J.D. KLINE WATER SUPPLY PLANT DISINFECTION INTERRUPTION – AFTER INCIDENT REPORT

September 19, 2024

Contents

Chapter 1 Introduction **3**

1.1 Background 3

1.2 Objectives and Scope 3

1.3 Sources of Information 3

Chapter 2 J.D. Kline Water Supply Plant **4**

2.1 Process Overview and Service Area 4

2.2 Minimum Treatment Requirements 7

2.2.1 Achieving Primary Disinfection at the JDKWSP 7

2.3 Electrical Service Overview 9

Chapter 3 After Incident Investigation **10**

3.1 Incident Description 10

3.2 Underlying Causes Leading to Boil Water Advisory 13

3.2.1 Cause #1: Mechanical and Electrial Failures 13

3.2.2 Cause #2: Fundamental Design Constraints 14

3.2.3 Other Compounding Factors 15

Chapter 4 Recommended Corrective Measures and Progress Status **16**

LIST OF TABLES

Table 3-1: Detailed event timelines on July 1st, 2024. 11

Table 4-1: Summary of recommended corrective measures 17

LIST OF FIGURES

Figure 2-1: A map of the area served by the JDKWSP indicated in red. This area was impacted by the boil water advisory on July 1st, 2024. 4

Figure 2-2: Aerial Photograph of the JDKWSP indicating the low lift pump station and the main facility building. 5

Figure 2-3: Treatment Plant schematic of the JDKWSP. 6

Figure 2-4: Simplified diagram showing primary disinfection process schematic and CT for the JDKWSP. .. 8

Chapter 1 INTRODUCTION

1.1 Background

On the afternoon of July 1st, 2024, an internal electrical issue occurred at the J.D. Kline Water Supply Plant (JDKWSP). As a result, backup safety systems at the low lift pump station were engaged that are designed to prevent damage to equipment and/or ensure fire suppression. These safety systems isolated power at the facility and during this electrical failure, prevented the main emergency generator from engaging. Additionally, the secondary, (auxiliary) generator located in the main treatment facility building, and that is designed to bridge the time between an external power (utility) outage and the primary emergency generator, failed. This then caused a loss of power to the main treatment facility building and the chlorination system.

As a result, for a sixteen (16) minute period, water did not have the final disinfection treatment with chlorine before leaving the JDKWSP. While all other treatment requirements were being met at the time, based on regulatory requirements and discussions and direction from NSECC, Halifax Water issued a boil water advisory.

1.2 Objectives and Scope

This report provides a post-incident review of what occurred on July 1st, 2024, and looks at the circumstances that lead to the release of unchlorinated filtered water from the JDKWSP into the Halifax Water distribution system and the subsequent boil water advisory. Specifically, this report will:

- Provide background information pertinent to the disinfection interruption incident review.
- Discuss regulatory framework requirements related to disinfection.
- Outline the sequence of events that occurred on July 1st, 2024, resulting in a boil water advisory.
- Identify underlying causes leading to the disinfection interruption.
- Provide recommendations for corrective measures.

This report covers the incident on July 1st, 2024, up to the issuance of the boil water advisory.

1.3 Sources of Information

The following sources of information were used in the preparation of this report:

- Nova Scotia Environment - Approval for Operation – Water Treatment Facility Approval No 2008-061444-09 PID # 00330985
- Nova Scotia Treatment Standards for Municipal Drinking Water Systems
- Operational plant logs
- Real time operational data from the JDKWSP
- Discussions with Halifax Water staff
- Standard operating procedures for the JDKWSP
- Technical reports:
    - Report on Halifax-Dartmouth Regional Water Supply – Canadian-British Engineering Consultants Limited (1970)
    - Chain Lake Emergency Source of Supply, Pre-Design Engineering Report, Pockwock Regional Water Supply – CBCL Limited (1979)

Chapter 2 J.D. Kline Water Supply Plant

2.1 Process Overview and Service Area

The JDKWSP serves approximately 201,000 customers in the communities of Beaver Bank, Middle and Lower Sackville, Hammonds Plains, Bedford, Halifax, Timberlea, Spryfield, Portions of Fall River, Windsor Junction and Herring Cove (Figure 2-1). Commissioned in 1977, the plant produces an average daily flow of approximately 85 ML/D (22.5 MGD) with a design capacity of 220 ML/D (58 MGD) and is the largest water supply plant in Atlantic Canada. Based on the source water quality at the time of design, the facility was designed as a direct filtration plant with raw water sourced from Pockwock Lake. The JDKWSP has two main buildings – the low lift pump station, and the main treatment facility building (Figure 2-2).

