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Town of Culpeper Water System Study

Draft Report
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List of Acronyms

Abbreviation	Definition
AFF	Available Fire Flow
AWWA	American Water Works Association
CCPP	Calcium Carbonate Precipitation Potential
DBP	Disinfection Byproduct
DIC	Dissolved Inorganic Carbon
Gpd	Gallons per day

Abbreviation	Definition
HAA	Haloacetic Acid
HRT	Hydraulic Residence Time
ISO	Insurance Standards
LCR	Lead and Copper Rule
LRAA	Locational Running Annual Average
MCL	Maximum Contaminant Level
MGD	Million gallons per day
MIB	Methylisoborneol
mg/L	Milligrams per liter
PAC	Powdered Activated Carbon
PACl	Polyaluminum Chloride
SF	Square foot
SMCL	Secondary Maximum Contaminant Level
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
UDF	Unidirectional Flushing
USEPA	United States Environmental Protection Agency
WTP	Water Treatment Plant

Executive Summary

In March 2019, the Town of Culpeper (Town) initiated the Water System Assessment project in response to requests from consumers to evaluate water quality and fire flow within the Town's distribution system. The Water System Assessment consists of four primary tasks: (1) the Water System Study; (2) the Fire Flow Study; (3) the Financial Rate Study; and (4) Public Outreach. The results of each task inform the Water System Assessment. This report presents the results of the first task, the Water System Study.

The Water System Study included: (1) reviewing and characterizing the Town's existing water supply system including treatment processes (i.e., surface water facilities and groundwater facilities) and distribution network; (2) reviewing applicable regulatory requirements; (3) evaluating the Town's water quality data; and (4) developing recommendations to improve water quality in the Town, where appropriate. Consumer reports documenting aesthetic water quality concerns at the tap were then compared to the technical analysis and, where appropriate, used to inform the recommendations (see Attachment A).

The study concluded that the Town's water supply is in compliance with current federal regulations pertaining to the purveyance of water. Specifically, the Town's water quality is within primary health-based Maximum Contaminant Levels (MCLs) and treatment requirements as promulgated by the Safe Drinking Water Act, as amended. The Town has experienced occasional levels above secondary guidelines for water supply aesthetics, which can affect water coloration, taste, and odor. The recommendations of this report focus on opportunities to further optimize water treatment and supply to address these issues pertaining to water supply aesthetics.

1. Introduction

The Town of Culpeper (Town) retained Hazen and Sawyer (Hazen) to perform an independent Water System Assessment. The Town of Culpeper initiated the Water System Assessment in March 2019 in response to consumer complaints and concerns regarding water quality and fire flow. The Water System Assessment consists of four primary tasks as shown in **Figure 1-1.**. Those four primary tasks include: (1) the Water System Study; (2) the Fire Flow Study (Attachment D); (3) the Financial Rate Study; and (4) Public Outreach. The results of each task will inform the Water System Assessment. Results from each task inform the Water System Assessment.

The analysis of available Fire Flow has been completed, and the results were presented at the Interim Public Outreach Meeting in August 2019. The Financial Rate Study is currently being completed based on the projects recommended by the Water System Study; a separate technical memorandum will be issued to summarize those findings. Public Outreach has been ongoing since the inception of this Assessment and to date has included two public meetings held on April 11, 2019 and August 20, 2019. Summaries of these meetings are included in Attachment A. The final public meeting will present the findings of this Water System Study. The date for this meeting will be coordinated with the Town.

This report presents the results of the Water System Study task focused on water quality analysis. The updated distribution system hydraulic model developed as part of the Fire Flow Analysis was used to support the analysis of distribution system water quality in the Water System Study. Outcomes of the Water System Study were incorporated into the Financial Rate Study to evaluate financial aspects of water quality recommendations. Findings from the Water System Study will be communicated to the public as part of the Public Outreach task.

This Water System Study included: (1) an evaluation of water treatment and distribution systems; (2) a review of regulatory compliance; (3) an analysis of the Town's water quality data; and (4) development of recommendations to improve water quality aesthetics in the Town, where appropriate. An analysis of the Town's water quality data was performed, including source water, treatment, and distribution system water quality. Consumer reports documenting aesthetic water quality concerns at the tap were characterized and contextualized.

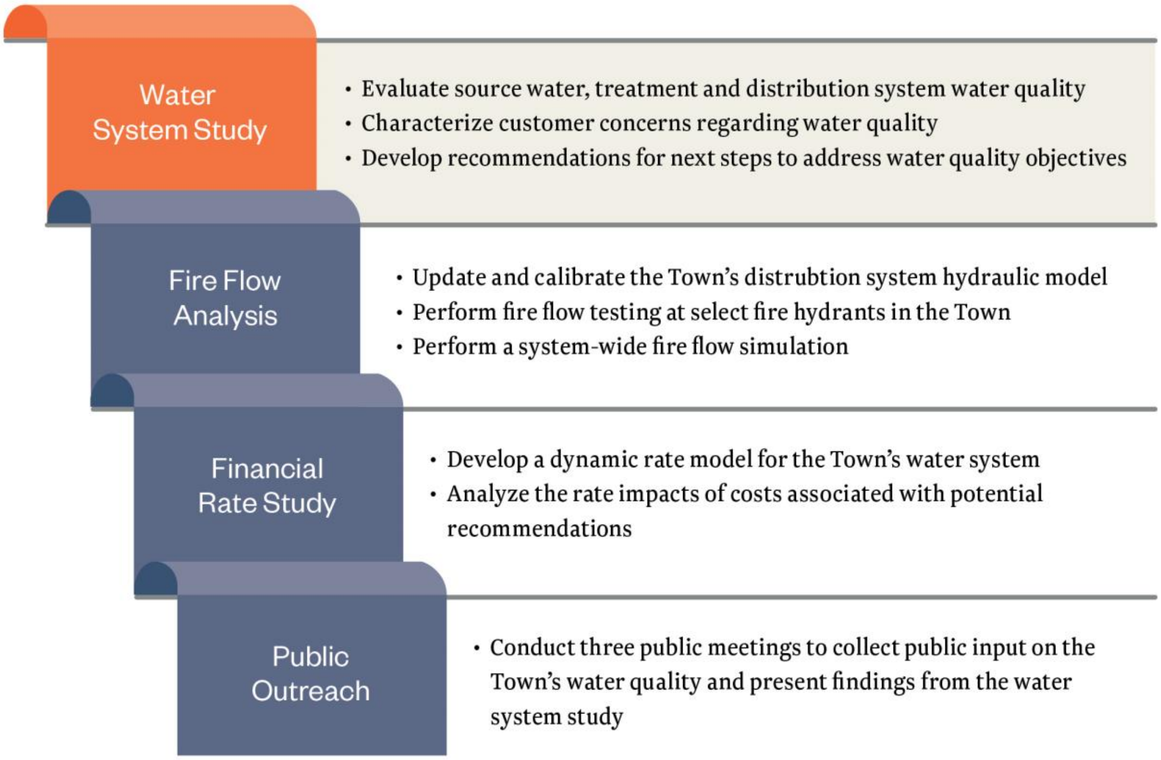

Figure 1-1. Summary of Water System Assessment Tasks and Objectives

1.1 Purpose

The purpose of the Water System Study was to identify and prioritize water quality objectives and develop recommendations to optimize water quality. The primary objectives of the Water System Study include:

- Evaluate and analyze source water, treatment, and distribution system water quality
- Review the water quality results against current regulations to determine the status of compliance
- Characterize and contextualize public concerns regarding water quality
- Develop and prioritize recommendations to address water quality objectives

1.2 Report Organization

This report consists of the following sections:

- **Section 1** – Introduction: This section describes the project background and purpose.

- **Section 2** – Town of Culpeper Water System: This section presents an overview and recent history of the Town's water system, including information on water sources, treatment processes, and the distribution system.
- **Section 3** – Town of Culpeper Drinking Water Quality Analysis: This section presents a summary of the Town's compliance data for primary drinking water regulations. It also presents an analysis of key water quality data related to water quality objectives and secondary drinking water standards affecting water aesthetics.
- **Section 4** – Recommendations: This section presents recommendations for next steps to address water quality objectives. Recommendations were organized into three categories to present near-term optimization recommendations, proactive water quality enhancement strategies, and master planning for the future to enhance water quality.
- **Section 5** – Conclusions: This section summarizes key findings from the Water System Study.

In addition, the study includes the following appendices referenced in the document to provide greater detail on the analysis presented herein:

- Attachment A: Technical Memorandum 1: Town of Culpeper Drinking Water System Evaluation
- Attachment B: Technical Memorandum 2: Town of Culpeper Water Quality Analysis
- Attachment C: Technical Memorandum 3: Town of Culpeper Water Quality Recommendations
- Attachment D: Independent Fire Flow Study

2. Town of Culpeper Water Supply System

This section presents an overview of the Town's water system, including a summary of recent water system initiatives, water supply sources, water treatment facilities, and the water distribution system.

2.1 Town of Culpeper Water Supply System Overview

The Town of Culpeper is an unincorporated town located in Culpeper County, Virginia with a population served by the water system of 17,411. The Town's water supply system consists of a combination of surface water and groundwater supplies and provides approximately 2 million gallons per day (mgd) to consumers. Until 2014, the Town water supply came exclusively from surface waters (i.e., Lake Pelham). Beginning in 2015, the Town began augmenting its surface supply with groundwater to proactively plan for potential future demand and provide water supply resiliency by cultivating an additional water supply source. The groundwater augments supply from the water treatment plant (WTP) and maintains system supply when the WTP is offline. Since 2015, the percentage of groundwater used to meet consumer demands has increased annually.

