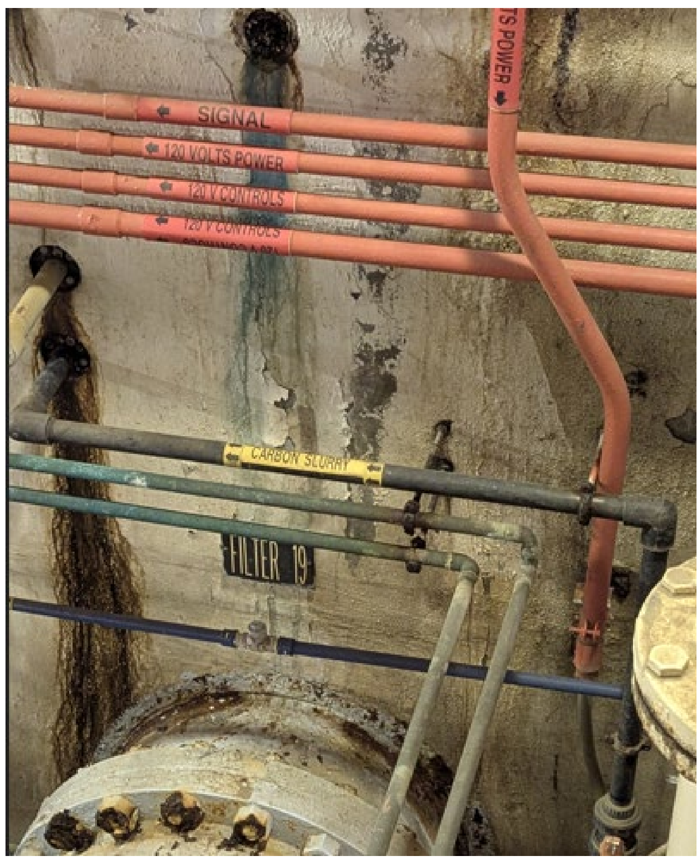
Piping and Filters – Plant #2

Walkway Supports – Plant #2

Walkway Supports – Plant #2

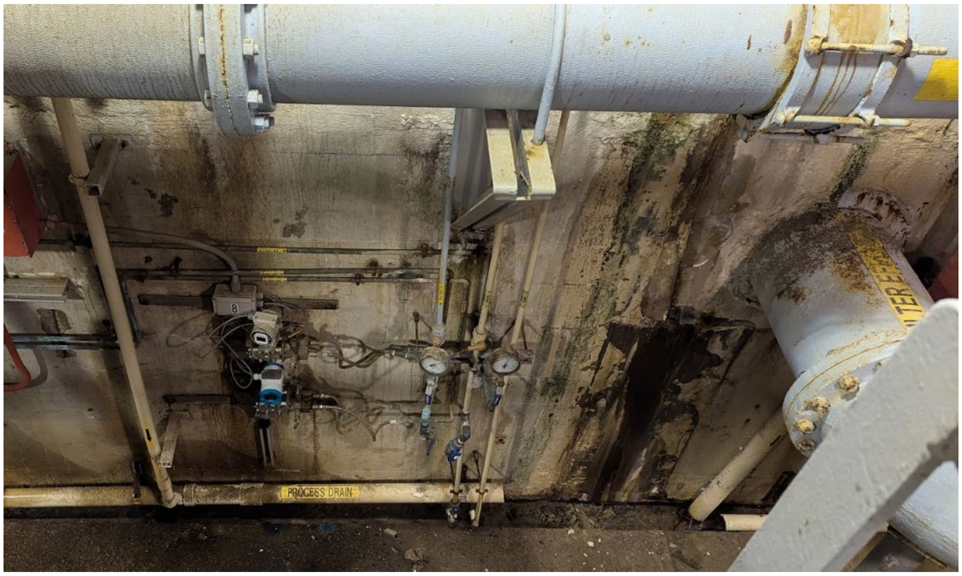
Walkway Supports – Plant #2

Filter Piping – Plant #2

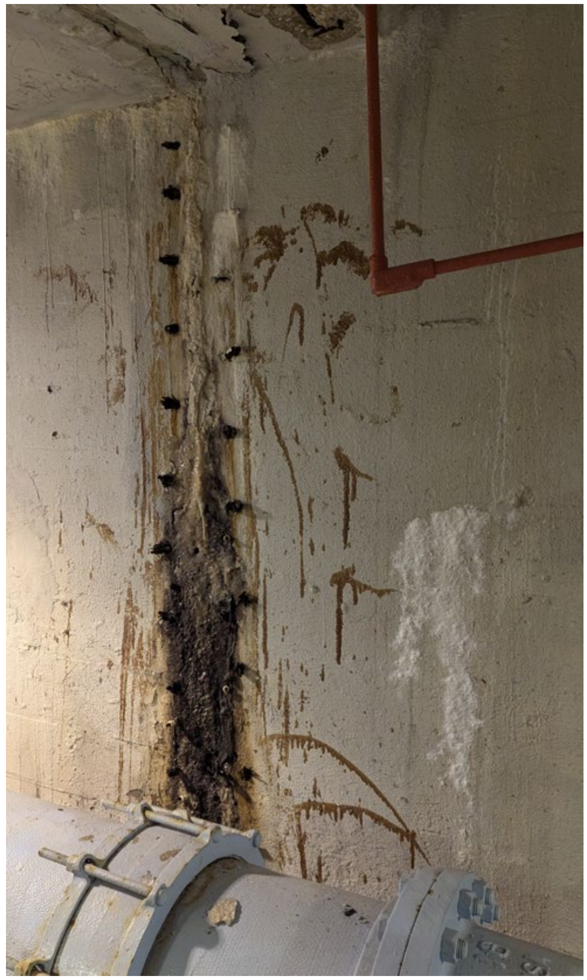


Filter 19 – Plant #2

2. There are significant coating failures as well as leaks in the concrete filter walls into the piping gallery. SEH recommends that the filter walls are repaired and re-coated.

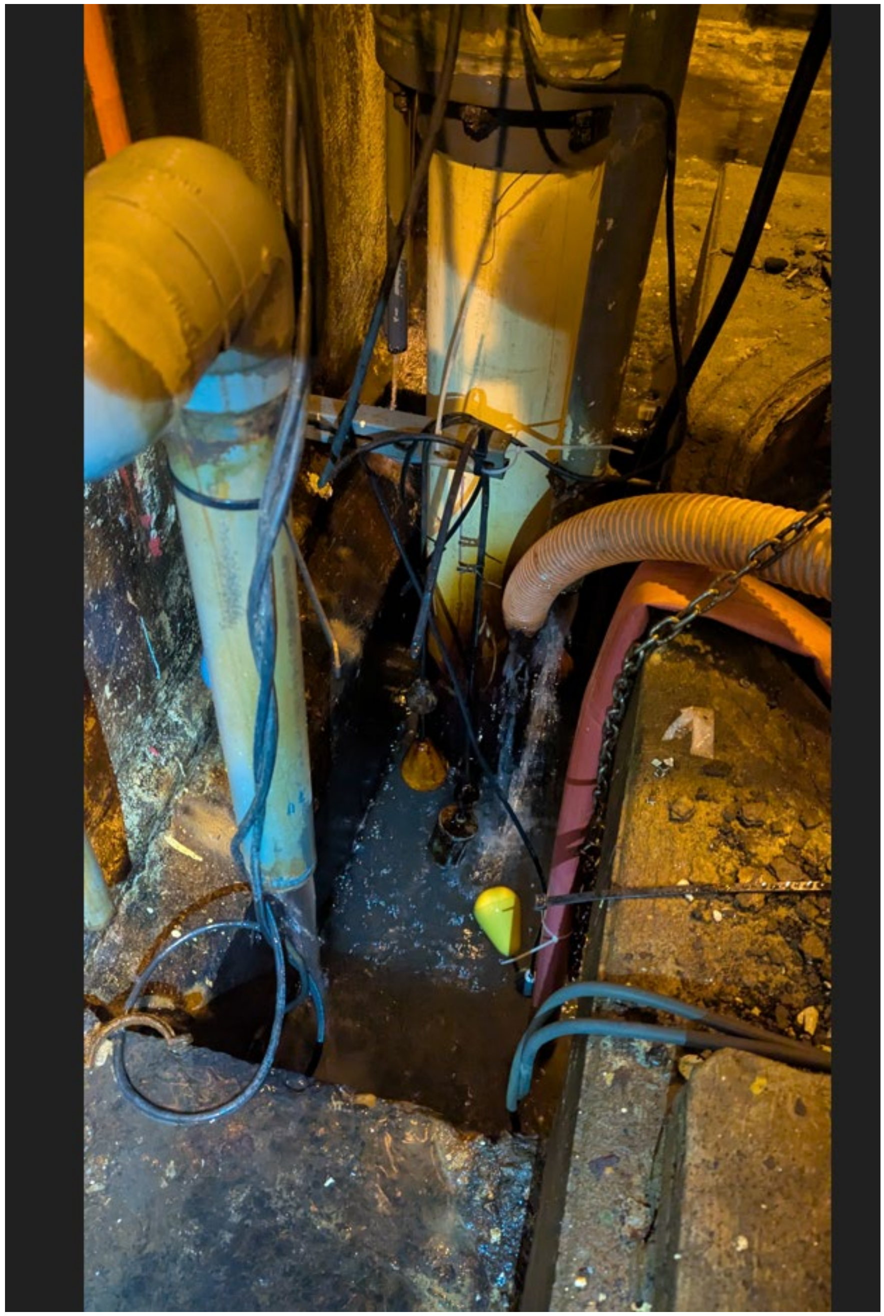


Filter 8 Wall Damage and Leaks – Plant #1



Filter 10 Wall Damage and Leaks – Plant #1

3. There are significant amounts of standing water in the lower level of both filter galleries (Plants 1 and 2) along with significant amounts of leaking water from the filter walls and piping. There were multiple sump pumps throughout the basement that were constantly discharging water to various process drains, with hoses and extension cords running throughout the area. The amount of water present contributes to very high humidity levels which is harsh on electronics and coating systems. Recommend that all source of leaks are identified and repaired, and all wall penetrations sealed. Once repairs have been completed, recommend installation of permanent sump pumps capable of removing water from minor leaks, seepage, condensation, and other analyzer or process drains. The sump pumps would not be expected to handle a process flood into the basement level.



Plant #2 – Sump Pumps with Wiring, Hoses, and Extension Cords

Sump Pump Hoses Routed to Additional Process Drains – Plant #2

Plant #2 Piping Gallery. Sump with Permanent Dewatering Suction Pipe and Standing

4. Plant #2 is controlled with both electrically and hydraulically actuated valves. The hydraulically actuated backwash waste, backwash supply, and filter to waste valves rely on house pressure, which is provided by the Korah 3 Pump Station. Hydraulically operated valves are prone to water seepage, which contributes to the humid environment in the filter gallery. The hydraulically actuated valves are in poor condition and at the end of their useful life. Recommend replacing the current hydraulic actuators in Plant #2 (backwash supply, backwash waste, filter to waste) with electric actuators to match the remainder of the facility. Actuators rated for immersion duty would provide additional operational reliability.
5. During the inspection, SEH observed what appeared to be a dead eel on the surface of Filter No. 11 located in Plant #2, which was currently offline. It is recommended that the facility implements an inspection procedure to periodically drain filter cells and perform visual inspections of the media, troughs, and filter walls. It is recommended that the facility performs annual evaluation of the placement, quantity, and condition of the filter media following the *Filter Evaluation Procedures for Granular Media, Second Edition, by AWWA (American Water Works Association)*

Filter No. 1 – Dead Eel on Surface of Media

6. There is a critical lack of overflows in the filter plant. The hydraulic profile of the plant is such that water gravity flows from upstream processes through the filters, which rely on the filtered water pumps to prevent water from rising above the filter clear wells. When pumping capacity is lost such as loss of power, pump failure, or loss of prime, the flow of water into the plant is such that the filter clearwells may begin to overtop within minutes.

7. The filter effluent valves are critical to preventing continued flow into the filter clearwells and flooding the lower level if filtered water pumping capacity is lost or reduced. Recommend replacing the filter effluent actuators in both plants (22 total) with electric actuators with mechanical fail-safe units. These valves would provide further operational redundancy should UPS or communication failure occur. Recommend actuators with immersion duty if possible to provide additional reliability.
8. The filter plant gallery is frequently subject to events where the clearwells surcharge and water floods into the lower level. Staff reported various such events throughout the years and generally able to mitigate damage through the use of dewatering equipment.
9. Due to frequent flooding in the filter pipe galleries, the facility has semi-permanently installed portable, diesel powered dewatering pumps. At Plant #1, a Godwin CD150M unit installed in 2006 provides a max pumping capacity of 2,290 GPM (3.3 MGD). At Plant #2, a Godwin NC150s series installed in 2014 provides a max pumping capacity of 1,770 GPM (1.7 MGD) was installed in 2014. The facility has installed rigid piping from the lower level piping gallery up to a quick-connect hose connection. These dewatering pumps are not designed nor capable of handling a full overflow condition at each plant (60 MGD and 72 MGD respectively). Due to the distance suction height required, the facility notes that priming the pumps can be difficult and takes several minutes.
   a. It is recommended that the facility increase the dewatering pump capacity, including the ability to handle full overflow conditions in the filter clearwell. Hydraulic submersible style dewatering pumps (flood pumps) may be one such method. However given the limited physical space and elevation constraints at the facility, this may not be feasible without extensive site work such as a below grade overflow structure. Further studies should be performed.

"Godwin" Portable Dewatering Pump – Plant #2

"Godwin" Portable Dewatering Pump Suction – Plant #2

"Godwin" Portable Dewatering Pump Suction – Plant #2

"Godwin" Portable Dewatering Pump Suction – Plant #2

"Godwin" Portable Dewatering Pump – Plant #1

10. There are some concrete failures on the Plant #2 filters that are not covered. Recommend repair.

Filter Walkway – Plant #2

11. Filter control and isolation valves cannot be accessed from the upper walkway in the piping gallery. Access to the filter piping including valves and instruments is very difficult, requiring staff to descend a ladder from the walkway to access each individual filter cell. Accessing valving is potentially hazardous, particularly in an emergency such as a power outage. There is no emergency lighting, and the amount of standing water and flooding risk poses significant danger to operations and maintenance personnel. It is recommended that the facility evaluate whether any valve actuators can be extended with extension tubes to be accessible at the walkway level. Consideration should be made to future piping gallery replacement or modification projects to locate actuators in accessible locations.
12. Recommend emergency lighting be installed within the filter piping galleries.
13. Due to the design of Plant #2, the gutter downspouts are run down into the piping gallery and discharge into the concrete drain conduit. Active leaks were observed at several penetrations. Recommend repair and sealing all penetrations into the piping galleries. It is recommended that the plant include inspections of roof drains in its maintenance program to ensure roof drains do not discharge into the filter or any conduits preceding the filters according to **12VAC5-590-874.L.**
14. The Plant #2 filters are not covered and are exposed to the elements including debris. Current VDH administrative code 12VAC5-590-874.C.4 notes that “The filter shall be covered by a superstructure if determined necessary under local climatic conditions.”
15. The backwashing system (piping and troughs) was noted to be up to 30 MGD. However, the current high rate backwash is limited to 24 MGD max due to the wastewater pumping capacity. The backwash rate appears to be sufficient for filter cleaning at this time but is limited. **12VAC5-590-874.K** notes that backwash flow rates shall provide at least 50% media expansion during all operating conditions, and recommends flow rates up to 20 gpm/ft^2. Currently the backwash water supply of 24 MGD equates to 15.5 gpm/ft^2.
16. Air scour of the filters in Plants 1 and 2 requires operation of both air scours blowers which are located in the upper floor of Plant #1, resulting in a lack of redundancy. It is recommended that the facility add an additional blower to provide redundancy as well as prioritize blower maintenance and replacement at end of life.
    a. While **12VAC5-590-874** requires for air scour rate to be 3 to 5 scfm/ft^2, the current air scour rate of 5 scfm/ft^2 may be higher than necessary. It is recommended that the facility evaluates reducing the air scour rate, potentially utilizing just one blower during a filter cleaning cycle rather than both. This could potentially eliminate the need to install a third blower system to provide the system redundancy.

2.9 Filtered Water Storage and Pumping

2.9.1 Description/Purpose/Elements

Filtered water in Plant #1 flows by gravity from the filter clearwells through two (2) 72” x 48” manually operated sluice gates into a cast-in-place concrete suction channel where four (4) filtered water pumps referred to as “Finished Water Pumps N1, N2, N3, N4” are used to pump water to the chlorine contact basins and also supply backwashing water for the filters. Similarly, filtered water in Plant #2 flows by gravity through two (2) 36” x 60” manually operated sluice gates into a suction channel with four (4) filtered water pumps (S1 to S4).

A 48”-diameter pipe connects both plant-filtered water suction wells, with a 48” manually operated isolation gate valve located in Plant #1. Due to limited filter clearwell and suction well volumes, the plant operates with the gate valve opened.

All eight filtered water pumps are horizontal split-case style centrifugal pumps in a suction lift configuration. The pumps are not self-priming, and utilize vacuuming priming systems located in each plant. The vacuum systems utilize liquid ring vacuum pumps and vacuum tanks to evacuate air to prime the filtered water pumps.

There is no designed overflow pipe in either plant filtered water clearwell.

2.9.2 Dimensions/Volumes/Capacity

The clearwells in each plant are irregular shaped, with plan drawings and previous VDH permits noting that the total usable clearwell capacity is approximately 790,000 gallons. At the maximum permitted flow rate of 132 MGD, this corresponds to a detention time of approximately 8.6 minutes. The ceiling of the clearwell in both plants is at elevation of 92.3’, with historical drawings noting a normal design clearwell operating level of 92.13’ in Plant #1, and 92.41’ in Plant #2. The design of the facility requires the ceiling of the pumping chamber to be slightly pressurized in both Plant #1 and Plant #2, which have finished floor elevations of 90.0’ and top of ceiling at 89.33’.

Each filtered water pump has the following nameplate data:

Plant #1:

- N1 – 11,805 GPM (17 MGD) @ 35’ TDH, 150 HP
- N2 – 11,805 GPM (17 MGD) @ 35’ TDH, 150 HP
- N3 – 14,583 GPM (21 MGD) @ 46’ TDH, 200 HP
- N4 – 14,583 GPM (21 MGD) @ 46’ TDH, 200 HP

Plant #2:

- S1 – 15,000 GPM (21.6 MGD) @ 31’ TDH, 250 HP
- S2 – 20,000 GPM (28.8 MGD) @ 44’ TDH, 350 HP
- S3 – 20,000 GPM (28.8 MGD) @ 44’ TDH, 350 HP
- S4 – 20,000 GPM (28.8 MGD) @ 44’ TDH, 350 HP

The pumps in Plant #1 and 2 are approximately 40 and 30 years old respectively and may be approaching their useful lives.

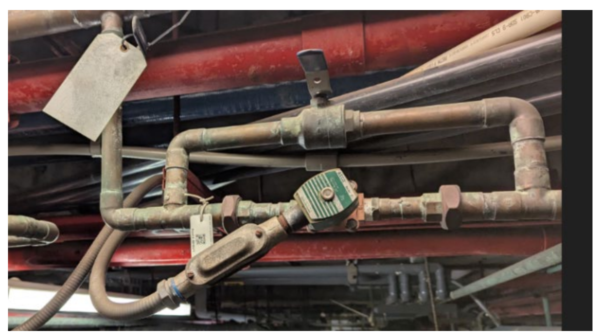
2.9.3 Operations/Maintenance

Plant staff reported that while the filtered water pumps themselves have been reliable, the facility struggles to operate them due to limitations in suction lift capability and extremely unreliable vacuum priming system. Operations staff reported that they must constantly monitor the clearwell levels and adjust filtered water flow and pump speeds to maintain a normal operating clearwell level between 89 feet and 92 feet. If the clearwell level drops below 89 feet, the filtered water pumps begin to lose prime, resulting in a drop in filtered water flow.

All plant operations and maintenance staff reported that the vacuum priming system is a highly unreliable, complicated, and manual process that has been an issue for many years. To start a pump, operators must first initiate the vacuum priming system located in the filtered water pumping rooms. Staff reported that the system is intended to automatically evacuate air and fill the pump suction piping with water. Once complete, the SCADA system should alert operators that the pump is ready to be started, at which point they can start the pump from SCADA. However, staff noted that the typical process requires an operator to physically visit the pump,

Plant #1 – Vacuum Priming System

Plant #2 – Vacuum Priming System



Plant #2 – Vacuum Priming Solenoid and Bypass

start the vacuum priming system, wait 3-5 minutes, and then start the pump from the SCADA system. Operators reported that the priming system often failed, and that they had to manually “trick” and bypass the priming system to start the pump. DPU staff noted that the facility has replaced the vacuum priming systems throughout the years and reported constant issues.

2.9.4 HVAC/Electrical

A Schneider Electric / Modicon M340 PLC provides monitoring and control for the Plant #2 filtered water pumps, whereas a relay panel provides monitoring and control for the Plant #1 filtered water pumps. Consequently, the Plant #2 filtered water pumps can be monitored and controlled via the SCADA system, but the Plant #1 filtered water pumps can be monitored and controlled only locally from the Plant #1 control room.

Filter Pumping Electrical Systems

Switchgear HDP-1 in Plant #1 Feeds the VFDs for Filter Pumps N3 and N4, as well as the load break switch feeding MCC-1 which houses the Soft Starters for Filter Pumps N1 and N2. The VFDs for Filter Pumps N3 and N4 are located on the operating level and were installed in 2016. MCC-1 is located on the mezzanine on the pump floor and was not submerged in the recent flood event. MCC-1 is over 30 years old and past its expected life. Replacement of MCC-1 and associated N1 and N2 Soft Starters is recommended withing the next 5 years.

Panel PP-2A

Panelboards PP1A, PP2A and LP2A are located on the pump floor and are over 30 years old and have reached their expected life. In addition, water levels during the recent flood event reached above the bottom levels of PP1A and PP2A and accelerated corrosion can be expected. Replacement of these panelboards is recommended within the next 3 years.

Medium Voltage MCC

In Plant #2, outdoor switchgear SG7 feeds the 4160V load breaker switch that in turn feeds the medium voltage MCC powering Filter Pumps S2, S3 and S4. Filter Pump S1 VFD is fed from 480V switchboard HDP-2. 480V Filter Pump S-1 VFD and 4160V S-3 VFDs are located on the main level and were not subject to water damage during the recent flood event. These VFDs are less than 10 years old and are in good condition. The medium voltage MCC controlling pumps S2, S3 and S4 is located on the pump floor and did experience partial flooding during the flood event. This MCC houses the starter for Filter Pump S2 and the breakers for S3 VFD and S4 VFD. The Benshaw VFD is mounted on the pump floor level next to the MCC. The Benshaw VFD dates from approximately 2005 with the rest of the gear over 30 years old. In addition to flood damage, this gear is past its expected life. Replacement and relocation to an upper level as soon as practical is recommended.

Panelboards PP-1, PP-2 and LP-1 on the Plant #2 side show signs of major corrosion and wear. These panelboards present a safety issue for operators and replacement as soon as practical is recommended.

Panel PP-1

Panel PP-2

Panel LP-1

There is abandoned electrical equipment in the boiler room in Plant #2. Removal of this equipment is recommended.

MCC-C provides power to the sanitary waste pumps is fed from a manual transfer switch located in the electrical room of Plant #2. This switch allows MCC-C to be fed from either switchboard HDP-2 in Plant #2 or HDP-1 in Plant #1. MCC-C has reached its expected life and is reportedly scheduled to be replaced. In the Waste Pump Room, Panel WHH1-1 is highly corroded and replacement is recommended. In addition, Panel WHH1, which feeds WHH1-7, is located on the level above and has reached its expected life. Panel F, mounted next to Panel WHH1, is also highly corroded. Replacement of Panelboards WHH1, WHH1-7 and Panel F is recommended.

Abandoned Electrical Equipment

MCC-C

Panel WHH1-7

Panel WHH1

MCC-C

Lighting on the pump and filter levels of both Plant #1 and Plant #2 is obsolete and replacement with high efficiency LED lighting is recommended. In addition, emergency lighting in the filter piping galleries is inadequate.

In addition to any capital improvements recommended, the following routine maintenance items are recommended for electrical distribution equipment, (panelboards, switchboards and motor control centers). This maintenance should be performed annually to ensure that the equipment is functioning properly and to extend its lifespan:

- Operate (exercise) the breakers. Check for proper functioning and freedom of movement. Replace any damaged or worn parts.
- Check all terminals for tightness and tighten any loose connections.
- Verify all grounded conductors, equipment grounding conductors and grounding electrode conductors are tightened properly.
- Check contacts for excessive wear and dirt accumulation.
- Check coils for evidence of overheating (cracking, melting or discoloration).
- Clean any dirt or dust accumulation from the equipment.

Summary:

1. Perform annual routing maintenance on electrical distribution equipment
2. Replace 480V, 800A MCC-1 within 5 years.
3. Replace two 150HP soft starters for N1 & N2 within 5 years
4. Replace 480V panelboards PP1A and PP2Awithin 3 years.
5. Replace 120/240V panelboard LP-2A within 3 years
6. Replace and relocate Medium Voltage MCC
7. Replace and relocate S4 VFD
8. Replace 480V panelboards PP-1 and PP-2
9. Replace 120/208V panelboard LP-1

10. Replace 480V panelboards WHH1 and WHH1-7
11. Replace 120/208V panelboard F
12. Replace lighting.
13. Add emergency lighting to pipe galleries.

2.9.5 Observations and Recommendations

1. At the time of the inspection, two pumps within Plant #2 were out of service. Pumps S2 and S3 were damaged and were in the process of being removed for refurbishment.
2. The design clearwell water level in Plant #2 is 92.41’ and 92.13’ in Plant #1. These elevations are above the floor elevation of the filtered water pumping room. Recommend review of the structural design and condition of the pump room floor slab to resist imbalanced water pressure forces.
3. The lack of designed overflows for the plant clearwell is a critical issue. DPU staff reported that filtered water frequently surcharges and floods the filter gallery and pumping rooms which are connected. In Plant #1, DPU staff note that water has surcharged out of a PVC vent pipe located approximately 8’ above the finished floor, discharging into the pump room. It appears that the vent pipe was previously raised. It is unlikely that a larger overflow pipe could be installed and extended further up out of the plant. During a surcharge event, the pump room floor slab may be subject to imbalanced water pressure forces that it may not


Vent Pipe in Plant #1

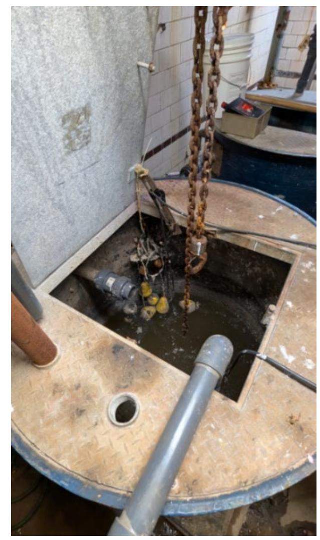
have been designed for. There is a large visible crack in the concrete adjacent to the clearwell hatch which may have resulted from such surcharge events.

4. In Plant #2, water primarily surcharges out of a bolted access hatch over the pump suction well. DPU staff noted that the hatch is not watertight, and water leaking around the edges of the cover is the first visible sign of the clearwell surcharging. The plan drawings noted a finished floor elevation of 90.0 feet in the filtered water pump room, which results in a normal operating band of 1.0 foot to prevent the pumps from losing prime and not surcharging water into the pump room.

Bolted Access Hatch and Concrete Crack in Plant #2

5. At the north end of the Plant #2 filtered water pumping room, there is a sanitary sewage ejector system consisting of two fiberglass tanks with sewage pumps that collect sanitary waste along with laboratory drains. The sewage pumps operate on floats to send sanitary wastewater to the Douglasdale Road Pump Station. While the tanks do not sit directly above the filtered water clearwell, there is no containment wall. There is potential for domestic waste to enter the clearwell through pipe penetrations and the bolted covers in the pump room as noted. It is recommended that the condition of the domestic wastewater system is further evaluated, and a containment wall is constructed to prevent contamination. The system should be relocated if possible, to eliminate the risk of cross contamination with filtered water storage and piping.
    a. There is an on-going project to replace the sanitary sewer equipment, reported to be in the design phase.

Sanitary Sewage Control Panel



Sanitary Sewage Tanks

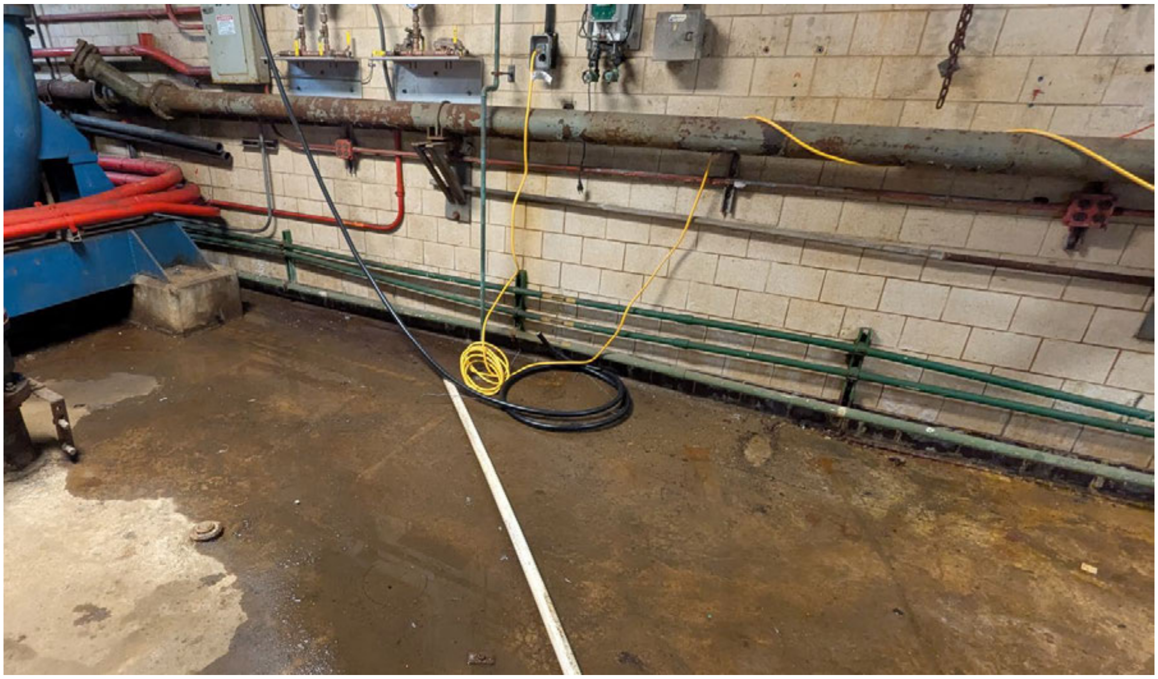
Sanitary Sewage Tank and Drains

6. Significant amounts of standing water was present in the vicinity of the sanitary waste system, along with laboratory drains that were discharged through hoses lying directly on the ground. Recommend properly routing process drains with air gaps.
7. As the plant is operated primarily by gravity and is constrained by clearwell capacity, the filtered water pumps are critical to the plant operation and preventing the clearwells from surcharging and damaging the facility and equipment. The horizontal centrifugal pumps installed are not recommended for suction lift applications as they are not self-priming, and all staff reported that the current vacuum priming systems have been unrealiable. It is recommended that all filtered water pumps are replaced with vertical turbine style pumps to eliminate the need for an external priming system. In addition, it is recommended that the vertical pumps are installed with lineshaft column assemblies that allow the motor to be installed on the main operating floor and above the plant hydraulic grade line.
   a. If vertical turbine pumps are not installed, recommend replacing the vacuum priming system and locating the new system on the main operating floor.
8. There were significant amounts of standing water and actively discharging water within the filtered water pumping areas, some without a nearby process drain. **12VAC5-590-1050A.8.** requires that a suitable outlet for drainage from pump glands be provided without discharging onto the floor. It is recommended that the drains are extended and properly routed to a floor drain.