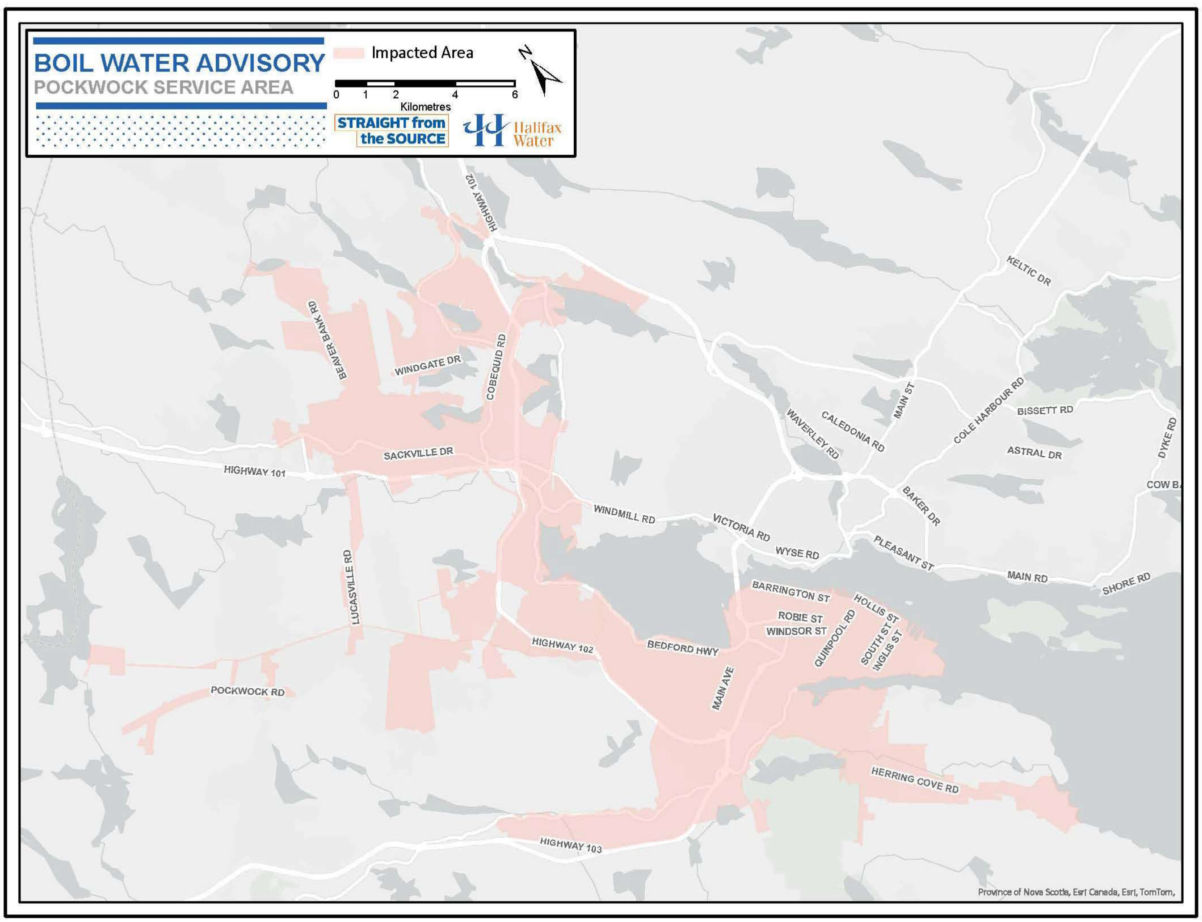

Figure 2-1: A map of the area served by the JDKWSP indicated in red. This area was impacted by the boil water advisory on July 1st, 2024.

Figure 2-2: Aerial Photograph of the JDKWSP indicating the low lift pump station and the main treatment facility building.

The low lift pump station is equipped with intake and screening equipment, six (6) vertical raw water turbines and an electrical room. Raw water is pumped from the low lift pump station to the main treatment facility building which consists of direct filtration (coagulation, hydraulic flocculation, granular media filtration) followed by chlorination for primary disinfection (Figure 2-3).