The Town's major water supply infrastructure is shown in **Figure 2-1.** Surface water is obtained from Lake Pelham and treated at the Town's WTP, which is typically operated daily over a single shift of approximately 12 hours. The WTP treatment process consists of coagulation, sludge blanket clarification, filtration, and disinfection. In addition, the Town operates a groundwater supply network consisting of three facilities – Chandler Street, Nalles Mill, and Rockwater Park. These groundwater facilities include three, two, and one well(s), respectively. The groundwater treatment process includes disinfection, corrosion control, and fluoridation. Treatment processes vary between surface water and groundwater due to the inherent differences in raw water between these two sources.

Once treated, supply from the surface water and groundwater sources are distributed to consumers through over 100 miles of pipe, four storage tanks, and two treated water pumping facilities. One pumping facility is located at the WTP and the other services the Town's high-pressure zone. The majority of the Town's distribution system pipes are ductile iron (73.5%) and cast iron (26%) with smaller portions comprised of galvanized pipe (0.3%) and copper (0.2%).

The water within the distribution networks is a mixture of surface water and groundwater, and the exact ratio of surface water to groundwater varies depending on location within the Town's distribution network. Water sources are monitored, and water quality is tested multiple times per day to ensure an adequate supply of drinking water that meets regulatory requirements.

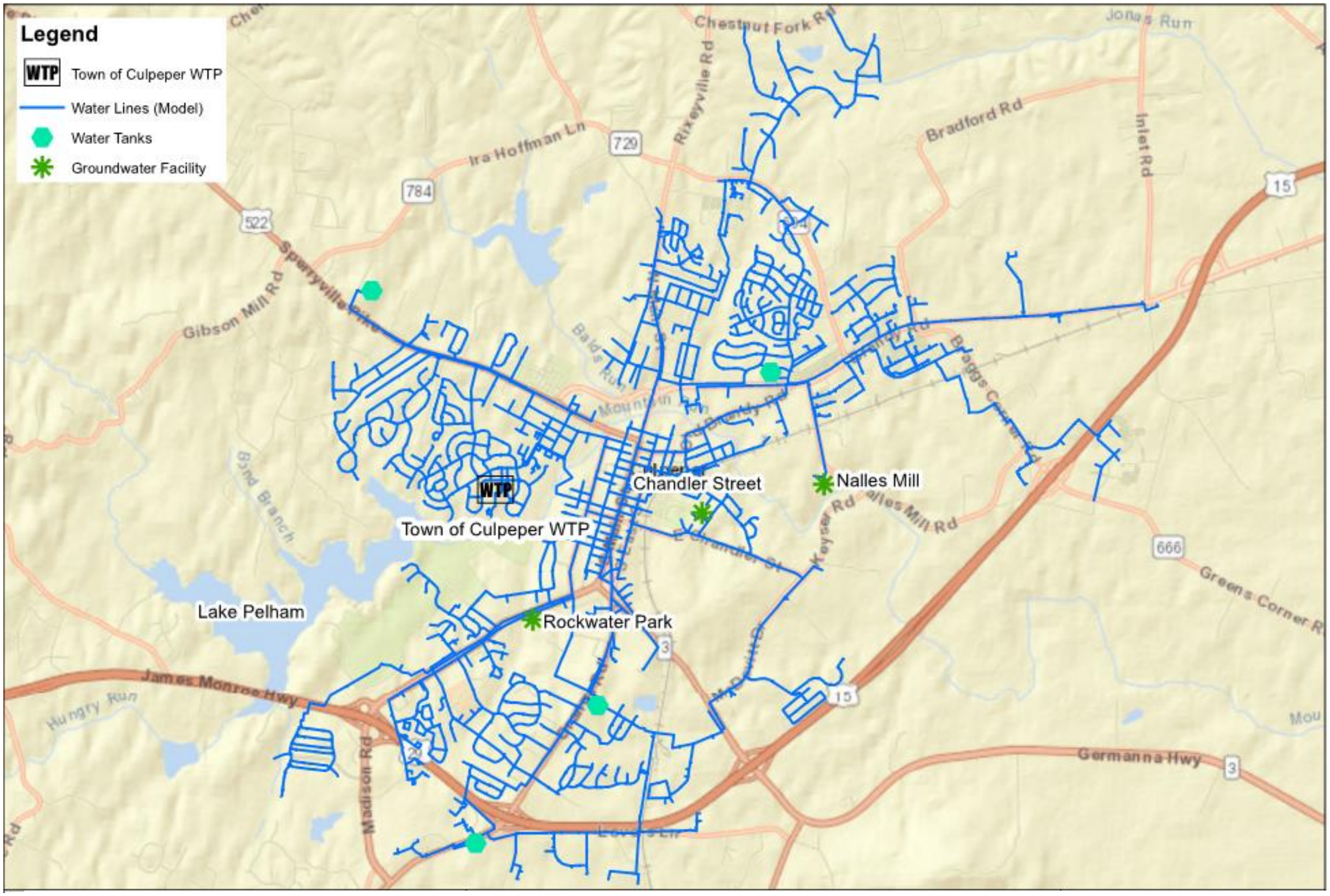

Figure 2-1: Town of Culpeper Water System Overview

2.2 Water Supply System Initiatives

The Town of Culpeper has implemented several water system initiatives over the years focused on maintaining regulatory compliance, protecting public health, operating and maintaining aging infrastructure and facilities, as well as planning for future water supply and capacity needs.

In 2008, the Town joined the American Water Works Association (AWWA) Partnership for Safe Water Program, which has a stated mission to "improve the quality of water delivered to customers by optimizing system operations". The voluntary program consists of treatment process optimization and distribution system optimization to enhance water quality through operational improvements without major capital improvements. The program includes a self-assessment to help utilities identify opportunities for system optimization.

Since joining the Partnership for Safe Water Program, the Town has initiated water system initiatives to improve water supply, system operations, and water quality. **Figure 2-2.** presents a summary of select water system initiatives in the Town since 2008. Key water system initiatives include the following:

- **High Pressure Zone** – In 2013, the Town implemented a high pressure zone in the southern portion of the distribution system to improve pressure and fire flow, and a new storage tank in the high pressure zone was completed in 2018.
- **Groundwater Supply** – In 2015, after years of groundwater well exploration and development, groundwater from Chandler Street wells was introduced into the distribution system to augment the total water supply in the system. In 2018, the Town introduced groundwater from the Nalles Mill and Rockwater Park wells into the distribution system to further increase groundwater capacity. The Town's FY 2018 Regional Water Supply Plan notes that the Town's 2011 Regional Water Supply Plan recommended development of an additional 3 MGD of capacity to meet the Town's growing needs and indicated that groundwater would provide a second source to avoid sole reliance on Lake Pelham. The addition of groundwater provides significant benefits for water supply resiliency in the Town. During drought conditions or periods with adverse water quality in Lake Pelham, groundwater provides a stable and reliable source of water for the Town.
- **Distribution System Operations** – The Town has implemented several initiatives since 2012 to improve distribution system operations. These improvements included painting storage tanks, installing tank mixers, installing dedicated sampling stations, and installing automatic flushing stations. These initiatives are consistent with best practices for distribution system operations. Storage tank mixing can improve water quality consistency and minimize water quality issues in tanks. Dedicated sampling stations are known to provide improved water quality data to manage the system, and automatic flushing stations can be beneficial for controlling water age of certain portions of the distribution system.
- **Treatment Process Optimization** – The Town has implemented a series of water treatment changes to optimize treatment performance and operations. Filter rehabilitation consisting of media replacement and underdrain repairs was completed in 2010. The Town changed the chemical used for pH adjustment from soda ash to lime in 2011 and changed the chemical used for chlorine disinfection from chlorine gas to sodium hypochlorite in 2013. In 2017, the Town

constructed a new chemical facility near Lake Pelham to add potassium permanganate for iron and manganese oxidation. In June 2018, the Town changed the coagulant at the water treatment plant from aluminum sulfate to polyaluminum chloride to improve turbidity removal. Improvements to the polymer chemical feed system at the water treatment plant were implemented in October 2018.

- **Water Main Cleaning** – As corrosion of cast iron mains and release of deposits can affect water discoloration, the Town performed water main cleaning to remove tuberculation and deposits. Finished water from the WTP is conveyed through an 18-inch diameter main towards the downtown area. Due to the size of this finished water main, the velocities needed to clean the pipe cannot be achieved, and alternate mechanical cleaning techniques are needed. In February 2018, the Town implemented a technology known as "ice pigging" which is a variation of the conventional pigging method, for cleaning of the 18-inch diameter finished water main and surrounding pipes where deposits were believed to exist. Ice pigging is a European technology that involves pumping a slurry of ice into a water main to remove sediment from the pipe. The Town found that ice pigging was effective for cleaning of 18-inch and 12-inch diameter mains, although a water main break occurred in the Oaklawn neighborhood during ice pigging, which resulted in service interruptions and discolored water.

- **Lake Pelham Dam Upgrades –** Upgrades to the Lake Pelham dam were completed in 2018 to improve dam safety, flood control, and the raw water intake. Upgrades to the reservoir drain valve near the raw water intake allowed the Town to flush accumulated sediments from the reservoir to improve raw water quality at the intake.