Discharging Water – Filtered Water Pump S4 (Plant #2)

Discharging Water – Unknown Source – Plant #1 Pumping Room

Standing Water and Temporary Sump Pump in Plant #1 – Pumping Room



Standing Water in Plant #1 – Pumping Room

9. General housekeeping in the Plant #2 filtered water pumping room is poor. SEH observed abandoned and disconnected HVAC ducts that prevents safe access around filtered water pump S4, valves, electrical equipment, and the discharge header. Recommend removal and disposal of abandoned equipment to comply with **12VAC5-590-470. Waterworks condition.** The waterworks shall be maintained in a clean and orderly condition.

Abandoned HVAC Ducts – Plant #2

Filtered Water Pump S4 – Plant #2

10. Several floor drains within the filtered water pumping room in Plant #2 were reported to be clogged, with temporary sump pumps installed. Recommend floor drains to be cleaned and further inspected.

Standing Water and Temporary Sump Pump in Plant #1 – Pumping Room

11. There is significant coating failure of the piping and walls throughout the filtered water pumping rooms in both Plants. Recommend blasting, recoating, and repairs. Bolts should be inspected and replaced in both Plants.

Filtered Water Pumping Room – Plant #2

Filtered Water Pump Discharge – Plant #2

12. The filtered water pump starters, VFDs, and control panels are in the filtered pump rooms. In Plant #1, most of the equipment is elevated at approximately 104', which is generally above the normal hydraulic grade line of the plant. However in Plant #2, the electrical gear is located on the finished floor elevation at 90' and subject to damage as seen on the January 6th, 2025 event. Recommend that all critical electrical equipment is relocated to the main operating floor.
13. The clearwell capacity is constrained due to site limitations. The clearwell is likely located below the ground water table which was noted to be approximately 107' at the north end of the plant in a geotechnical report completed by CH2M Hill in 2003.

2.10 Chlorine Contact Basins

2.10.1 Descriptions/Purpose/Elements

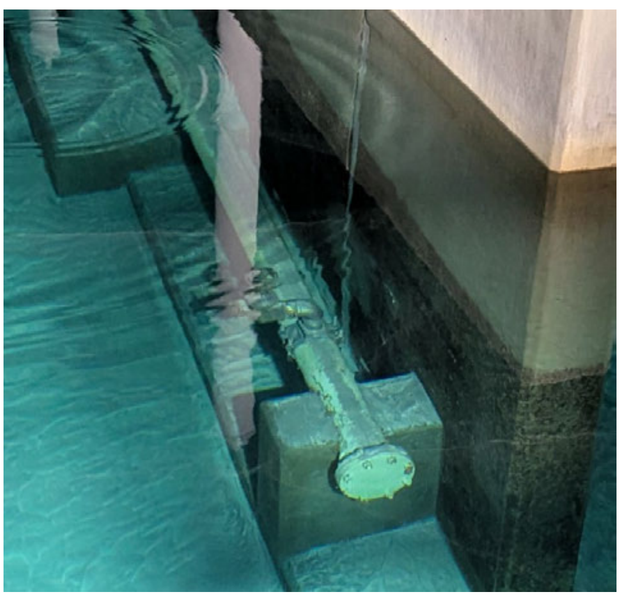
The filtered water discharge header in each plant flows through a vault (one per plant) where chlorine and ammonia are added for disinfection, lime for pH adjustment, and fluoride. During normal operations, the filtered water pumps in Plant #1 send filtered water to the Plant #1 (North) chlorine contact basins and Plant #2 pumps send filtered water to the Plant #2 (South) chlorine contact basins. The discharge headers from the two filtered water pumping stations are interconnected, which allows interchangeable operation between plants if needed.

The two chlorine contact basins are used to provide adequate contact time for chloramine disinfection. The basins were originally used as aeration basins and have been modified throughout the years including the addition of covers for both in 2011. There are two level transmitters in each basin, located near the inlet and outlet.

Caustic soda and corrosion inhibitor are added at the end of each chlorine contact basin, before the finished water from both basins combine and enter the Korah Pump Stations and the distribution system. The plant can isolate the effluent of each basin as needed.

The north chlorine contact basin overflows through a 30” diameter pipe, into a concrete channel, and into the filtered water clearwell through a 48” x 36” sluice gate.

There is ductile iron piping installed within the basins to facilitate draining and cleaning for maintenance. A 6” pipe header allows nonpotable water to be sprayed and flushed into the head of the basin. As the basin slopes towards the outlet, a basin drain suction line is installed at the end of the basin. Portable pumping equipment is connected, and discharges the water back towards the front of the plant and into Plant #1 where it flows into the backwash waste conduit.



North Chlorine Contact Basin – Submerged Flushing Header

North Chlorine Contact Basin – Drain Suction and Discharge

2.10.2 Dimensions/Volumes/Capacity

Historical records note the north and south chlorine contact basins to have operating volumes of 1.3 MG and 3.26 MG respectively, with an operating depth of approximately 7 feet 8 inches. At the permitted max flow rate of 132 MGD, this results in a detention time of approximately 0.83 hours.

2.10.3 Operations/Maintenance

The WTP feeds caustic soda at the end of the chlorine contact basin to maintain a pH range, and flow paces zinc orthophosphate corrosion inhibitor approximately halfway down the basin. The plant has the ability to feed additional ammonia as well as lime at the end of the basin but does not currently do so.

2.10.4 HVAC/Electrical

Schneider Electric / Modicon Quantum PLCs provide monitoring and control of sodium hypochlorite, ammonia, and ZOP (anti-corrosion) chemical infusion, although Schneider Electric / Modicon M340 PLCs monitor and control caustic infusion at the Korah 1 and Korah 2/3 pump stations.

2.10.5 Observations and Recommendations

1. There are catwalks in the chlorine contact basins that do not have a solid floor. Shoe scrapings and dirt can fall directly into the water, violating **12VAC5-590-1081**. Recommend installing solid floor with raised edges.

Catwalks in Chlorine Contact Basin

2. SEH observed significant amounts of floating brown scum/foam at the outlet of both chlorine contact basins. Recommend identifying source of contamination and cleaning.

Chlorine Contact Basin

Chlorine Contact Basin

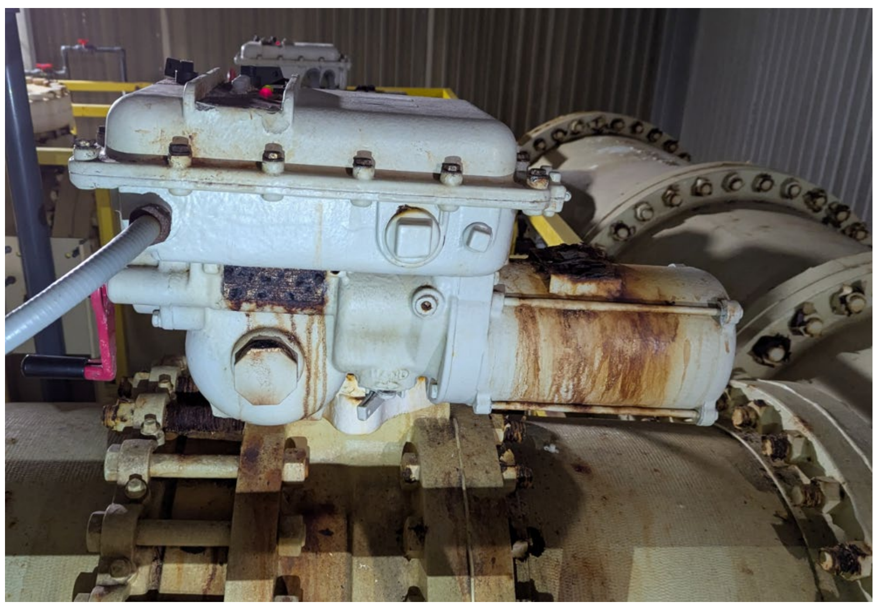
Plant #2 – North Chlorine Contact Basin

3. The chlorine contact basins showed signs of water intrusion. **12VAC5-590-1081 Section H** notes that roof and sidewalls shall be watertight and that all pipes running through the roof or sidewall should be connected to standard wall castings with flanges imbedded in the concrete. The basins have multiple pipe penetrations which utilize Link-Seal type penetrations. Recommend detailed inspection of structure to identify repairs to seal all penetrations to ensure that the roof and sidewalls are watertight.

North Chlorine Contact Basin

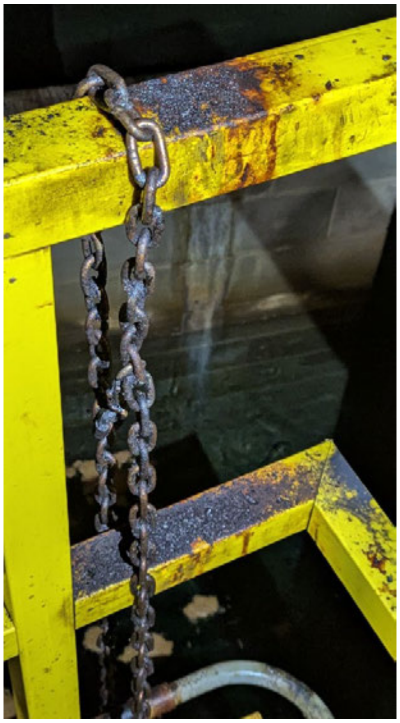
4. The piping and valves within both chlorine contact basins is in moderate condition. Several support beams were observed to have significant damage from chlorine vapors. Recommend the facility implement a monitoring program.

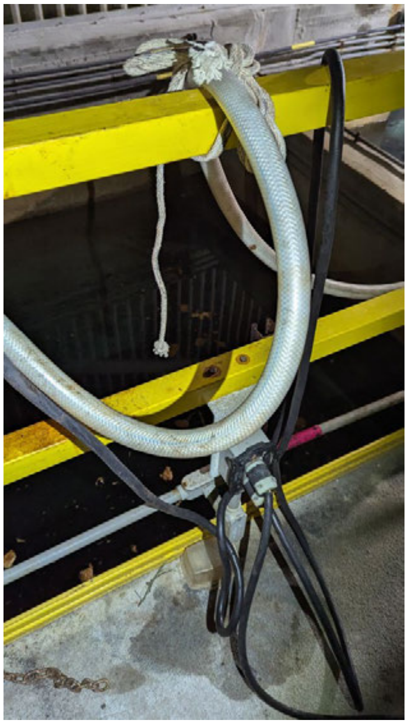
Chlorine Contact Basin – Plant #1



Piping in Chlorine Contact Basin 1

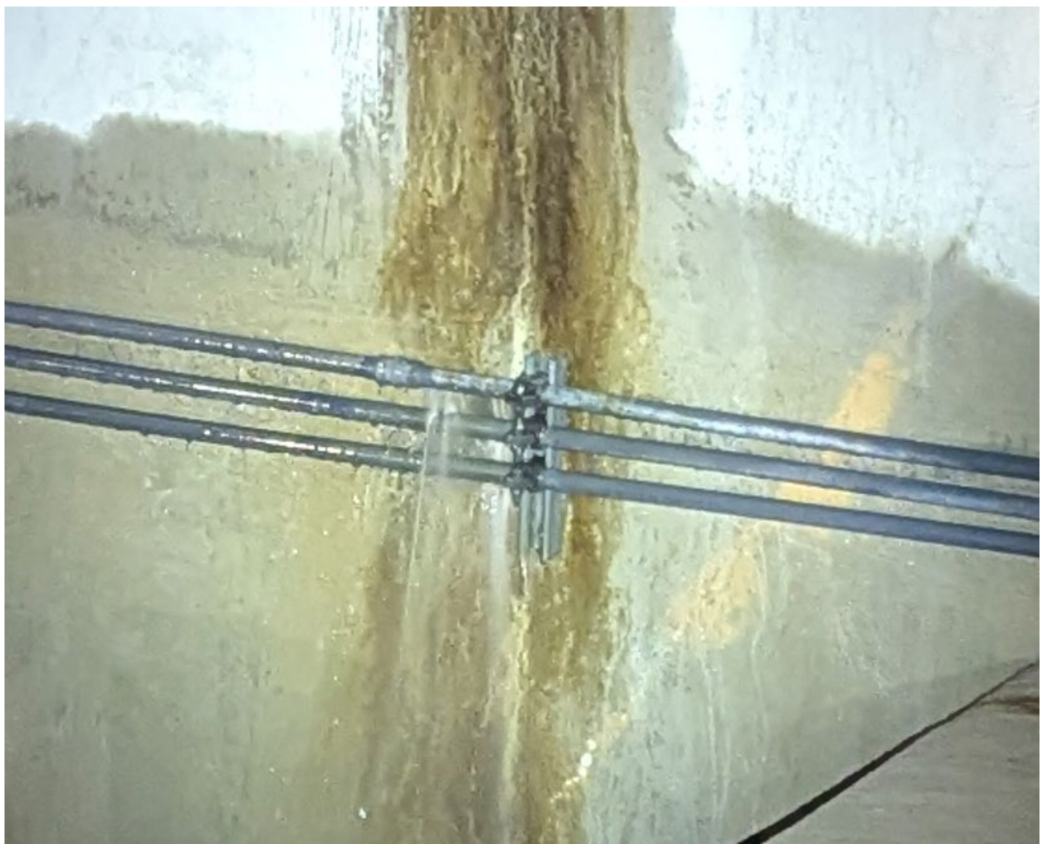
5. General housekeeping in the chlorine contact basins is poor. Sampling pumps are installed with corroded chains and dangling cords and hoses, which poses safety hazards and contamination risks. **12VAC5-590-470. Waterworks condition.** The waterworks shall be maintained in a clean and orderly condition.





6. Piping supports throughout both basins appeared to be severely corroded and damaged. In Plant #1, several supports were broken, with two sampling or conduits hanging loose. One pipe appeared to have been pulled up onto the concrete wall, while another was found hanging below the water surface. Recommend replacing piping and supports.

7. A PVC sample line in the north chlorine contact basin appeared to be broken and spraying significant amounts of water. Recommend replacement of the PVC pipe.



8. The chlorine contact basins utilize suction and discharge connections that allow portable dewatering pumps to be connected when the basins must be drained and cleaned for maintenance. Recommend proper signage on the connections.

Plant #1 – Drain Suction and Discharge Connection

Plant #1 – Drain Suction Connection

9. The Plant #1 filtered water clearwells and underdrain are vented into the north chlorine contact basin. While this does not appear to violate code, the presence and condition of any screens could not be evaluated.

Filter Plant #1 Vent into Chlorine Contact Basin

10. The below grade chlorine contact basin is located below the ground water table, which was noted to be approximately 107' in a geotechnical report completed by CH2M Hill in 2003. The flood wall constructed in 1999 protects the basin and the plant from 100-year flood events.
11. There are several alternate feed locations for ammonia within the chlorine contact basins that are not currently utilized. The primary feed location for ammonia is at the meter vaults upstream of the basins and was added around 2011 as part of an improvements project to cover the basins. It is not clear whether the facility is using chloramine for primary or secondary disinfection. VDH staff during the visit were not certain whether the disinfection calculations were based on log-inactivation using chlorine or chloramine. It is recommended that the facility review log removal/inactivation calculations with the ODW to ensure compliance with the Surface Water Treatment Rules as covered in **12VAC5-590-340.**

2.11 Chemical Feed Systems

The City of Richmond WTP utilizes a variety of common treatment chemicals to make the water from the James River potable. The following sections describe the chemicals utilized, with all chemical observations and recommendations at the end of the section.

2.11.1 Copper Sulfate

2.11.1.1 Descriptions/Purpose/Elements

Copper sulfate ($CuSO_4$) is used as an algaecide to control algae growth in the raw water. The copper sulfate is added directly from bags into the head of the pre-sedimentation basin.

2.11.1.2 Storage/Volumes/Capacity

N/A

2.11.1.3 Operations/Maintenance

The facility only adds copper sulfate during the warmer summer months, when the water temperatures are over 60°F and provide an optimal temperature for algae growth. Operators add roughly one 50-pound bag when needed. The facility does not have an established guideline or procedure as to when copper sulfate is added.

2.11.1.4 HVAC/Electrical

N/A

2.11.2 Potassium Permanganate

2.11.2.1 Descriptions/Purpose/Elements

Potassium permanganate is a strong oxidant used to oxidize concentrations of organic material contained in the raw water and help with taste and odor control. The use of potassium permanganate is often selected because it does not form disinfection by-products (DBP). The facility normally feeds potassium permanganate into the raw water channel immediately downstream of the raw water pumps.

The chemical feed and storage equipment is located on the first floor of the West Chemical Facility constructed in 2004. The potassium permanganate is fed as a dry powder using two makedown systems. Each makedown system consists of mixes the dry permanganate product with water forming a solution, which then flows by gravity into the raw water channels just downstream of the raw water pump discharge. The potassium permanganate is mixed into the raw water as it flows down the channel and into the inline channel mixer.

West Chemical Facility

2.11.2.2 Storage/Volumes/Capacity

The potassium permanganate feeder receives dry chemical directly from stainless steel totes that are placed on top with a forklift. The plant stores additional totes on a small mezzanine storage area directly above the feeder equipment.

2.11.2.3 Operations/Maintenance

Potassium permanganate is reported to be fed seasonally between May and October. Operators report controlling the potassium permanganate feeder by setting a desired lbs per hour feed rate.

Operators reported that the potassium permanganate system often plugs when it is not used and allowed to sit, making permanganate difficult to remove from the tote.

2.11.2.4 HVAC/Electrical

The permanganate storage area is served by the building's central HVAC system, which consists of four packaged rooftop air handling units with gas heat. Two of the units include condensers for additional cooling of the alum and PAC areas. Two electric fan-forced wall heaters provide additional heat in the stairwells. The equipment appears to be in good overall condition.

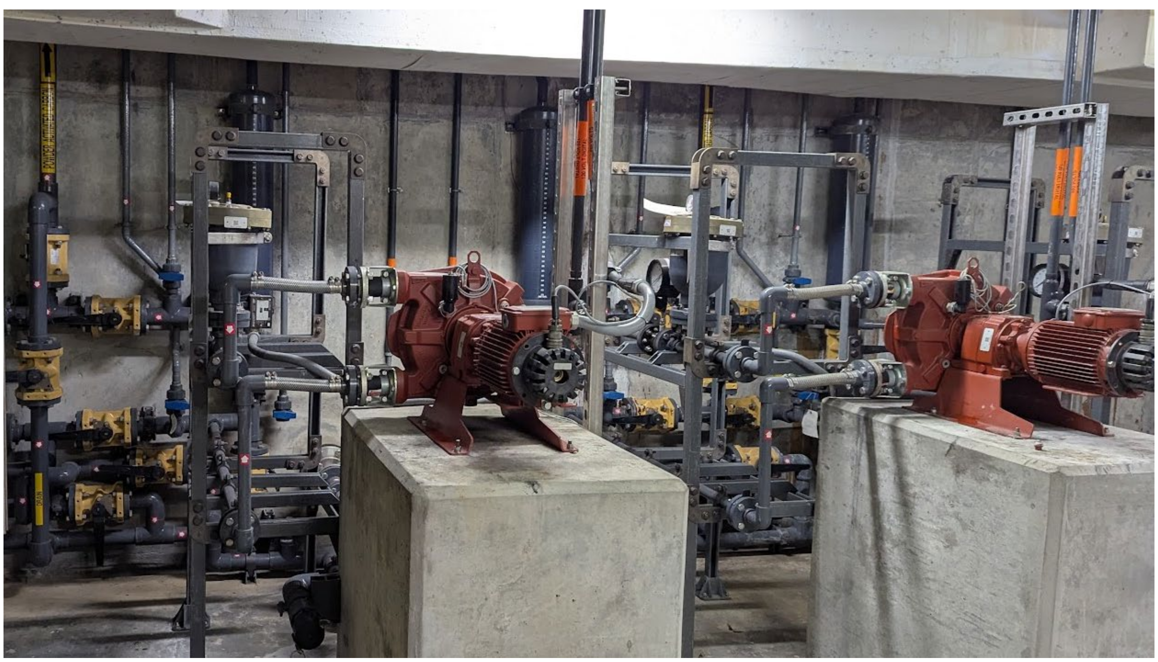
Electrical Distribution:

The building is fed at 4160V from two feeders in outdoor switchgear SG7. 4160V to 480/277V transformers located outside of the building feed the left and right sides of the 480V switchgear located in the electrical room. All electrical equipment appears to be in good condition.

2.11.3 Powdered Activated Carbon

2.11.3.1 Descriptions/Purpose/Elements

Powdered activated carbon (PAC) is fed into the raw water at the WTP for taste and odor control. The PAC feed system utilizes a slurry system, where delivered PAC is stored within a concrete tank built into the middle of the West Chemical Facility. A mechanical mixer and air mixing lines with nozzles are used to keep the slurry in suspension. Four positive displacement pumps feed the PAC slurry to the raw water channel immediately downstream of the raw water pumps.



PAC Slurry Feed Pumps

2.11.3.2 Storage/Volumes/Capacity

The concrete PAC tank has plan dimensions of approximately 8.5'W x 8.5'L with a maximum carbon slurry height of 25.5', resulting in a nominal capacity of approximately 14,000 gallons.

The slurry mixer is powered by a 50 HP motor, and two 30 HP air compressors provide air for the mixing lines.

2.11.3.3 Operations/Maintenance

Operations staff reported that the PAC is rarely fed at the facility and only utilized when the plant receives taste or odor complaints from the public. When required, operators typically target 2.0 to 2.5 mg/L (ppm) of PAC to the raw water channel. Staff reported that PAC is fed approximately once a year or less. Operations reported that to avoid excessive PAC slurry age, the facility will use up all the slurry by applying it as treatment every 2 to 4 years and then replenishing it.

2.11.3.4 HVAC/Electrical

See Section 2.11.2.4.

2.11.4 Alum

2.11.4.1 Descriptions/Purpose/Elements

Aluminum sulfate (alum) is used as a coagulant to destabilize and attract suspended particles and turbidity present in the raw water. Currently the alum is primarily added into the raw water channel, immediately upstream of inline rapid channel mixers. Alum was previously fed at the rapid mixers located by the flocculation basins. The facility receives and stores bulk deliveries of alum in six (6) bulk tanks at the West Chemical Facility, which is then automatically pumped to two (2) smaller day tanks and feed pumps located in the Plant #2 building.

2.11.4.2 Storage/Volumes/Capacity

Each of the six alum bulk tanks are 24,500-gallon vertical fiberglass tanks built in 2006. The tanks are all connected, resulting in a total storage capacity of 147,000 gallons. Three (3) positive displacement hose pumps automatically transfer alum to two (2) 4,000 gallon horizontal fiberglass days tanks. The day tanks are connected, providing a total capacity of 8,000 gallons. Twelve (12) positive displacement hose pumps feed alum to the points of injection.

2.11.4.3 Operations/Maintenance

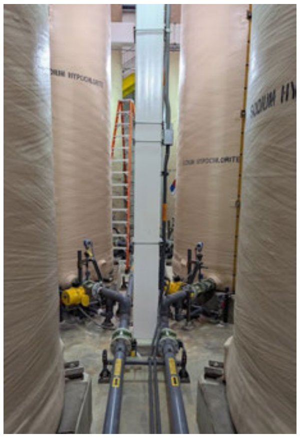
The facility previously fed alum to the rapid mix basins, but now feeds alum immediately upstream of inline channel mixers located in each raw water channel. Operations staff reported that the alum feed is designed to be flow paced. However operators noted that due to current on-going flow meter issues, operators compare several flow readings and perform manual dosing calculations and adjust the dosing pump rate in SCADA. Operators adjust dosage using a combination of zeta and streaming current monitors, and report that the typical dosage is approximately 39 mg/L.

2.11.4.4 HVAC/Electrical

See Section 2.11.2.4.

2.11.5 Sodium Hypochlorite

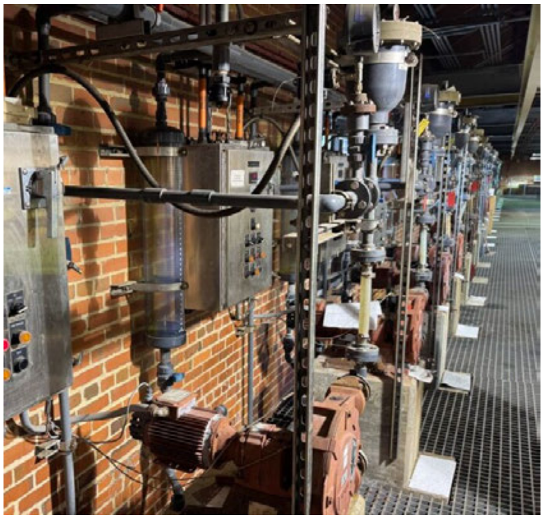
2.11.5.1 Descriptions/Purpose/Elements



Sodium hypochlorite, often called chlorine bleach (chlorine), is fed at the WTP for disinfection of the treated water. It is also combined with ammonia chemical feed to form chloramines to maintain a disinfectant residual in the distribution system. There are three locations where the plant can feed chlorine; into the raw water channel downstream of the raw water pumps; in the applied water channel after the plate settlers; and into the filtered water meter vaults immediately upstream of the chlorine contact basins. The facility receives and stores bulk deliveries of sodium hypochlorite in six (6) bulk tanks at the West Chemical Facility, which is then automatically pumped to two (2) smaller day tanks and feed pumps located in the Plant #2 building.

2.11.5.2 Storage/Volumes/Capacity

Each of the six sodium hypochlorite bulk tanks are 24,500-gallon vertical fiberglass tanks built in 2006. The tanks are all connected, resulting in a total storage capacity of 147,000 gallons. Three (3) positive displacement hose pumps automatically transfer sodium hypochlorite to two (2) 4,000 gallon horizontal fiberglass days tanks. The day tanks are connected, providing a total capacity of 8,000 gallons. Fourteen (14) positive displacement hose pumps feed sodium hypochlorite to the various points of injection.



Hypochlorite Feed Pumps

Hypochlorite Day Tanks

2.11.5.3 Operations/Maintenance

The facility currently only feeds sodium hypochlorite into each of the four applied water channels after the plate settlers; and into the filtered water meter vaults immediately upstream of the chlorine contact basins. Operations staff reported that the hypochlorite feed is designed to be flow paced. However as noted with the alum feed, operators compare several flow readings and perform manual dosing calculations and adjust the dosing pump rate in SCADA. Operators report targeting a 2.0 ppm chlorine dosage into the applied water channel as measured by chlorine analyzers located in each plant.

Plant #1 – Applied Water Chlorine Analyzers

Plant #2 – Applied Water Chlorine Analyzers

2.11.5.4 HVAC/Electrical

The bulk sodium hypochlorite tanks and transfer pumps are located in the West Chemical Facility, see See Section 2.11.2.4.

2.11.6 Polymer

2.11.6.1 Descriptions/Purpose/Elements

A coagulation polymer is fed at the WTP to the first stage of each flocculation basin to improve the coagulation of solids in the flocculation and sedimentation basins. Plant #1 and Plant #2 each have separate chemical storage and feed equipment.

2.11.6.2 Storage/Volumes/Capacity

Not noted.

2.11.6.3 Operations/Maintenance

Plant operators periodically manually mix the coagulant-aid polymer into poly 275-gal totes which serve as the feed tank.

In each Plant, there is a single peristaltic hose pump that feeds polymer into a common dilution line that feeds to each of the four flocculation basins.

The polymer feed is not flow-paced and must be manually adjusted.

2.11.6.4 HVAC/Electrical

The polymer room in Plant #1 contains panelboard PP2-A fed from Panel PP2, which shows signs of corrosion and is over 30 years and at its expected life.

The polymer room in Plant #2 contains an abandoned control panel. Panel “A” in Plant #2 Polymer Room is fed from the main panelboard and shows signs of corrosion and is over 30 years old and at its expected life.

Summary:

1. Replace panelboard "A" within 5-10 years.
2. Replace panelboard PP-2A within 5-10 years.
3. Remove abandoned control panel, electrical equipment, and conduits in Plant #2 Polymer Room.

2.11.7 Lime

2.11.7.1 Descriptions/Purpose/Elements

Lime is fed at the WTP for pH adjustment and alkalinity control. Originally, lime was designed to be fed at the raw water conduit (pre-lime) and at the end of the chlorine contact basin (post-lime). There is an old lime house located near the Korah Pump Stations that contains non-functional lime slaking equipment.

Lime is currently only fed at the filtered water meter in each Plant #1 and 2, immediately prior to the chlorine contact basins. Currently the facility purchases lime in the form of liquid calcium hydroxide slurry, which is stored in a vertical welded steel tank and packaged pump room within a concrete containment wall. The current lime equipment was constructed in 2014.