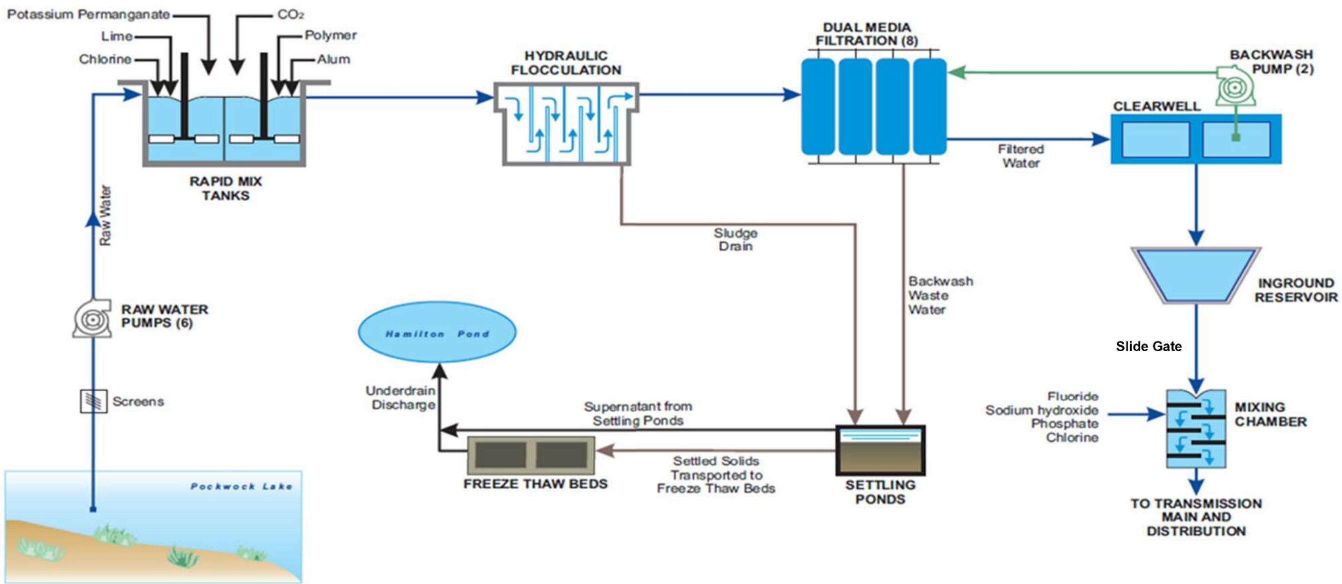

Figure 2-3: Treatment schematic of the JDKWSP.

2.2 Minimum Treatment Requirements

The minimum treatment requirements for an Approval Holder of a Municipal Drinking Water Supply in Nova Scotia are described in *Nova Scotia Treatment Standards for Municipal Drinking Water Systems (June 2022), Nova Scotia Environment and Climate Change.* These minimum standards must be met to achieve compliance with the health-based treatment guidelines in accordance with Health Canada's Guidelines for Canadian Drinking Water Quality, as amended from time to time.

These requirements are described based on the type of source water and type of treatment technology. The JDKWSP is a direct filtration plant using a surface water source (Pockwock Lake). The facility uses free chlorine for primary disinfection. As such, the following overall general treatment is required per the Treatment Standards:

- Through both engineered filtration and disinfection, a minimum treatment efficiency:
    a. 3.0-log reduction for protozoa (Giardia and Cryptosporidium), and
    b. 4.0-log reduction for viruses,

At the JDKWSP, primary disinfection, through the use of chlorine, shall achieve a minimum of 0.5-log inactivation for Giardia when used in conjunction with filtration. The JDKWSP also requires a minimum 3.0-log inactivation for viruses to be achieved by disinfection with chlorine.

The effectiveness of a chemical disinfectant is based on the residual concentration, water temperature, pH and contact time (the time that the given disinfectant residual is held before the first service connection). This relationship is commonly referred to as CT Disinfection. CT is simply the product of the residual concentration of the disinfectant (C) measured in mg/L and the disinfectant contact time (T) measured in minutes. CT Disinfection is the water treatment industry standard for disinfection and is a requirement of Nova Scotia's Treatment Standards to ensure water provided to customers is safe. Failure to provide either adequate disinfectant concentration or contract time may result in the failure to achieve minimum treatment requirements to achieve primary disinfection.

2.2.1 Achieving Primary Disinfection at the JDKWSP

The JDKWSP was constructed in the 1970's to allow gravity flow through the treatment facility via the multimedia filters into the hydraulically connected clear wells and facility reservoir, and then consolidated into the treated water mixing chamber where chlorination occurs prior to leaving the plant through the finished water conduit into the transmission main (1500mm) to Halifax. There is no storage of chlorinated water onsite, and therefore chlorination at the outlet mixing chamber is always required to achieve primary disinfection. Primary disinfection is achieved in the finished water conduit at the treatment plant and in the transmission main between the facility and the first customer (Figure 2-4).

The original design narrative from the 1970's for the JDKWSP indicated that in the event a shutdown was required, a 1500mm cast iron slide gate located prior to the treated water mixing chamber could isolate treated water in the clear wells and prevent water flow to the city, and that water would be provided to customers from distribution system storage in the event of a shutdown. This gate is not operational and using it would impose significant risk as there are now several developments serviced directly from the transmission main. These developments introduced the functional requirement to have no isolation of flow from the plant.