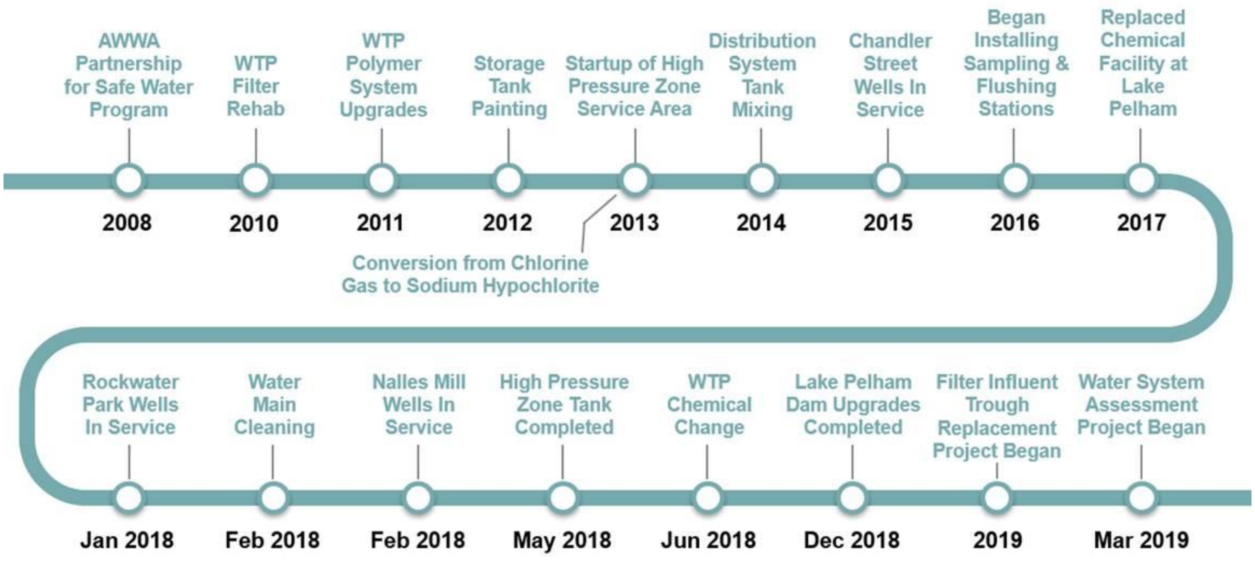

Figure 2-2. Timeline of Recent Town of Culpeper Water System Initiatives

2.3 Drinking Water Sources

Historically, the Town has utilized surface water for their drinking water supply. However, in 2015, the Town began introducing groundwater into the system to increase system resiliency. **Figure 2-3** presents the total water production rates by source. The Town's total water supply rate has increased steadily by an average of approximately 2.6% per year from 2009 to 2018 due to growth. The percentage of groundwater supply in the system has increased since 2015 to approximately 37% of overall production.

According to the Town's FY2018 Regional Water Supply Plan, the Town estimated that the system will need approximately 6.4 MGD of supply over the next 40-year period to continue to ensure a robust and reliable supply.

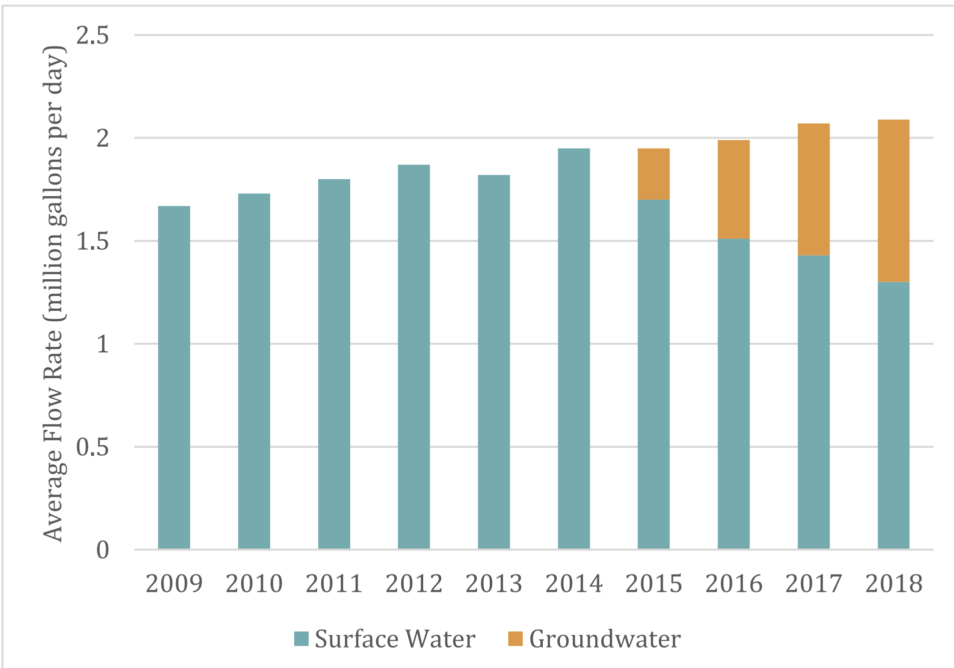

Figure 2-3. Town of Culpeper Water Supply Sources

2.3.1 Surface Water Sources

The Town's primary surface water sources are Lake Pelham and Mountain Run Lake, which discharges via Mountain Run into Lake Pelham. Water is withdrawn from an intake near the dam at Lake Pelham.

In addition to water supply, Lake Pelham provides flood control for areas downstream. The Lake Pelham Dam was recently rehabilitated to meet dam safety regulations, including construction of a spillway and a revised intake structure. Construction of these rehabilitation improvements was completed in August 2018.

Currently the safe yield of Lake Pelham and Mt. Run Lake, as reported in the 2004 Regional Water Supply Plan, is 5.1 MGD. However, the Town's FY18 Rate Study indicated that the Town believes the effective safe yield to be closer to 4.0 MGD based on experiences in prior droughts.

Lake Pelham experiences seasonal algae growth and applies a peroxide-based algaecide to the reservoir to control the growth. The Town previously applied a copper sulfate algaecide to the lake and switched to a peroxide-based product to enhance algae control. The Town currently uses the product GreenClean by Biosafe, which has NSF 60 certification for drinking water application and is registered with the U.S. Environmental Protection Agency (USEPA) under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for use in reservoirs.

2.3.2 Groundwater Wells

Table 2-1 summarizes the Town's groundwater well sources. During the planning phase for the introduction of groundwater into the system, groundwater was tested for numerous water quality parameters regulated by USEPA under the Primary and Secondary Drinking Water Standards (discussed further in Section 3) by Emery and Garrett Groundwater Investigations and National Testing Laboratories. Test results showed that groundwater quality parameters were in compliance with Primary Drinking Water Standards.

Table 2-1. Town of Culpeper Groundwater Facilities Wells

Facility	Date in Service	Number of Wells	Well Depth
Chandler Street	March 2015	3	560 – 640 feet
Nalles Mill	February 2018	2	320 – 380 feet
Rockwater Park	January 2018	1	350 feet

2.4 Water Treatment Facilities

The Town owns and operates four water treatment facilities:the Lake Pelham Water Treatment Plant (WTP), the Chandler Street groundwater treatment facility, the Nalles Mill treatment groundwater facility, and the Rockwater Park groundwater treatment facility.

2.4.1 Lake Pelham Water Treatment Plant

The Lake Pelham WTP was constructed in 1992 and is located west of downtown Culpeper near Lake Pelham. The WTP consists of conventional treatment processes with proprietary clarification and filtration technologies and has a design flow rate of 4 MGD. The WTP is operated for a portion of the day as needed to produce water to meet consumer demands. From January 2015 (when Chandler Street wells were introduced) through February 2019, the WTP was in operation for an average of 12.3 hours per day according to the Town's monthly operation reports. The WTP is not in service during the night.

A schematic of the WTP treatment process is presented in **Figure 2-4,** and additional details of the treatment process are presented in Attachment A. The treatment process generally consists of rapid mixing, clarification, filtration, and disinfection before release to the distribution system.

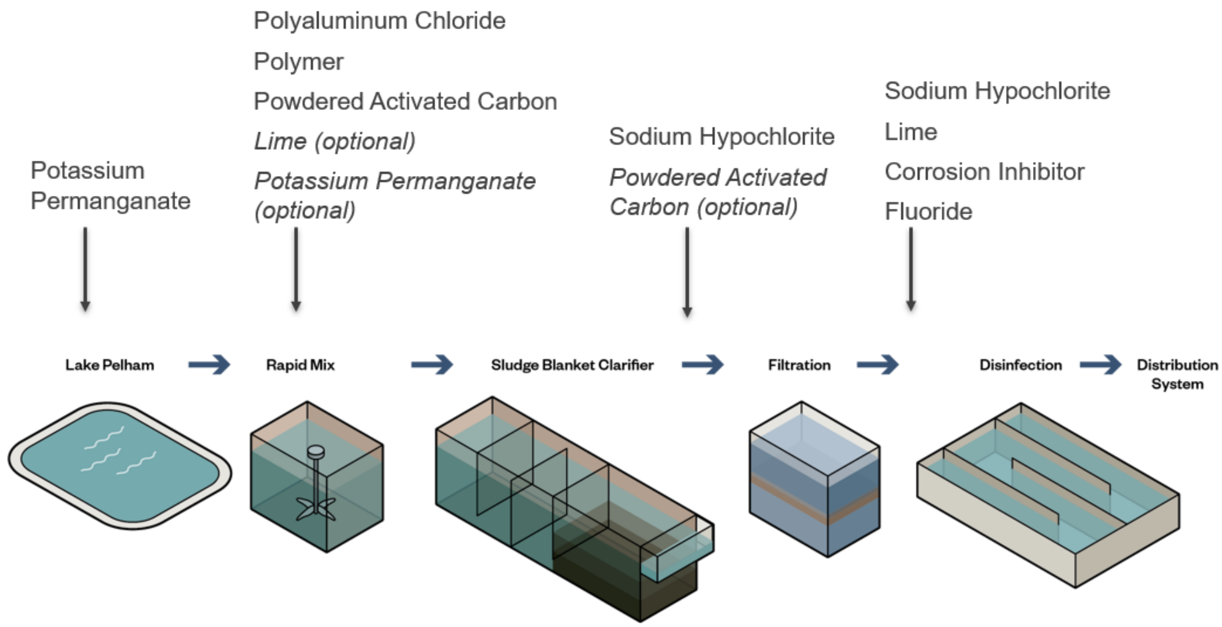

Figure 2-4. Town of Culpeper Water Treatment Plant Process and Chemical Addition

Prior to rapid mixing, water sourced from Lake Pelham can be treated with potassium permanganate, which is an oxidant that can be added to raw water to oxidize dissolved iron and manganese. The water is then directed to a rapid mix basin where polyaluminum chloride (PACl) is added as a coagulant to facilitate removal of particles during clarification. At this stage, polymer is added to assist with sludge blanket formation and control. Powdered activated carbon can be added to assist with removal of taste and odor compounds in raw water. The WTP has the capability to add lime to the raw water to adjust the pH during coagulation and to the filter effluent to adjust the finished water pH at the point of entry into the distribution system. Since the conversion to PACl for coagulation, the WTP has generally not needed to add lime to the raw water for pH adjustment and only adds lime to filter effluent to maintain the target finished water pH.