Lime Slurry Tank and Feed Equipment

2.11.7.2 Storage/Volumes/Capacity

Not noted.

2.11.7.3 Operations/Maintenance

Operators noted that the lime addition to the filtered water is flow paced, and that the facility targets 7-8 ppm dosage. The storage tank was noted to be insufficient, with the plant receiving deliveries daily during the summer and 2-3 times per week in the winter.

2.11.7.4 HVAC/Electrical

The current packaged lime building has an electric unit heater.

2.11.8 Caustic Soda

2.11.8.1 Descriptions/Purpose/Elements

Caustic soda is used at the WTP for additional pH adjustment. The facility currently feeds caustic at the end of each of the chlorine contact basins. The facility receives and stores bulk deliveries of caustic in two (2) bulk tanks. The dosing pumps are located inside of the Korah 1 Pump Station, with the bulk tanks located directly outside to the west of the building.

2.11.8.2 Storage/Volumes/Capacity

The bulk tanks are noted to be 11,990 gallons and approximately 9,000 gallons, and are connected to provide a total capacity of approximately 21,000 gallons.

There are four (4) dosing pumps that feed caustic to each of the two chlorine contact basins.

2.11.8.3 Operations/Maintenance

Caustic soda is automatically controlled with pH analyzers installed at the end of the chlorine contact basin, with the transmitter installed in the caustic pump room.

2.11.8.4 HVAC/Electrical

See Korah No. 1 Pump Station

2.11.9 Ammonia

2.11.9.1 Descriptions/Purpose/Elements

The WTP adds aqueous ammonia to form chloramines for disinfection. The ammonia is currently fed at the filtered water meter vault, but can also be fed in the chlorine contact basins. The facility receives bulk liquid deliveries at a truck off-loading and containment area located between Plants 1 and 2. The ammonia storage tanks and chemical feed equipment is located on the upper floor of the east end of Plant #1 building. Ammonia vapors are controlled by venting through a passive scrubber. The ammonia room also contains an emergency vapor scrubber system with air monitoring.

2.11.9.2 Storage/Volumes/Capacity

There are three (3) welded steel ammonia storage tanks with a nominal capacity of 6500 gallons.

2.11.9.3 Operations/Maintenance

The ammonia is flow paced with the filtered water meter. Operators typically target an ammonia dose of 1.0 to 1.2 mg/L, with a 4:1 chlorine to ammonia ratio.

The facility monitors free ammonia concentrations to ensure levels do not exceed 0.1 mg/L into the distribution system.

2.11.9.4 HVAC/Electrical

2.11.10 Fluoride

2.11.10.1 Descriptions/Purpose/Elements

Fluoride is fed at the WTP for dental health. The liquid feed system delivers hydrofluorosilicic acid, which contains between 23% and 25% fluoride, into the filtered water meter vault immediately upstream of each chlorine contact basin. The facility receives and stores chemical deliveries to a partially buried bulk tank located in front of Plant #1. The chemical dosing pumps are located in the lower level of Plant #1, adjacent to the filtered water pumps.

2.11.10.2 Storage/Volumes/Capacity

City staff reported that the bulk tank had an approximate capacity of 4,000 to 6,000 gallons.

2.11.10.3 Operations/Maintenance

The WTP control system automatically feeds fluoride using an online fluoride analyzer. There are three chemical pumps, one per chlorine contact basin with a swing standby.

2.11.10.4 HVAC/Electrical

N/A

2.11.11 Corrosion Inhibitor

2.11.11.1 Descriptions/Purpose/Elements

Zinc orthophosphate (ZOP) is a corrosion inhibitor that is added into the treated water for control of lead and copper in the distribution system. The chemical can be injected directly into each chlorine contact basin near the inlet and also roughly halfway down the basin. The facility receives bulk liquid deliveries at a truck off-loading and containment area by the loading dock at Plant #1. The ZOP storage tanks and chemical feed equipment is located on the upper floor of the west end of Plant #1.

2.11.11.2 Storage/Volumes/Capacity

There are two (2) horizontal storage tanks each with a nominal capacity of 6,150 gallons.

2.11.11.3 Operations/Maintenance

The phosphate is flow paced with the filtered water meter. Operators typically set a target dose of 1.5 mg/L as ZOP product.

2.11.11.4 HVAC/Electrical

2.11.12 Observations and Recommendations

1. There are no established or readily available SOPs for chemical treatment processes. The facility relies on institutional operator knowledge to effectively treat the water and manage chemical feeds. The method of chemical feed is not consistent between feed systems or operations personnel. As noted previously, staff have a general distrust in the flow instrumentation data. Operations staff appear to use a combination of flow instruments to determine the various flow rates to calculate chemical feed rates. Staff were observed performing manual dosing calculations for some chemicals and updating feed rates (lbs/hour) in the SCADA system, while other chemicals were set with dosages. Recommend the facility standardize chemical programs and prepare updated SOP’s, providing training and making them readily available to operators to meet **12VAC5-590-360** responsibilities of waterworks owners to protect public health.
    a. Copper sulfate addition is not applied per any standardized procedure, including when or how much to add. Operators do not test water quality before or after application.
    b. PAC application is not applied per any standardized procedure. Due to infrequent use, the facility periodically applies PAC even without taste and odor complaints in order to drain and turnover the PACstorage tank.
    c. Alum addition is not applied per any standardized procedure. The streaming current monitors at the rapid mix basins are generally referenced and trended by operators, but most operators utilize zeta potential to determine a dosage. This is not consistent between all personnel. **12VAC5-590.874L** states “High rate filtration shall be provided with precise coagulation control”

2. There were multiple sodium hypochlorite and alum dosing pumps that were in various stages of dis-assembly or missing.

3. The polymer systems are fed from totes without secondary containment walls or pallets. Housekeeping is very poor in both polymer rooms, with significant amounts of debris and evidence of spills. Polymer spills are slippery and pose trip and slip hazards. There is abandoned chemical piping and electrical equipment in both Plant #1 and Plant #2 polymer rooms. Recommend addition of secondary containment and removal of unused piping. **12VAC5-590-470. Waterworks condition.** The waterworks shall be maintained in a clean and orderly condition.

Plant #1 – Polymer Chemical Storage and Feed

4. Polymer in each plant is injected into a common dilution/motive water header using a single metering pump without a static mixer. The header then immediately splits to each flocculation basin through the use of manual ball valves and a rotameter. There is no means for the facility to accurately ensure proper chemical feed. It is recommended that the facility construct a common polymer storage and feed room in Plant #2. A polymer blending/makedown system should be installed with dedicated dosing pumps for each flocculation basin, along with static mixers.

Plant #1 – Polymer Chemical Storage and Feed

Plant #2 – Polymer Feed

5. The polymer feed system is not flow-paced and must be manually adjusted. The rotameters displaying diluted polymer flow to each basin do not have markings and appeared to be maxed out. Recommend replacing rotameters and adding flowmeters so that polymer feed to each basin can be controlled.
6. It is not clear what type of polymer product is in use at the facility. **12VAC5-590-395.B** requires owners to certify in writing to the VDH when polymers containing acrylamide or epichlorohydrin are used, they do not exceed specified levels. If these polymers are used, the lack of accurate polymer feed carries risk of exceeding these levels.
7. After the inspection and during review of DPU provided files including on-going project list, SEH discovered that the current lime storage and feed system at the site was installed in 2014 as an interim system provided as a rental equipment from a chemical vendor. The facility has an ongoing project that would replace the old lime slaking equipment which appeared to have been started in 2023 and is still in the design phase. This project should address the minimal storage available. **12VAC5-590-860.D.1** says that “Space shall be provided where at least 30 days of chemical supply can be stored, based on the average dose and average annual WTP flow rate. Storage shall be at a location that is convenient for efficient handling and safety.” It was noted by the City that the VDH has approved a variance to this requirement, with a planned storage capacity of approximately 22 days.
8. The chemical tubing for lime feed at the filtered water meters are routed along the ground, wrapped in electrical heating tape and insulation. Recommend permanently installing chemical feed lines in such a manner to protect them from freezing and damage and minimize trip hazards. **(12VAC5-590-860 – Chemical Application)**

Lime Chemical Hose

9. At the time of inspection, the west half of the entire Plant #2 main level was cordoned off due to a major chemical leak in the sodium hypochlorite day tank in the floor above. A previous EPA inspection in 2022 noted active leaking and chemical crystallization on multiple chemical tanks. Chemical leaks pose significant hazards to staff as well as operational interruptions. Recommend the facility add routine chemical tank inspections to its operating procedures.

Plant #2 – Main Level Corridor

10. **12VAC5-590-860.D** states that “chemicals that are incompatible shall not be fed, stored, or handled together. The EPA categorizes aluminum sulfate as a Group III: Salts & Polymers, and sodium hypochlorite as a Group II: Base. Both chemicals are stored in a common room within Plant #2. The chemical pumps and day tanks are located on grating above containment sumps. It is not clear whether there is sufficient, separated containment below the grating. There is no easy way to visually observe whether the containment areas have filled and there are not leak detection sensors. Based on previous observation noting severe hypochlorite chemical leak and damage, it is recommended that the facility evaluate the containment volume available, add chemical leak detectors, and separate the alum and hypochlorite chemicals into dedicated chemical storage rooms.
11. The caustic soda sampling panel is in poor condition. The sampling flow rate, pressure gauge, and pH readings were not similar between the north and south chlorine contact basins, which showed pH readings of 8.03 and 7.60 s.u. respectively. The pH of the north chlorine contact basin reading of 8.03 s.u. does not meet **12VAC5-590-1002.C.** which states when chloramination is used for disinfection that “pH adjustment facilities shall be provided to maintain pH in the range of 7 to 8”. It is unclear what pH range the facility targets. Recommend calibration and/or replacement of the sampling instrumentation and sampling pump.

pH Sampling Panel

12. One of the caustic tanks appeared to be labelled incorrectly, displaying “88880 Gallons”. Recommend proper labelling for safety and to avoid confusion in emergency situations.

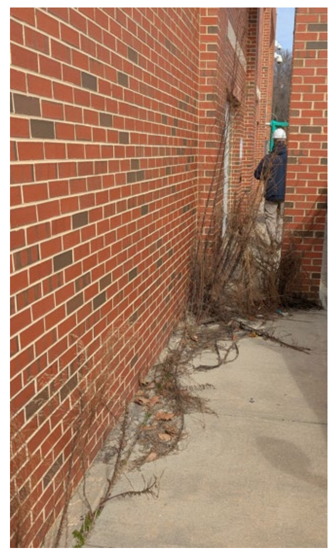
Caustic Storage Tanks – Left Tank Mislabeled

13. The caustic tanks were noted to be constructed in 1999 and may be approaching their end of life. Consider replacement within 5 years.
14. At the caustic loading panel, one of the level transmitter readings appeared to show a negative value. At the top of both caustic storage tanks, bricks were observed supporting the electrical conduit for level transmitters. An incorrect level reading poses potential overfill hazard when chemical delivers are made. Recommend providing proper conduit support to prevent damage. Replace level instrumentation.

Caustic Storage Tank Level Indicator

Caustic Storage Tank Level Transducer

15. The fluoride pumping equipment including control panels are located in the lower level of Plant #1 below the plant hydraulic grade line, and subject to damage during a surcharge event. The facility is currently undergoing a project to replace the existing fluoride pumps. It is recommended that the pumping equipment is relocated to the main floor or higher.
16. There is a significant amount of unused and abandoned chemical feed equipment and piping throughout the facility. Recommend demo and removal of unused equipment.
17. During the evaluation, operations staff were not confident in all the available chemical feed locations, as the plant has been modified and upgraded throughout the years. Some feed points been abandoned in place.
18. Vegetation was observed growing alongside the West Chemical Facility.



West Chemical Facility

2.12 Residuals Processing

2.12.1 Descriptions/Purpose/Elements

The COR WTP has a wastewater pump station, two sludge pumping stations, and a residuals settling lagoon that are used in concert to receive and process spent liquids and solids generated by the plant. There is also a stormwater pumping station adjacent to the West Chemical Facility that sends storm water over the flood wall and into the residuals settling lagoon.

Residuals Settling Lagoon

When the facility was originally constructed in 1927, wastewater was directed into the wastewater channel located within the triple conduit. The waste channel was discharged directly into the

James River. Following the Clean Water Act which prohibited this practice, a major waste water improvement project was completed in 1976. A settling basin adjacent to what is now the current pre-sedimentation basin was converted into a settling lagoon. The lagoon serves to collect the plant's filter backwash water and allow solids to settle. Process wastewater from the wastewater pump station flows into the start of the lagoon at the south end, and flows to the end at the north end. Decanted water then flows into the head of the pre-sedimentation basin through the recycle structure described previously.

Pre-sedimentation Basin on the Left, Residuals Settling Lagoon on the Right

Wastewater Pump Station

The wastewater pump station is located at the west end of Plant #2 ("West Head House") and is used to convey primarily filter backwash along with other plant process drainage to the residuals settling lagoon. The pump station consists of four (4) horizontal end suction centrifugal pumps in a suction lift configuration. The pumps are not self-priming, and utilize a vacuum priming system located in each plant. The vacuum systems utilize liquid ring vacuum pumps and vacuum tanks to evacuate air to maintain prime for the wastewater pumps.

Lagoon Sludge Pump Station

The Lagoon Sludge Pump Station is an abandoned sludge storage, mixing, and pumping station located east of the West Chemical Facility. Previously, the plant owned dredging equipment and took settled solids from the residuals settling lagoon into a concrete tank with mixers and submersible pumps. The station then pumped the settled solids to the off-site Douglasdale Road Pump Station for conveyance to the City's wastewater plant for further treatment. The plant now contracts with a third party for dredging activities, and does not utilize this sludge processing facility.

Basin Sludge Pump Station

Sludge that is automatically removed from the sedimentation basins (Cable-Vac sludge collectors) is conveyed by gravity the Basin Sludge Pump Station. The station consists of three (3) submersible, centrifugal-style sludge pumps. The sludge is normally pumped off-site to the Douglasdale Road Pump station which is then conveyed to the City's wastewater treatment plant. The pump station also has the ability to convey sludge to the residuals settling lagoon or the abandoned Lagoon Sludge Pump Station if needed.

Stormwater Pump Station

When the West Chemical Facility was constructed in 2004, a stormwater pump station was built at the west corner directly adjacent to the building. The pump station collects runoff from the impervious surface around the building and contains two sump pumps driven by 15-HP motors. The pumps send water over the flood wall and into the residuals settling lagoon.

Stormwater Pump Station

2.12.2 Dimensions/Volumes/Capacity

The residuals settling lagoon nearly identical in size to the pre-sedimentation basin, which is noted to be approximately 10’ deep and 300’ wide, with a capacity of approximately 42.5 million gallons. The settling lagoon provides very long detention times for the solids in the filter backwash waste to settle out. Supernatant overflows to the head of the presedimentation basin.

According to a 2020 Water Filtration Evaluation by WRA & Hazen, three of the wastewater pumps are rated for 8 MGD at 21’ TDH and driven by 50-HP motors, and one newer pump is rated for 13.5 MGD at 26’ TDH with a 75-HP motor. The wastewater pump station has a firm pumping capacity (with the largest pump offline) of 24 MGD. The wastewater pumping capacity limits the plant to backwashing only one filter at a time, and prevents the plant from backwashing filters at rates higher than 15.5 gpm/ft^2.

2.12.3 Operations/Maintenance

Residuals Settling Lagoon

DPU staff noted that based on visual observations, they believed the residuals settling lagoon needs to be dredged yearly at a minimum but has not been done for several years. Staff noted that they were not aware of how the dredged solids were handled, as it is performed by contractors. The City reported that it is in the process of establishing a process to continuously dredge/clean the lagoon.

Basin Sludge Pump Station

Each of the three submersible pumps are noted to be at 300 gpm at 44’ TDH, and driven by 7.5-HP motors.

The basin sludge well contains level instrumentation that automatically starts and stops the pumps based on water level. DPU staff did not note any issues or concerns with the station.

Wastewater Pump Station

The wastewater pumps are automatically controlled by a level sensor in the waste conduit where the pump suctions are located, with flow metered out to the lagoon.

Plant staff reported that they do not experience many issues with pump suction and the vacuum priming system on the wastewater pumps. Operators did not report having to manually prime or override the system.

2.12.4 HVAC/Electrical

There is HVAC ductwork located near the floor of the wastewater pump station. The ductwork was submerged during the recent flooding event and should be replaced.

2.12.5 Observations and Recommendations

1. The wastewater pumps take suction from the wastewater channel that originally continued through the plant flood wall and discharged into the James River. As such, there is no wastewater equalization tank or storage. The facility depends on the wastewater pumps to pump water from the lower level of Plant #2 up to the residuals settling lagoon. The firm pumping capacity with one wastewater pump offline is 24 MGD, which matches the current high-rate filter backwash. As the facility has other process drains including roof runoff, there

is risk of surcharging the wastewater channel. It is recommended that the facility consider future capacity upgrades to the wastewater pump station.

   a. Maintaining wastewater pumping equipment including priming system should be considered a high priority.

2. While several motors appear to newer, the wastewater pumps appear to be original and past useful life. It is recommended that the wastewater pumps are replaced and provide increased capacity to handle higher filter backwash rates.

   a. There appears to be a current capital project that is expected to replace the four existing waste pumps and vacuum priming system. It is unclear if the design includes increasing the pump station capacity. It is recommended that the facility consider alternative pump styles that do not require a vacuum priming system such as vertical turbine pumps. Similar to the filtered water pumps, it is recommended that the motors and associated electrical equipment are installed on the main operating floor to protect them from flooding damage. At a minimum, the wastewater pump motors should be replaced with immersion duty motors to prevent damage in case of future flood events.

3. The motor for wastewater Pump No. 2 was missing, with exposed wiring. Recommend sealing the wiring properly in a junction box. Recommend replacing the equipment as soon as possible, given the critical nature of the wastewater pumping station noted above.

Wastewater Pump No. 2 Motor Missing

4. The wastewater piping and valves are in poor condition. Recommend cleaning and recoating.

5. There is a significant amount of standing water in the pumping station (room). The floor did not appear to be sloped properly to floor drains located in the center of the room. Recommend fixing floor drainage.

Wastewater Pump Station Floor

Wastewater Pump Station Piping

6. While operations staff noted that the vacuum priming system for the wastewater pumps was generally reliable, some of the priming equipment appears original (1976) and past its useful life. Recommend replacement.

7. The discharge isolation gate valve on wastewater Pump No. 2 was actively spraying water, with a diverter placed to prevent spraying on personnel. Recommend replacing all backwash isolation gate valves.

Leaking Gate Valve with Diverter

8. There is HVAC ductwork located near the floor of the wastewater pump station. The ductwork was submerged during the recent flooding event and should be replaced. The local heating control panel displayed active alarms for smoke detector, dirty filter, and low space temperature. Recommend replacing HVAC equipment.

Wastewater Pumping Station Damaged Ducts and Heating Control Panel

9. The Stormwater Pump Station pumps storm runoff over the flood wall into the residuals settling lagoon. This water flows to the end of the lagoon and decanted water recycles to the head of the pre-sedimentation basin before entering the head of the treatment plant. **12VAC5-590-395** lists spent filter backwash water, thickener supernatant, or liquids from dewatering processes as streams that can be recycled. The VAC does not list floor/roof drains, analyzer waste, or storm water as permissible recycle streams.
    a. It is recommended that the site storm water pumping station is directed to the Kanawha Canal.
10. All of the plant's process and floor drains along with roof drainage is conveyed into the waste channel, which is then pumped into the residuals settling lagoon. The water in the residuals settling lagoon is eventually recycled to the head of the pre-sedimentation basin supplying the facility. **12VAC5-590-395** lists spent filter backwash water, thickener supernatant, or liquids from dewatering processes as streams that can be recycled. The VAC does not list floor/roof drains, analyzer waste, or storm water as permissible recycle streams.
    a. It is recommended that roof drains are disconnected from the backwash wastewater channel and directed to the Kanawha Canal. Process drains and general filter gallery sump pumps should be separated and sent to the Douglasdale Pumping Station to be conveyed to the City wastewater treatment plant

3 Distribution System

The Richmond distribution system consists of 12 pump stations, ten storage facilities, nine pressure zones, and various pressure reducing valve (PRV) stations interconnecting the pressure zones.

Following treatment at the WTP, water is pumped to the distribution system from the three onsite pumps stations; Korah No. 1, Korah No. 2, and Korah No. 3. Korah No. 1 pumps directly to the City's largest tank of Byrd Park Reservoir, Korah No. 2 pumps either to Byrd Park Reservoir or Zone 1 South pressure zone, and Korah No. 3 pumps to Henrico County's Three Chopt Facilities but can pump to Zone 4 pressure zone. Additionally, a 54-inch reinforced concrete gravity fed conduit from the WTP's chlorine contact basins provides water to Byrd Park Main and Byrd Park Reserve pump stations where Byrd Park Reserve pumps to Byrd Park Reservoir and Zone 2 South pressure zone, and Byrd Park Main pumps to Byrd Park Reservoir. From Byrd Park Reservoir, Trafford and Columbus pump stations pump to the remaining pump stations and pressure zones.

The distribution system sites are controlled by local programmable logic controllers (PLC) that use a variety of methods to communicate with the central SCADA system located at the Richmond WTP. These methods include communication back to the WTP using fiber optic cables, radio telemetry, and plain old telephone service (POTS). At the WTP the various pumping stations and reservoirs can be monitored.

Chapter 3 provides a detailed evaluation of each pump station and storage facility's elements and purpose, building interior, exterior, and security, capacities, operation and maintenance, and electrical equipment within the City owned distribution system. At the end of each section, observations from the site visits, as well as recommendations for improvement, are listed.

3.1 Pumping Stations

3.1.1 Korah No. 1 Pump Station

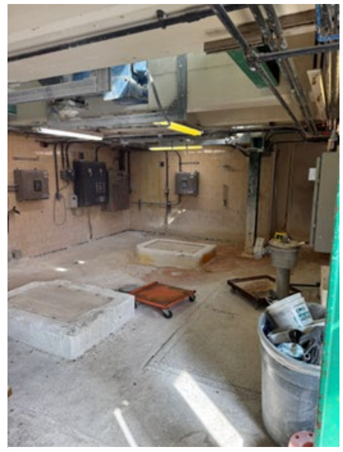
3.1.1.1 Descriptions/Purpose/Elements

Pump Discharge Valve with Cylinder Actuator

Korah No. 1 is located on the same site as the Richmond WTP, which is located at 3920 Douglasdale Road, adjacent to the chlorine contact basins, and was originally constructed in 1938 with recent improvements to the pump station occurring in 2009. The pump station consists of two (2) horizontal split-case centrifugal pumps (K1-1 and K1-2). The pumps take suction from the chlorine contact basin through a suction chamber underneath each pump. Two (2) sluice gates with electric actuators control the flow into each chamber. Both pump discharges consist of a discharge valve that is hydraulically actuated by a Pratt cylinder actuator, and a butterfly valve with a handwheel. Each cylinder actuator has its own control panel mounted on the wall. Both pumps discharge into a common header that fills the Byrd Park Reservoir through a dedicated 36-inch water main. The discharge header is fitted with two (2) redundant Cla-Val pressure relief valves that discharge over into a pit/channel that runs along the north side of the pump station building. The pumps and motors, discharge valves, sluice gates, and pressure relief valves were replaced as part of the pump station upgrades project completed in 2009. The flow meter for the pump station exists in a meter vault along the 36-inch water main after the connection with Korah Pump Station No. 2. Each pump has a suction and discharge pressure gauge and transmitter, and the discharge header has its own pressure gauge and transmitter.

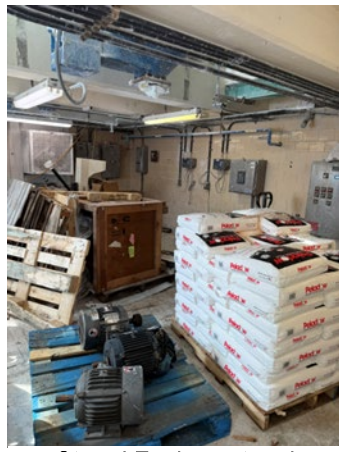
3.1.1.2 Building Interior, Exterior, and Security

The pump station building is constructed of brick and is composed of two sections. The roof of both sections is constructed of metal trusses, wood decking, and asphalt shingling. The south section has a single door and double door on the south side. Both doors are hollow metal doors and have large lites (windows). The single door also has a large adjacent window that extends to the ground. The north section has one (1) single hollow metal door with a large lite. The pump station building itself has windows throughout that appear to be the same vintage as the building.



The south section is two stories tall and used to house the plant's old lime slakers. The space still contains unused electrical equipment for the lime slakers, and is currently storing equipment and supplies, such as ice-melt. The first story of the south section has polished brick walls, concrete ceiling, and metal I-beams. The north section is one story tall and houses the plant's caustic feed system on the west side and the pump station on the east side. The pump station is located within the basement with a walkway/balcony on the first floor above the pump station. The pump station does not have any floor drains but does have a trough system around the perimeter of the basement that drains to a sump pump.

Being on the same site as the plant, the site security is as mentioned earlier in the report. Specific to the pump station building, the two doors on the south side of the south section of the building have keycard readers and the double door has a door contact (unknown if the single door has a door contact). The door on the north side of the north section does not have a keycard reader nor a door contact and the door was found to be left unlocked during the visit. The building does not have security cameras.



Stored Equipment and Supplies

3.1.1.3 Dimensions/Volumes/Capacity

Both pumps are constant speed pumps that have a rated capacity of 11,806 gpm at 190 feet of total dynamic head (TDH) and are made by Patterson. The pumps each have 800 HP, 4160volt, 60 Hz, 3 phase inverter duty motors made by Emerson. Neither pump is VFD controlled but both have soft starters. The pumps and motors were installed as part of the pump station upgrades project completed in 2009.

Korah No. 1 Pump Station

3.1.1.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated, but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

The pressure relief valves are not on a set maintenance schedule.

Within the pump station is a 5-ton crane for pump and motor removal.

The pump station is operated manually by the operator to fill Byrd Park Reservoir.

3.1.1.5 HVAC/Electrical

The pump station does not have heat but has a louver located on the first floor on the north wall, and inlet vent on the first floor on the north wall that extends to the basement, and an exhaust fan located on the west wall of the first floor. Additionally, the south section of the pump station also has two inlet vents on the south wall and two exhaust fans on the west wall. The system is controlled by a thermostat and were installed as part of the pump station upgrades project completed in 2009. The pump station does not have any dehumidification.

Louver on North Wall

Exhaust Fan on West Wall

Switchgear SG9 serves Korah #1 and is fed from outdoor switchgear SG6. This 4160V switchgear dates from the early 1990s and is over 30 years old. Overall, the equipment is well maintained but is showing signs of corrosion. Replacement within 5 years is recommended due to the age of the equipment, corrosion and its critical role in the operation of the WTP. The following routine maintenance items are recommended to ensure that the equipment is functioning properly and to extend its lifespan:

Switchgear SG-9

- The equipment is currently tested and maintained every three years. Maintenance was last performed in 2022 and is expected in 2025. Continue with routine maintenance schedule.
- Clean any dirt or dust accumulation from the equipment.

Two 4160V Benshaw Variable Frequency Drives, (VFDs), control pumps K1-1 and K1-2. These drives were installed around 2012 and are in good condition. A bypass isolation automatic transfer switch, (ATS), allows the 120/208V distribution to be fed from either of two 112.5kVA 4160V-120/208V transformers. The ATS was installed in 2024 and is in excellent condition. The 400A, 120/208V Panel K1 and sub-panel K1-B provide house power, and the Limehouse Panel Main Breaker feeds 120/208V to the Limehouse Panel. Except for Panel K1-A, which was replaced in 2012, all the 120/208V equipment has reached its expected life and is showing sign of corrosion. Replacement is recommended.

Panel K1

Xfmr Secondary Breaker and Limehouse Panel Breaker

The pump control panels are located on the lower level, and although the panel exteriors appear to be pitted, the panel interiors were upgraded in 2012 and are in good condition.

Pump Control Panel Exteriors

Pump Control Panel Interiors

3.1.1.6 Observations and Recommendations

- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- Significant dust build up was observed on various equipment and chipped off paint from the walls in the basement was observed along the floor, including in the trough system. It is recommended to employ good housekeeping.
- It is recommended to blast and repaint the walls of the basement.
- Multiple pressure gauges were showing different readings than the corresponding pressure transmitters. Additionally, the discharge pressure gauge on the discharge header read 70 psi while the discharge pressure gauge for K1-1 read 60 psi. It is recommended that the pressure gauges and transmitters be calibrated or replaced.
- An air gap for a process drainpipe exists above the pump station equipment and was observed to be dripping water. It is recommended that any leaks or spilling be remedied.
- It is unknown if the pressure relief discharge has a screen. It is recommended that if one does not exist, a corrosion resistant screen be installed.
- Cracked gutters and dislodged downspouts were observed. It is recommended that they be replaced or repaired.
- The wooden fascia and soffits were observed to be rotting in areas and are in need of repair and repainting. The overhang above the door on the north side is also in need repair and repainting.
- It is recommended that a door contact and keycard reader be installed for the north door. Additionally, the door contacts do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff

each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.