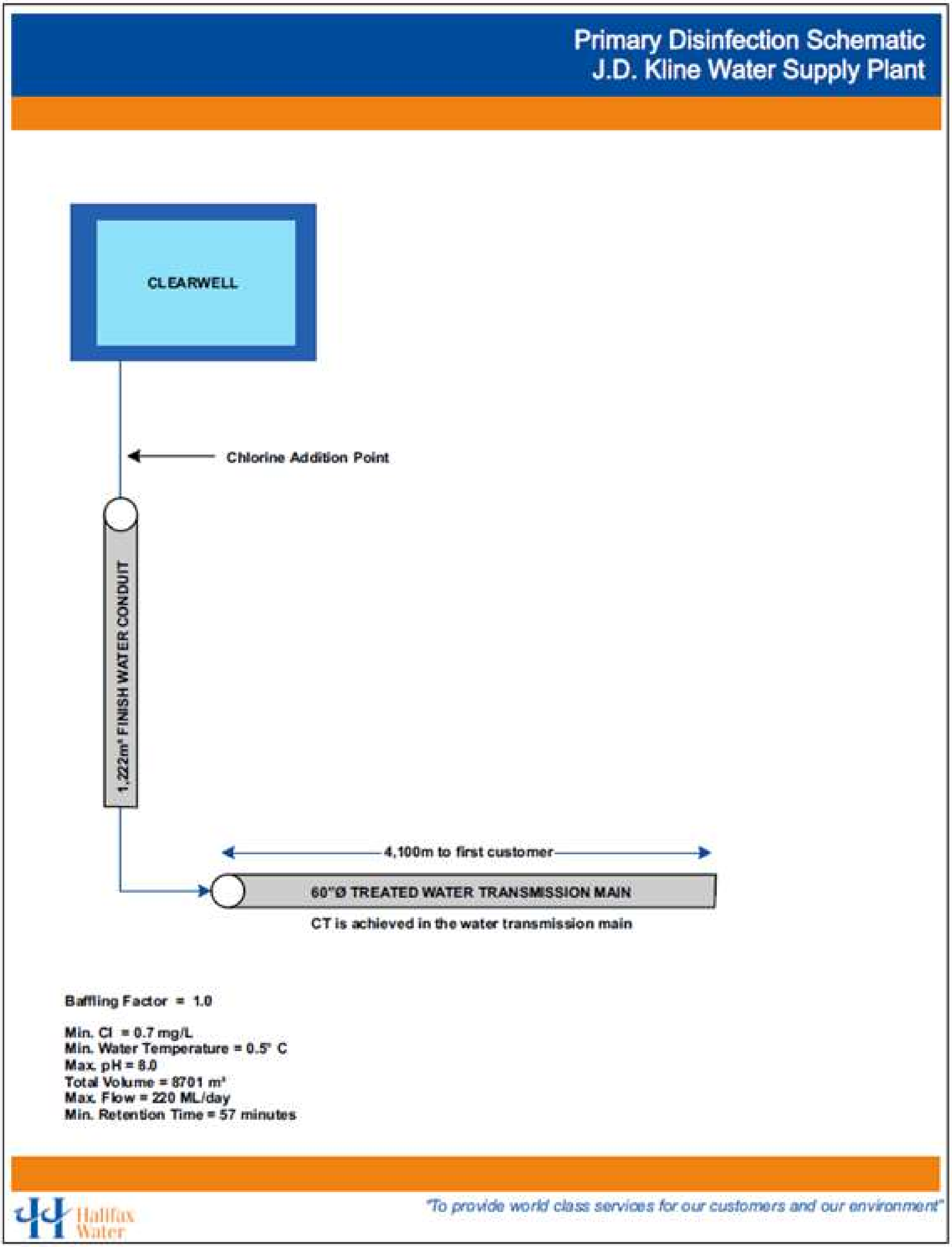

Figure 2-4: Simplified diagram showing primary disinfection process schematic and CT for the JDKWSP.

2.3 Electrical Service Overview

The JDKWSP receives electricity from Nova Scotia Power through high voltage overhead lines to a pad-mounted transformer and an eight-cell medium voltage distribution switchgear system. This switchgear system is composed of electrical disconnect switches, fuses or circuit breakers, and generator panels, that are designed to protect and isolate electrical equipment to the low lift pump station and the main power feed to the treatment facility.

The external Nova Scotia Power feed enters the low lift pump station and power is subsequently routed from the low lift pump station to the main treatment facility through switchgear via an overhead distribution line where the voltage is stepped down feeding a motor control center (MCC) located at the main treatment facility. A diesel standby generator located at the low lift pump station provides standby power in the event of loss of utility power to the switchgear. The main treatment facility is equipped with a diesel standby generator (referred to as “auxiliary generator”) in the event there is an interruption of the power feed from the low lift switchgear. The auxiliary generator is designed to provide temporary power in the event of a power interruption as all plant power, including the main generator, is routed through the low lift pump station. Figure 2-5 provides a simplified schematic of the power flow to both buildings.