Following the rapid mix, the water flows to the sludge blanket clarifiers where floc accumulates in the bottom of the clarifier to form a "sludge blanket", and excess floc is periodically removed from the clarifier at the top of the blanket. As coagulated solids pass through the solids blanket layer, they contact solids in the blanket and are removed.

Following clarification, the water flows to the filters which capture particles that are not removed by clarification. The filter system provides filter backwash by gravity by reversing flow from the filter effluent weir chamber into the filter. Sodium hypochlorite is added to the filter influent and to the filter effluent for disinfection. The sodium hypochlorite dose added to the filter effluent is based on the amount needed to provide disinfection in the clearwells and maintain detectable chlorine residuals in the distribution system as required by Primary Drinking Water Standards.

To achieve disinfection of the finished drinking water, the WTP uses free chlorine addition coupled with contact time in the onsite clearwells. Sodium hypochlorite is added to the filter effluent, which flows into the downstream clearwells. A blended phosphate corrosion inhibitor is added for corrosion control and for sequestration of iron and manganese; fluoride is added to the filtered water to promote dental health. Finished water is then pumped from the clearwells into the distribution system.

Residuals produced in the treatment process, including solids removed from the sludge blanket clarifier and filter backwash waste, are discharged to a lagoon on the WTP site, and the supernatant is drained to the sanitary sewer. Residuals are periodically removed from the lagoons and disposed of offsite.

2.4.2 Groundwater Treatment Facilities

Each groundwater treatment facility consists of a chemical treatment building with piping and valves, chemical storage, and a laboratory. At the Chandler Street and Nalles Mill facilities, groundwater from multiple individual wells is pumped to a central treatment building, whereas the Rockwater Park facility treats groundwater from a single well. At all three facilities, the groundwater treatment process consists of chemical addition in the following sequence (from upstream to downstream):

- **Sodium Hydroxide** – The treatment facilities include provisions for addition of sodium hydroxide to increase pH if needed, but they are not typically used.
- **Corrosion Inhibitor** – A blended phosphate corrosion inhibitor containing 50% orthophosphate and 50% polyphosphate is added for corrosion control and for sequestration of iron and manganese.
- **Sodium Hypochlorite** – Free chlorine is added for disinfection, and chlorine contact time for virus inactivation occurs in the finished water pipe prior to entering the distribution system.
- **Fluoride** – Fluoride is added using hydrofluorosilicic acid to promote dental health.

2.5 Water Distribution System

The Town’s distribution system includes 100 miles of pipe, four storage tanks, and six automatic flushing stations. In 2018, the Town created a high-pressure zone (HPZ) in the southern portion of the distribution system to increase pressure. In 2018, construction of a storage tank in the high-pressure zone was completed.

Table 2-2 provides an overview of the four storage tanks. The storage tanks provide a total of approximately 2.4 million gallons (MG) of storage capacity in the distribution system. The hydraulic residence time for each tank was estimated based on 2019 tank level records provided by the Town. The hydraulic residence time affects the overall water age and distribution system water quality. The Route 522 Standpipe had the highest hydraulic residence time (5 days) during the period of analysis.

Table 2-2. Town of Culpeper Distribution System Storage Tanks

Tank	Year Built	Volume (MG)	Hydraulic Residence Time
Route 29 Elevated Storage Tank (T-1)	1961	0.5	2 days
Route 15 Standpipe (T-2)	1967	0.5	4 days
Route 522 Standpipe (T-3)	1993	1	5 days
HPZ Elevated Storage Tank (T-HPZ)	2018	0.4	3 days

Distribution system pipe materials include ductile iron, cast iron, copper, and galvanized. Approximate percentages of pipe type are presented in **Table 2-3**. The Town provided a map of the distribution system pipe materials developed based on staff knowledge. Pipe sizing is shown in **Table 2-4**. The date of pipe installation for all materials is not known.

Table 2-3. Summary of Distribution System Pipe Materials

Material	Percent
Ductile Iron	73.5%
Cast Iron	26.0%
Copper	0.2%
Galvanized	0.3%

Table 2-4. Summary of Distribution System Pipe Size

Diameter	Percent
2 in	1.5%
4 in	5%
6 in	19%
8 in	52%
10 in	0.5%
12 in	22%
18 in	0.5%

The Town has six automatic flushing stations located to control water age in localized areas. The Town also performs conventional hydrant flushing throughout the distribution system. There are 20 locations, known as "Bacti" Sites, within the Town's distribution network that are monitored for coliform bacteria, pH, temperature, turbidity, chlorine, manganese, iron, alkalinity and hardness on a monthly basis. In March 2019, the Town started monitoring orthophosphate and total dissolved solids.

Service lines convey water from the distribution system main to each building and can influence water quality. The portion of the service line on the private side of the meter is the owner's responsibility; the meter and the remaining portion of the service line on the public side is owned by the Town. Service line materials in the Town consist of copper, plastic, or galvanized iron, and the Town is not aware of lead service lines in the system. Specific service line materials at each customer connection in the Town are not known.

2.5.1 Independent Fire Flow Evaluation

One of the core tasks in the study was an independent evaluation of available fire flow in the distribution system. As part of this effort, Hazen updated and calibrated the Town's existing distribution system hydraulic model to simulate current system operations. The process included expanding the extent of distribution system mains in the model, updating customer demand allocation in the model, and calibrating the model based on recent hydrant test results (Attachment D).

The service pressure and fire flow capacity of the Town's distribution system was evaluated using the calibrated model. The predicted maximum hour pressures in the model are generally above 40 psi, except the areas near the T-2 and T-3 tank sites where 31-40 psi minimum pressures are predicted. All pressures were greater than the 20 psi minimum pressure required under maximum hour conditions by the Virginia *Waterworks Regulations*. Similarly, the model runs predicted that the available fire flow (AFF) for all 772 hydrants in the Town of Culpeper is greater than the Insurance Services Office (ISO) minimum of 500 gallons per minute (gpm). It should be noted that the actual flow out of a single hydrant may be restricted by the headloss through the hydrant valve and opening of hydrant port(s).

2.5.2 Distribution System Blending Analysis

Using the updated and calibrated hydraulic model, Hazen performed a source trace simulation to analyze the zone of influence of each water source in the distribution system and to evaluate blending patterns between the surface water and groundwater supplies.

The blending patterns between surface water and combined groundwater supply from three treatment facilities were evaluated. The portion of the distribution system located adjacent to the WTP receives primarily surface water. The midpoint of the blending zone between surface water and groundwater (i.e., 50% surface water and 50% groundwater) is predicted to occur in the downtown area. The influence of groundwater generally increases in the eastern portion of the system near the Chandler Street and Nalles Mill groundwater facilities.

2.5.3 Distribution System Water Age

The updated distributon system hydraulic model was also used to perform water age simulations of the distribution system. Water age represents the duration of water in the distribution system after treatment and prior to use by consumers. Higher water age is typically correlated with the potential for lower chlorine residuals and elevated disinfection byproducts (DBPs) in the distribution system.

The water age in the central portion of the distribution system and downtown area is generally less than 24 hours. Higher water age occurs at the extremities of the distribution system, and approximately 5% of the pipe length in the distribution system has an estimated water age greater than 6 days. West of the WTP, the water age increases due to limited customer demands and high hydraulic residence time in the Route 522 Standpipe (Tank T-3). Higher water age values occur in dead-end mains in the north and east portions of the distribution system as well as in the high pressure zone, as water stored in the Route 15 Standpipe is pumped into the high pressure zone, increasing overall residence time in the system.

Additional hydraulic modeling was performed to determine if increased turnover in the Route 522 Standpipe (Tank T-3) would reduce the residence time of the water in the tank. Analyses were performed for both 12-hr and 24-hr WTP operation under both current hydraulic conditions and assuming that Tank T-3 was forced to turnover more rapidly by pumping the stored water out of the tank and into the distribution system. The results of the analysis suggest that pumping, when coupled with plant operating time adjustments, could provide benefits relative to water age in the vicinity of Tank T-3. However, if the focus of the water age reduction is to reduce disinfection byproducts (particularly TTHMs), then tank aeration may provide a more reliable and economic alternative. TTHMs in Tank T-3 could be reduced by as much as 30 to 40% based on the operating data and proposed aeration system provided by the Town. DBP sampling at the compliance point will inform the magnitude of potential benefits at the compliance point based on tank fill and draw cycles.

3. Town of Culpeper Drinking Water Quality Analysis

To assess the Town's water quality, a Water System Assessment (Attachment A) was conducted to review primary and secondary drinking water regulations and consumer reports regarding water quality. Findings from the assessment were used to prioritize future steps for the subsequent Water Quality Analysis (Attachment B) and Water Quality Recommendations (Attachment C).

To inform the assessment, the Town provided Hazen with data and information detailing the Town's water system assets, including sources, treatment facilities, and distribution network. The Town provided historical regulatory reports from 2010 to 2019 to facilitate the regulatory review. The Town also provided historical consumer complaint records which were reviewed to characterize consumer aesthetic concerns. In addition, Hazen staff visited the Town's facilities and interviewed Town staff to develop an understanding of system operations and learn about recent water system initiatives which have been implemented to improve the Town's source water resiliency, water quality, and infrastructure.