- It is recommended that cameras be added to the pump station in strategic positions.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- If deemed necessary or beneficial, it is recommended to consider installing a magnetic flow meter within the pump station to accurately measure flow from the pump station should Korah No. 2 be used concurrently to supply water to Byrd Park Reservoir.
- The ductile iron process drain piping was observed to have excessive corrosion and is in need of blasting and recoating.
- It is recommended that dehumidification be installed.
- Multiple overhead lights were observed to be burned out.
- A password for the control panel's HMI screen was not observed. It is recommended that a password be added to prevent unauthorized access.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- While K1-1 was operating the suction pressure read 10 psi and the discharge pressure read 60 to 70 psi, depending on which pressure gauge is relied upon, which equates to a TDH of 115 to 139 feet. After reviewing this TDH, it appears that the pump is operating on the far right of its pump curve and most likely not operating at its best efficiency point (BEP). This may be due to faulty pressure gauges/transmitters. A study to further evaluate this is recommended.
- It is recommended that heating be installed.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.
- It is recommended that the pump station operation be automated based on Byrd Park Reservoir levels.
- Perform annual routing maintenance on electrical distribution equipment
- Replace 4160V Switchgear SG-9 within 5-10 years.
- Replace Panel K1 within 3 years
- Replace Transformer Secondary Breakers and Limehouse Feeder Breaker

3.1.2 Korah No. 2 Pump Station

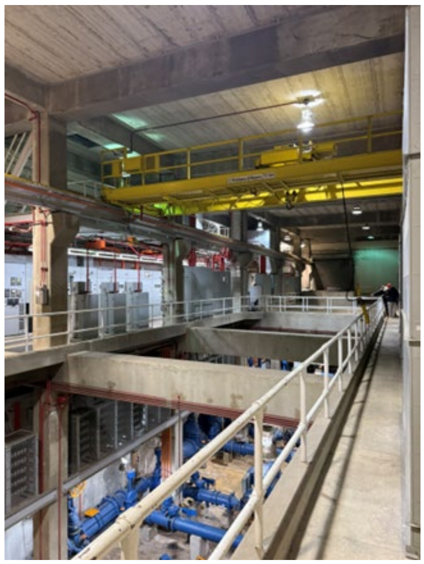
3.1.2.1 Descriptions/Purpose/Elements

Korah No. 2 is located on the same site as the Richmond WTP, which is located at 3920 Douglasdale Road, near Korah No. 1, and was originally constructed in 1981 with recent improvements occurring in 1996. The building houses both Korah No. 2 and Korah No. 3. The pump station consists of five (5) horizontal split-case centrifugal pumps (K2-1, K2-2, K2-3, K2-4, and K2-5). The pumps take suction from the chlorine contact basins, typically from the south chlorine contact basin, through a concrete suction manifold on the south side of the pump station. A manually operated butterfly valve is located outside the pump station to be able to control which chlorine contact basin is utilized. Each pump has a manually operated butterfly valve on the suction line. Pump discharges for K2-1, K2-2, and K2-3 consist of an electrically actuated butterfly valve and tilted disc check valve. Pump discharges for K2-4 and K2-5 consist of an electrically actuated discharge valve with Mercoid switches and gate valves. All five (5) pumps discharge into a common header (as seen at the top of the photo below) that can fill the Byrd Park Reservoir through the same dedicated 36-inch water main used by Korah No. 1 when water is directed through the header to the left, but is also used to supply water to the Zone 1 South pressure zone (Cofer Tanks) where water is directed through the header to the right. Currently K2-1 and K2-2 are used to fill the reservoir, and K2-3, K2-4, and K2-5 are used to supply Zone 1 South pressure zone. The discharge header is fitted with a pressure surge station comprised of two (2) pressure relief valves and two water supply pressure tanks that discharge back to the concrete suction manifold. Pumps K2-4 and K2-5 were added as part of the Korah Pumping Stations No. 2 and No. 3 and Solids Handling Improvements Project in 1996. The other three pumps appear to be original to the construction of the pump station. A magnetic flow meter exists on the discharge header when water is sent to the Zone 1 South pressure zone, and water is metered by the same meter vault used for Korah No. 1. Each pump has a suction and discharge pressure gauge, and the discharge header has a pressure gauge and transmitter.

Korah No. 2 Pump Station

3.1.2.2 Building Interior, Exterior, and Security

The pump station building is constructed of CMU walls with brick facing, a precast plank ceiling, and aluminum roofing. Both the north and south end have one hollow metal single door which have a lite, as well as a rollup garage door on the south end. The building does not have any windows besides the door lites. The pump station is located within the basement of the building, and the building itself has various concrete and grating platforms/walkways at various elevations. A walkway runs along the west side of the building in the basement with stairs and ladders to the basement floor to access the pump station. The basement has a sump pump with a gutter drain running along the west side that directs to the sump.



Interior of Korah No. 2

Unisex Bathroom (Lab Sink Behind)

A unisex bathroom and small lab sink, for various plant water quality analyzers, are located on the north side of the building just inside the single door.

Being on the same site as the plant, the site security is as mentioned earlier in the report. Specific to the pump station building, neither of the single doors have door contacts but both do have keycard readers. All four (4) corners of the building are fitted with two (2) cameras.

3.1.2.3 Dimensions/Volumes/Capacity

The K2-1, K2-2, and K2-3 pumps are 2-speed pumps that have a rated capacity of 9,720 gpm at 248 feet of TDH and are made by Worthington. The pumps each have 900/450 HP, 4000volt, 60 Hz, 3 phase induction motors made by General Electric. The pumps and motors were installed with the pump station in 1981.

The K2-4 and K2-5 pumps are constant speed pumps that have a rated capacity of 9,720 gpm at 248 feet of TDH and are made by Worthington. The pumps each have 900 HP, 4160volt, 60 Hz, 3 phase induction motors made by Toshiba. The pumps and motors were installed with the 1996 project.

3.1.2.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

The pressure relief valves are not on a set maintenance schedule.

Within the pump station is a 10-ton crane for pump and motor removal.

The pump station is operated manually by the operator to fill Byrd Park Reservoir and supply Zone 1 South pressure zone.

3.1.2.5 HVAC/Electrical

The pump station is heated with multiple electric radiant heaters and electric unit heaters strategically placed throughout the building. Some of the heaters appeared original to the pump station building. On the west side of the building are five (5) intake louvers that extend down to the basement, and on the east side are five (5) exhaust fans that extend to the roof. These units appear to be original to the building and are controlled by thermostats. The pump station does not have any dehumidification.

Switchgear SG8 serves Korah #2 & #3 electrical equipment and is fed from outdoor switchgear SG6. This 4160V switchgear dates from the early 1990s and is over 30 years old. Overall, the equipment is well maintained but is showing signs of corrosion. Immediate replacement is not required, replacement within 5 years is recommended due to the age of the equipment, corrosion and its critical role in the operation of the WTP. The following routine maintenance items are recommended to ensure that the equipment is functioning properly and to extend its lifespan:

- The equipment is currently tested and maintained every three years. Maintenance was last performed in 2022 and is expected in 2025. Continue with routine maintenance schedule.
- Clean any dirt or dust accumulation from the equipment.

MCC-2, MCC-CC Bus-1 and SG8*

Control panel contains Bristol Babcock controllers which are scheduled to be replaced as the station controls are upgraded. The controllers are working well, but replacement parts are not readily available. As the controllers are retired, parts can be salvaged to keep controllers in service functioning until they are replaced.

The original MCC construction consisted of two MCC busses extending from each side of switchgear SG8. On the MCC-CC8-Bus-1 side, Pumps K3-3, K3-4 and K3-5 are controlled via drum controllers, which date from the 1970's. These drum controllers are obsolete, and replacement within 5 years is recommended. On the other side, MCC-CC8-Bus-2 contains 2-speed starters for Pumps K2-1, K2-2 and K2-3. These starters have also reached their expected life and replacement is recommended. Improvements in 1996 included adding MCC-2 next to existing MCC-C8-Bus-1 which included new starters for added pumps K2-4 and K2-5. MCC-2 and associated starters are 29 years old and at their expected life. Replacement within 10 years is recommended. Toshiba VFDs for K3-2 and K3-2 were added and are in good condition, although there are complaints regarding the excessive noise levels while they are operating. Staff reported that the manufacturer has tested the drives and have reported that the noise levels are normal, and the drives are functioning properly. No further action is recommended currently.


K3-3, 4 & 5 Drum Controllers


K2-4 & 5 Comb. Starters

K3-1 VFD

Low voltage, (480V and below), electrical equipment is also over 30 years old has reached its expected life. This includes 480V MCC-1, 480/277V Panel PA and 120/208V Panel PB. Replacement of this equipment in 5-10 years is recommended.

MCC-1

Panel PA

Panel PB

3.1.2.6 Observations and Recommendations

- Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- Several areas of the process piping and equipment were observed to have moderate corrosion. It is recommended that they be blasted and recoated to extend the life and prevent further corrosion.
- Pump K2-1's discharge piping has an unidentified hose tapped into the piping that runs along the floor. It is recommended that this be removed as it is a potential cross-connection.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- While K2-1 was operating the suction pressure read 5 psi and the discharge pressure read 82 psi which equates to a TDH of 178 feet. After reviewing this TDH, it appears that the pump is operating on the far right of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended.
- The pressure transmitter on the discharge header read a pressure of 51.998 psi while the discharge pressure for K2-1 read 82 psi. This likely can be attributed to the fact that the pressure transmitter is located on the main level while it is tapped into the discharge header in the basement.
- A password for the control panel's HMI screen was not observed. It is recommended that a password be added to prevent unauthorized access.

- It is recommended that door contacts be installed on all exterior doors. Additionally, the door contacts at other sites do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- Bollards do not exist on the exterior of the building for the rollup garage door. It is recommended that bollards be installed to prevent accidental damage to the building.
- It is recommended that dehumidification be installed.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.
- It is recommended that the pump station operation be automated based on Byrd Park Reservoir levels and system pressures.
- Perform annual routing maintenance on electrical distribution equipment
- Replace 4160V Switchgear SG-9 within 5-10 years.
- Replace K3-4, K3-4 and K3-5 Drum Controllers within 5 years
- Replace K2-1, K2-2 and K2-3 2-speed starters within 5-10 years
- Replace K2-4 and K2-5 Combination Starters.
- Replace MCC-1 within 5-10 years
- Replace Panel PB within 5-10 years
- Replace Panel PA within 5-10 years

3.1.3 Korah No. 3 Pump Station

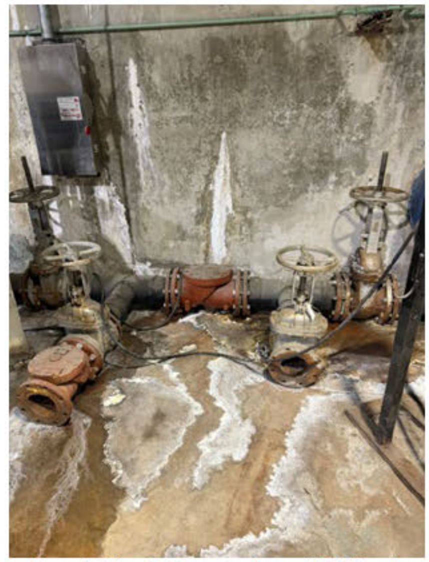
3.1.3.1 Descriptions/Purpose/Elements

Korah No. 3 is located on the same site as the Richmond WTP, which is located at 3920 Douglasdale Road, near Korah No. 1, and was originally constructed in 1981 with recent improvements occurring in 1996. The building houses both Korah No. 3 and Korah No. 2. The pump station consists of five (5) horizontal split-case centrifugal pumps (K3-1, K3-2, K3-3, K3-4, and K3-5). The pumps take suction from the chlorine contact basins, typically from the north chlorine contact basin, through a concrete suction manifold on the south side of the pump station.

A manually operated butterfly valve is located outside the pump station to be able to control which chlorine contact basin is utilized. Each pump has a manually operated butterfly valve on the suction line. Pump discharges for K3-1 and K3-2 consist of an electrically actuated discharge valve with a single Mercoid switch for K3-1 and an Ashcroft switch for K3-2, followed by gate valves. Pump discharges for K3-3, K3-4, and K3-5 consist of an electrically actuated butterfly valve with a single Mercoid switch, followed by a gate valve. All five (5) pumps discharge into a common header (as seen at the top of the photo below) that supplies water to Henrico County via the County's Three Chopt Road Pumping Station, and if needed to Zone 4 pressure zone. The discharge header is fitted with pressure surge station comprised of two (2) pressure relief valves and two (2) 10-gallon water supply pressure tanks that discharges back to the concrete suction manifold. Pumps K3-1 and K3-2 were added as part of the Korah Pumping Stations No. 2 and No. 3 and Solids Handling Improvements Project in 1996. The other three pumps appear to be original to the construction of the pump station. A magnetic flow meter exists on the discharge header. Each pump has a suction and discharge pressure gauge and the discharge header has a pressure gauge and transmitter.

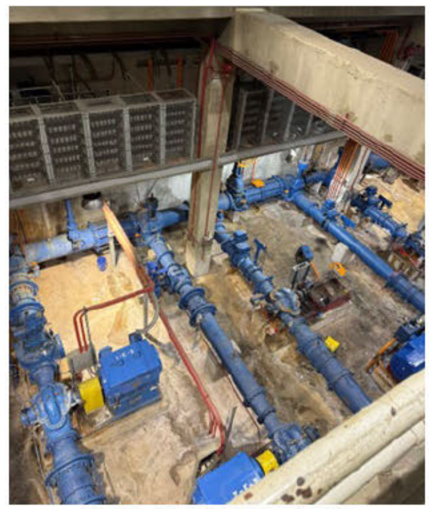
Korah No. 3 is also utilized to supply the plant with house water through a hydraulically operated PRV, which is located on a platform below the main level. The supply line comes off the discharge header and includes a magnetic flow meter. A temporary set up has been installed with connections between Korah No.2 and Korah No. 3's pressure surge stations (see photos below) to supply the plant with water in the event Korah No. 3 is taken offline.

Korah No. 3 Pressure Surge Station Connection



Korah No. 2 Connection with Korah No. 3

Korah No. 2 Pressure Surge Station Connection



Korah No.3 Pump Station

3.1.3.2 Building Interior, Exterior, and Security

See Korah Pump Station No. 2.

3.1.3.3 Dimensions/Volumes/Capacity

The K3-1 and K3-2 pumps are VFD controlled pumps that have a rated capacity of 4,860 gpm at 378 feet of TDH and are made by Worthington. K3-1 has a 700 HP, 4160volt, 60 Hz, 3 phase induction motor made by Toshiba. K3-2 has a 700 HP, 4000volt, 60 Hz, 3 phase motor made by General Electric. The pumps and motors were installed with the 1996 project.

The K3-3, K3-4, and K3-5 pumps are speed controlled with a drum controller. The pumps have a rated capacity of 4,860 gpm at 378 feet of TDH and are made by Worthington. The K3-4 pump motor is a 700 HP, 4000volt, 60 Hz, 3 phase induction motor made by General Electric. The K3-3 motor was pulled for maintenance during the onsite visit and K3-5 did not have a motor tag, so the motors could not be verified but are known to be 700 HP motors. The pumps and motors were installed with the pump station in 1981.

3.1.3.4 Operations/Maintenance

See Korah Pump Station No. 2.

The pump station is operated automatically based on system pressures.

3.1.3.5 HVAC/Electrical

See Korah Pump Station No. 2.

3.1.3.6 Observations and Recommendations

- Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- K3-3 and K3-4 were out of service during the onsite visit for maintenance.
- K3-5 pump's Mercoid switch cover was removed and left hanging off the switch during the site visit. It is recommended that cover be reinstalled.
- Pumps K3-2 and K3-5 were running at the time of the site visit. K3-2 suction pressure read 0 psi and the discharge pressure read 150 psi, which equates to a TDH of 346 feet. The pump has a rated capacity of 4,860 gpm at 378 feet and is likely operating at this condition via the VFD. K3-5 suction pressure read 0 psi and the discharge pressure read 135 psi, which equates to a TDH of 312 feet. After reviewing this TDH, it appears that the pump is operating on the far right of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended. K3-5 also had two suction pressure gauges that read different pressures and other pressure gauges in similar locations were also reading different pressures. It is recommended that pressure gauges be calibrated or replaced.
- Several areas of the process piping and equipment were observed to have moderate corrosion. It is recommended that they be blasted and recoated to extend the life and prevent further corrosion.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- The pressure gauge on the discharge header read a pressure of 132 psi while the discharge pressure for K3-2 read 150 psi and the discharge pressure for K3-5 read 135 psi. The difference in pressure from K3-2 likely can be attributed to the fact that the discharge header pressure gauge is located on the main level while it is tapped into the discharge header in the basement, though the similar reading with K3-5 further indicates the pressure gauges need to be calibrated or replaced.
- A password for the control panel's HMI screen was not observed. It is recommended that a password be added to prevent unauthorized access.

- It is recommended that door contacts be installed on all exterior doors. Additionally, the door contacts at other sites do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- Bollards do not exist on the exterior of the building for the rollup garage door. It is recommended that bollards be installed to prevent accidental damage to the building.
- It is recommended that dehumidification be installed.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- The concrete pedestal pipe support is showing signs of deterioration in at least one location. It is recommended that pipe supports be repaired.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.

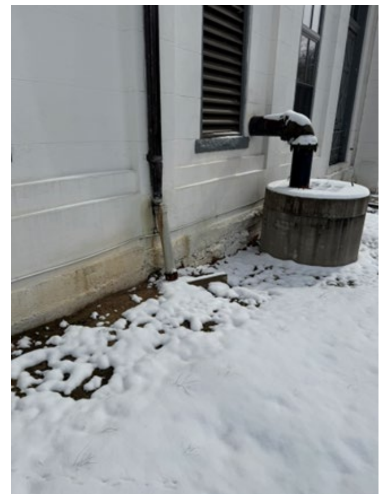
3.1.4 Byrd Park Reserve Pump Station

3.1.4.1 Descriptions/Purpose/Elements

Byrd Park Reserve is located 1706 Pump House Drive and was originally constructed in 1909 with improvements occurring in 1982, 1985, and 2002. The pump station consists of four (4) horizontal split-case centrifugal pumps (R1, R2, R3, and R4). R1, R3, and R4 were installed in 1982 and R2 was installed in 2002. The pumps take suction from the chlorine contact basins through the 54-inch reinforced concrete gravity fed conduit that parallels the James River. R1 has a manually operated butterfly valve, and R2, R3, and R4 have a manually operated gate valve on the suction line. In addition to the butterfly valve, R1 has a Mueller Steam Specialty basket strainer fitting. It is believed R1 used to be used as a raw water pump which required the use of the fitting for removal of foreign matter. The pump discharge for R1 consists of a discharge valve that is hydraulically actuated by a Pratt cylinder actuator, and a gate valve. The cylinder actuator has its own control panel mounted adjacent to the valve. Water supply for the cylinder actuator and for priming R1 comes from piping tapped to the combined discharge for R2, R3, and R4. Additionally, there is a pump discharge switch. R1 pumps to the Byrd Park Reservoir. The pump discharge for R2, R3, and R4 consists of electrically actuated discharge valves and manually operated butterfly valves. Additionally, there are pump suction and discharge switches. R2's discharge exits the pump station building before reentering and tying into the combined discharge header. The combined discharge for R2, R3, and R4 has a pressure relief valve that discharges into a catch basin on the south side of the building. A solenoid valve on the pressure relief valve notifies staff when the valve is open. R2, R3, and R4 pump to Zone 2 South pressure zone (Jahnke Road Tank). Flow from R1 is measured with a venturi flow meter on the suction side, and the combined flow from R2, R3, and R4 is measured with a magnetic flow meter on the discharge header. The pump station bypass is located in a concrete vault adjacent to the building. R1 was observed to be missing a pump suction pressure gauge. There is a single pressure transmitter which is for Zone 2 South pressure zone.

R4

R1



Pressure Relief Valve Discharge

3.1.4.2 Building Interior, Exterior, and Security

The pump station building is constructed of masonry walls with stucco facing. The roof is constructed of wood trusses, wood decking, and slate shingles. The ceilings for the first and second floors are insulated suspended acoustic tiles, and the floor for the second floor is constructed of steel beams, steel decking, and concrete. The north end of the building includes a hollow metal double door, hollow metal single door, and three large wooden double doors. The east end of the building includes a hollow metal single door and an unused double door that has been boarded up. The south end of the building includes a large wooden double door. The east end of the building does not have any doors. Multiple large windows are on each side of the building. Some of the windows are original while others have been replaced over the years.

The first floor of the east end of the building includes a shop area, electrical repair area, locker room, shower, bathroom, and lounge. Wastewater from the bathroom and sinks goes to an underground tank which is pumped to a drainfield. The second floor of the east end of the building includes an assembly area, storage room, instrument repair area, and two (2) offices. These areas are currently used for storage. The basement of the building is used for some storage but also contains the boiler as well as a sump and pump due to groundwater intrusion.

The first floor of the west end of the building houses the pump station in a sub-level below the first floor with a walkway/platform around the perimeter. Beyond the sub-level is a crawl space that extends to the east below the first floor. Within the pump station area, as well as in the crawl space are sumps and pumps that discharge to a catch basin on the south side of the building. A trench along the south end of the sub-level drain to the sump in the pump station area. Raised conduits were also observed being used as drains which connect to the sump.

Stored Material on the First Floor

Crawl Space

The site of the pump station is fenced in with an approximately 6 ft fence with barbed wire. The south (river side) side of the site is not fenced in, and the fence stops along Pump House Drive when it reaches past the bridge to Byrd Park Pump House. The gates for driveway to the site are locked with padlocks. An inoperable call box exists by the gate. None of the doors to the pump station have keycard readers nor door contacts. The site does not have security cameras.

3.1.4.3 Dimensions/Volumes/Capacity

R1 is a constant speed pump that has a rated capacity of 7,986 gpm at 166 feet of TDH and is made by Worthington. The pump motor is made by Continental. A motor tag was not available, but it is known to be a 400 HP motor.

R2 is a constant speed pump and is made by Worthington. The pump tag does not display the capacity of the pump but it is known to be 3,100 gpm at 120 feet of TDH. R2 has a 200 HP, 4160volt, 60 Hz, 3 phase motor made by US Motors.

R3 is a constant speed pump that has a rated capacity of 5,764 gpm at 110 feet of TDH and is made by Worthington. R3 has a 200 HP, 4000volt, 60 Hz, 3 phase AC induction motor and is made by Continental.

R4 is a constant speed pump that has a rated capacity of 5,764 gpm at 110 feet of TDH and is made by Worthington. R4 has a 200 HP, 4000volt, 60 Hz, 3 phase AC induction motor and is made by Continental.

All four (4) pumps were replaced as part of the 1982 Byrd Park Reserve Pumping Station Improvements project, though R2 was replaced subsequently when pumping was changed to pump to Zone 2 South pressure zone.

3.1.4.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

The pressure relief valves are not on a set maintenance schedule.

Within the pump station is a 7,000 lbs crane for pump and motor removal.

The boiler system is on an annual inspection program.

R2, R3, and R4 are operated automatically based on Jahnke Road Tank levels. R1 is operated manually by the operator.

3.1.4.5 HVAC/Electrical

The pump station is heated with a portable heater in addition to the boiler system and radiators. An air conditioning unit was observed on the south side of the building and is believed to only cool the office spaces. A window air conditioner was observed within the boarded up double door on the east side of the building. Within the pumping area are louvers and an exhaust fan that are controlled by a thermostat. The pump station does not have any dehumidification.

Boiler

Boarded Up Double Door

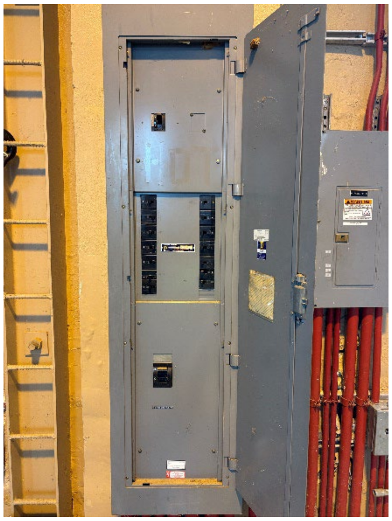
Air Conditioning Unit

Switchgear SG4 serves SG10 in Byrd Park Reserve and MCC-CC1 in Byrd Park Main. SG4 is in the Storage & Garage Building. This 4160V switchgear dates from the early 1990s and is over 30 years old. Overall, the equipment is well maintained but has reached its expected lift. Immediate replacement is not required, replacement within 5-10 years is recommended due to the age of the equipment. The following routine maintenance items are recommended to ensure that the equipment is functioning properly and to extend its lifespan:

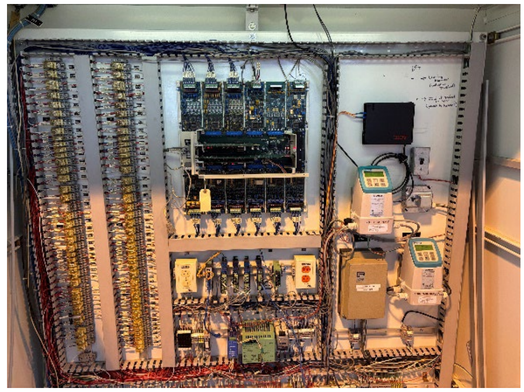
- The equipment is currently tested and maintained every three years. Maintenance was last performed in 2022 and is expected in 2025. Continue with routine maintenance schedule.
- Clean any dirt or dust accumulation from the equipment.

Switchgear SG10/MCC contains starters for Pumps R1, R2, R3 and R4. The switchgear and equipment are over 30 years old and have reached their expected life. Replacement is recommended within 5-10 years.

480/277V and 120/208V distribution panels MP and RP are over 30 years old and have reached their expected life. Replacement is recommended within 5-10 years.



Control panel contains Bristol Babcock controllers which are scheduled to be replaced as the station controls are upgraded. The controllers are working well, but replacement parts are not readily available. As the controllers are retired, parts can be salvaged to keep controllers in service functioning until they are replaced.
The UPS provides backup to the control panel and is in good condition.

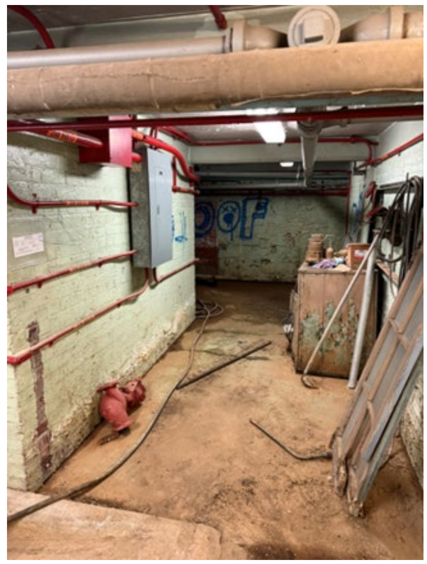


3.1.4.6 Observations and Recommendations

- It is recommended to operated R1 automatically based on Byrd Park Reservoir levels.
- Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Several areas of the process piping and equipment were observed to have moderate corrosion. It is recommended that they be blasted and recoated to extend the life and prevent further corrosion.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- The large wooden double doors do not adequately seal the doorways with large gaps observed. It is recommended that these doors be repaired with weatherstripping.
- Pumps R1 and R2 are missing covers for the shaft and should be reinstalled.
- It is recommended that door contacts be installed on all exterior doors. Additionally, the door contacts at other sites do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff

each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.

- Staining and mildew was observed on the exterior of the building should be power washed.
- The boarded up double door on the east side is showing signs of rotting and should be replaced.
- Two downspouts were observed to be disconnected and should be reconnected.
- Graffiti was observed in the basement.



Basement Showing Graffiti

- R1 was offline during the site visit because the suction side butterfly valve was reported to have a leaking valve seat resulting in water leaking continuously out of the pumps drain lines, as well as a sample tap on the discharge side of the pump. The floor drain near the pump was also observed to be clogged. It is recommended that floor drains be cleaned.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.

Floor Drain Adjacent to R1

- The pressure relief discharge pipe is inserted into the catch basin. It should be cut off to provide an air gap of at least one foot. It is unknown if the discharge is screened but should be screened with a corrosion resistant screen if not (12VAC5-590-1160).
- All four pumps were offline during the site visit.
- The discharge headers pressure gauge read a pressure of 100 psi while the pressure transmitter read a pressure of 97.558 psi. It is recommended that the pressure gauges and transmitters be calibrated.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- A past water main break in the park caused a flood of water to wash into the building.
- It is recommended that a suction and discharge pressure transmitter be installed for each pump.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.

- The pump station lies within the 500-year floodplain.

FEMA Flood Zone Map

- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.
- Perform annual routing maintenance on electrical distribution equipment
- Replace 4160V Switchgear SG-4 within 5-10 years.
- Replace switchgear SG10 within 5-10 years.
- Replace R1, R2, R3 and R4 4160V motor starters within 5-10 years.
- Replace 480/277V panel MP within 5-10 years.
- Replace 120/208V panel RP within 5-10 years.

3.1.5 Byrd Park Main Pump Station

3.1.5.1 Descriptions/Purpose/Elements

Byrd Park Main is located at 1706 Pump House Drive on the same site as Byrd Park Reserve Pump Station and was originally constructed in 1923. The pump station consists of three (3) horizontal split-case centrifugal pumps (P1, P2, and P3). The pumps take suction from the chlorine contact basins through the 54-inch reinforced concrete gravity fed conduit that parallels the James River. All three pumps' suction lines come up through the East Branch Tuckahoe Creek and have manually operated valves with extension stems coming up through the pump house floor.

Pump Suction Lines

Pump Discharge Lines

The pump discharges consist of check valves, manually operated gate valves with extension stems that come up through the building's main floor, and venturi flow meters. All three (3) pumps discharge into a combined header with manually operated gate valves with extension stems that come up through the building's main floor, but three (3) separate discharge lines leave the pump station to fill Byrd Park Reservoir. The pump station is not currently on SCADA but will be when a planned future project will bring fiber to both Byrd Park Main and Byrd Park Reserve. A single suction pressure transmitter and a single discharge pressure transmitter and gauge measure pressures at the pump station. The pumps do not have their own pressure gauges or transmitters.

3.1.5.2 Building Interior, Exterior, and Security

The pump station building is constructed of concrete for the lower section, and brick with steel beams and stucco and terracotta facing. The roof is constructed of steel beams, concrete, and slag. The east side of the building includes a hollow metal double door, and the west side of the building includes a wooden double door. The original drawings also show a single door on the east end from the basement. All four sides of the building have large windows that appear original.

The main floor of the building overlooks the basement and contains a room with the discharge valve handwheels, a water heater, and electrical equipment, as well as a bathroom with a toilet and shower. The second floor overlooks the main floor and basement and contains a generator room, which still contains the original hydro plant generators, a gate room where large gates controlled water flow to the hydro plant, and a mezzanine area that houses electrical equipment. The basement area underneath the hydro plant generators was not looked at but contains two (2) turbine rooms.


Byrd Park Main Pump Station

The basement on the east side of the building houses the pump station. Floor drains were observed, and the original drawings show that these floor drains drain out the south side of the building.

The site of the pump station is as detailed for Byrd Park Reserve. None of the doors to the pump station have keycard readers nor door contacts. The site does not have security cameras.

3.1.5.3 Dimensions/Volumes/Capacity

B1 and B2 are constant speed pumps with a rated capacity of 14,000 gpm at 165 feet of TDH and are made by DeLaval. Only B2's motor tag was legible and shows the motor to be a 750 HP, 4000volt, 60 Hz synchronous motor made by General Electric.