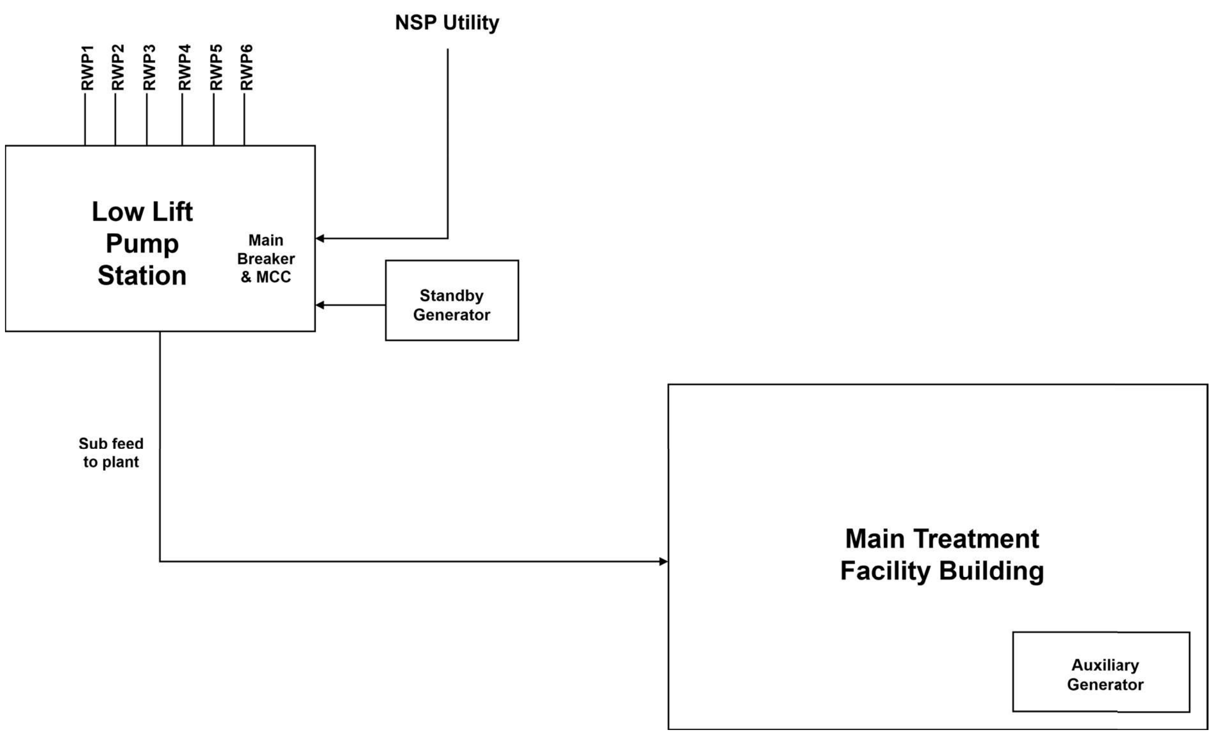

Figure 2-5: Simplified overview of power flow and relevant electrical components at the JDKWSP.

Chapter 3 AFTER INCIDENT INVESTIGATION

3.1 Incident Description

Midday of July 1st, 2024, operations staff were conducting routine work, managing water plant flow demands through the industrial control system to conduct a routine switch from the operation of raw water pump #2 (RWP2) to raw water pump # 1 (RWP1). During this switch, RWP1 faulted during start-up, which resulted in an immediate loss of power at both the low lift pump station and the main treatment facility building.

Under the normal operation sequence during a power failure of the Nova Scotia Power feed, the standby generator located at the low lift pump station would come online and restore power to both locations. However, power remained offline at the low lift pump station and the immediate cause of the outage was not known at the time. When this occurred, staff attempted to manually engage the standby generator at the low lift pump station, however it did not come online because there was no disruption to the Nova Scotia Power feed.

During the power disruption at the low lift pump station, the auxiliary generator located at the main treatment facility building immediately restored power per its design, and allowed controls, operational, and treatment requirements to be maintained.

However, after approximately 30 minutes, this generator triggered its overtemperature alarm and shut down. Power was subsequently lost at the main treatment facility building and all associated systems including the primary chlorination equipment were without power.

Staff immediately began to initiate the standard operating procedures for the emergency chlorination process. Throughout this period, filtered unchlorinated water from the plant entered the distribution system. This is because water from the clear well cannot be operationally isolated from the distribution system, as described in Section 2.2.1. This resulted in a failure to achieve primary disinfection.

Staff connected the portable gas generator used to power emergency chlorination equipment, already located onsite, to restore chlorination to the finished water. It should be noted that all other treatment requirements at the time were met, and the water was fully treated aside from primary disinfection. Staff also implemented operational adjustments to the distribution system to minimize the amount of water leaving the facility.

As outlined in Section 5.1 (4) of the Guidelines for Monitoring Public Drinking Water Supplies Part I – Municipal Public Drinking Water Supplies (October 2021), Nova Scotia Environment and Climate Change:

> *Section 5.1 Deficiencies that require a boil water advisory include*
>
> > *(4) lack of disinfection (i.e., all systems) or failure of a key water treatment process (e.g. filtration process for systems relying on surface water or GUDI sources).*

Based on the loss of primary disinfection on July 1st, 2024, the scenario described in Section 5.1 (4) required the issuance of a boil water advisory.

The advisory was issued before the unchlorinated water reached the first customer in the distribution system. A detailed account of the events that led to the issuance of the boil water advisory on July 1st, 2024, is provided below in Table 3-1.

Table 3-1: Detailed event timelines on July 1st, 2024.