3.1 Regulatory Review

A review of applicable Primary and Secondary Drinking Water Standards was performed. This section provides an overview of key federal and state regulatory requirements applicable to the Town of Culpeper and describes the Town's compliance status.

3.1.1 Primary Drinking Water Standards (Health)

The Town's water supply system is regulated by the USEPA under the Safe Drinking Water Act of 1974, as amended, which are administered by the Virginia Department of Health (VDH). The Safe Drinking Water Act was established to protect the quality of drinking water and requires public water systems to comply with primary (health-related) standards established by the USEPA.

The applicable Primary Drinking Water Standards include the following:

- Long Term 2 Enhanced Surface Water Treatment Rule
- Stage 2 Disinfectants and Disinfection Byproducts Rule
- Lead and Copper Rule
- Revised Total Coliform Rule
- Groundwater Rule
- Maximum Contaminant Levels (MCLs)

The Primary Drinking Water Standards establish regulations for contaminants that may cause adverse health effects. The Town tests water quality at multiple locations throughout the water system (i.e., within the source water, throughout the treatment process, and within the distribution network) as required by the Primary Drinking Water Standards to monitor compliance with these regulations.

Table 3-1 summarizes the drinking water regulatory review for the Town. Details on each regulation are presented in Attachment A.

Table 3-1. Summary of Town of Culpeper Regulatory Review

Regulation	Requirements	Compliance Status
Long Term 2 Enhanced Surface Water Treatment Rule	• Treatment techniques for Cryptosporidium removal • Filter effluent turbidity below required level • Disinfection CT values maintained • Distribution system chlorine residuals meet required minimum levels • Annual sanitary surveys performed by VDH	✓ ✓ ✓ ✓ ✓
Stage 2 Disinfectants and Disinfection Byproducts Rule	• TTHM and HAA LRAA levels below MCLs • TOC removal above required minimum level	✓ ✓
Lead and Copper Rule	• 90th percentile lead and copper levels below the respective Action Levels • Additional monitoring requirements after significant source or treatment change	✓ ✓
Revised Total Coliform Rule	• Distribution system bacteriological testing absent for total coliform • Annual sanitary surveys performed by VDH	✓ ✓
Ground Water Rule	• Free chlorine disinfection of groundwater • Annual sanitary surveys performed by VDH	✓ ✓
Primary Maximum Contaminant Levels	• Levels of 96 regulated chemical, radiological, and bacterial contaminants below MCLs	✓

As demonstrated in the table above, the Town has maintained compliance with these Primary Drinking Water Standards and has experienced no reported violations.

3.1.2 Secondary Drinking Water Regulations (Aesthetics)

The USEPA has established National Secondary Drinking Water Regulations, also known as secondary standards, which are non-mandatory guidelines for aesthetic water issues such as taste, odor, or color in drinking water. USEPA does not enforce these Secondary Maximum Contaminant Levels (SMCLs), which are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations. According to the USEPA, these contaminants are not considered to present a risk to human health and testing for SMCL constituents by public water systems is voluntary.

The Town has experienced occasional levels of iron, manganese, color, sulfate, and total dissolved solids above the SMCL guidelines. The aesthetic effects and frequency of detection of these exceedances within the Town are described below:

- **Iron** – Occasional distribution system samples contain iron levels above the SMCL, which can contribute to water discoloration.
- **Manganese** – Occasional point-of-entry and distribution system samples contain manganese levels above the SMCL, which can contribute to water discoloration.
- **Color** – The Town has tested color in certain distribution system samples collected in response to customer complaints, and color values above the SMCL have been occasionally observed.
- **Sulfate** – Sulfate concentrations above the SMCL were observed at the Chandler Street wells. According to USEPA NSDWRs, sulfate may affect water taste. Sulfate can influence corrosion in distribution system mains and premise plumbing.

- **Total Dissolved Solids (TDS)** – TDS levels are often above the SMCL at the Chandler Street wells and are rarely above the SMCL at the Rockwater Park wells. The TDS may influence corrosion and associated water discoloration, cause deposits on fixtures, and affect water taste.

These occasional exceedances of the SMCL guidelines are consistent with consumer reports related to discoloration, taste, and odor within the Town's water supply system, although the Town's supply and distribution system remains in compliance with the Primary Drinking Water Standards, including Primary Maximum Contaminant Levels (MCLs). A summary of consumer reports is presented in Attachment A.

3.2 Review of Aesthetic Concerns

Historical consumer complaint data received by the Town was combined with data that was solicited from consumers via an online tool to characterize consumer experiences with water quality and aesthetics. This data was used to characterize water aesthetic issues reported by a minority of the Town's customers and identify and prioritize water quality objectives for the Town.

As is common with voluntary reporting, only a small minority of the Town's customer connections had either submitted a complaint to the Town or chose to participate in the online survey, and, of those that participated, the experiences reported were largely negative. Throughout the industry, consumer reporting of water quality is inherently negative, and consumers typically report unusual or unpleasant water quality issues rather than positive experiences. Thus, the majority of consumers in the Town who chose not to voice their concerns either directly to the Town or via the online tool can be presumed to have no concerns worth reporting with the Town's water quality. Certain consumers who attended a public meeting for the Water System Study expressed approval of the quality of water they receive from the Town and noted that water quality has improved in 2019 (refer to Attachment A for meeting summaries). Due to the inherent nature of water quality reporting, these positive consumer experiences with the Town's water quality are likely underrepresented in the consumer complaint dataset. A review of the available data indicated that issues with water quality aesthetics focused on water discoloration and taste and odor.

3.2.1 Water Discoloration

Water discoloration in drinking water is commonly caused by the appearance of iron and manganese that is not dissolved (i.e., iron and manganese that is in particulate form). Iron and manganese are naturally occurring metals present in both of the Town's source waters and are monitored daily in the treated water leaving the WTP and groundwater facilities. In the distribution system, iron can be released to drinking water from cast iron and galvanized iron pipe materials.

The Town performs routine monthly monitoring of the distribution system to sample and evaluate water quality at 20 locations throughout the water supply network. The Town's iron and manganese data from January 2014 to February 2019 was reviewed and compared to the SMCLs for iron and manganese.

Iron

A review of the data indicated that iron levels in treated water leaving the WTP and in groundwater sources are typically below the SMCL of 0.3 mg/L; therefore, it is unlikely that iron in treated water is causing water discoloration experienced by consumers.

Iron levels as documented during the routine monthly distribution system sampling were below the SMCL in approximately 99.5% of samples. Beginning in September 2016 through April 2019, the Town responded to consumer reports of water discoloration by conducting additional targeted sampling at these locations, typically from the consumer's meter. A total of 604 additional samples were collected. The results of this additional sampling showed iron levels above the SMCL in 40% of these targeted samples. Therefore, while iron levels are normally below the SMCL at the WTP, periodic excursions have occurred in the distribution system likely due to the corrosion of iron pipes (galvanized and cast iron).

The majority of the Town's water distribution system consists of ductile iron pipe, which is the Town's standard material for new distribution system construction. Ductile iron is a corrosion resistant material containing an internal cement lining. This pipe material is commonly used today for water distribution and is considered acceptable by the AWWA. Older portions of the Town's distribution system consist of cast iron pipe and galvanized iron pipe, which were commonly used pipe materials prior to the development and common adoption of ductile iron pipe in the industry due to its reliability and corrosion resistance advantages. Cast iron and galvanized iron pipe are susceptible to internal corrosion (often referred to as "tuberculation") that can cause water discoloration when iron from the pipe scale is released to water. As a result, it was concluded that there was likely a connection between the distribution system and water discoloration as a result of iron release at certain locations served by galvanized and cast iron pipes. The release of iron corrosion byproducts from iron distribution system mains and consumer owned premise plumbing can also contribute to water discoloration at the tap. As such, an evaluation of corrosion control treatment processes was performed for the Town's treatment facilities.

The Town adds a blended phosphate corrosion inhibitor containing 50% orthophosphate and 50% polyphosphate at all treatment facilities, and the finished water pH at the WTP is adjusted with lime. Maintaining sufficient orthophosphate levels throughout the water supply system is essential. The ideal pH range for orthophosphate to be effective is typically 7.2 to 7.8 (USEPA, 2016), and lower pH values may increase the risk of iron, lead, and copper release.

The corrosion inhibitor dosing at the WTP is adjustable. As a result of adjusted doses, observed orthophosphate concentrations in treated water and in the distribution system have been highly variable and often below the range recommended in USEPA guidelines (USEPA, 2016). To maximize the effectiveness of orthophosphate in controlling corrosion, consistent pH levels should be maintained throughout the Town's water system. Daily average finished water pH levels at the WTP have generally remained in the range of 7.2 to 7.6, indicating that pH adjustment with lime has been effective in maintaining desired pH levels in the surface water system. The treated water pH values at the groundwater treatment facilities, however, are not adjusted with chemical treatment. As a result, observed treated water pH levels at the groundwater facilities are variable and often considerably lower than the surface water supply. Finished water pH levels at the Chandler Street facility have decreased since startup in 2015, and pH values at Nalles Mill and Rockwater Park have often been below 7.2.

Variability in both inhibitor dosing and pH levels allow for potential release of corrosion byproduct from the iron pipes within the distribution system. These conditions warrant further evaluation to optimize corrosion control within the Town's water supply system.