B3's tags were not legible but is a constant speed pump and is known to have a capacity of 7,000 gpm and is made by DeLaval.

3.1.5.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a 10-ton crane for pump and motor removal.

The pump station is operated manually by the operator to fill Byrd Park Reservoir.

3.1.5.5 HVAC/Electrical

The pump station is heated with a single gas wall mounted heater installed in 2013. Baseboard heaters were observed in the bathroom. An old electric wall mounted coil heater that appears to no longer be in use was also observed with a wall mounted fan to distribute the heat. Air conditioning and ventilation was not observed. The pump station does not have any dehumidification.

Switchgear SG5 is fed from SG4 and distributes 4160V power in the Byrd Main Pumping Station. SG4 is in the Storage & Garage Building, (see Byrd Park Reserve for a description of SG4). SG5 dates from the early 1990s and is over 30 years old. Overall, the equipment is well maintained but has reached its expected life. Immediate replacement is not required, replacement within 5-10 years is recommended due to the age of the equipment. The medium voltage MCC contains medium voltage starters for the three pumps, P-1, P-2 and P-3. This MCC is over 30 years old and in addition to reaching its expected life, it has signs of corrosion and replacement within 5 years is recommended. The following routine maintenance items are recommended to ensure that the equipment is functioning properly and to extend its lifespan:

- The equipment is currently tested and maintained every three years. Maintenance was last performed in 2022 and is expected in 2025. Continue with routine maintenance schedule.
- Clean any dirt or dust accumulation from the equipment.

Switchgear SG5

MCC

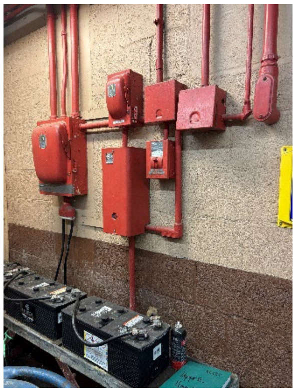
Control panel contains Bristol Babcock controllers which are scheduled to be replaced as the station controls are upgraded. The controllers are working well, but replacement parts are not readily available. As the controllers are retired, parts can be salvaged to keep controllers in service functioning until they are replaced.

120/240V panels A and B are in poor condition and replacement is recommended. Panel A has exposed bus bar, which is a safety hazard for anyone operating a breaker within the panel.

Panel A

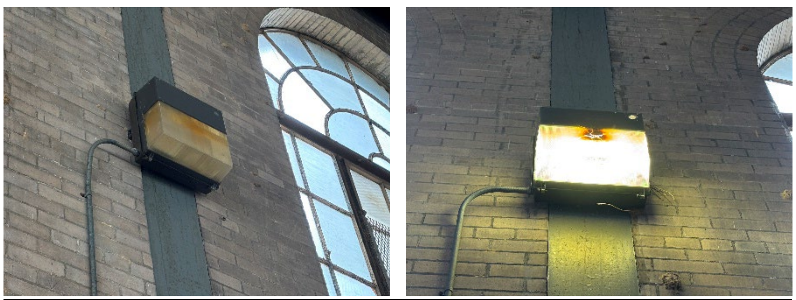
Panel B

The DC backup system for the valves, although reported to be functioning properly, is dated and a more effective backup, such as a modern UPS is recommended to replace this system.



Valve battery system

Wall mounted lighting fixtures are in poor condition and replacement is recommended.



Wall mounted lighting fixtures

3.1.5.6 Observations and Recommendations

- It is recommended to operate the pump station automatically based on Byrd Park Reservoir levels.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- The pumps and motors are at the end of their useful life. All three (3) pumps and controls will be replaced with a planned future project and VFDs will be installed. As VFDs will generate considerable heat in the pump station it is recommended to conduct an HVAC analysis study to determine the need for air conditioning and/or ventilation.
- Graffiti was observed on the side of the building on the river side.
- Spalling concrete was observed in a few areas on the exterior of the building with exposed rebar. It is recommended to repair areas with spalled concrete.
- The large wooden double door does not adequately seal the doorway with large gaps observed. A crack in the door was also observed. It is recommended that the door be replaced.

- The hollow metal double doors were observed to be dislodged exposing a gap in the door. It is recommended to repair or replace the doors.
- The baseboard heaters are at the end of their useful life. Following the recommended HVAC analysis study, their replacement should be determined.
- The process piping is recommended to be blasted and recoated.
- It is recommended to blast and repaint the floors, walls, and ceilings throughout the building.
- It is recommended that door contacts be installed on all exterior doors. Additionally, the door contacts at other sites do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- The discharge pressure gauge read a pressure of 70 psi while the pressure transmitter read a pressure of 60.146 psi. It is recommended that they be calibrated.
- The pump drains discharge back into the pump bases.
- With the age of the building, it is recommended that the floor drains be cleaned out as part of the pump replacement project.
- B1 and B2 were operating at the time of the site visit.
- It is recommended that suction and discharge pressure transmitters be installed for each pump.
- It is recommended that the windows be replaced. Additionally, a window was observed to be open while the temperature outside was below freezing.
- Significant dust and dirt were observed on the process piping and floors. It is recommended to employ good housekeeping and remove unused and/or unwanted equipment.
- Dehumidification equipment should be installed.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- The pump station partially lies within the 100-year and 500-year floodplain.

FEMA Flood Zone Map

- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.
- Perform annual routing maintenance on electrical distribution equipment
- Replace 4160V Switchgear SG-5 within 5-10 years.
- Replace MCC and associated P1, P2 and P3 starters within 5 years.
- Replace 120/208V Panels A and B
- Replace valve batteries with UPS.
- Replace lighting

3.1.6 Trafford Pump Station

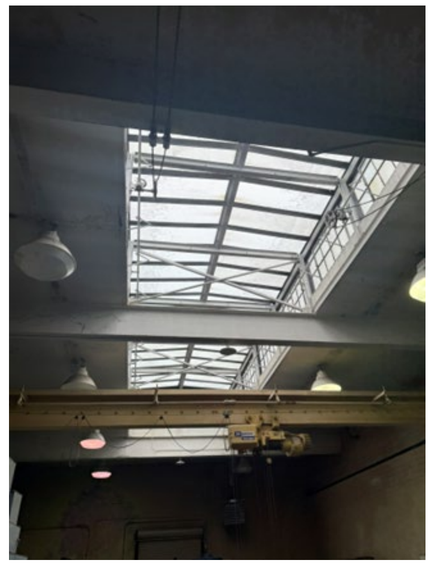
3.1.6.1 Descriptions/Purpose/Elements

Trafford is located at 2701 Police Memorial Way adjacent to the south side of the Byrd Park Reservoir. Improvements to the pump station occurred in 1982. The pump station consists of one (1) vertical split-case centrifugal pump (T1) and four (4) horizontal split-case centrifugal pumps (T2, T3, T4, and T5). The pumps take suction from Byrd Park Reservoir, but can also take suction directly from Korah No. 1, Byrd Park Main, and Byrd Park Reserve if the reservoir needs to be bypassed. Suction lines for each pump include an outside buried gate valve and a venturi flow meter (venturi flow meter is on the discharge side for T5). Pump discharges for T1 and T2 consist of a check valve and manual operated gate valves. Pump discharges for T3 and T5 consist of an electrically actuated butterfly valve, check valve, and manually operated gate valve. Pump discharges for T1, T2, and T4 consist of a check valve and manually operated gate valve. All five (5) pumps discharge into a combined header with manually operated gate valves but five (5) separate discharge lines leave the pump station to supply water to Zone 2 North pressure zone (Ginter Park Tank). A single suction pressure transmitter and a single discharge pressure transmitter measure pressures at the pump station though staff stated there are suction pressure switches on each pump that will turn off the pump when pressure gets too low. The suction pressure transmitter is tapped into the suction line for T5, and the discharge pressure transmitter is tapped into the combined discharge header.

3.1.6.2 Building Interior, Exterior, and Security

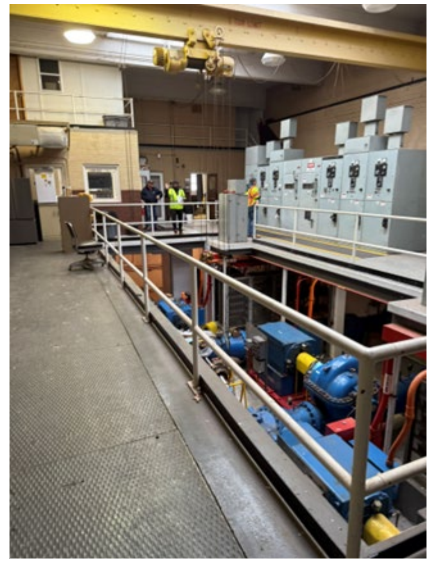
The pump station building is constructed of concrete for the foundation, and brick with steel beams and stucco and terracotta facing. The roof is constructed of steel beams and concrete and includes a large skylight. It is unknown what the surface of the roof is composed of. The main floor is concrete and is supported by steel beams and concrete columns. The north end of the building has a hollow metal double door and south end of the building has a hollow metal single door that is part of a rollup garage door. A 1-ton crane exists outside of the roll up garage door. Windows exist on the north side of the building as well as the northeast and northwest corners. The basement has ten windows with five (5) on the west side, three (3) on the east side, and two (2) on the south side of the building. The windows appear to be original.

T1 Motor and Door on South End



Skylight and Crane

The main floor of the building overlooks the basement and contains electrical equipment, an operations room where a water operator is stationed, a break room, a vestibule area, and a bathroom. A mezzanine area exists on the north side of the building above the operations room, break room, vestibule area, and bathroom, which appears to be used for storage. The basement of the building houses the pump station and the boiler system in a separate room with a crawl space off the boiler room. Floor drains were observed in the basement.



Trafford Pump Station

The site of the pump station is fenced in with an approximately 8 ft fence with barbed wire. All gates are locked with padlocks though the main vehicle gate is an automatic gate that can be opened from within the pump station or with the operator's gate opener. A single camera exists on the north side of the building that is directed towards the gate. Both the north side and south side exterior doors have door contacts but neither have keycard readers.

The adjacent Byrd Park Reservoir does have cameras that are currently down due to the ongoing construction though construction cameras are currently set up.

3.1.6.3 Dimensions/Volumes/Capacity

T1 is a VFD controlled pump. The pump tag was missing but is known to have a rated capacity of 11,111 gpm at 135 feet of TDH. T1 has a 450 HP, 4160volt, 3 phase polyphase induction motor made by The Ideal Electric and Manufacturing Company.

T2 is a VFD controlled pump that has a rated capacity of 7,800 gpm at 145 feet of TDH and is made by Worthington. T2 has a 350 HP, 4000volt, 60 Hz, 3 phase induction motor made by General Electric. Owner's documents list the capacity as 8,612 gpm at 135 feet of TDH with a 300 HP motor.

T3 is a constant speed pump that has a rated capacity of 10,000 gpm at 145 feet of TDH and is made by Worthington. T3 has a 450 HP, 4000volt, 60 Hz, 3 phase induction motor made by General Electric. Owner's documents list the capacity as 10,764 gpm at 135 feet of TDH with a 300 HP motor.

T4 is a VFD controlled pump. The pump tag was missing but is known to have a rated capacity of 8,612 gpm at 135 feet of TDH and is made by Worthington. The motor tag was not legible but is known to be a 350 HP, 4000volt, 60 Hz, 3 phase induction motor made by General Electric. Owner's documents list the motor as 300 HP.

T5 is a constant speed pump that has a rated capacity of 10,400 gpm at 145 feet of TDH and is made by DeLaval. Owner's documents list the capacity as 11,806 gpm at 135 feet of TDH. The motor tag was not legible but is known to be a 450 HP induction motor made by General Electric.

T2, T3, and T4 were replaced as part of the 1982 Water Distribution System Improvements Trafford Pumping Station project.

3.1.6.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a 5-ton crane for pump and motor removal.

The electrically actuated butterfly valves on T3 and T5 and the pumps are controlled by an old electrical panel within the operations room and requires the operator to turn on the pumps with the panel. A planned future project will allow these pumps and valves to be controlled through SCADA.

The boiler system is on an annual inspection program.

The operator stationed at Trafford manually operates the pump station based on pressures observed in Zone 2 North pressure zone. Zone 2 North pressure is maintained between 45 and 50 psi.

3.1.6.5 HVAC/Electrical

The operations room, break room, vestibule area, and bathroom are heated with a baseboard radiator while the rest of the building is heated with a single wall mounted gas heater. The basement has two (2) exhaust fan units that were installed as part of the 1982 project. Two (2) intake fans also exist within the skylight. Two (2) air conditioning units were observed on the exterior of the building. The operations room was observed to receive air conditioning. It is unknown what other rooms have air conditioning. An unknown vent was observed in the northwest corner above one of the windows. The pump station does not have dehumidification.

A fenced area approximately 100 feet east of the pumping station encloses two electrical substations and a backup generator. Power to 34.5kV switchgear SG1 is provided by two Dominion Energy feeders. This switchgear contains the underground feeder for the Filter Plant Substation #2 and the Trafford 34.5kV-4160V Transformer #1, which feeds 4160V switchgear SG2, also located within the fence. SG2 Feeds Byrd Park Pumping Station switchgear SG4 FDR-1 and FDR-2, and Trafford Pumping Station switchgear SG3 FDR-1 and FDR-2. (The Columbus pumping station feeder located in this switchgear is not in use).

All switchgear was manufactured in 1992 and is over 30 years old. Replacement should be considered within the next 10 years.

The backup generator is manually connected using 15 parallel cables. According to the operator, this generator has not been needed in the last 30 years but is available if needed. The generator is on a regular maintenance schedule, which includes monthly, quarterly and annual maintenance. Additional backup is provided by the Columbus Pumping Station which also has a backup generator and automatic transfer switch.

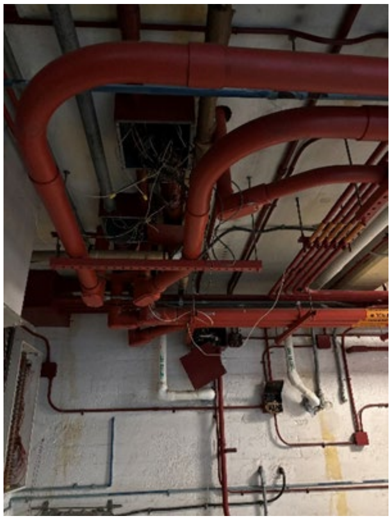
The Trafford Pumping Station switchgear SG-3 is located within the building. This switchgear is over 30 years old, and replacement is recommended within 10 years.

Two older control panels from a previous project that were never installed are sitting on the plant floor. This equipment is abandoned, and disposal is recommended.

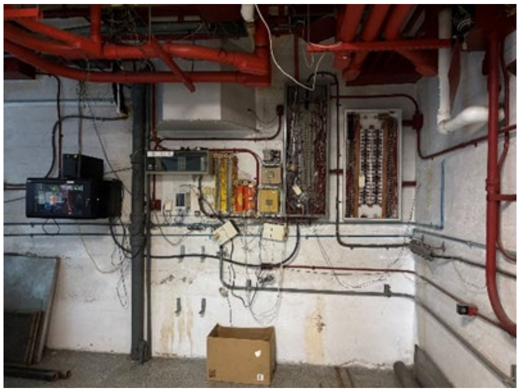
480V panels PP-1 and PP-2, as well as 120/240V panels LP-1 and LP-2 are over 30 years old and replacement is recommended within 10 years.

Open electrical boxes and wire management issues were noted in the basement, along with abandoned communication panels and hanging cables. Abandoned electrical wiring and equipment should be removed, boxes closed, and cable management employed to organize cabling.

IMG_8103



IMG_8196



IMG_8185

The building lighting is metal halide and fluorescent and several fixtures appear to be non-functional. Overall, lighting is in poor condition and replacement with higher efficient LED lighting is recommended.

New control panels have been installed, and equipment control is being phased over to the new panels. T3 and T5 Valves have yet to be converted and are still controlled by the existing obsolete panel. Temporary wiring is draped along the top of the control panels and is exposed. This is a violation of the NEC and also presents issues for troubleshooting. Migrate control to the new panel and remove the obsolete control panel. Remove old wiring, manage cabling to allow effective troubleshooting and code compliance.

In addition to any capital improvements recommended, the following routine maintenance items are recommended for electrical distribution equipment, (panelboards, switchboards and motor control centers). This maintenance should be performed annually to ensure that the equipment is functioning properly and to extend its lifespan:

IMG_8090

- Operate (exercise) the breakers. Check for proper functioning and freedom of movement. Replace any damaged or worn parts.
- Check all terminals for tightness and tighten any loose connections.
- Verify all grounded conductors, equipment grounding conductors and grounding electrode conductors are tightened properly.
- Check contacts for excessive wear and dirt accumulation.
- Check coils for evidence of overheating (cracking, melting or discoloration).
- Clean any dirt or dust accumulation from the equipment.

3.1.6.6 Observations and Recommendations

- It is recommended that the pump station operation be automated based on system pressures or Ginter Park Tank water levels.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- Several areas of the process piping and equipment were observed to have moderate to excessive corrosion. It is recommended that they be blasted and recoated to extend the life and prevent further corrosion.

Combined Discharge Header with Excessive Corrosion

- T1 is at the end of its useful life and should be replaced. Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The T2, T3, T4, and T5 appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- T5's packing gland was leaking at the time of the site visit, and the pump was unable to get any suction pressure. Staff believe construction at the Byrd Park Reservoir caused something to lodge into the suction pipe. Once the issue is resolved staff will be able to adjust the packing gland.
- Pressure gauges are missing for the locations below. It is recommended to install pressure gauges and transmitters for the suction and discharge of each pump.
  - T1 suction and discharge
  - T4 suction
  - T5 discharge

T1

- During the site visit water was observed to be on the floor around T5 due to a plugged floor drain which had to be resolved prior to the site visit.
- The fence's barbed wire is angled into the property. It is recommended to direct the barbed wire to the exterior of the property.
- One (1) fence post on the east side of the property was observed to be disconnected from the top rail and should be reconnected/repaired.
- The exterior crane and railing should be blasted and recoated.
- All windows are recommended to be replaced including the screens for the basement windows. Many of the screens were observed to be damaged.

Exterior Crane

- Some minor mildew and staining were observed on the exterior of the building and should be pressure washed.
- Multiple light bulbs were observed to be burnt out and should be replaced.
- The existing door contacts were observed to be antiquated and should be replaced. Additionally, the door contacts do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- It is recommended to consider installing shutoff valves within the pump station on each of the suction lines.
- With the age of the building, it is recommended that all the floor drains be cleaned out.

- Significant dust was observed on the process equipment. It is recommended to employ good housekeeping.
- The RPZ in the boiler room was last tested in 2019. RPZs are required to be tested annually.
- At the time of the site visit the pump run times were as follows:
  - T1: 24337 hours
  - T2: 12549 hours
  - T3: 4995 hours
  - T4: 15126 hours
  - T5: 530 hours

  The large disparity between the hours indicates an uneven workload distribution which can cause uneven wear and tear, reduced lifespan, and reduced reliability. It is recommended that pumps be used evenly.
- It is recommended that dehumidification be installed.
- Process equipment drains were observed to be laid across the floor and/or into drains. It is recommended to provide an adequate air gap and install corrosion resistant screens on these drains.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- The pump station currently has water quality analyzers due to the ongoing construction at Byrd Park Reservoir. These analyzers are maintained by the contractor and will go away upon completion of the project.
- Perform annual routing maintenance on electrical distribution equipment
- Replace 34.5kV switchgear SG-1 within 5-10 years.
- Replace 4160V switchgear SG-2 within 5-10 years.
- Replace 4160V switchgear SG-3 within 5-10 years.
- Dispose of unused control panels
- Replace (2) 480V panels within 5-10 years.
- Replace (2) 120/240V panels within 5-10 years.
- Replace lighting
- Migrate controls and remove existing control panel.
- Remove existing abandoned wiring and equipment, provide cable management and close electrical boxes.

3.1.7 Columbus Pump Station

3.1.7.1 Descriptions/Purpose/Elements

Columbus is located at 2801 Grant Street adjacent to the north side of the Byrd Park Reservoir and was originally constructed in 1939. The pump station consists of four (4) horizontal split-case centrifugal pumps (C1, C2, C3, and C4). The pumps take suction from Byrd Park Reservoir. Suction lines for each pump include a manually operated butterfly valve. Pump discharges for each pump consist of an electrically actuated butterfly valve, silent check valve, and venturi flow meter. All four (4) pumps discharge into separate lines leaving the pump station to supply water to Zone 2 North pressure zone (Ginter Park Tank). The station’s suction pressure transmitter is tapped into the line that feeds C4. The station's discharge pressure transmitter is tapped into C2’s discharge line.

3.1.7.2 Building Interior, Exterior, and Security

The pump station building is constructed of brick with stucco facing on the north, west, and east sides. The roof is supported with metal trusses. It is unknown what the roof is composed of but does not appear original to the building. The pump station has a series of walkways at various elevations with the pump station located on the bottom floor. The pump station does not have any windows, and the lone door is a hollow metal double door.

The cascade pump for the fountain on the north side of the building is located within the pump station. A sink is located on the northeast corner within the building. Floor drains were observed in the floor of the pump station.

There is a small crawl space on the suction side of the pump station with what appears to be filtered vents. Cold air was observed to be coming through the crawl space.


Crawl Space

The entrance to the pump station is fenced in with an approximately 8 ft wrought iron fence with a padlocked gate. The door does not have a door contact or keycard reader, and there are no cameras. The fenced in area's light pole is controlled with a photo eye.

A separate electrical building, that is five years old, is located east of the pump station and is a single-story building constructed of CMU with stucco facing. The roof is constructed of concrete. The east end of the building is a room at a lower elevation than the rest of the building and houses the generator. Floor drains were not observed in the electrical room but floor drains in the generator room route to a sump with two pumps. It is unknown if the sump pump's control panel sends a high water alarm to SCADA. The diesel tank for the generator has a level transmitter that communicates with SCADA. The building has a hollow metal double door on the east side and a single hollow metal door on the west side.

Electrical Building

The electrical building is fully fenced in, except for a section of the north side of the building, with concrete and wrought iron fencing at various heights. The gate is locked with a padlock. The doors do not have door contacts or keycard readers, and there are no cameras.

The adjacent Byrd Park Reservoir does have cameras that are currently down due to the ongoing construction though construction cameras are currently set up.

3.1.7.3 Dimensions/Volumes/Capacity

All three pumps are VFD controlled with a rated capacity of 10,500 gpm at 145 feet of TDH and are made by Patterson. The pump motors are all 500 HP, 460volt, 60 Hz, 3 phase motors made by General Electric.

3.1.7.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a crane for pump and motor removal.

The operator stationed at Trafford manually operates the pump station by setting the pump speeds based on pressures observed in Zone 2 North pressure zone. Zone 2 North pressure is maintained between 45 and 50 psi.

3.1.7.5 HVAC/Electrical

The pump station building is heated with two (2) electric wall mounted heaters. Three (3) louvers are located on the south side of the building and an exhaust fan is located on the west side of the building. The louvers and exhaust fan are controlled by a thermostat. The pump station does not have dehumidification.

The electrical building is heated with heat pump and distributes heat through ducts. One (1) louver is located on the south side of the building and an exhaust fan is located on the east side of the building. The generator room has two (2) louvers on the south side of the building and an exhaust fan on the west side of the building. The generator room also has a single wall mounted electric heater.

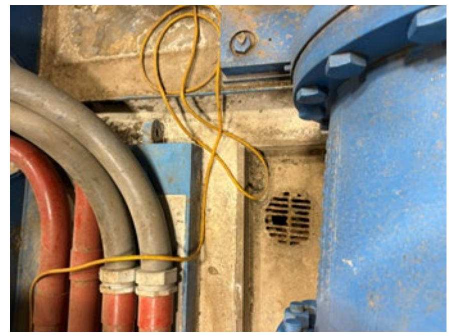
Utility power provided by Dominion. A backup generator exists on site. All electrical equipment in building 1 is only 5 years old and in good condition. It should be noted that due to the distance between building 1 where the electrical room is located and building 2 where the pumps are located inefficiencies in between the VFDs and motors might lead to increased equipment degradation. Since the installation of the new VFDs 5 years ago it is noted that all of them have had failures with their capacitor banks. This was said to be due to power quality issues from Dominion. The VFDs were designed by Greely and Hanson. A separate study was conducted to assess the issue of the capacitor banks which was resolved. In building 1 there is no flood switch. This is a concern due to the low spot the building entrance inhabits along with a low entrance threshold. It is recommended that a flood switch be installed to protect the electrical equipment in building 1. The electrical equipment in building 2 is also new as of 5 years ago and all of it is in good condition.

When we first arrived to the site and went into building 2 it was observed that the city was in the middle of cleaning the pump station. Two employees were using leaf blowers to supposedly clean the dust off of the equipment. This is concerning if this cleaning practice is the same in other sites since there are multiple control panels throughout the various sites that have holes exposing the interior PLC circuit boards to blown dust particles. This could lead to short-circuiting and damage to the control equipment at the various distribution sites.

3.1.7.6 Observations and Recommendations

- It is recommended that the pump station operation be automated based on system pressures or Ginter Park Tank water levels.

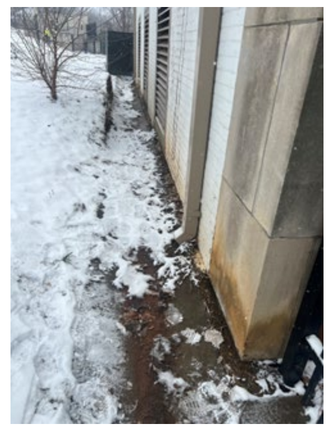
- It is unknown how old the pumps are, but pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but may be approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- The floor drains are damaged and recommended to be replaced.
- It is recommended that dehumidification be installed.
- Significant dust and dirt were observed within the pump station. it is recommended that good housekeeping be employed.
- The RPZ within the pump station was last tested in 2019. RPZs should be tested annually. The RPZ within the electrical building has also not been tested in the last year.



Broken Floor Drain

- The pump station currently has water quality analyzers due to the ongoing construction at Byrd Park Reservoir. These analyzers are maintained by the contractor and will go away upon completion of the project.
- With the age of the building, it is recommended that all the floor drains be cleaned out.
- Spot areas of the process piping should be blasted and recoated.
- C2 and C4 were running at the time of the site visit at 7.94 MGD and 10.52 MGD respectively. The set pump speeds were 71% and 78% respectively. Standard operating procedure is for the operator to manually select the pump speeds.
- C1 was out of service due to issues with the VFD.
- The HMI screens do not have passwords. It is recommended that passwords be added.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- It is recommended that door contacts be installed on all exterior doors. Additionally, the door contacts existing at other sites do not send an alarm to staff through SCADA but instead logs activity in SCADA. It is recommended that the SCADA system send an alarm to staff each time the door is opened, and an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- The section of railing as you walk into the pump station is not adequately secured to the bases resulting in significant movement. It is recommended that the railing be repaired.

- On the HMI screen, the pump station suction pressure does not correlate with Byrd Park Reservoir's water level. The suction pressure is from the suction pressure transmitter within the pump station that is tapped into the suction line for C4 which is at a different elevation than the floor of Byrd Park Reservoir.
- On the HMI screen, the discharge pressure setpoint is 0.00 psi. This is because the pump station was running off set pump speeds. If the pump station is operated off discharge pressure, a setpoint will be entered there.
- Due to the size of the floor space and the large pumps, motors, and process piping and equipment, it is difficult to walk around the pump station and may make maintenance of the facility difficult.
- The pump station's suction pressure read 4.37 psi and the discharge pressure read 40.37, which equates to a TDH of 83 feet. After reviewing this TDH, it appears that the pump is on the far right of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended.
- It is recommended that the brick on the south side of the building be repainted.
- Some minor spalling of the stucco and missing grout between the stucco plates were observed.
- Pressure gauges are missing for the locations below. It is recommended to install pressure gauges and transmitters for the suction and discharge of each pump.
  - C1 suction
  - C2 suction
  - C4 suction
- The south side of the pump station building was observed to have water staining up to approximately two feet up the wall potentially from runoff down the hill. It is recommended to consider regrading the site or installing a barrier between the building and the hill.



Water Staining on South Side

3.1.8 Westhampton Pump Station

3.1.8.1 Descriptions/Purpose/Elements

Westhampton is located at 215 North Hamilton Street. The pump station consists of four (4) horizontal split-case centrifugal pumps (W1, W2, W3, and W4). The pumps take suction from Zone 2 North. Suction lines for W1 and W4 consist of a manually operated valve buried outside of the building. Suction lines for W2 and W3 consist of a manually operated valve buried outside of the building and magnetic flow meters. Discharge lines for each pump consist of a tilted disc check valve, and magnetic flow meters for W1 and W4. The station bypass line is located within the pump station and has a tilted disc check valve. All four (4) pumps discharge into separate lines leaving the pump station to supply water to Zone 4 pressure zone. The station's suction pressure transmitter is tapped into the suction side of the bypass line. The station's discharge pressure transmitter is also tapped into the bypass line on the discharge side. The station has two discharge pressure transmitters for redundancy. An Ashcroft suction pressure switch shuts down pumps if suction pressure gets too low to prevent cavitation.

3.1.8.2 Building Interior, Exterior, and Security

The pump station building is constructed of brick. The slate roof is supported with metal trusses. The fascia is decorative wood. The main floor is composed of retrofitted walkways above the pump station on the bottom floor. The pump station does not have any windows, and the lone door is a hollow metal door on the west side of the building. The bottom floor contains the main pump station room, an empty room on the north end of the building that contains the pressure transmitters and Ashcroft pressure switch, a room on the south end of the building that contains the station bypass line, and a bathroom off of the bypass line room. Floor drains were observed in the pump station.

The site is not fenced in and does not have any security cameras. The door does have a door contact but does not have a keycard reader.

3.1.8.3 Dimensions/Volumes/Capacity

W1 is a constant speed pump with a soft starter and rated capacity of 2,800 gpm at 135 feet of TDH and is made by Patterson. W1 has a 150 HP, 460volt, 60 Hz, 3 phase motor made by Baldor-Reliance.

W2 is a VFD controlled pump with a rated capacity of 5,600 gpm at 135 feet of TDH and is made by Patterson. W2 has a 250 HP, 460volt, 60 Hz, 3 phase motor made by Baldor-Reliance.