Time	Description
12:28 to 13:04	The Duty Operator used the industrial control system to start raw water pump #1. The pump immediately failed to start and power to the low lift pump station and the main treatment facility building was interrupted. The Duty Operator immediately called the Facility Supervisor, who instructed them to call both the On-Call Operator and the On-Call Electrician for assistance on-site. The Supervisor proceeded to the treatment facility to assist. The auxiliary generator immediately started and restored power to the main treatment facility building but the low lift pump station was still without power. The primary chlorination system was still operational at this time.
13:04	The Duty Operator reported to the Facility Supervisor that the auxiliary generator stopped working and all associated systems were without power. Primary disinfection of treated water goes offline. The Facility Supervisor instructed the Duty Operator to engage the emergency chlorination equipment immediately.
13:05 to 13:20	The Duty Operator and the On-Call Operator activate the portable gas generator located onsite and engage the emergency backup chlorination system as per the Standard Operating Procedure.
13:20	Primary disinfection of treated water is restored using the emergency backup chlorination system.
13:30 to 13:35	The Facility Supervisor informs the Director of Operations of the situation. Manager of Distribution (West) is contacted to aid in limiting flow from the plant to the city and to help manage the distribution system.
13:35 to 13:52	Facility staff work with electricians to restore power to the facility. The On-Call Electrician in consultation with the facility's regularly assigned Electrician restored utility power to the low lift pump station and main facility by resetting the main utility breaker following facility safety protocols. On-Call Electrician then investigates the auxiliary generator failure at the main treatment facility building and discovered a water coolant alarm which indicated that the generator faulted out on high coolant water temperature due to a failed solenoid valve. The cooling water by-pass valve was opened by the Facility Supervisor to restore the auxiliary generator to standby status.
13:52	The Facility Supervisor was informed that power had been restored to the main treatment facility building and that the auxiliary generator was back to standby status.
13:55 to 14:00	Raw water pump #5 was started and water flow was restored to the treatment process. The primary disinfection chlorination system was verified for correct operation and was restored. The emergency chlorination system remained operational at this time to provide continuity of chlorination in case of further unforeseen complications.

	Raw water flow was rotated to pump #4 as part of routine operations.
14:21 to 15:33	Raw water flow was rotated to pump #2 to manage water demands. Facility staff continued to assess cause of outage at the low lift pumping station.
15:33 to 15:35	At this point, the root cause of the initial outage was still unknown. With both electricians on site, raw water pump #1 was started to test whether it was operational or the root cause of the outage. When raw water pump #1 was given a start command, the main power feed was once again interrupted to the pumping station and treatment facility. The auxiliary generator at the main facility ran normally and primary chlorination system remained operational.
15:40	Facility Supervisor updated the Director of Operations.
15:43	Staff electricians restored utility power by resetting the main breaker at the pumping station. It was theorized that raw water pump #1 was the cause of the outage.
15:45	Lack of primary disinfection occurrence was reported by the Facility Supervisor to Halifax Water's Regulatory Compliance Department through the reporting process as outlined in standard operating procedures.
15:45 to 15:55	Water Quality Program Supervisor who was on call, reported the lack of primary disinfection to the Acting Director of Regulatory Services. Water Quality Program Supervisor also reported the situation to NSECC through the after-hours protocols.
15:49 to 16:25	Acting Director of Regulatory Services, Acting General Manager, Director of Operations and Acting West Water Operations Manager commence a call to assess the situation and discuss ways to mitigate the impact of unchlorinated water in the system (e.g., flushing, isolating areas of the system). It was determined that no type of operational intervention could occur that would ensure the unchlorinated water would not reach customers.
16:25	Halifax Water Communications are notified, and communications materials and alerts are developed for a Boil Water Advisory.
16:40 to 16:52	Due to failure to achieve primary disinfection, and the requirements outlined in the *Guidelines for Monitoring Public Drinking Water Supplies* to issue a boil water advisory under these circumstances, further attempts are made to contact NSECC directly. The NSECC Duty Inspector was reached and took the information. After discussion, it was determined they would try to get someone to respond to us quickly.
16:57	Attempts to reach senior staff within NSECC continue due to the nature of the event. The Interim Director of the Water Branch of Applied Science Division of NSECC is reached by phone and given information to determine course of action.
17:21	Interim Director of Water Branch NSECC calls to confirm that a Boil Water Advisory needs to be issued for the entire Pockwock System.
18:00	A Public Service Announcement (PSA) announcing the boil water advisory was distributed to news media outlets and other key stakeholders via email and on social media. Additionally, HRM redistributed the PSA on its HFXAlerts system and used its social media channels to amplify the message.

	Note: At this time, the unchlorinated water had moved approximately 5 km down the transmission main and not yet reached the first service connection.
18:02	Small Systems Supervisor is contacted to increase dose in re-chlorination stations in the Pockwock system by 0.2 mg/l as a precaution. The doses were changed remotely.
19:30	Halifax Water was notified that the provincial alert system was available for this type of event. Staff learned the parameters and approvals process for this system and began developing an effective alert based on the delivery platform (mobile text alerts).
20:49	Nova Scotia alert issued for the boil water advisory via the Provincial Emergency Management Office.

3.2 Underlying Causes Leading to Boil Water Advisory

3.2.1 Cause #1: Mechanical and Electrial Failures

In response to the electrical problems, a contractor was dispatched to identify any potential issues with motors and/or wiring. It was during this initial inspection that the contractor identified that the electrical insulation on the RWP1 motor failed, causing a ground fault. The RWP1 motor was tested to confirm that the pump insulation was the cause and was removed for repairs.

As a result of the insulation failure, there was a surge in current that then caused the safety systems to be triggered (as designed) to prevent further damage. Each pump has two integrated safety mechanisms, including digital motor protection relays and fuses, and a third layer of protection through the main utility breaker.