Manganese

The treatment processes at the WTP are designed to provide manganese removal and are generally effective at doing so; however, as is common with many water supply utilities, the potential for intermittent release of manganese into the distribution system exists. Manganese levels in finished water at the WTP based on the Town's prior monitoring exceeded the SMCL of 0.05 mg/L on approximately 3% of days; manganese levels exceeded a more aggressive treatment goal commonly used in the industry of 0.02 mg/L on approximately 37% of days. Manganese levels as documented during the routine monthly distribution system sampling exceeded the SMCL in approximately 4.4% of samples. The results of the targeted sampling conducted in response to consumer reports showed manganese levels above the SMCL in 27% of samples and above the 0.02 mg/L goal in 69% of samples.

The Town has historically quantified manganese concentrations using Hach Method 8149, which is a method commonly used in the industry to monitor manganese. In October 2019, the Town collected split samples at the WTP to compare Hach Method 8149 to other techniques. Observed manganese levels in surface water were slightly lower (by an average of 0.008 mg/L) using the other technique (EPA Method 200.8) than by Hach Method 8149, especially for samples with manganese concentrations below approximately 0.05 mg/L. These initial results suggest that actual manganese levels may be lower than values historically reported by the Town. While use of the Hach Method 8149 will still be necessary for process monitoring at the WTP, the Town should consider performing periodic comparative sampling with EPA Method 200.8 to assess finished water manganese levels.

Review of data for the groundwater facilities indicated that manganese concentrations reported by the Town for the Chandler Street facility have historically been higher than the Nalles Mill and Rockwater Park facilities. In 2018, the Town adjusted the manganese test procedure at the Chandler Street wells due to high source water hardness per the recommendation of the manufacturer of the test kits to improve accuracy of manganese quantification. This adjustment resulted in improved accuracy and lower observed manganese levels, although these levels remained often above the industry standard 0.02 mg/L goal at this facility. Observed manganese levels at the Nalles Mill and Rockwater Park facilities have generally been below the industry standard goal of 0.02 mg/L and in fact remained below the goal on approximately 93% and 94% of days, respectively.

Manganese present in treated water can accumulate in distribution system pipes and episodically release. Episodic release of these legacy deposits of manganese can cause correlated episodes of elevated manganese levels and water discoloration. Manganese concentrations in the distribution system were intermittently higher than typical treated water concentrations, providing evidence of cyclic manganese accumulation and release from distribution system deposits. Since manganese levels at the WTP and groundwater treatment facilities have often been below the 0.02 mg/L goal, testing throughout the distribution systems indicates accumulation and periodic release from distribution system legacy deposits.

3.2.2 Taste and Odor

Consumer reports suggested that periodic taste and odor events have occurred within the system. This is not atypical of systems supplied by reservoirs (i.e., Lake Pelham), which can be susceptible to taste and odors resulting from seasonal reservoir turnover or seasonal algal blooms. Taste and odor can be caused by a variety of unregulated compounds which are not often monitored or quantified by utilities. The Town has limited historical data to directly quantify and characterize potential taste and odor issues. Therefore, a qualitative evaluation of potential factors affecting reported taste and odor issues in the Town was performed.

Lake Pelham has experienced seasonal algal growth, and algae growth within the reservoirs can result in reports of "earthy, musty, or moldy" tastes and smells in water. The Town treats the reservoir with a peroxide-based algaecide to control algal growth and adds powdered activated carbon at the WTP to reduce taste and odor issues. Some water distribution system piping may also harbor biofilms which can cause earthy, musty, or moldy flavors. Corroded cast iron pipes and galvanized mains in the Town's distribution system could provide an environment for biofilm growth. Increased taste and odor issues may occur where free chlorine residuals decay as a result of water age or pipe wall reactions in the distribution system.

The Town uses free chlorine for disinfection and free chlorine can have a noticeable taste and odor at typical levels. Chlorine in the presence of naturally occurring organic carbon, organic nitrogen, and ammonia in surface water may contribute to odorous byproduct and result in reports of chlorinous taste and odor issues in the Town.

4. Recommendations

The results of the water quality data analysis indicate the Town is meeting all state and federal primary drinking water quality regulations for water treatment and distribution. Analysis of the available data suggests periodic potential aesthetic water quality issues. Customer water quality reports also cite aesthetic issues, primarily associated with water discoloration, taste and odor.

These recommendations to optimize water quality build upon the many ongoing efforts in place at the Town to protect public health, maintain regulatory compliance, operate, and maintain aging infrastructure and facilities, and plan for future water supply and capacity needs. These efforts are critical and indispensable aspects of water system management that must remain a priority for the Town while implementing recommendations to address secondary aesthetic issues.

4.1 Water Quality Objectives

Based on the water quality data analysis, opportunities to optimize water quality to address these aesthetic issues were identified. These opportunities are characterized as water quality objectives, which are summarized in **Table 4-1** along with the justification for selecting these objectives based on the results of the water quality analysis. Recommendations were then developed to achieve the water quality objectives.

Table 4-1: Summary of Water Quality Objectives

<table>
<tr><th>Aesthetic Concern</th><th>Water Quality Objective</th><th>Justification</th></tr>
<tr><td rowspan="2">Discolored Water</td><td>Distribution System Optimization</td><td>• Data analysis provides evidence of:
  • Periodic release of legacy deposits in the distribution system that may contribute to water discoloration
  • Corrosion of iron distribution system mains and premise plumbing materials may contribute to water discoloration
  • Variable distribution system water quality conditions and hydraulic patterns associated with source water blending</td></tr>
<tr><td>Treatment Optimization and Proactive Treatment Enhancements</td><td>• Data analysis suggests that:
  • Lake Pelham raw water periodically contains high levels of iron and manganese
  • Historical iron and manganese levels in finished water have occasionally exceeded common industry goals
  • pH and orthophosphate variability may influence water discoloration due to iron corrosion in the distribution system
  • DBP levels at one location in the distribution system have been recently elevated, indicating potential limitations for iron and manganese treatment strategies
• The revised Lead and Copper Rule, due for release in 2020, will soon require many water systems to optimize corrosion control for lead and copper</td></tr>
<tr><td>Taste and Odor</td><td>Proactive Treatment Enhancements</td><td>• Data analysis suggests that Lake Pelham water may periodically contain high levels of organics and taste- and odor-causing compounds
• Algae growth in Lake Pelham may contribute to episodic taste and odor complaints</td></tr>
</table>

4.2 Developing and Prioritizing Recommendations

Once the water quality objectives were identified, recommendations to address them were developed and prioritized into the following categories: near-term recommendations to be completed as soon as possible; proactive water quality enhancement strategies to be completed based upon the outcomes of those recommendations; and, lastly, master planning for the future. These recommendations, described below, are summarized in **Figure 4-1**. Implementation guidance in the form of flow chart graphics were developed to describe the methodical stepwise approach for implementation of recommendations. The Town should monitor and assess the impacts of adjustments recommended in each step before advancing further.

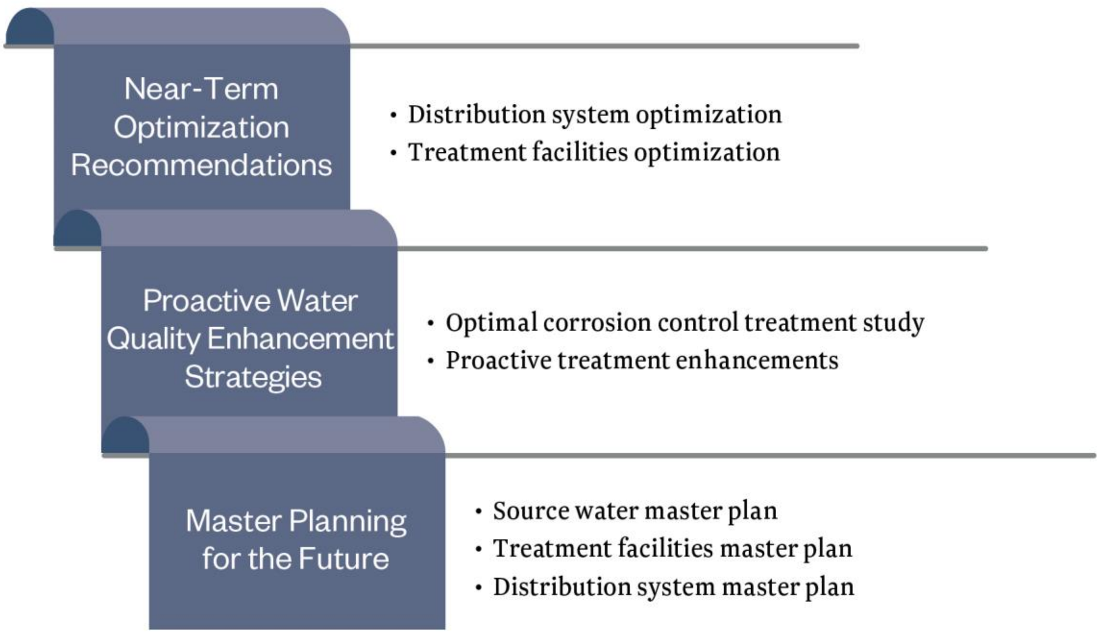

Figure 4-1: Town of Culpeper Recommendations

- **Near-term Optimization Recommendations:** These improvements and recommendations can be implemented in the near-term to further improve water quality aesthetics by optimizing operations of the existing system without major capital improvements. The goals of the recommended optimization strategies include:
    - ***Distribution System:*** This includes flushing and cleaning to remove historical legacy deposits containing iron and manganese and optimizing current corrosion control approaches to decrease the potential for future iron corrosion and disturbance of pipe scales and deposits.
    - ***Treatment Facilities:*** This includes filtration optimization to minimize future accumulation of distribution system iron and manganese deposits and finished water chemical feed monitoring improvements to enhance process control and improve stability.

  These strategies must be implemented methodically to ensure improvement in water quality while avoiding potential unintended consequences. Each strategy should be implemented with careful monitoring to provide an opportunity to review performance and assess the need for additional enhancement and/or optimization measures before proceeding to the next step. Assuming a program start date in 2020, it is anticipated that these near-term recommendations can be initiated within one year and completed within three years.