W3 is a VFD controlled pump with a rated capacity of 2,800 gpm at 135 feet of TDH and is made by Patterson. W3 has a 150 HP, 460volt, 60 Hz, 3 phase motor made by Baldor-Reliance.

The W4 pump and motor were pulled for maintenance during the site visit and couldn't verify the pump and motor capacities.

3.1.8.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

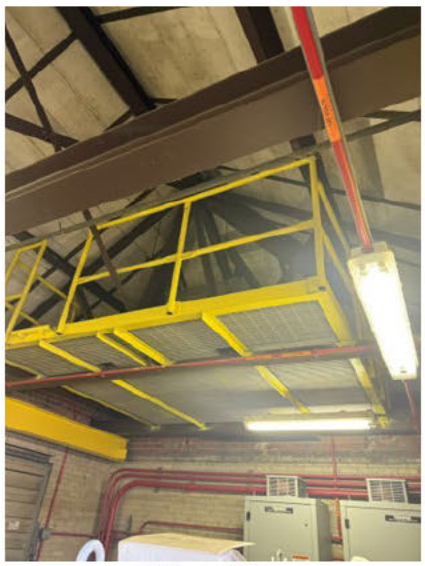
Within the pump station is a 3-ton crane for pump and motor removal.

The pump station is operated based on the operator selected pressure setting. During the site visit, W2 was selected as the lead pump, W1 was selected as the lag pump, and W3 was selected as the second lag pump.

The pump station has a "main break operation mode" which shuts off the pumps when pumps operate too far to the right on the pump curve (high flow with lower discharge pressure).

3.1.8.5 HVAC/Electrical

The pump station is not heated. Two (2) louvers are located on the east side of the building and the building has three (3) exhaust fans with two (2) mounted on platforms near the ceiling and the third one located outside that exhausts the station bypass room, which are controlled by the building's thermostat. The exhaust fans on the platforms appear to be retrofitted while the exhaust fan located outside appears to be original to the pump station. An additional inoperable exhaust fan is located outside on the northeast corner and appears to have once exhausted the air in the room with the pressure transducers and Ashcroft switch. The pump station does not have dehumidification. The HMI screen has a password that is required to make any changes.



Exhaust Fan

Exterior Exhaust Fan

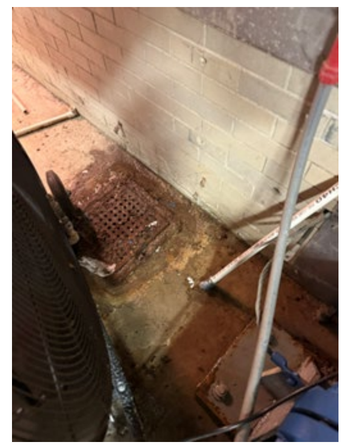
Inoperable Exhaust Fan

The Westhampton Main Circuit Breaker is fed at 480V from a 750kW Dominion owned transformer. It feeds a Square D I-line switchboard that contains a generator bypass-switch and contains overcurrent protection for the 4 pumps located within the building. This equipment along with all of the AFDs, motor starter for W-1, and PLC control panel are in good condition. The switchboard has overcurrent protection for a 480V:208V transformer that feeds panel LP-2 which feeds LP-1. The transformer's coat of paint is chipping and may need cleaning. LP-2 is in good condition while LP-1 is showing signs of corrosion around the door and hinges. The interior of this panel is in okay condition. The generator connection box is located on the outside of the building. It is a Nema type 3R enclosure in good condition.

One light was broken and needed to be fixed. The rest of the lighting was in good condition. HVAC louvre to the left of AFD-W4 had exposed wiring. In addition to this, the junction box it was fed from had a poorly fitted cover plate.

3.1.8.6 Observations and Recommendations

- It is unknown how old the pumps are, but pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but may be approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- It is recommended to remove unused equipment from the pump station.
- During the site visit, someone was camped out on the patio next to the exterior exhaust fan.
- Due to the age of the building, it is recommended that the floor drains be cleaned out. Additionally, the floor drains were observed to be severely corroded and are recommended to be replaced.
- It is recommended that dehumidification be installed.
- The RPZ within the pump station was last tested in 2018. RPZs should be tested annually.
- A pressure gauge was missing for the discharge of W4. It is recommended to provide suction and discharge pressure gauges and transmitters for each pump.
- W2 was running during the site visit and the measured flow was 6.56 MGD. The suction pressure read 38.1 psi while the discharge pressure read 77.9 psi, which equates to an added head of 92 feet. With a rated capacity of 5,600 gpm at 135 feet the pump is likely operating at that point because of the VFD.



Corroded Floor Drain

- While K1-1 was operating the suction pressure read 10 psi and the discharge pressure read 60 to 70 psi which equates to a TDH of 115 to 139 feet. After reviewing this TDH, it appears that the pump is on the far right of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended.
- Many of the pump shafts were observed to be uncovered or covered with a rubber mat laid on top. It is recommended to adequately cover pump shafts for safety reasons.
- It is recommended to consider installing shutoff valves within the pump station on each of the suction lines.
- It is recommended that temperature and flood switches be installed and connected to SCADA to alarm staff.
- It is recommended to ensure that the building’s HVAC systems are included in the existing maintenance management system.

- It is recommended that the door contact send an alarm to staff through SCADA each time the door is opened, and that an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- Due to the location of the pump station, it is recommended that a security fence with barbed wire be installed around the site.
- Graffiti was observed on the east side of the building.
- The wooden fascia was observed to be in need of repainting.
- The double door and frame were observed to be in need of repainting/refinishing.
- The patio on the north side of the building is in need of regrouting.
- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.
- It is recommended the broken light fixture be replaced as soon as possible.
- Site lighting is recommended above the entrance door and surrounding building to deter loitering.
- It is recommended exposed wiring near left louvre be fixed using a new junction box and conduit fittings.

North Side Patio

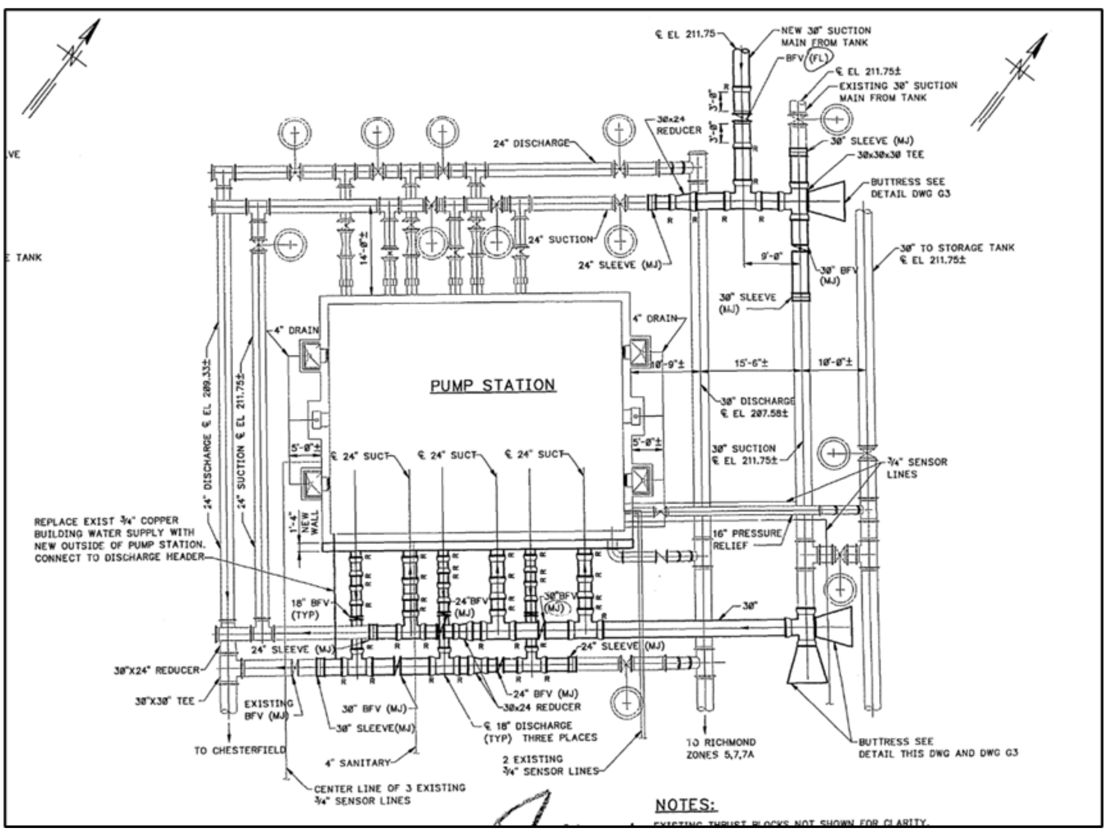
3.1.9 Jahnke Road Pump Station


3.1.9.1 Descriptions/Purpose/Elements

Jahnke Road is located at 5330 Jahnke Road. The pump station consists of six (6) horizontal split-case centrifugal pumps (J1, J2, J3, J4, J5, and J6). The pumps take suction from Jahnke Road Tank, which is fed by Zone 2 South pressure zone (Woodside Tank and Warwick Tank). Suction lines for J1, J2, and J3 consist of outside buried manually and electrically actuated valves. These pumps are on the north side of the building. Discharge lines for the pumps consist of a hydraulically actuated discharge valve with a Mercoid switch and solenoid switches, an outside buried venturi flow meter, and outside buried manually and electrically actuated valves. Additionally, there are pump suction and discharge Mercoid switches, and a pipe tapped between the suction and discharge side of the pump with a Mercoid temperature switch connected to the pipe. Staff stated that these temperature switches determine if the pump is running but the discharge valve is closed, thus the pump would recirculate water continuously, warm up the water, and tell the pump to shut down. J3 had this Mercoid temperature switch but no line tapped between the suction and discharge side of the pump.

Suction lines for J4, J5, and J6 consist of an electrically actuated butterfly valve, and outside buried manually and electrically actuated valves. These pumps are on the south side of the building. Discharge lines for the pumps consist of an electrically actuated discharge valve and outside buried manually and electrically actuated valves. Additionally, there are pump suction and discharge switches, as well as a differential pressure Ashcroft switch. Flow meters do not exist for these pumps.

All six (6) pumps discharge into separate lines and can supply water to either Zone 5 pressure zone or Chesterfield County, though currently, J2 and J3 are supplying water to Zone 5, and J4, J5, and J6 are supplying water to Chesterfield County. The SCADA screen shows that the outside electrically actuated valve is closed and not supplying water to J1, so it is unknown how that pump is currently being used. On the east side of the building are the pressure transmitters for the pump station suction pressure, Chesterfield County suction pressure, and City discharge pressure. On the west side of the building is the Chesterfield County discharge pressure transmitter. All six (6) pumps have suction and discharge pressure gauges. A pressure relief valve is in the southeast corner of the building that relieves discharge pressure for J1, J2, and J3, and discharges to the water main feeding Jahnke Road Tank. This pressure relief valve can also relieve discharge pressure for J4, J5, and J6, though only if they are being used to supply water to Zone 5, all pumps are supplying to Chesterfield County, or all pumps supplying both Chesterfield County and Zone 5.



Pump Station Drawings Showing Suction and Discharge Lines

3.1.9.2 Building Interior, Exterior, and Security

Sump Pump

The pump station building was originally constructed in 1972 with improvements occurring in 1996. The building is constructed of brick. The roof is constructed of asphalt shingles, wooden decorative fascia, and supported with metal trusses, which appear to be retrofitted. The main floor is a walkway around the perimeter, where electrical equipment is located, with the pump station located within the bottom floor. In the southwest corner on the walkway is a bathroom. The building does not have any windows. On the north side of the building is a single hollow metal door as well as a hollow metal double door. The bottom floor has floor drains connected to a soil pipe drain system but also has a trench along the perimeter that drains to the sump in the southeast corner. The sump is fitted with a pump mounted on a shelf above the sump, but also has two (2) redundant pumps with one right above the sump and the other located on the bottom floor on the east side of the building that discharges through a filter mounted for an opening through the wall.

The site is fenced in with an approximately 5 ft chainlink fence, though the fence does not surround the south, east, and west sides of the building. The vehicle gate for the fence is locked with a padlock. The single door does not have a door contact, it is unknown if the double doors have a door contact, and the doors do not have a keycard reader. The pump station does not have security cameras.

3.1.9.3 Dimensions/Volumes/Capacity

J1 is a constant speed pump, and J2 and J3 are variable speed pumps, with all three having a rated capacity of 4,200 gpm at 234 feet of TDH and are made by DeLaval. They have 350 HP, 2400volt, 60 Hz, 3 phase motors made by General Electric.

Pump tags were not available for pumps J4, J5, and J6, but J4 and J6 are known to be constant speed pumps that have a rated capacity of 10 MGD at 250 feet of TDH, and J5 is known to have a rated capacity of 8.5 MGD at 220 feet of TDH. All three pumps have a 600 HP, 2300volt, 60 Hz, 3 phase motor made by US Motors. J5 has a dedicated spare motor stored within the pump station building.

3.1.9.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a 5-ton crane for pump and motor removal. An additional 2-ton crane is located next to the double doors.

The pump station is operated to maintain a pressure of 85 psi in Zone 5 and can be operated off of tank levels or system pressure for Chesterfield County.

3.1.9.5 HVAC/Electrical

The pump station is heated with four (4) electric wall mounted heaters, with two (2) on the main floor and two (2) on the bottom floor. The bottom floor contains two (2) intake fans on the west side and one (1) intake fan on the east side that were installed in 1996. A fourth intake location on the east side has been sealed but still has a filter for the location. Both the east side and west side gables have two (2) exhaust fans that appear not original to the building. The pump station does not have dehumidification. A flood alarm is located on the bottom floor, but it is unknown if it is connected to SCADA.

Removed Air Intake Location

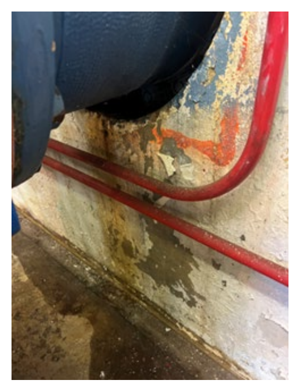
Sump Pump and Floor Flood Alarm

Old S&C switchgear is fed from two separate 1386V Dominion transformers for redundancy. The tie bus is mechanically operated by chain mechanisms. The area in front of the switchgear is obstructed with storage cabinets that violate NEC workspace clearance codes. Switchgear feeds MCC-1 section built in 1997. This equipment is in fair condition. It provides power to the 6 pumps located inside the building. Pumps J1-3 are powered by an old General Electric medium voltage starter cabinet and pumps J2 & J3 are controlled by drum controllers that are slated to be replaced. The rest of the pumps are powered by Westinghouse medium voltage motor starters. The Westinghouse motor starters are in good condition. Transformer LT-1 (2400V:208V) feeds panelboard LP-1 which feeds LP-2. Transformer LT-2 (2400V:208V) feeds panelboard LP-3. Panelboard LP-3 has a hole cut into the panel door for an aftermarket breaker locking mechanism keeping the MCB in the Off position. This compromises the interior of the panel and could lead to increased deterioration. Currently LP-3 and its associated transformer LT-2 are in good condition. Panelboard LP-2 had the same modifications made to it along with a generator receptacle attachment on the right side of the panel, and this is in fair condition. Panelboard LP-1 is in fair condition and has a 150A disconnect modification added to the left side of the panel that acts as feed through lugs for panelboard LP-3. LP-3 feeds the Rectifier and DC system. The DC system contains a battery cabinet and 125V DC distribution panel that powers the actuators for pumps J4-6. One of the rectifiers has been removed and an open conduit still protrudes from the Battery Cabinet. The DC distribution panel is in fair condition and is showing signs of corrosion. The enclosure is Nema 1 rated and dust has built up on the inside of the panel. There was a standing pool of water surrounding the DC system. It was not apparent if this is due to poor drainage or recent build up.

Instrumentation Panel IP-4 was in fair condition. It is noted that there is a square hole on the right enclosure door where an OIT was previously mounted. The second instrumentation cabinet also had holes in its enclosure door. It is recommended that these holes be covered to protect the internal equipment from the outside environment.

3.1.9.6 Observations and Recommendations

- The EPA inspection report noted that all six (6) pumps were operating together. It is recommended to not operate all the pumps at the same time and only operate up to the pump station's firm capacity (capacity with the largest pump offline), so that one pump is available for emergencies.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- Water was observed to be pooling around J1 and J2 from an unknown source.
- It is recommended to install dehumidification equipment.
- Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. It is recommended to replace pumps and motors at the end of their useful life. The pumps appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install magnetic flow meters for J4, J5, and J6.
- Staff stated that Hioaks Tower experiences low turnover. It is recommended to operate the pump station off of Hioaks Tower levels, instead of system pressure, to help turnover the water in the tower and reduce water age.
- A small fenced in area with barbed wire was observed on the north side of the building. Staff stated that an old radio tower was once located there.
- Staff stated that the area has high groundwater necessitating the need for the two extra (2) sump pumps. Groundwater was observed leaking through the linkseal for one of the pump's discharges, and other locations showed evidence of past leakage. It is recommended that drainage issues for the site be remedied.
- A vault was observed in the south side of the building. Staff stated it may have housed the old meter for Chesterfield County.
- It is unknown where the sump pumps discharge to. It is recommended to determine their locations.
- It is recommended to consider installing shutoff valves within the pump station for both the suction side and discharge side for J1, J2, and J3, as well as a shutoff valve for the discharge side for J4, J5, and J6.



Groundwater Leak through Linkseal

- Dirt and sediment were observed on the bottom floor including within the trench drain system. It is recommended to employ good housekeeping.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- The existing flood switch is at the end of its useful life and should be replaced. Additionally, it is recommended that a temperature switch be installed and that both the temperature switch and flood switch be connected to SCADA to alarm staff.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- It is recommended that a door contact be installed for all exterior doors to alarm staff through SCADA each time the door is opened, and that an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- It is recommended to replace the fencing with a taller (6 ft or more) security fence with barbed wire.
- Both exterior doors and frames were observed to be in need of repainting/refinishing.
- Spot areas of the process piping are in need of blasting and repainting.
- The hydraulically actuated discharge valves for J1, J2, and J3 are at the end of their useful life and should be replaced.
- At the time of the site visit, J5 and J6 were out of service. J2 was running at the time of the inspection and had a discharge pressure of 80 psi and a suction pressure of 14.5 psi, which equates to a TDH of 151 feet. After reviewing this TDH, it appears that the pump is on the far right of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended.
- The switchgear has reached the end of it's useful life and replacement is recommended within 5-10 years.
- The motor starters for pumps J1, J2, and J3 are nearing the end of their useful life. It is recommended that they be replaced within 10 years.
- The instrumentation panel controls are nearing the end of their useful life and replacement is recommended within 10 years. It is recommended an updated PLC and OIT system be installed.

Water Pooling Around Electrical Equipment

- The old radio antenna for the pump station still exists and is in use with a newer remote telemetry unit located inside near the instrumentation panels. The old telemetry equipment that is not being used should be removed.
- Water was observed to be pooling around electrical equipment.
- It is recommended the unused conduit extending from the battery cabinet be capped or removed.
- Throughout the lower level conduits, junction boxes, and receptacles showed signs of corrosion and will need replacement within 5 years.
- It is recommended that all receptacles in the lower level of the building be replaced with GFI waterproof versions within 5 years.

- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.

3.1.10 Huguenot Road Pump Station

3.1.10.1 Descriptions/Purpose/Elements

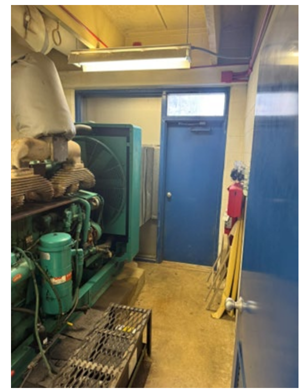
Huguenot Road is located at 8800 West Huguenot Road. The pump station consists of two (2) horizontal split-case centrifugal pumps (H1 and H2). The pumps take suction from Huguenot Road Tank from a combined header, which is fed by Zone 5 pressure zone (Hi Oaks Tank). Suction lines for the pumps consist of a manually operated gate valve. A Mercoid switch on the suction header will shut off the pumps when suction pressure gets too low to prevent cavitation. Discharge lines for the pumps consist of a hydraulically actuated valve with solenoid valves and a manually operated gate valve. A Mercoid switch on the discharge header will shut off the pumps when discharge pressure gets too high. Additionally, both pumps have a pipe tapped between the suction and discharge side of the pump with a second pipe tapped into the discharge side with a temperature switch (one pump has a Mercoid switch and the other has a CCS switch) tapped into that. There is evidence that each pump had an old temperature switch tapped into the pipe tapped between the suction and discharge side of the pump. Similar to Jahnke, staff stated these temperature switches determine if the pump is running but the discharge valve is closed, thus the pump would recirculate water continuously, warm up the water, and tell the pump to shut down.

Both pumps discharge into a combined header to supply water to Zone 7 pressure zone. The suction pressure transmitter and gauge are tapped into the combined suction header and the discharge pressure transmitter and gauge are tapped into the combined discharge header. There is also a bank of differential pressure switches that will shut down the pumps as that would indicate the hydraulically actuated discharge valves are not opening while the pump is running. The individual pumps do not have their own suction and discharge pressure gauge. In the generator room is a pressure gauge and transmitter for measuring the Huguenot Tank levels. Staff stated that SCADA, as well as hardwiring in the pump station, will shut down the pump station if tank levels get too low (~ 6 ft).

3.1.10.2 Building Interior, Exterior, and Security

The pump station building is constructed of brick and is located within the bottom level of Richmond Fire Station 25 on the west end. The ceiling of the pump station is constructed of concrete decking and the walls are constructed of CMU. A generator room is located on the west side within the pump station. The pump station area of the building does not have any windows except for a lite above the exterior generator room door. The pump station has two (2) exterior doors and cannot be accessed from elsewhere within the building. The door to the pump station is a hollow metal double door and the door to the generator room is a hollow metal single door though there is a sealed opening adjacent to the door for accessing the generator.

Floor drains were observed within the pump station.
The site is not fenced in and the doors do not have door contacts or keycard readers. The pump station does not have security cameras.



Generator Room

3.1.10.3 Dimensions/Volumes/Capacity

Both pumps are variable speed pumps with each having a rated capacity of 1,400 gpm at 100 feet of TDH and are made by Allis-Chalmers. They each have a 100 HP, 230/460volt, 60 Hz, 3 phase motor made by Reliance.

3.1.10.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station are cranes for each pump for pump and motor removal.

The pump station is operated to maintain a pressure within Zone 7 and the lead pump currently has a setpoint pressure of 59 psi.

The pump station has a “main break operation mode” which shuts off the pumps when pumps operate too far to the right on the pump curve (high flow with lower discharge pressure).

3.1.10.5 HVAC/Electrical

The pump station is heated with three (3) electric wall mounted heaters with two (2) of them in the pump station room and one (1) in the generator room. There are two (2) air intakes with one located within the pump station room and the other in the generator room. Both these intakes are filtered. An exhaust fan is located on the north wall within the pump station room. The pump station does not have dehumidification and a flood alarm was not observed.

The main service disconnect for this site is a General Electric 7700 Line Control Center that is over 45 years old. This equipment is operating past its expected life. It is fed from an outdoor transformer and also an indoor natural gas 175kW generator from 1974. The generator and associated ATS panel is slated to be replaced. Two AFDs are fed from the Line Control Center. One is a TECO model while the other is a newer Toshiba model. Both of which are housed in old Eaton IS 5000+ enclosures. These enclosures are slated to be replaced, but the AFDs are not. The TECO model uses a resistor bank mounted externally 10ft away. Panel L is fed from a

General Electric 15kVA transformer. The panel has an externally mounted surge suppressor that is fed from a UPS installed in 2019. This provides the backup power for the control cabinets. Both of these use outdated Bristol Babcock PLCs that use touchpads. The blue control cabinet has a hole in the front door. Both of these control cabinets and associated PLCs are slated to be replaced.

This site does not have any door alarm contacts. It does have site lighting.

3.1.10.6 Observations and Recommendations

- It is unknown how old the pumps are, but pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. The pumps appear to have been well maintained but may be approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- It is recommended to install dehumidification equipment.
- It is recommended to install security fencing (6 ft or more) with barbed wire for the site.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- It is recommended to install a temperature and flood switch that is connected to SCADA to alarm staff.
- It is recommended to ensure that the building’s HVAC systems are included in the existing maintenance management system.
- It is recommended that door contacts be installed for both exterior doors to alarm staff through SCADA each time the door is opened, and that an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- General Electric 7700 Line Control Center is at the end of its life and replacement within 5 years is recommended.
- Panel L and it’s associated transformer are at the end of their expected life and replacement within 5 years is recommended.
- It is recommended to provide suction and discharge pressure gauges for each pump.
- Spot areas of the process piping are in need of blasting and repainting.
- The pump station does not have remote control and the pressure setpoint is chosen manually. Staff state that every Tuesday the operator switches which pump is the lead/lag pump manually. It is recommended that the pump station operation be automated based on system pressures.
- Adjacent to the site to the west is Chesterfield Pump Station which is owned and operated by the County. An awarded project will soon bring the pump station onto Richmond’s SCADA system. Within the pump station is a PRV that can feed Zone 7 if Huguenot loses power.

- One (1) pump was operating at the time of the site visit. The discharge pressure read 58 psi while the suction pressure read 10 psi which equates to a TDH of 111 feet. After reviewing this TDH, it appears that the pump is on the left side of its pump curve and most likely not operating at its BEP. A study to further evaluate this is recommended.
- The hydraulically actuated discharge valves continuously dump water through a hose which is tapped into the side of each valve. These hoses were observed to be inserted deep into the floor drain. These valves should not be operated this way and the taps on the side of each valve should be plugged as these taps are meant for additional valve piping to modify the function of these valves. Additionally, an unprotected hose inserted into the floor drain is a potential cross-connection and continuously dumping water into the floor drain is a waste of water.

Hydraulically Actuated Valve with Hose to Floor Drain

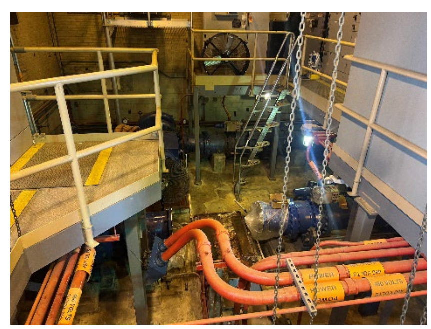
3.1.11 Church Hill Pump Station

3.1.11.1 Descriptions/Purpose/Elements

Church Hill is located at 714 North 30th Street and was originally constructed in 1953 with improvements occurring in 1991, 1994, 1996, and 2005. The pump station consists of three (3) horizontal split-case centrifugal pumps (CH1, CH2, and CH3). CH3 was installed in 2005, and CH1 and CH2 were installed in 1996. The pumps take suction from Church Hill Tank. Suction lines for the CH1 and CH2 consist of a manually operated butterfly valve which contains a solenoid valve but also have outside buried manually operated valves. The suction line for CH3 does not consist of a shutoff valve within the pump station but does have an outside buried manually operated valve. All three (3) suction lines have a pressure switch that shuts down the pumps if the suction pressure gets too low to prevent pump cavitation. The discharge lines for each pump consist of an electrically actuated butterfly valve with upstream and downstream pressure switches, and a manually operated butterfly valve. The station bypass line is located within the pump station and has a tilted disc check valve and manually operated butterfly valve. A suction and discharge pressure transmitter are located in the bottom floor as well as the Church Hill Tank Pressure transmitter. Each pump has their own suction and discharge pressure gauge except for a discharge pressure gauge for CH2. The station flow meter is located within a vault outside of the fence line. Within the pump station is a fourth pump slot. Record drawings indicate the pump station used to have four (4) pumps.

3.1.11.2 Building Interior, Exterior, and Security

The pump station building is constructed of brick. The slate roof is supported with metal trusses. The fascia is decorative wood. The main floor is composed of walkways above the pump station on the bottom floor, as well as a generator room on the west side. The pump station does not have any windows and has a hollow metal double door on the south side and north side of the building. The bottom floor contains the main pump station room as well as a storage closet and a bathroom. Floor drains were observed in the pump station that are routed to the sewer.



Church Hill Pump Station

The site is fully fenced in with an approximately 8 ft wrought iron fence with padlocked gates. The main gate is fitted with a callbox and keycard reader though they are not operational. A security camera is located on the south side and north side of the building as well as one security camera within the pump station. The doors do not have door contacts or keycard readers.

3.1.11.3 Dimensions/Volumes/Capacity

All three (3) pumps are VFD controlled though pump tags were not available to verify their capacities. CH2 was pulled for maintenance at the time of the site visit. CH1 has a 350 HP, 460volt, 60 Hz, 3 phase motor made by General Electric. CH3 has a 350 HP, 460volt, 60 Hz, 3 phase motor made by US Motors.

3.1.11.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a 4-ton crane for pump and motor removal.

The pump station can be operated based off a constant discharge pressure at the pump station or based off Henrico County system pressure.

3.1.11.5 HVAC/Electrical

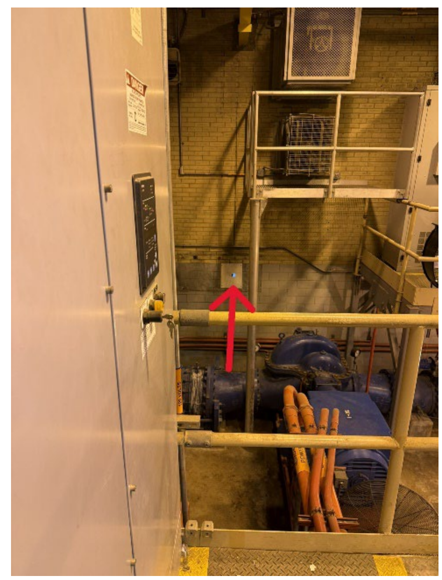
The pump station is heated with three (3) electric wall mounted heaters. The main floor consists of three (3) exhaust fans and a louver that are operated by a thermostat. The bottom floor also contains an intake fan. An exhaust fan and louver are also located in the generator room. The heaters, fans, and louvers were modified in 2005. The pump station does not have dehumidification. A floor flood alarm is located for the bottom floor though it is unknown if it is connected to SCADA.