However, during this event, the electrical protection coordination failed when the digital motor protection relay and the fuses for RWP1 were not triggered. As designed, the digital motor protection relay is connected to a temperature sensor embedded in the RWP1 motor, but during this incident, there were no temperature alarms generated by the protective relay. The fuses for RWP1 did not detect the surge (e.g., were not blown).

Based on the post-incident inspection, it has been determined that instead of the fuses and digital motor protection relay safety systems engaging, the main utility breaker tripped and isolated the power supply to both the low lift pump station and the main treatment facility building. When this occurred, it took both the low lift pump station and main treatment facility building offline because the power feed for both is located at the low lift pump station, and both loads are downstream of the breaker.

When the ground fault occurred on RWP1 it was significant enough that it tripped the main utility breaker before the other layers of protection could react. The sequence of trip alarms/signals between the digital motor protection relay, fuses and main utility breaker is complex and dated due to varying vintages of equipment technology. As a result, it can have an impact on switching speed and sensitivity, which may have had a role in why the main utility breaker detected the ground fault and tripped before the other layers of protection.

Through a visual inspection, the On-Call Electrician determined that there were no alarms on the standby generator at the low lift pump station. Staff then briefly and unsuccessfully attempted to manually engage this generator. However, even if the generator had started, the power would still have been isolated, as the main utility breaker was open and functioning as designed to prevent the power supply from being restored without a reset. When the On-Call Electrician observed that the lockout safety relay for the station had not tripped, they were able to determine that there was utility power from the Nova Scotia Power grid and that the generator did not engage, because that is how the safety mechanism was designed.

While the standby generator at the low lift pump station did not engage, the auxiliary generator located at the main treatment facility building did start and immediately restored power to that building. However, after running for approximately 30 minutes, the auxiliary generator failed. When the On-Call Electrician visually inspected the automatic transfer switch for the auxiliary generator it appeared to be normal. Further inspection of the auxiliary generator control panel found a water coolant alarm, and it was then determined that the generator faulted out on high coolant water temperature. It was then established that that the cooling water was not circulating because a solenoid valve had failed. While there was a by-pass valve on the auxiliary generator that allows for circulation of cooling water, it was closed, as per routine operation. Upon this observation, staff opened the by-pass valve to allow for coolant water circulation, as per the standard operating procedure.

The main utility breaker was reset by the On-Call Electrician once it was safe to do so. With power restored, operators attempted to start RWP1 remotely to confirm that it was the underlying cause of the power failure. However, this interrupted the power at the low lift pump station once again, but with the by-pass for the cooling water now open the auxiliary generator at the main treatment facility building ran normally.

Based on the issues identified and the solutions used to address them, staff confirmed that the main cause of the incident was the switch over from RWP2 to RWP1 and subsequent insulation failure on RWP1 which led to the main utility breaker for the low lift pump station to trip. With the breaker tripped, the standby generator did not power up the low lift pump station and main treatment facility. This resulted in the auxiliary generator coming online briefly, but quickly overheating and failing due to lack of coolant water from a failed solenoid valve. The combined insulation and solenoid valve failures were a root cause of loss of primary disinfection with chlorine.

3.3 Cause #2: Fundamental Design Constraints

During the incident on July 1st, 2024, flow from the JDKWSP could not shut down to prevent unchlorinated water from entering the distribution system. As currently designed, the JDKWSP has constraints that prevent adequate treated water storage at the facility which directly impacts the ability to shut down without significant interruption to water quantity or quality. As a result, during the incident on July 1st, 2024, staff could not prevent unchlorinated water from entering the distribution system. Staff did however implement operational adjustments to the distribution system to minimize the amount of water leaving the facility.

All treated water in storage at the JDKWSP is unchlorinated. The additional finished water chlorine application only occurs when all filtered water is consolidated into a single mixing chamber before leaving the plant through a finished water conduit. At this point in the process, it is not possible to interrupt flow from the finished water conduit, and chlorination at the outlet mixing chamber is required at all times to achieve primary disinfection and to meet regulatory requirements. Both chlorination and flow, therefore, cannot be interrupted without incurring a significant water quantity or quality event.

Halifax Water's design records indicate that the point of chlorination has not changed since the facility was constructed in the 1970's. The criticality of the location at that time was offset by the fact that flow from the facility was capable of being interrupted at the time if needed through an installed outlet sluice gate.

According to planning and design documents, the Pockwock transmission system was configured with intention of having the JDKWSP connected by transmission primarily to other reservoirs and not directly to customers. By using reservoirs, the utility could store chlorinated water downstream to provide water service to customers and would allow flow leaving the plant to be isolated at any time.

Accordingly, it was also originally intended that if JDKWSP required a shutdown for maintenance, or encountered a failure, that it could be simply shutdown by closing the outlet sluice gate and thereby isolating the plant from city. While this may have been the original intention, this gate valve is no longer operational and closing poses significant risks to the entire system. In the decades since the JDKWSP was constructed, several developments have been serviced directly from the transmission main and introduced the functional requirement to have no isolation of flow from the plant. As a result, the facility has very limited shutdown or disruption window, which has now become a significant constraint.