- **Proactive Water Quality Enhancement Strategies:** Implementation of these proactive water quality enhancement strategies is dependent on the outcome of near-term optimization recommendations. The need for or scale of these improvements and recommendations may change contingent on performance of the implemented optimization strategies. The recommended proactive water quality enhancement strategies include:
    - ***Distribution System:*** Driven by forthcoming revisions to the Lead and Copper Rule (anticipated in 2020), a corrosion control study should be performed to identify and implement an optimal corrosion control treatment strategy, while incorporating additional focus on iron corrosion control to address water discoloration episodes.
    - ***Treatment Facilities:*** In the event that the results of the near-term optimization strategies result in the need to further alter WTP operations to ensure ongoing compliance with applicable regulations (particularly increased DBPs) or significant and recurring taste and odor challenges from Lake Pelham occur, the following studies may need to be performed:
        - A proactive evaluation of potassium permanganate dosing and implementation of liquid sodium permanganate should be performed to optimize control of iron and manganese and minimize DBPs.
        - An evaluation of taste and odor (T&O) control, focused on monitoring for T&O compounds and evaluating Powdered Activated Carbon improvements, should be performed to optimize WTP response to the intermittent T&O challenges.

  The degree to which these strategies must be implemented will be directly affected by the results of the near-term optimization strategies and the ultimate schedule set by the revised Lead and Copper Rule, which is to be finalized in 2020.

- **Master Planning for the Future:** To augment the Town’s long-term plans, this phase consists of building upon ongoing master planning to guide the selection of potential future capital improvements and operational improvements. Planning activities will focus on ensuring adequate water quantity and quality, while addressing current and future regulatory and water quality drivers, both health-based and aesthetic. The focus of these planning efforts will be heavily impacted by the outcomes of the optimization and enhancement strategies, along with future regulatory, economic and population drivers. The goals of the future master planning efforts include:
    - ***Distribution System:*** A master plan addressing conveyance to an expanding population while maintaining high water quality, performing necessary maintenance and replacement, and addressing infrastructure resiliency should be performed.
    - ***Treatment Facilities:*** Planning efforts should address opportunities for expanding water treatment capabilities to serve an increasing population. It is also anticipated that new regulatory drivers may require additional treatment strategies, either conventional or advanced.

- ***Source Water:*** It is recommended that the Town continue to explore diversification of source water resources and develop plans for monitoring and maintaining quality of sources currently utilized.

Conceptual planning-level costs are presented for each recommendation and are intended to screen and evaluate recommended strategies only. Additional site-specific factors and design criteria during detailed design may impact project scope and cost. Planning-level costs reflect 2020 dollars, and future costs may vary depending on market conditions at the time of implementation.

4.3 Near-Term Optimization Recommendations

This section describes recommendations for near-term optimization of the system, which are summarized in **Table 4-2** below. These optimization recommendations focus on the distribution system and the water treatment facilities. Assuming a start year of 2020, it is anticipated that implementation of these strategies will begin within one year and can be completed within three years. Additional detail on these recommendations can be found in Attachment C.

Table 4-2: Summary of Near-Term Optimization Recommendations

Recommendation	Description	Planning-Level Cost
	Distribution System Optimization	
Systemwide Unidirectional Flushing (UDF)	• High-velocity flushing at strategic locations in the distribution system to clean pipes • Field inspections to confirm valve and hydrant operability and locations to inform UDF planning	*See Note 1*
Storage Tank Inspection and Cleaning	• Inspection and cleaning of distribution system storage tanks to remove deposits	*See Note 1*
Maintain Consistent Corrosion Control Treatment	• Increase finished water pH at all facilities to 7.6, consistently within 7.4 to 7.8 • Add sodium hydroxide at groundwater facilities using existing feed systems • Maintain consistent corrosion inhibitor doses of current product; dosing should be consistent across all treatment facilities	*$4,000/year*
Distribution System Water Quality Monitoring	• Water quality monitoring before, during, and after UDF and treatment changes to adjust finished water pH and corrosion inhibitor feed	$30,000
	Treatment Facilities Optimization	
Filter Optimization	• Routinely monitor chlorine residuals in individual filter effluent • Perform a pre-filter chlorine demonstration study to evaluate DBP impacts of increased chlorine doses on the filters • Pending DBP results, maintain a constant filter effluent residual of at least 0.5 mg/L to enhance iron and manganese removal • Maintain consistent plant operations during backwash cycles	$70,000 *$5,000/year*
Improved Finished Water Chemical Feed Control	• Install a readily accessible sample tap on the post-filter conveyance pipeline prior to the clearwells, to be used for chemical dosing, and monitoring of pH, chlorine residual, and orthophosphate	$45,000
		Total Capital Cost = $145,000 *Total Annual Cost = $9,000*

Notes:
1. It is assumed that these recommendations will be implemented by the Town and will not require costs for third-party assistance.

To ensure methodical and stepwise implementation of recommendations in the distribution system optimization and water treatment optimization categories, two flowcharts were developed to identify the recommended step-by-step process (see **Figure 4-2** and **Figure 4-3**).

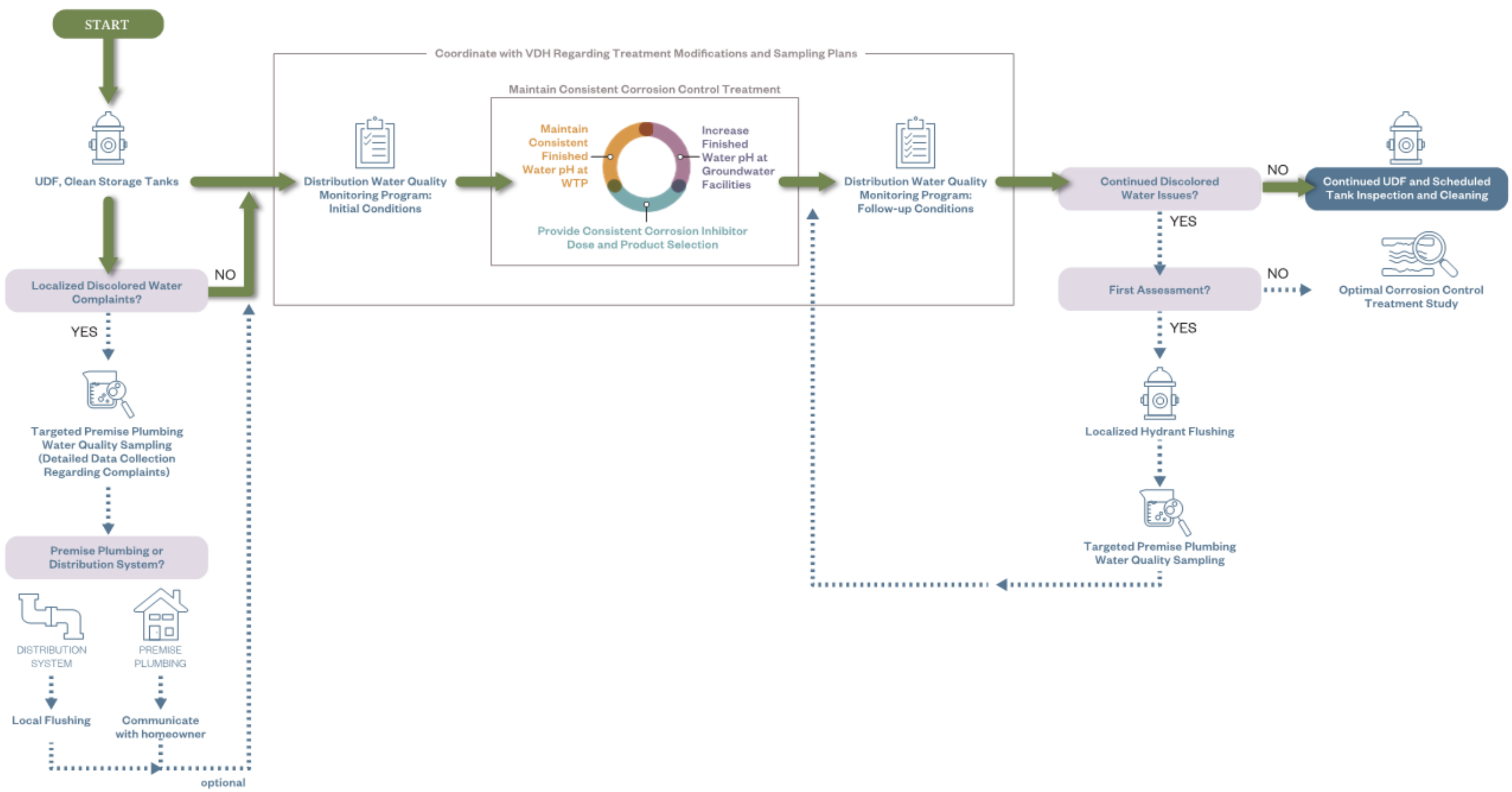

Figure 4-2: Near-Term Distribution System Optimization: Remove Legacy Deposits and Control Discoloration