Site is fed from one Dominion utility transformer and has a 750kVA backup generator on-site. The generator is from 2012 and is in good condition. The C.T. enclosure is mounted on the outside of the building and feeds into MCC-CC2. There is an ATS controller in MCC-CC2 that switches power between the utility and backup generator. MCC-CC1 is fed from MCC-CC2. Pumps CH-1 and CH-2 are fed from MCC-CC2. Pumps CH-3 and CH-4 are fed from MCC-CC1. The MCC sections are from the 1990s and are in fair condition, however switchboard SB1-4B was modified to act as the MCB for MCC-CC1 and is in fair condition but nearing the end of it’s useful life. Each of the Toshiba VFDs are in good condition. A 30kVA 480V:208V transformer is fed from MCC-CC2 and feeds Panelboard LP-LB. The panelboard is showing signs of corrosion around the door, but the interior and rest of the panel are in fair condition. A 125V DC distribution panel and battery system is fed from MCC-CC2 and is in good condition. The network rack for the camera system is mounted about the entrance door and is hard to access. It is recommended this equipment is re-mounted to a serviceable height. IP and DPC control panels are from 1997 and are both in good condition. There is a lack of security for the OIT on the DPC control panel.

3.1.11.6 Observations and Recommendations

- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.

- The SCADA screen for the pump station indicates the pump suction valve's solenoid valves are not operational as the SCADA screen does not indicate if the valve is open or closed.
- Significant dust and dirt were observed on the process equipment. It is recommended to employ good housekeeping.
- It is recommended to install dehumidification equipment.
- It is recommended to install a temperature switch and ensure that both the temperature switch and existing flood switch are connected to SCADA to alarm staff.
- It is recommended to ensure that the building's HVAC systems are included in the existing maintenance management system.
- It is recommended that door contacts be installed for both exterior doors to alarm staff through SCADA each time the door is opened, and that an unlabeled pushbutton or keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.
- Spot areas of the process piping are in need of blasting and repainting.
- It is recommended to provide a suction and discharge pressure gauge and transmitter for each pump.
- An old transformer vault exists adjacent to the building on the east side. A hole, approximately a few inches in diameter, through the wall to the old vault let's in daylight. Additionally, numerous unused wall penetrations were observed in the walls of the bottom floor. It is recommended to patch unused wall penetrations.
- Due to the size of the floor space, and head space in the bottom floor, and the large pumps, motors, and process piping and equipment, it is difficult to walk around the pump station and may make maintenance of the facility difficult.
- It is recommended to consider installing a shutoff valve within the pump station for the suction side of CH3.
- The pump emergency shutoff buttons were observed to be uncovered. It is recommended to provide covers.



Hole Through Wall to Vault

- Switchboard SB1-4B is nearing the end of it's useful life and replacement is recommended within 5-10 years.
- DPC control panel contains old Bristol Babcock PLC that is hard to maintain and find replacement parts for. It is recommended this equipment be upgraded to a newer PLC system within 5 years.
- Security equipment exists at the site but is not fully operational. It is recommended this system's data be saved to a cloud based server rather than using the current local storage configuration.

3.1.12 Cofer Road Pump Station

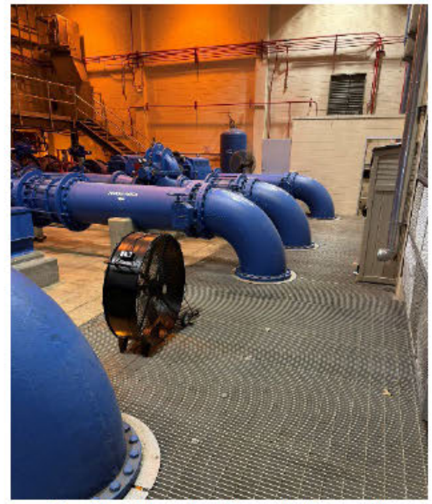
3.1.12.1 Descriptions/Purpose/Elements

Cofer Road is located at 2834 Cofer Road and was originally constructed in 1993. The pump station consists of four (4) horizontal split-case centrifugal pumps (CR1, CR2, CR3, and CR4). CR1, CR2, and CR3 appear original to the pump station but CR4 was installed at a later date. The pumps take suction from Cofer Road Tanks. All four (4) pumps take suction off of a common suction header that is located within a trench within the pump station. Suction lines for each pump consist of a manually operated butterfly valve. Discharge lines for CR1, CR2, and CR3 consist of electrically actuated discharge valves and a manually operated butterfly valve. Mercoid switches are located on the discharge of the pumps that shut down the pumps if pressure gets too high. The discharge line for CR4 consists of a hydraulically actuated valve with a control panel and solenoid valves, and a manually operated butterfly valve. Supply water for the valve comes from a bladder tank located near the bathroom. The bladder tank supplies house water as well and gets its supply from a connection to the discharge header. The supply line to the bladder tank is metered. All four (4) pumps discharge into a common header with a magnetic flow meter. A pressure transmitter is tapped into the discharge header. The pump station bypass line is located outside of the pump station and consists of a manually operated butterfly valve and check valve that can be accessed in a vault adjacent to the building on the east side. Both the suction and discharge headers are fitted with a pressure surge station comprised of two (2) pressure relief valves that discharge into separate manholes in the parking lot. A fifth open slot for a future pump is located south of CR4.

Cofer Road Pump Station

3.1.12.2 Building Interior, Exterior, and Security

The pump station building is constructed of concrete columns, CMU, and brick facing. The roof is constructed of concrete decking and EPDM membrane. The main floor consists of the pump station room, a control room on the southeast corner, and a bathroom on the northeast corner. A mezzanine on the west side contains the electrical equipment. The pump station does not have any windows. The south side of the building contains a hollow metal single door and rollup garage door, and the northeast corner of the building contains a hollow metal single door. Floor drains were observed in the pump station which drain to the sump located within the suction header trench. The sump contains one (1) sump with an additional pump above the sump. Both pumps discharge to the same manhole as the suction side pressure surge station. The sump has a high water level alarm panel though it is unknown if it is connected to SCADA.



Suction Header Trench Beneath Grating

The site is fully fenced in with an approximately 6 ft chainlink fence with barbed wire. The main gate is locked with a padlock. The single door does not have a door contact or a keycard reader. The pump station does not have security cameras.

3.1.12.3 Dimensions/Volumes/Capacity

CR1, CR2, and CR4 are VFD controlled pumps with a rated capacity of 6,100 gpm at 185 feet of TDH and are made by A-C Pump. The pump tag for CR3 was unavailable but it is known to be VFD controlled pump with a rated capacity of 6,100 gpm at 185 feet of head. CR1 and CR2 were installed in 1992, and CR4 was installed in 2000. CR1, CR2, and CR3 have a 500 HP, 460volt, 60 Hz, 3 phase motor made by US Motors. CR4 has a 500 HP, 460volt, 60 Hz, 3 phase motor made by Emerson.

3.1.12.4 Operations/Maintenance

Pumps and motors are on a 5-year maintenance schedule where the entire unit is sent off for evaluation and the pump base is rehabilitated but will be going to a maintenance schedule based off of usage. Additionally, electrical components of the motors are assessed monthly, vibration analyses are conducted on a 6-month schedule, and motor oil is assessed on a 6-month schedule.

Within the pump station is a 4-ton crane for pump and motor removal.

The pump station can be operated off of tank levels in either Woodside Tank or Warwick Tank.

3.1.12.5 HVAC/Electrical

The pump station is heated with a gas furnace that distributes heat throughout the building through ducts. The control room has its own packaged air conditioner and heater. Exhaust fans are located in the mezzanine area on the northwest and southwest corners, as well as through the roof. Louvers are located on the northeast and southeast corners, and a filtered air intake is on the east side of the building. The louvers and fans are controlled by a thermostat.

The site is fed by two separate overhead Dominion power feeds (one is 13.2kV and the other 34.5kV). Each pole has a manual switch disconnect. These feed two separate utility transformers at an outdoor substation. There is an Automatic Transfer switch that is able to switch between the utility feeds. There is also a 750kW Trailer mounted backup generator on site that can be used to power the pumping station in the event of loss of power from both utility feeds. It was stated that previously the connection cables for the backup generator had been stolen. The outdoor substation provides overcurrent protection for the MCC-CC1 along with separate circuit breakers for pumps CR1, CR2, CR3, and CR4. The substation is in fair condition along with MCC-CC1. The MCC has missing/broken indicator lights. There are VFDs for CR1, CR2, CR3, and CR4. The 2016 Toshiba VFDs are in good condition. There is a 125V DC battery and distribution system fed from a panel in MCC-CC1 for pump valve actuators. The battery system is from 2017 and is in good condition. The DPC control panel has a hole in its enclosure door where the Cofer Road Tank level indicator used to be. The DPC control panel is in fair condition. It should be noted the OIT did require a password to access. The PLC is a Bristol Babcock system that is slated to be replaced. It should be noted that the network rack in the main room is mounted above 6ft. It is recommended this equipment is re-mounted at a lower height to be accessed more easily for maintenance.

3.1.12.6 Observations and Recommendations

- Pumps generally have a lifespan of 30-50 years depending on their maintenance cycle. It is recommended to replace pumps and motors at the end of their useful life. The pumps appear to have been well maintained but are approaching the end of a typical life cycle. It is recommended to prepare a budget to plan for their replacement.
- It is recommended to install security cameras in strategic locations.
- It is recommended to install keycard readers for all exterior doors.
- Process equipment drains were observed to be running along the floor and either inserted into or on top of drains. It is recommended to provide an adequate air gap for these drains and install a corrosion resistant screen.
- The shaft for CR1 and CR2 are not adequately covered.
- The RPZ for the bladder tank shows that it was last tested in 2018. RPZs should be tested annually.
- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- Upon loss of SCADA, the pump station can operate off of discharge pressure.
- The control room computer does not have a password. It is recommended that a password be added.


Missing Shaft Cover

- The surge stations discharge to a manhole without a screen. Current standards require these discharges to be at least one foot above ground and provided with a screened, downward facing elbow (12VAC5-590-1160).
- It is recommended to install dehumidification equipment.
- It is recommended to install temperature and flood switches that are connected to SCADA to alarm staff. The high level sump alarm should also be connected to SCADA.
- It is recommended to ensure that the building’s HVAC systems are included in the existing maintenance management system.
- It is recommended that door contacts be installed for all exterior doors to alarm staff through SCADA each time the door is opened, and that an unlabeled pushbutton or

keypad be installed for staff to use when entering and leaving the facility to disarm and rearm the alarm.

- Hydraulically operated valves are generally recommended to be maintained annually. It is recommended that a maintenance schedule be implemented for these valves.
- The emergency shutoff button for CR4's discharge valve was observed to be uncovered. It is recommended to provide covers.
- It is recommended more security measures be installed including security cameras covering the substation area and extending the fenced area around the substation to enclose the generator as well.
- MCC equipment is at the end of it's useful life and should be replaced within 5 years.
- It was observed that conduits penetrating the floor beneath the MCC section show signs of corrosion. It is recommended that these are replaced within 5 years.

3.2 Distribution System Storage

3.2.1 Byrd Park Reservoir

3.2.1.1 Descriptions/Purpose/Elements

Byrd Park Reservoir consists of two (2) connected but separate buried concrete basins and is located in Byrd Park adjacent to Columbus and Trafford pump stations.

3.2.1.2 Exterior and Security

The site is fully fenced in with an approximately 8 ft chainlink fence with barbed wire and locked gates. The site has various security cameras along the perimeter. One of the basins is currently under construction and is utilizing the contractor's furnished security cameras.

3.2.1.3 Dimensions/Volumes/Capacity

Byrd Park Reservoir has a storage capacity of 54.8 MG with a useable storage capacity of 41.8 MG. Due to construction on one of the basins, the current useable storage capacity is 20.9 MG.

3.2.1.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule, which dictates rehabilitation needs, though an inspection report was not available for review. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

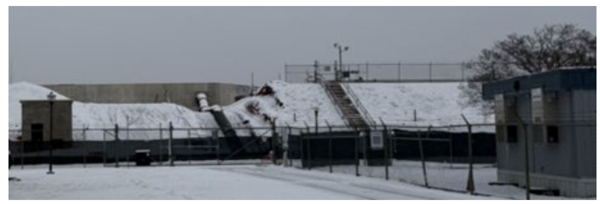
Storage tank inspection reports were not available for review for any of the storage tanks.

3.2.1.5 Electrical

Due to ongoing construction at the site for the west basin, the reservoir could not be fully inspected.

3.2.1.6 Observations and Recommendations

- Due to ongoing construction at the site for the west basin, the reservoir could not be fully inspected.
- A new overflow, which did not exist previously, was observed to be installed.



New Overflow

3.2.2 Ginter Park Elevated Tank

3.2.2.1 Descriptions/Purpose/Elements

Ginter Park Elevated Tank is a multi-legged elevated steel water tank located at 4515 North Avenue. The tank serves the Zone 2 North pressure zone and is supplied water by Columbus and Trafford Pump Stations.

3.2.2.2 Exterior and Security

The site is fully fenced in with an approximately 8 ft chainlink fence with barbed wire and a padlocked vehicle gate. The RTU, cathodic protection, and tower controls box were observed to be locked with a padlock. The door to the dry riser was also observed to be locked with a padlock. Staff stated that roof hatches are also locked.

3.2.2.3 Dimensions/Volumes/Capacity

Ginter Park has a storage capacity of 1.0 million gallons (MG) and has an overflow elevation of 325 feet.

3.2.2.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule, which dictates rehabilitation needs, though an inspection report was not available for review. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.2.5 Electrical

The site is fed from a 120V utility meter mounted on the main power/instrumentation panel. The conduit that connects the utility meter is missing its cover. It is recommended that this is fixed along with providing a weather-rated enclosure to replace the existing panel. The communication panel and equipment is in good condition.

3.2.2.6 Observations and Recommendations

- Condition of the altitude vault was not observed.
- Areas of the barbed wire are facing into the site and areas of the barbed wire were observed to be loose. It is recommended to repair the barbed wire and direct the barbed wire outwards from the site.
- Unused cable brackets on one of the tank legs extend from the ground to the bottom of the tank. While not a security risk, it is recommended that these brackets be cut to prevent people from climbing the tank.
- The cathodic protection was observed to be not operating. Additionally, the exterior coatings were observed to be chalked with areas of rusting. A full coatings rehabilitation is likely needed in the future. During the next rehabilitation project, it is recommended to remove the cathodic protection system. Industry standard is to remove cathodic protection systems as current coating systems utilize a zinc primer.

Unused Cable Brackets

- The overflow pipe is buried and staff noted that the overflow is directed into a manhole. It is unknown if there is an air gap or screen on the discharge. Current design standards require the overflow to be discharged above grade and be fitted with a 3/8-inch or larger corrosion-resistant screen or a flap valve 12VAC5-590-1080)

3.2.3 Church Hill Tank

3.2.3.1 Descriptions/Purpose/Elements

Church Hill Tank is a ground storage concrete tank located at 714 North 30th Street. The tank supplies water to Church Hill Pump Station to serve Zone 3 pressure zone and is supplied water by Zone 1 North pressure zone.

3.2.3.2 Exterior and Security

The tank sits on the same site as the Church Hill Pump Station and is fully fenced in with an approximately 8 ft high wrought iron fence. The tank ladder extends to the ground and is protected by a locked cage. Staff stated that the roof hatches are locked. A pole with two (2) security cameras is located in the corner of the site.

Security Cameras

3.2.3.3 Dimensions/Volumes/Capacity

Church Hill has a storage capacity of 5.0 MG and has an overflow elevation of 228 feet.

3.2.3.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.3.5 Electrical

Tank instrumentation and vault electrical box fed from panelboard LP-LB located in pump station.

3.2.3.6 Observations and Recommendations

- The tank ladder extends to the ground and is protected by a locked ladder cage.
- The overflow pipe is downturned and has a flapper valve. The overflow dumps into its own catch basin that connects to the storm sewer.


Tank Ladder


Overflow


Flapper Valve

- The tank drain dumps into a drainage structure with a catch basin that is connected to a storm sewer. The tank drain discharge is protected with a screen.

Tank Drain Discharge Structure

Tank Drain Discharge with Screen

- A vault containing the inlet and outlet to the tank sits adjacent to the tank. The inlet is controlled via an altitude valve. An electrical box sits on top of the vault with the tank level transmitter and altitude valve power switch on the side of the electrical box.

Vault

Electrical Box

- The exterior of the tank was observed to be in good shape. An inspection report from April 2023 noted some minor recommendations for the interior and exterior of the tank that should be addressed at the next inspection or rehabilitation project.

3.2.4 Cofer Road Tanks

3.2.4.1 Descriptions/Purpose/Elements

Cofer Road Tanks are two ground storage steel tanks located at located at 2834 Cofer Road. The tanks are in Zone 1 South pressure zone and supply water to Cofer Road Pump Station to serve Zone 2 South pressure zone.

3.2.4.2 Exterior and Security

The tanks sit on the same site as the Cofer Road Pump Station and is fully fenced in with an approximately 6 ft high chain link fence with barbed wire. The tank ladders extend to the ground and are protected by locked ladder shields. Both ladders have ladder cages. Staff stated that the roof hatches are locked.

3.2.4.3 Dimensions/Volumes/Capacity

Both tanks have a storage capacity of 1.0 MG each and have an overflow elevation of 236 feet.

3.2.4.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule, which dictates rehabilitation needs, though an inspection report was not available for review. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.4.5 Electrical

Tank instrumentation and electrical box fed from panel LA in pumping station.

3.2.4.6 Observations and Recommendations

- A vault adjacent to the tanks contains the suction line for the pump station and is protected by bollards. The tank level transmitter is located within this vault. The process piping coatings were observed to be in good condition.

Vault

Vault Process Piping

The vault's sump pump discharges out of the side of the vault above grade. It is recommended that the discharge be brought further away from the vault, or a splash pad be installed, to prevent erosion along the vault.

- An unknown pipe with a gate valve and downturned elbow penetrates the vault's wall.
- Both tank overflows are downturned onto their own catch basin. One of the catch basins appeared to be flooded. The overflow discharges contain a screened flapper valve.

Sump Pump Discharge

Screen Flapper Valves

Flooded Catch Basin

- Each tank has its own inlet line vault with an altitude valve.
- The effluent pipe for one of the tanks is above grade before entering the vault and is protected with insulation.
- Both tanks have inlets with passive mixing nozzles. Staff stated each inlet has either two or four mixing nozzles.
- The exterior coatings were observed to be in good condition.

3.2.5 Woodside Elevated Tank

3.2.5.1 Descriptions/Purpose/Elements

Woodside Elevated Tank is a multi-legged elevated steel water tank located south of 4024 Wythemar Street. The tank serves the Zone 2 South pressure zone and is supplied water by Cofer Road Pump Station and Byrd Park Reserve Pump Station.

3.2.5.2 Exterior and Security

The site is fully fenced in with an approximately 6 ft chainlink fence with barbed wire and padlocked gates. The cathodic protection and tower controls box were observed to be locked with a padlock. The RUT box was found to be unlocked. The door to the dry riser was also observed to be locked with a padlock. Staff stated that roof hatches are also locked.

3.2.5.3 Dimensions/Volumes/Capacity

Woodside has a storage capacity of 1.0 million gallons (MG) and has an overflow elevation of 325 feet.

3.2.5.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.5.5 Electrical

Utility service fed from 120V meter with locked disconnect outside of fenced area. Electrical equipment was in good condition except for power/instrumentation enclosure which showed signs of corrosion and was not outdoor rated. It should be noted the telecommunications equipment resided in an unlocked enclosure.

3.2.5.6 Observations and Recommendations

- It is recommended to lock the RTU box.
- Vegetation was observed to be encroaching on the site fencing. It is recommended to provide a sterile zone along the fence line.

Vegetation Encroaching on Fencing

- The vehicle gate was observed to have a large gap between the two gates. Additionally, the hinges for the gates are turned to the exterior of the fence line providing an access to climb the tank. It is recommended to turn the hinges inward which would also close the gap between the two gates.

Vehicle Gate

- Barbed wire was observed to be facing into the site. It is recommended to direct the barbed wire away from the site.
- The exterior coatings were observed to be chalked with areas of minor rusting. A full coatings rehabilitation is likely needed in the future. During the next rehabilitation project, it is recommended to remove the cathodic protection system. Industry standard is to remove cathodic protection systems as current coating systems utilize a zinc primer. An inspection report from February 2023 noted recommendations for the interior and exterior of the tank that should be addressed at the next rehabilitation project (5 years).
- The overflow pipe is buried and is directed into a manhole. It is unknown if there is an air gap or screen on the discharge. Current design standards require the overflow to be discharged above grade and be fitted with a 3/8-inch or larger corrosion-resistant screen or a flap valve 12VAC5-590-1080)
- The overflow manhole was found to be full of water, a tire, and a log. It is recommended to clear out the manhole to provide adequate drainage for the overflow function of the tank. Additionally, the manhole discharges into a brick drainage structure that currently has chainlink and snow fencing around it. Staff stated this is to prevent children from playing on and around the structure. Staff stated that the structure is planned for reconstruction.

Manhole and Drainage Structure

- Process piping coatings within the altitude valve vault were found to be in poor condition. It is recommended that the process piping be blasted and recoated. The vault contains a sump and pump.

Process Piping within Vault

3.2.6 Warwick Road Elevated Tank

3.2.6.1 Descriptions/Purpose/Elements

Warwick Road Elevated Tank is a fluted column elevated steel water tank located adjacent to Richmond Fire Station 22 on Warwick Road. The tank serves the Zone 2 South pressure zone and is supplied water by Cofer Road Pump Station and Byrd Park Reserve Pump Station.

3.2.6.2 Exterior and Security

The site is not fenced in. The tower consists of a rollup garage door and a locked hollow metal single door. The single door does not have a door contact. Staff stated that roof hatches are also locked.

3.2.6.3 Dimensions/Volumes/Capacity

Warwick Road has a storage capacity of 2.0 MG and has an overflow elevation of 325 feet.

3.2.6.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.6.5 Electrical

Utility service fed from 240V meter mounted on exterior of water tower. Electrical equipment inside water tower was in good condition except for panelboard. Panelboard frame had shifted to expose interior compartment. There were also conduits with paint chipping off, however conduit itself seemed in fair condition.

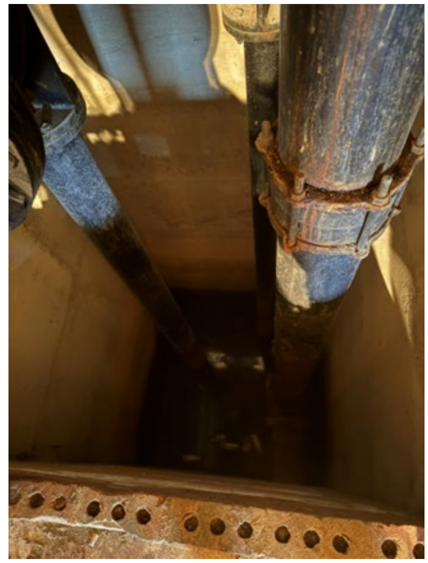
3.2.6.6 Observations and Recommendations

- The process piping within the tank is in poor condition and need of blasting and recoating.



Process Piping

- A vault within the tower that is connected to the dry riser containing the riser, overflow, and drain pipe does not have any fall protection. It is recommended to provide a railing to protect the opening.

Unprotected Vault

- Heat tape was observed on the altitude valve and heat lamps were observed to be mounted above the rest of the process piping.
- The altitude valve bypass piping dips down under the slab on grade flooring and then back up through the floor before connecting to the riser pipe. This may be to allow access to the altitude valve for installation and removal, though the valve can be accessed on the other side.

Altitude Valve Bypass Piping

- The process piping is supported by inadequate pipe supports, including a pieces of wood. It is recommended to install adequate pipe supports.

Pipe Supports

- Exterior coatings were observed to be in good shape but with some minor rusting and mildew growth. It is recommended to pressure wash the tank. During the next rehabilitation project, it is recommended to remove the cathodic protection system. Industry standard is to remove cathodic protection systems as current coating systems utilize a zinc primer. An inspection report from February 2023 noted recommendations for the interior and exterior of the tank that should be addressed at the next inspection or rehabilitation project (5 years).
- The overflow pipe and drain discharge into the storm sewer. It is unknown if there is an air gap or screen on the discharge. Current design standards require the overflow to be discharged above grade and be fitted with a 3/8-inch or larger corrosion-resistant screen or a flap valve 12VAC5-590-1080)

- Brackets on the exterior of the tank are unused and act as a ladder to the tank roof. It is recommended to cut off these brackets.


Unused Brackets

- It is recommended to install security fencing (6 ft or more) with barbed wire for the site.
- It is recommended site lighting be added above the tank entrances.

3.2.7 Jahnke Road Tank

3.2.7.1 Descriptions/Purpose/Elements

Jahnke Road Tank is a ground storage steel tank located at located at 5330 Jahnke Road. The tank is in Zone 2 South pressure zone and supplies water to Jahnke Road Pump Station to serve Zone 5.

3.2.7.2 Exterior and Security

The tank sits on the same site as the Jahnke Road Pump Station and is fully fenced in with an approximately 6 ft high chain link fence with a padlocked gates. The tank ladder does not extend to the ground and is protected by a locked ladder shield. Staff stated that the roof hatches are locked.

3.2.7.3 Dimensions/Volumes/Capacity

The tank has a storage capacity of 2.5 MG each and has an overflow elevation of 251 feet.

3.2.7.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.7.5 Electrical

Electrical equipment located in the vaults near the tank show signs of corrosion and water damage. Replacement is recommended within 5 years. Conduit gaskets and equipment enclosures should be inspected periodically.

3.2.7.6 Observations and Recommendations

- The tank is in need of a full exterior coatings rehabilitation. During the next rehabilitation project, it is recommended to remove the cathodic protection system. Industry standard is to remove cathodic protection systems as current coating systems utilize a zinc primer. An inspection report from January 2023 noted recommendations for the interior and exterior of the tank that should be addressed at the next inspection or rehabilitation project (5 years).

- The tank has two altitude valve vaults, each containing a sump pump, and one containing the tank level transmitter. Staff stated that the altitude valves are alternated. The process piping within the vaults are in need of blasting and recoating. In one of the vaults an altitude valve was observed to be leaking, one of them was observed to be leaking in groundwater onto an electrical box, and the discharge piping for the sump pump in one of the vaults was leaking and allowing discharged water to dump back into the sump.

Altitude Valve Vaults

- A third vault, located next to the overflow, contains the tank drain which discharges into a manhole. The vault contains a sump pump. The process piping within the vault is in need of blasting and recoating.

Vault with Tank Drain

- A new altitude valve was observed to be stored at Hioaks Elevated Tank to replace one of the Jahnke Road Tank altitude valves. Staff stated that the lay length of the new altitude valve is different than the existing and will require modification of the site piping to install.
- The overflow is downturned and screened and discharges into a catch basin.

Overflow

- Water was observed to be pooling around the tank. It is recommended to regrade the site to provide drainage away from the tank.

Pooled Water

3.2.8 Hioaks Elevated Tank

3.2.8.1 Descriptions/Purpose/Elements

Hioaks Elevated Tank is a concrete and steel composite elevated water tank located at 201 Hioaks Road. The tank serves the Zone 5 pressure zone and is supplied water by Jahnke Road Pump Station.

3.2.8.2 Exterior and Security

The site is fully fenced in with an approximately 8 ft fence with barbed wire and padlocked gates. The tower consists of a rollup garage door and a locked hollow metal single door. The single door does have a door contact. Staff stated that roof hatches are also locked.

3.2.8.3 Dimensions/Volumes/Capacity

Hioaks Elevated Tank has a storage capacity of 2.0 MG and has an overflow elevation of 400 feet.

3.2.8.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.8.5 Electrical

Site is fed from a 240V utility meter mounted on an outdoor pedestal within the fenced area. There is site lighting leading to the water tower and above the door entrance. These are fed from a lighting contactor panel that uses a photocell for control of the exterior lighting. Panelboard DP has internal surge protection. All electrical equipment was installed in 2009 and is in good condition.

3.2.8.6 Observations and Recommendations

- The tank does not contain a mixer or have passive mixing.
- The tank has a separate influent (riser) and effluent. Each line has their own magnetic flow meter and the inlet contains an altitude valve and an altitude valve bypass line.

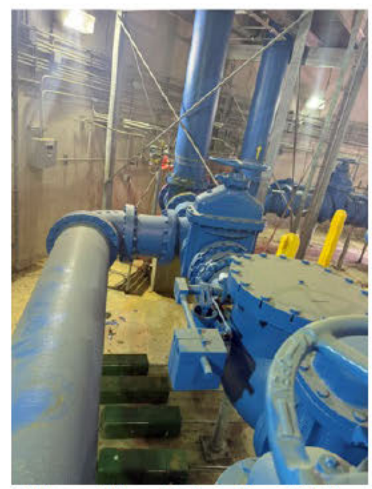
Influent and Effluent Lines

Altitude Valve and Bypass Line

- The tank drain comes off the tower effluent line and then connects into the overflow pipe.

Tank Drain Line

- The tank effluent line has a swing check valve.



Effluent Line Swing Check Valve

- The tank level transmitter is tapped into the riser pipe.

Tank Level Transmitter

- The process piping within the tower was observed to be covered in dust and with areas in need of blasting and recoating. It is recommended to employ good housekeeping.

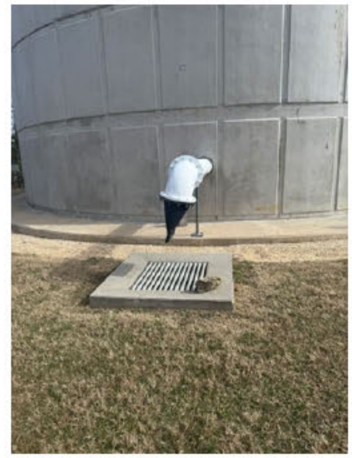
Damaged Process Piping Coating

- Heat lamps exist for the process piping.

Heat Lamp

- The inlet and effluent lines both have bends indicating the influent and effluent mains were installed in the wrong locations.

- The overflow discharge is downturned with a duckbill check valve. The overflow discharges into a dedicated catch basin. The discharge elbow is turned at an angle indicating the catch basin was installed in the wrong location and not centered on the overflow discharge.



Overflow

- The front gate is bent likely due to the hinges being rotated differently. It is recommended to repair the gate.