As a result, isolating the JDKWSP from the city during the event that occurred on July 1st, 2024, was not a viable option to minimize the release of unchlorinated water from entering the Pockwock distribution system.

3.3.1 Other Compounding Factors

In addition to the electrical failures and the fundamental design constraints outlined above, the following factors may have had a compounding effect on the incident response time on July 1st, 2024:

- **Resource Capacity:** The JDKWSP has experienced staff shortages in recent years, resulting in hiring new personnel at the facility. At the time of the event, there were a total of seven (7) water treatment plant operators who work at this facility and one vacant day operator position, with one operator on shift during the incident. There is only one operator onsite at the JDKWSP per shift on evenings, weekends, and holidays, with an additional day operator on-call, which makes response in a complex situation such as this incident a challenge to manage the multiple priorities. The new personnel working at the JDKWSP may not have been exposed to emergency response through experience with past incidents. Exposure to tabletop emergency response exercises happen once per year through Environmental Management System (EMS) requirements. Resource capacity challenges are compounded by the age of the facility and limited historical facility specific knowledge.
- **Standard Operating Procedures (SOP):** Multiple SOPs were needed during the July 1st events; thus, staff were required to consult a number of documents that created an added layer of complexity during critical moments in response. As standalone SOPs, they did not provide sufficient details when several failures occurred simultaneously, and subjective language in certain documents may have compounded the impacts or contributed to delay in response.
- **Communications:** Halifax Water issued the boil water advisory notice prior to the volume of non-disinfected water reaching customers. However, during the incident there were limited staff on site, and those at the facility were focused on stabilizing the incident, which led to a delay in reporting. Communications between the various groups/departments and the regulator (NSECC) could have been more efficient to decrease response timelines.
- **Other:** The emergency lighting at the JDKWSP is designed to facilitate safe exit from the facility during emergencies. During the July 1 events, these lights could not provide sufficient visibility to address issues and added to the challenges in engaging the backup chlorination system and further response to the incident.

Chapter 4 Recommended Corrective Measures and Progress Status

Based on the after-incident review described in this report, several short, medium and long term corrective measures have been recommended to manage risk and improve resiliency at the JDKWSP. Table 4-1 below provides a summary of recommended corrective measures as well as the status at the time this report was prepared.

Table 4-1: Summary of recommended corrective measures.

#	Cause	Corrective Measure	Timeline	Status*
1	Electrical and Mechanical Failures	Assess and conduct repairs as required on raw water pumps and components.	Short term	Raw water pump 1 complete, other pumps ongoing
2	Electrical and Mechanical Failures	Assess the emergency generators.	Short term	Complete
3	Electrical and Mechanical Failures	Install a temporary generator to power the main plant building, replacing the auxiliary generator.	Short term	Complete
4	Electrical and Mechanical Failures	Install standby electrical system to power emergency chlorination equipment, in the event of a complete power failure, to reduce time to initiate the system and remove immediate need for portable gas-powered generator.	Short term	Temporary solution complete, permanent solution ongoing
5	Electrical and Mechanical Failures	Install an uninterrupted power supply (UPS) that will be able to supply power to necessary instrumentation in the event of a power failure.	Short term	Temporary solution complete, permanent solution ongoing
6	Electrical and Mechanical Failures	Conduct thermal scanning of electrical equipment at the low-lift pump station.	Short term	Ongoing
7	Electrical and Mechanical Failures	Assess main incoming power bus and associated utility, emergency breakers, as well as transfer controls. Assess the sequence settings that control the safety systems at the pump station. Re-program the sequence as necessary based on the assessment.	Short term	Ongoing
8	Electrical and Mechanical Failures	Assess layers of engineered protection on raw water pumps and install additional layers as needed.	Short term	Ongoing
9	Other Compounding Factors	Complete formal incident debrief with various levels of staff.	Short term	Ongoing
10	Other Compounding Factors	Increase operator staffing on shift to minimize response time to emergency incidents.	Short/medium term	Ongoing
11	Other Compounding Factors	Review and update SOPs for clarity. Ensure staff understanding through training.	Short/medium term	Ongoing
12	Other Compounding Factors	Conduct emergency exercises to enhance knowledge on response to varying incidents.	Short, medium, and long term	Ongoing

13	Other Compounding Factors	Improve emergency lighting throughout the facility.	Short/medium term	Ongoing
14	Electrical and Mechanical Failures	Install a permanent generator to replace the auxiliary generator.	Medium term	Ongoing
15	Fundamental Design Constraints	Upgrade and increase resiliency of incoming power feed. Consider adding a new, dedicated utility service to the main water supply plant building.	Long term	Ongoing
16	Fundamental Design Constraints	Address fundamental design constraints by provision for adequate treated water storage, and ability to shut down for maintenance or failure conditions, without interruption to water quantity or quality.	Long term	Ongoing

*Ongoing status indicates that corrective measures will be implemented within the short term (6-months), medium term (1-year), and long term (5 to 10 years).