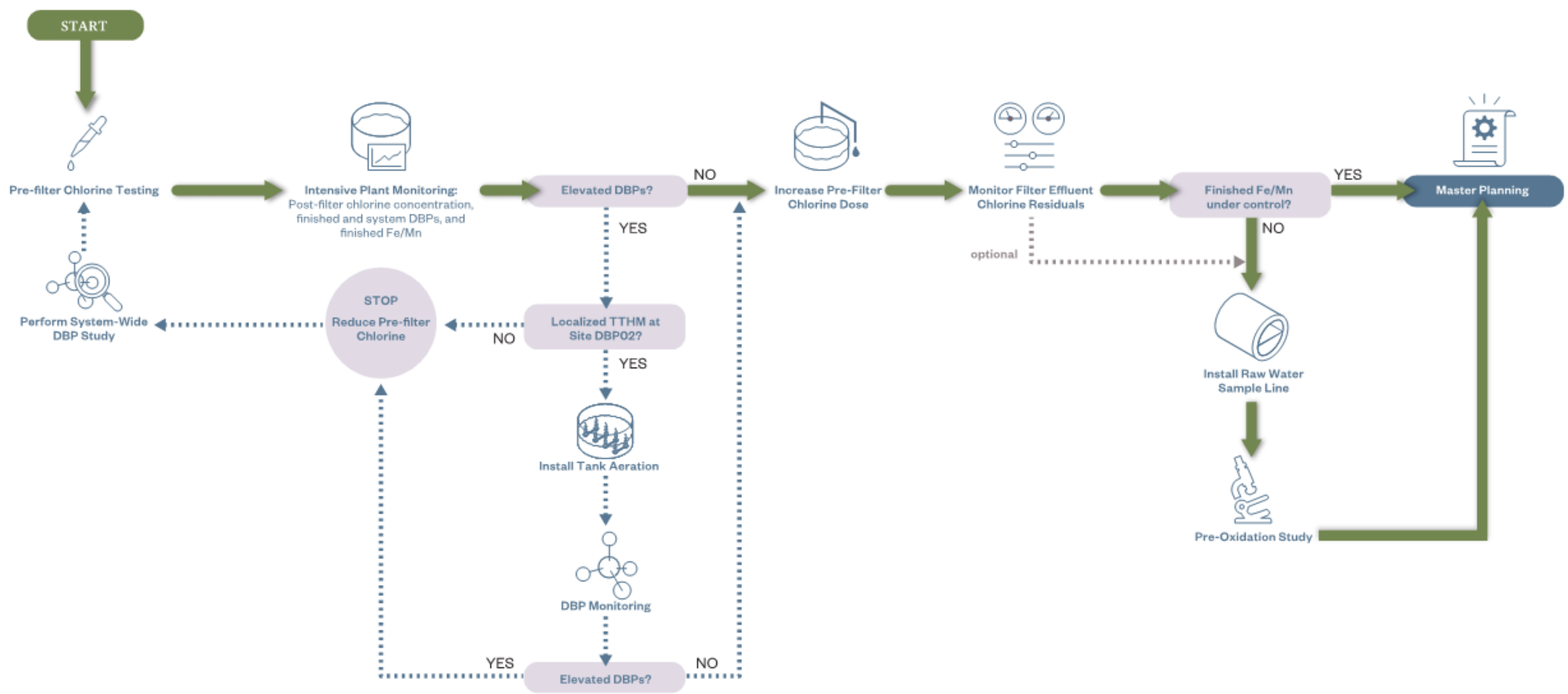

Figure 4-3: Near-Term Treatment Plant Optimization: Control Water Discoloration

4.4 Proactive Water Quality Enhancement Strategies

Following implementation of the near-term optimization recommendation, and dependent on the outcomes thereof, potential proactive water quality enhancement strategies have been identified that focus on acquiring additional data to inform proactive treatment enhancement, as detailed in **Table 4-3**. Additional detail on these strategies can be found in Attachment C.

Table 4-3. Summary of Proactive Water Quality Enhancement Recommendations

Recommendation	Description	Cost
	Optimal Corrosion Control Treatment Study	
Optimal Corrosion Control Study	• Perform corrosion testing to evaluate optimal corrosion control strategy used at all treatment facilities • Test a corrosion inhibitor with a higher orthophosphate and lower polyphosphate content • Implement gradual adjustments to system-wide optimal corrosion control, in accordance with USEPA recommendations	$250,000
	Proactive Treatment Enhancements	
Pre-Oxidation Study	• Evaluate benefits of optimizing the use of potassium permanganate or implementing sodium permanganate	$50,000
Powdered Activated Carbon (PAC) Study	• Monitor and understand magnitude of reservoir T&O challenges, and optimize response strategies • Conduct bench-scale testing to determine best performing PAC product and dosing strategy to maximize T&O removal in treatment	$80,000
Raw Water Sample Tap	• Install raw water sample tap prior to permanganate addition to quantify raw water quality and guide chemical addition	$90,000

4.5 Master Planning for the Future

The Town has recently performed several planning initiatives focused on maintaining regulatory compliance, protecting public health, operating and maintaining aging infrastructure and facilities, as well as planning for future water supply and capacity needs. The Town has augmented its surface supply with groundwater to proactively plan for potential future demands and provide water supply resiliency by cultivating an additional water supply source.

To build upon the Town's long-term planning efforts, it is recommended that the Town develop a master plan to balance water system capacity, quality, and resiliency objectives and develop a framework to expand and upgrade the water system to meet the Town's long-term needs. Critical decisions regarding water quality and treatment, including potential capital improvements to water treatment infrastructure, depend on projected customer demands and planned future water sources. The outcome of the master plan will allow the Town to make informed, methodical decisions regarding possible future investments for water infrastructure that are consistent with the Town's long-term vision for water supply and water quality.

In addition, the water quality master plan should consider emerging water quality issues and possible future regulatory requirements. This will allow the Town to further optimize water quality and aesthetics while positioning for future regulatory compliance.

The master planning efforts build upon the Town's on-going water system initiatives and have been categorized into the following tasks which are summarized as follows:

- **Source Water Master Plan** – The Town has recently added groundwater supply to improve source water resiliency. To build upon these efforts, the source water master plan should evaluate quantity, quality, and resiliency aspects of the Town's future water supply. The master plan should evaluate water demand projections and identify the Town's planned future water sources, including additional groundwater or surface water supplies, to develop a long-term strategy for source water management and supply. The master plan should evaluate source water quality characteristics and strategies to maintain source water quality. In particular, the source water master plan should evaluate opportunities to augment the Town's current algae management program for Lake Pelham.

- **Treatment Facilities Master Plan** – Since the Town joined the Partnership for Safe Water program in 2008, the Town has been working to optimize WTP performance and improve water quality. The treatment facilities master plan should evaluate potential future changes to the Town's treatment facilities based on capacity needs and regulatory drivers. The master plan should consider goals for maintaining water quality aesthetics, anticipated future regulatory issues, and an evaluation of potential alternate treatment technologies, including conventional and advanced treatment. In particular, the master plan should evaluate 24-hour operation of existing treatment facilities and potential long-term capital upgrades.

- **Distribution System Master Plan** – The distribution system influences system capacity, pressure, fire flow, and water quality. The master plan should evaluate opportunities to optimize distribution system water quality as the distribution system is expanded and renewed in the future to serve the Town's customers. The Town is currently performing ongoing distribution system pipe replacement efforts, and the master plan provides an opportunity to augment the Town's current pipe replacement efforts into a methodical replacement approach with defined replacement rate goals and budgets. By leveraging continued distribution system water quality sampling (e.g., chlorine residuals, iron levels), periodic fire flow tests and review of reported discolored water events, the asset management and replacement program can be optimized each year to focus on priority pipeline segments within the replacement goal for a particular year. In particular, the distribution system master plan should evaluate potential changes to the source water blending strategy to optimize the distribution system.

Key aspects of each master plan category are described in Attachment C. The anticipated cost for a master plan covering these topics is approximately $500,000.

5. Conclusion

Since joining the AWWA Partnership for Safe Water program in 2008, the Town has been working to improve water quality and treatment through a series of water system initiatives. Some consumers have voiced concerns regarding water quality, so the Town commissioned the preparation of this Water System Study as part of a larger Water System Assessment. The purpose of the Water System Study was to evaluate the Town's water quality data and develop recommendations to address water quality priorities as identified by the study. An analysis of the Town's water quality data was performed for the source water, treatment facilities, and distribution system and was supplemented by limited on-site field testing to investigate key water quality priorities. Public concerns regarding water quality were characterized through an analysis of the Town's prior customer complaint records, a 2019 customer online reporting tool, and public meetings. Water quality complaints were reported by a small minority of the Town's water system customers and given the inherent nature of water quality complaint reporting in the industry, positive consumer experiences with the Town's water quality are likely underrepresented in the consumer report dataset.

The drinking water regulatory review indicated that the Town has maintained compliance with applicable primary drinking water regulations that serve to protect public health. Further, the Town has made and continues to make improvements to water quality parameters, both related to health and aesthetics.

The USEPA has established non-enforceable secondary standards for water quality parameters that can affect water aesthetics, including discoloration and taste and odor issues. The Town has historically experienced levels of iron and manganese intermittently above the recommended levels for these secondary standards for aesthetics, consistent with consumer reports of episodic water discoloration that have influenced public perception of water quality.

Water quality objectives were developed to identify opportunities for the Town to build upon ongoing initiatives to further improve water quality aesthetics, namely water discoloration, taste, and odor. As the analysis identified that causes of water discoloration at customer taps was linked to corrosion of iron distribution piping as well as intermittent release of legacy deposits, recommendations were developed to address these causes, release of distribution system legacy deposits and iron corrosion. Improving robustness of iron and manganese removal and improving consistency of finished water quality through treatment will serve to reduce sources of legacy deposit and reduce potential for corrosion in the distribution system.

In addition, based on an evaluation of source water and treatment, the study determined that reported taste and odor issues are likely caused by a combination of algae growth in Lake Pelham, reactions between free chlorine and naturally occurring compounds, and distribution system biofilms. Limited data was available from the Town to quantify substances potentially causing taste and odor issues, and recommendations were presented for additional data collection on common compounds causing taste and odor issues to inform future decision-making regarding treatment for taste and odor.

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Attachment A: Technical Memorandum 1 – Town of Culpeper Drinking Water System Evaluation

Attachment B: Technical Memorandum 2 – Water Quality Data Analysis

Attachment C: Technical Memorandum 3 – Water Quality Recommendations

Attachment D: Independent Fire Flow Study