Table 3-1 – The exterior coatings were observed to be in good condition. An inspection report from May 2023 noted some minor recommendations for the interior and exterior of the tank that should be addressed at the next inspection or rehabilitation project.

Bent Gate

- It was observed that the communications equipment was not properly installed. A router was using a metal folding chair as a shelf. There was also a piece of equipment ziptied to conduit. This equipment should be properly mounted to the backboard or have wall mounted enclosures installed for their protection.

Communication Equipment

Equipment in top right of image is mounted on conduit using ziptie.

3.2.9 Huguenot Road Tank

3.2.9.1 Descriptions/Purpose/Elements

Huguenot Road Tank is a ground storage steel tank located at 8820 West Huguenot Road. The tank is supplied from Zone 5 and provide water for the Huguenot Road Pump Station to supply Zone 7.

3.2.9.2 Exterior and Security

The tank sits on the same site as the Huguenot Road Pump Station and is fenced in on the north side of the property with an approximately 6 ft high chain link fence. The tank ladder does not extend to the ground and is protected by a locked ladder shield. Staff stated that the roof hatches are locked.

3.2.9.3 Dimensions/Volumes/Capacity

The tank has a storage capacity of 0.75 MG and has an overflow elevation of 353 feet.

3.2.9.4 Operations/Maintenance

Half of all the tanks are visited by staff on Saturdays and the other half on Sundays with all of them visited on Tuesdays and Thursdays.

Staff stated that storage tanks are on a five-year inspection schedule which dictates rehabilitation needs. Per AWWA's Manual of Water Supply Practices for Steel Water-Storage Tanks (M42), it is recommended that the tank be washed out, to remove any built up sediment on the bottom of the tank, and inspected at least once every 3 years. If the tank has a noted sediment problem, it is recommended to washout the tank annually.

3.2.9.5 Electrical

Electrical equipment in vault fed from panel L in pump station.

3.2.9.6 Observations and Recommendations

- The tank exterior was observed to have mildew and rust was observed along the base plate. Staff stated that the tank is planned to be pressure washed in the near future. During the next rehabilitation project, it is recommended to remove the cathodic protection system. Industry standard is to remove cathodic protection systems as current coating systems utilize a zinc primer. An inspection report from April 2023 noted recommendations for the interior and exterior of the tank that should be addressed at the next inspection or rehabilitation project (5 years).

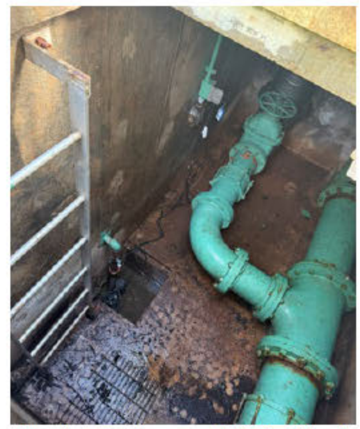
Mildew on Tank Exterior

Corroded Base Plate

- The altitude valve is located within a vault. The vault also contains the altitude valve bypass line, the tank effluent line, and a sump pump. The process piping within the vault is in need of blasting and recoating and a section of the piping has never been painted.

Altitude Valve Vault

- A second vault on the other side of the tank contains the tank's overflow and tank drain. The vault contains a sump pump.



Tank Overflow and Drain Vault

- The overflow discharge, an unknown discharge, and a discharge line from a nearby catch basin discharge into a common drainage structure. The drainage structure is damaged and in need of repair. It was thought the unknown discharge is the tank drain though the tank drain discharges into the overflow pipe. Both the overflow and unknown pipes are screened.

Damaged Drainage Structure

- It is recommended to install security fencing (6 ft or more) with barbed wire to surround the entire site. The existing fence on the north side of the site is damaged in areas and vegetation was observed to be encroaching on the site fencing. It is recommended to provide a sterile zone along the fence line and repair the damaged areas of the fence.

Damaged Fence

4 Recommended Improvements and Estimated Costs

Previous sections of this report described physical and operational issues in need of rehabilitation or upgrade. Below is an itemized summary of the recommended improvement projects included with an opinion of probable cost. These estimates are provided so that facility areas in need of improvement can be compared and prioritized as they relate to cost. Separate summary estimates are included for the WTP and distribution system.

City of Richmond Water Treatment Plant									
Area of Concern									
Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
General Facilities and Grounds									
x	x			Demolition of abandoned electrical and process equipment	$50,000	$10,000	$60,000	$9,000	$69,000
x		x	3	Facility weatherproofing: roof and general exterior repairs, including selective roof repairs, exterior tuckpointing, weather stripping, roof drain/leader selective replacement	$250,000	$50,000	$300,000	$45,000	$345,000
	x	x	3	Plant #1 and #2 HVAC evaluation/study	$0	$0	$0	$0	$0
	x	x	1, 3	Lower level Plant #1 and #2 HVAC Improvements	$0	$0	$0	$0	$0
Raw Water Supply									
x	x			Acquire easements/ROW to access intakes rather than crossing active railroad	$0	$0	$0	$0	$25,000
x	x		1	Perform detailed feeder channel inspection	$0	$0	$0	$0	$50,000
x	x		1,3	Repair identified deficiencies with feeder channel including a noted visible hole	$200,000	$40,000	$240,000	$36,000	$276,000
x			2	Install screens on air relief/blowoff valves at 5-Mile Intake	$5,000	$1,000	$6,000	$900	$6,900
x				Perform inspection and evaluation on prestressed concrete cylinder pipe (PCCP) Korah K3 discharge piping.	$0	$0	$0	$0	$50,000
x				Add water quality monitoring instrumentation at head of pre-sedimentation basin (turbidity, pH, temperature)	$150,000	$30,000	$180,000	$27,000	$207,000
Pre-Sedimentation/Intake Basins									
x				Install flow measurement on the recycled supernatant from the residuals settling lagoon.	$500,000	$100,000	$600,000	$90,000	$690,000
x			3	Repair mechanically cleaned bar screens to permit automatic cleaning.	$100,000	$20,000	$120,000	$18,000	$138,000
Raw Water Pumping									
x				Evaluation of in-channel flow meters for raw water and applied water channels.					$50,000
x		x		Replace failed Plant #2 magnetic flowmeter	$100,000	$20,000	$120,000	$18,000	$138,000

City of Richmond Water Treatment Plant										
Coagulation										
	x	x			Permanently install alum feed lines to in-line channel rapid mixers	$40,000	$8,000	$48,000	$7,200	$55,200
Filtration										
				3	Evaluate and perform detailed inspection on condition of clearwells and triple conduit structures	$0	$0	$0	$0	$40,000
		x	x	3	Repair concrete filter walls, selective crack repair and waterproofing in filter galleries	$250,000	$50,000	$300,000	$45,000	$345,000
		x	x		Plant #1 and #2 filter piping rehab - Blast, verify thickness, recoat. Replace corroded bolts	$750,000	$150,000	$900,000	$135,000	$1,035,000
		x	x		Replace walkway within Plant #2	$250,000	$50,000	$300,000	$45,000	$345,000
	x				Replace temporary sump pumps in Plant #1 and #2 with additional permanently installed pumps and piping.	$200,000	$40,000	$240,000	$36,000	$276,000
				3	Install permanent hydraulic submersible dewatering pumps capable of handling full overflow	$0	$0	$0	$0	$0
	x				Replace all filter effluent actuators in both plants (22 total) with electric actuators with fail safe units (mechanical)	$1,100,000	$220,000	$1,320,000	$198,000	$1,518,000
	x				Replace current hydraulic actuators in Plant #2 (backwash supply, backwash waste, filter to waste) with electric actuators	$720,000	$144,000	$864,000	$129,600	$993,600
	x				Install additional air scour blower system to provide redundancy.	$250,000	$50,000	$300,000	$45,000	$345,000
Filtered Water Pumping										
	x				Replace all eight (8) horizontal end suction pumps with vertical turbine style pumps. Install with below-grade style discharge head, with motors installed above on main operating level. Associated architectural and electrical improvements including relocation of all electrical distribution and control panels.	$8,000,000	$1,600,000	$9,600,000	$1,440,000	$11,040,000
	x		x		*Replace vacuum priming system in both plants (if vertical turbine pumps not utilized)*	$100,000	$20,000	$120,000	$18,000	$138,000
		x		3	Replacement/improvements to Plant #2 sewage ejector system	$200,000	$40,000	$240,000	$36,000	$276,000
				2	Clean and repair floor drains in both filtered water pumping rooms.	$30,000	$6,000	$36,000	$5,400	$41,400

City of Richmond Water Treatment Plant										
			x		Blast and coat piping within filtered water pumping rooms. Replace all corroded bolts.	$250,000	$50,000	$300,000	$45,000	$345,000
Chlorine Contact Basins										
	x				Evaluate and perform detailed inspection on condition of chlorine contact structures	$0	$0	$0	$0	$40,000
	x				Install solid floor with raised edges on catwalks.	$100,000	$20,000	$120,000	$18,000	$138,000
	x				Replace damaged sampling equipment, broken sampling piping and supports	$5,000	$1,000	$6,000	$900	$6,900
	x			1	Evaluate water intrusion	$0	$0	$0	$0	$30,000
	x		x		Replace pH sampling panel	$25,000	$5,000	$30,000	$4,500	$34,500
Residuals Handling										
	x		x	3	Replace all four (4) horizontal end suction wastewater pumps with vertical turbine style pumps. Install with below-grade style discharge head, with motors installed above on main operating level. Associated architectural and electrical improvements including relocation of all electrical distribution and control panels.	$2,750,000	$550,000	$3,300,000	$495,000	$3,795,000
			x		Replace 16" backwash waste valves (4)	$100,000	$20,000	$120,000	$18,000	$138,000
	x		x		Replace vacuum priming system	$100,000	$20,000	$120,000	$18,000	$138,000
			x		Blast and recoat piping	$50,000	$10,000	$60,000	$9,000	$69,000
Chemical Systems										
	x	x			Construct new common polymer storage and feed room in Plant #2. Install polymer blending/makedown system with dedicated dosing pumps, static mixers, and piping. Demo existing polymer feed equipment	$500,000	$100,000	$600,000	$90,000	$690,000
	x	x		3	Replace chemical hoses for lime with permanent installation	$40,000	$8,000	$48,000	$7,200	$55,200
		x			Add chemical leak detectors to alum and hypochlorite day tank storage areas	$10,000	$2,000	$12,000	$1,800	$13,800
		x			Separate alum and hypochlorite chemical systems - add separate containment curb, construct separate chemical rooms, modify HVAC	$150,000	$30,000	$180,000	$27,000	$207,000
	x				Replace caustic level tank instrumentation.	$20,000	$4,000	$24,000	$3,600	$27,600

City of Richmond Water Treatment Plant										
	x				Relocate fluoride chemical feed pumps to main floor - utilize existing Plant #1 polymer room.	$50,000	$10,000	$60,000	$9,000	$69,000
Electrical Systems										
			x	1	Replace 4160V switchgear SG-6	$1,500,000	$300,000	$1,800,000	$270,000	$2,070,000
			x	1	Replace 4160V Switchgear SG-7	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
			x	1	Replace 4160V Switchgear SG-8	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
			x	1	Replace 4160V Switchgear SG-9	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
			x		Replace Panelboards PPA-3 & PPA-4	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace Panelboard LPA-3 & LPA-4	$12,000	$2,400	$14,400	$2,160	$16,560
			x		Replace RWP-3 & RWP-4 VFDs	$80,000	$16,000	$96,000	$14,400	$110,400
			x	1	Replace Switchboards HDP-1 & HDP-2	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
			x	1	Replace MCC-1	$500,000	$100,000	$600,000	$90,000	$690,000
			x	1	Replace N1 & N2 VFDs	$80,000	$16,000	$96,000	$14,400	$110,400
			x		Replace Panelboards PP1A and PP2A	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace Panelboard LP2A	$6,000	$1,200	$7,200	$1,080	$8,280
			x	1	Replace and relocate MV MCC (south side)	$250,000	$50,000	$300,000	$45,000	$345,000
			x	1	Replace and relocate S4 VFD (south side)	$200,000	$40,000	$240,000	$36,000	$276,000
		x	x		Replace Panelboards PP-1 & PP-2	$25,000	$5,000	$30,000	$4,500	$34,500
		x	x		Replace Panelboard LP-1	$6,000	$1,200	$7,200	$1,080	$8,280
			x		Replace Panelboards WHH1 & WHH7	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace panelboard F	$6,000	$1,200	$7,200	$1,080	$8,280
			x		Replace Lighting	$75,000	$15,000	$90,000	$13,500	$103,500
		x			Add emergency lighting to pipe galleries	$80,000	$16,000	$96,000	$14,400	$110,400
Total Estimated Project Cost						**$17,395,000**	**$3,479,000**	**$20,874,000**	**$3,131,100**	**$34,909,200**

1 - Cost and scope should be refined by additional study/evaluation

2 - Work may be performed in-house

3 - Some or all of the recommended project improvements may be covered in City's current projects

4 - Cost included with another recommendation

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
Korah No. 1 Pump Station										
	x				Install dehumidification and heating equipment and install temperature switch	$18,000	$3,600	$21,600	$3,240	$24,840
	x		x		Blast and repaint basement walls and select areas of process piping	$50,000	$10,000	$60,000	$9,000	$69,000
	x				Calibrate or replace pressure gauges and transmitters	$20,000	$4,000	$24,000	$3,600	$27,600
	x			2	Install corrosion resistant screen on pressure relief discharge pipe	$0	$0	$0	$0	$500
	x				Conduct pump station hydraulic analysis study	$0	$0	$0	$0	$75,000
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x				Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$50,000
		x			Install keycard reader and door contact on north door	$12,000	$2,400	$14,400	$2,160	$16,560
		x			Install security cameras	$30,000	$6,000	$36,000	$5,400	$41,400
		x			Provide a password for HMI screen	$0	$0	$0	$0	$2,500
			x		Facility weatherproofing: Replace gutters, downspout, fascia, soffits, and tuckpoint areas of brick	$100,000	$20,000	$120,000	$18,000	$138,000
			x		Replace 4160V Switchgear SG-9	$2,000,000	$400,000	$2,400,000	$360,000	$2,760,000
			x		Replace Panel K1	$6,000	$1,200	$7,200	$1,080	$8,280
			x		Replace Transformer Secondary Breakers and Limehouse Feeder Breaker	$15,000	$3,000	$18,000	$2,700	$20,700
						$0	$0	$0	$0	$0
Korah No. 2 Pump Station										
	x				Install dehumidification equipment (4) and temperature switch	$22,000	$4,400	$26,400	$3,960	$30,360
	x		x		Blast and repaint select areas of process piping and equipment	$10,000	$2,000	$12,000	$1,800	$13,800
	x			4	Conduct pump station hydraulic analysis study	$0	$0	$0	$0	$0

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x			4	Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$0
		x			Provide a password for HMI screen	$0	$0	$0	$0	$2,500
		x			Install door contacts for both doors	$10,000	$2,000	$12,000	$1,800	$13,800
		x			Install bollards to protect garage door	$3,000	$600	$3,600	$540	$4,140
					Replace 4160V Switchgear SG-8	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
					Replace K3-4, K3-4 and K3-5 Drum Controllers	$900,000	$180,000	$1,080,000	$162,000	$1,242,000
					Replace K2-1, K2-2 and K2-3 2-speed starters	$750,000	$150,000	$900,000	$135,000	$1,035,000
					Replace K2-4 and K2-5 Combination Starters	$400,000	$80,000	$480,000	$72,000	$552,000
					Replace MCC-1	$250,000	$50,000	$300,000	$45,000	$345,000
					Replace Panel PB	$12,000	$2,400	$14,400	$2,160	$16,560
					Replace Panel PA	$6,000	$1,200	$7,200	$1,080	$8,280
Korah No. 3 Pump Station										
	x			4	Install dehumidification equipment (4) and temperature switch	$0	$0	$0	$0	$0
	x		x		Blast and repaint select areas of process piping and equipment	$10,000	$2,000	$12,000	$1,800	$13,800
	x			4	Conduct pump station hydraulic analysis study	$0	$0	$0	$0	$0
	x			2	Calibrate or replace pressure gauges	$0	$0	$0	$0	$1,000
	x				Repair concrete pipe supports	$5,000	$1,000	$6,000	$900	$6,900
	x			4	Install floor flood switch	$0	$0	$0	$0	$0
		x		4	Provide a password for HMI screen	$0	$0	$0	$0	$0
		x		4	Install door contacts for both doors	$0	$0	$0	$0	$0
		x		4	Install bollards to protect garage door	$0	$0	$0	$0	$0
					See Korah 2 for Electrical Estimates	$0	$0	$0	$0	$0

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
Byrd Park Reserve Pump Station										
	x				Install dehumidification equipment and temperature switch	$12,000	$2,400	$14,400	$2,160	$16,560
	x		x		Blast and repaint select areas of process piping and equipment and remove graffiti	$10,000	$2,000	$12,000	$1,800	$13,800
	x				Repair leaking butterfly valve	$10,000	$2,000	$12,000	$1,800	$13,800
	x				Provide air gap for pressure relief valve discharge and install corrosion resistant screen	$1,500	$300	$1,800	$270	$2,070
	x				Calibrate or replace pressure gauges and transmitter	$5,000	$1,000	$6,000	$900	$6,900
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x			4	Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$0
		x			Install keycard reader and door contact (3)	$36,000	$7,200	$43,200	$6,480	$49,680
		x			Install security cameras	$30,000	$6,000	$36,000	$5,400	$41,400
	x				Weatherproofing: Reconnect downspouts, replace boarded up door, and provide weatherstripping on wooden double doors	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace 4160V Switchgear SG-4	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
			x		Replace switchgear SG10	$750,000	$150,000	$900,000	$135,000	$1,035,000
			x		Replace R1, R2, R3 and R4 4160V motor starters	$1,000,000	$200,000	$1,200,000	$180,000	$1,380,000
			x		Replace 480/277V panel MP	$12,500	$2,500	$15,000	$2,250	$17,250
			x		Replace 120/208V panel RP	$6,000	$1,200	$7,200	$1,080	$8,280
Byrd Park Main Pump Station										
	x				Conduct HVAC analysis study	$0	$0	$0	$0	$30,000
	x			1	Install air conditioning and/or ventilation	$0	$0	$0	$0	$0
			x	1	Replace electric baseboard heaters	$0	$0	$0	$0	$0
	x			1	Install dehumidifcation equipment	$0	$0	$0	$0	$0
	x			1	Install temperature switch for building	$0	$0	$0	$0	$0

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
	x		x		Blast and repaint walls, floors, ceilings, and process equipment	$125,000	$25,000	$150,000	$22,500	$172,500
	x				Install floor flood switch	$50,000	$10,000	$60,000	$9,000	$69,000
	x			4	Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$0
		x			Install keycard reader and door contact (2)	$24,000	$4,800	$28,800	$4,320	$33,120
		x		4	Install security cameras	$0	$0	$0	$0	$0
			x		Repair spalled concrete on exterior of building	$15,000	$3,000	$18,000	$2,700	$20,700
			x		Replace wooden double door	$15,000	$3,000	$18,000	$2,700	$20,700
			x		Replace hollow metal double door	$15,000	$3,000	$18,000	$2,700	$20,700
			x		Replace windows	$150,000	$30,000	$180,000	$27,000	$207,000
			x		Replace 4160V Switchgear SG-5	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000
		x			Replace MCC and associated P1, P2 and P3 starter	$1,500,000	$300,000	$1,800,000	$270,000	$2,070,000
			x		Replace 120/208V Panels A and B	$12,000	$2,400	$14,400	$2,160	$16,560
			x		Replace lighting	$30,000	$6,000	$36,000	$5,400	$41,400
Trafford Pump Station										
	x		x		Blast and repaint process piping, exterior crane, and exterior railing	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace T1 pump and motor	$300,000	$60,000	$360,000	$54,000	$414,000
			x		Replace windows and screens	$25,000	$5,000	$30,000	$4,500	$34,500
		x			Install keycard readers and door contacts (2)	$24,000	$4,800	$28,800	$4,320	$33,120
	x				Install dehumidification equipment and temperature switch	$12,000	$2,400	$14,400	$2,160	$16,560
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x			4	Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$0
			x		Replace 34.5kV switchgear SG-1	$2,500,000	$500,000	$3,000,000	$450,000	$3,450,000
			x		Replace 4160V switchgear SG-2	$1,500,000	$300,000	$1,800,000	$270,000	$2,070,000
			x		Replace 4160V switchgear SG-3	$1,200,000	$240,000	$1,440,000	$216,000	$1,656,000

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
	x				Dispose of unused control panels	$2,000	$400	$2,400	$360	$2,760
			x		Replace (2) 480V panels	$25,000	$5,000	$30,000	$4,500	$34,500
			x		Replace (2) 120/240V panels	$12,000	$2,400	$14,400	$2,160	$16,560
			x		Replace lighting	$30,000	$6,000	$36,000	$5,400	$41,400
	x				Migrate controls and remove existing control panel	$20,000	$4,000	$24,000	$3,600	$27,600
		x			Remove existing abandoned wiring and equipment	$48,000	$9,600	$57,600	$8,640	$66,240
Columbus Pump Station										
	x				Install dehumidificaiton equipment and temperature switch	$12,000	$2,400	$14,400	$2,160	$16,560
	x				Blast and repaint areas of the process piping and exterior wall	$15,000	$3,000	$18,000	$2,700	$20,700
	x			4	Modify SCADA controls to make pump operation automated	$0	$0	$0	$0	$0
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x				Regrade site to prevent runoff from draining onto building	$20,000	$4,000	$24,000	$3,600	$27,600
		x			Provide a password for HMI screen	$2,500	$500	$3,000	$450	$3,450
		x			Install keycard readers and door contacts (3)	$36,000	$7,200	$43,200	$6,480	$49,680
		x			Install security cameras	$30,000	$6,000	$36,000	$5,400	$41,400
Westhampton Pump Station										
	x		x		Remove unused/unwanted equipment	$5,000	$1,000	$6,000	$900	$6,900
	x				Install dehumidification equipment and temperature switch	$12,000	$2,400	$14,400	$2,160	$16,560
	x		x		Blast and repaint wooden fascia, door, and remove graffiti	$15,000	$3,000	$18,000	$2,700	$20,700
	x			4	Conduct pump station hydraulic analysis study	$0	$0	$0	$0	$0
	x				Install floor flood switch	$5,000	$1,000	$6,000	$900	$6,900

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
		x			Install keycard reader and modify existing door contact to alarm in SCADA	$12,000	$2,400	$14,400	$2,160	$16,560
		x			Install security fencing	$24,000	$4,800	$28,800	$4,320	$33,120
		x			Install security cameras	$30,000	$6,000	$36,000	$5,400	$41,400
	x				Light fixture replacement	$500	$100	$600	$90	$690
		x			Site Lighting	$2,500	$500	$3,000	$450	$3,450
	x				Conduit/Junction box upgrades	$500	$100	$600	$90	$690
Jahnke Pump Station										
	x				Install dehumidification equipment and temperature switch	$12,000	$2,400	$14,400	$2,160	$16,560
	x		x		Blast and repaint doors and frames and areas of process piping	$20,000	$4,000	$24,000	$3,600	$27,600
	x				Modify SCADA controls to operate pump station off Hioaks Tank levels	$2,500	$500	$3,000	$450	$3,450
	x		x		Replace existing floor flood switch	$5,000	$1,000	$6,000	$900	$6,900
	x		x		Replace existing J1, J2, and J3 pump discharge valves (3)	$120,000	$24,000	$144,000	$21,600	$165,600
	x			4	Conduct pump station hydraulic analysis study	$0	$0	$0	$0	$0
		x			Install keycard reader and door contact	$12,000	$2,400	$14,400	$2,160	$16,560
		x			Install security fencing	$31,000	$6,200	$37,200	$5,580	$42,780
		x			Install security cameras	$30,000	$6,000	$36,000	$5,400	$41,400
	x		x		Install waterproofing barrier around foundation and install foundation drain and sump pump	50,000.00	10,000.00	60,000.00	9,000.00	69,000.00
	x				Install magnetic flow meters (3)	90,000.00	18,000.00	108,000.00	16,200.00	124,200.00
			x		Switchgear replacement	1,200,000.00	240,000.00	1,440,000.00	216,000.00	1,656,000.00
			x		Motor starter replacement	300,000.00	60,000.00	360,000.00	54,000.00	414,000.00
		x			Conduit/Receptacle replacement	25,000.00	5,000.00	30,000.00	4,500.00	34,500.00
			x		Control Panel replacement	100,000.00	20,000.00	120,000.00	18,000.00	138,000.00

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
Huguenot Pump Station										
	x				Install dehumidification equipment and temperature switch	12,000.00	2,400.00	14,400.00	2,160.00	16,560.00
	x		x		Blast and repaint areas of process piping	2,500.00	500.00	3,000.00	450.00	3,450.00
	x				Install floor flood switch	5,000.00	1,000.00	6,000.00	900.00	6,900.00
	x			4	Conduct pump station hydraulic analysis study	0.00	0.00	0.00	0.00	0.00
	x				Modify SCADA controls to make pump operation automated	2,500.00	500.00	3,000.00	450.00	3,450.00
		x			Install security fencing	28,500.00	5,700.00	34,200.00	5,130.00	39,330.00
		x			Install keycard readers and door contacts (2)	24,000.00	4,800.00	28,800.00	4,320.00	33,120.00
		x			Install security cameras	30,000.00	6,000.00	36,000.00	5,400.00	41,400.00
			x		Line Control Center replacement	500,000.00	100,000.00	600,000.00	90,000.00	690,000.00
			x		Panelboard and step down transformer replacement	12,000.00	2,400.00	14,400.00	2,160.00	16,560.00
Church Hill Pump Station										
	x				Install dehumidification equipment and temperature switch	12,000.00	2,400.00	14,400.00	2,160.00	16,560.00
	x				Connect existing floor flood switch to SCADA	4,000.00	800.00	4,800.00	720.00	5,520.00
		x			Intall keycard readers and door contacts (2)	24,000.00	4,800.00	28,800.00	4,320.00	33,120.00
	x		x		Blast and repaint areas of process piping	2,500.00	500.00	3,000.00	450.00	3,450.00
			x		SB1-4B replacment	250,000.00	50,000.00	300,000.00	45,000.00	345,000.00
			x		DPC control panel replacement	100,000.00	20,000.00	120,000.00	18,000.00	138,000.00
Cofer Road Pump Station										
	x				Install dehumidification equipment and temperature switch	12,000.00	2,400.00	14,400.00	2,160.00	16,560.00
	x				Install floor flood switch	5,000.00	1,000.00	6,000.00	900.00	6,900.00
		x			Provide a password for the controls computer	0.00	0.00	0.00	0.00	2,500.00
		x			Install keycard readers and door contacts (2)	24,000.00	4,800.00	28,800.00	4,320.00	33,120.00
		x			Install security cameras	30,000.00	6,000.00	36,000.00	5,400.00	41,400.00

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
			x		MCC replacement	500,000.00	100,000.00	600,000.00	90,000.00	690,000.00
	x				Corroded conduit replacement	5,000.00	1,000.00	6,000.00	900.00	6,900.00
		x			Substation security improvements	50,000.00	10,000.00	60,000.00	9,000.00	69,000.00
Ginter Park Elevated Tank										
	x				Cut unused cable brackets	10,000.00	2,000.00	12,000.00	1,800.00	13,800.00
		x			Weather-rated enclosure for electrical equipment (with locks)	5,000.00	1,000.00	6,000.00	900.00	6,900.00
Woodside Elevated Tank										
	x		x		Blast and repaint vault process piping	20,000.00	4,000.00	24,000.00	3,600.00	27,600.00
		x			Weather-rated enclosure for electrical equipment (with locks)	5,000.00	1,000.00	6,000.00	900.00	6,900.00
Warwick Road Elevated Tank										
	x		x		Blast and repaint process piping	20,000.00	4,000.00	24,000.00	3,600.00	27,600.00
		x			Install railing to protect interior vault	10,000.00	2,000.00	12,000.00	1,800.00	13,800.00
	x				Install pipe supports	8,500.00	1,700.00	10,200.00	1,530.00	11,730.00
	x				Cut unused cable brackets	10,000.00	2,000.00	12,000.00	1,800.00	13,800.00
	x				Fix panelboard enclosure	1,000.00	200.00	1,200.00	180.00	1,380.00
		x			Install security fencing	34,000.00	6,800.00	40,800.00	6,120.00	46,920.00
		x			Site Lighting	1,500.00	300.00	1,800.00	270.00	2,070.00
Jahnke Road Tank										
	x		x		Complete interior and exterior tank coatings rehabilitation	1,123,100.00	224,620.00	1,347,720.00	202,158.00	1,549,878.00
	x		x		Blast and repaint vault process piping (3)	60,000.00	12,000.00	72,000.00	10,800.00	82,800.00
	x				Regrade tank site	20,000.00	4,000.00	24,000.00	3,600.00	27,600.00
	x				Electrical equipment upgrades in vault	10,000.00	2,000.00	12,000.00	1,800.00	13,800.00
Hioaks Elevated Tank										
	x		x		Blast and repaint areas of process piping	2,500.00	500.00	3,000.00	450.00	3,450.00
	x				Fix communications equipment mounting	2,000.00	400.00	2,400.00	360.00	2,760.00

	Area of Concern									
	Operations	Safety	End of Life	Note	Improvement Item	Est Const. Cost	20% Contingency	Total Const. Cost	15% Engineering	Budget Cost
Huguenot Road Tank										
	x		x		Blast and repaint vault process piping (2)	40,000.00	8,000.00	48,000.00	7,200.00	55,200.00
	x		x		Repair drainage structure	5,000.00	1,000.00	6,000.00	900.00	6,900.00
		x		4	Install security fencing	0.00	0.00	0.00	0.00	0.00
Total Estimated Project Cost						23,053,100.00	4,610,620.00	27,663,720.00	4,149,558.00	31,977,278.00

1 - Cost and scope should be refined by additional study/evaluation

2 - Work may be performed in-house

3 - Some or all of the recommended project improvements may be covered in City's current projects

4 - Cost included with another recommendation

Figures

Building a Better World for All of Us®

Sustainable buildings, sound infrastructure, safe transportation systems, clean water, renewable energy, and a balanced environment. Building a Better World for All of Us communicates a company-wide commitment to act in the best interests of our clients and the world around us.

We're confident in our ability to balance these requirements.

JOIN OUR SOCIAL COMMUNITIES