Hazen *Technical Memorandum*

January 21, 2020

To: Town of Culpeper

From: Hazen and Sawyer

Town of Culpeper Drinking Water System Evaluation

DRAFT

A Water System Evaluation was performed to develop a detailed understanding of the Town of Culpeper water system, benchmark performance of the system against applicable drinking water regulations, catalogue and contextualize recent customer drinking water aesthetic concerns, and prioritize future steps in the Water System Study.

The Culpeper Water System has consistently been in compliance with all federal and state primary drinking water regulations. In response to public comments, the Town has engaged in outreach and information gathering focused on aesthetic aspects of water quality. Water discoloration, unusual tastes and odors, and hardness were the most frequently reported public concerns.

Further efforts in the Water Quality Study will focus on identifying potential causes of these episodic aesthetic concerns and providing the Town with achievable short- and long- term strategies to improve drinking water aesthetics and continue to provide high quality reliable drinking water service to their customers.

31164-001

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1. Introduction

The Town of Culpeper (Town) retained Hazen and Sawyer (Hazen) to perform an independent Water System Assessment. A Water System Study evaluating source water, treatment, and distribution was performed as part of the Assessment, and the results are summarized in three technical memoranda: (1) Water System Evaluation; (2) Water Quality Analysis; and (3) Water Quality Recommendations. The objectives of each memorandum are detailed in **Figure 1-1.**

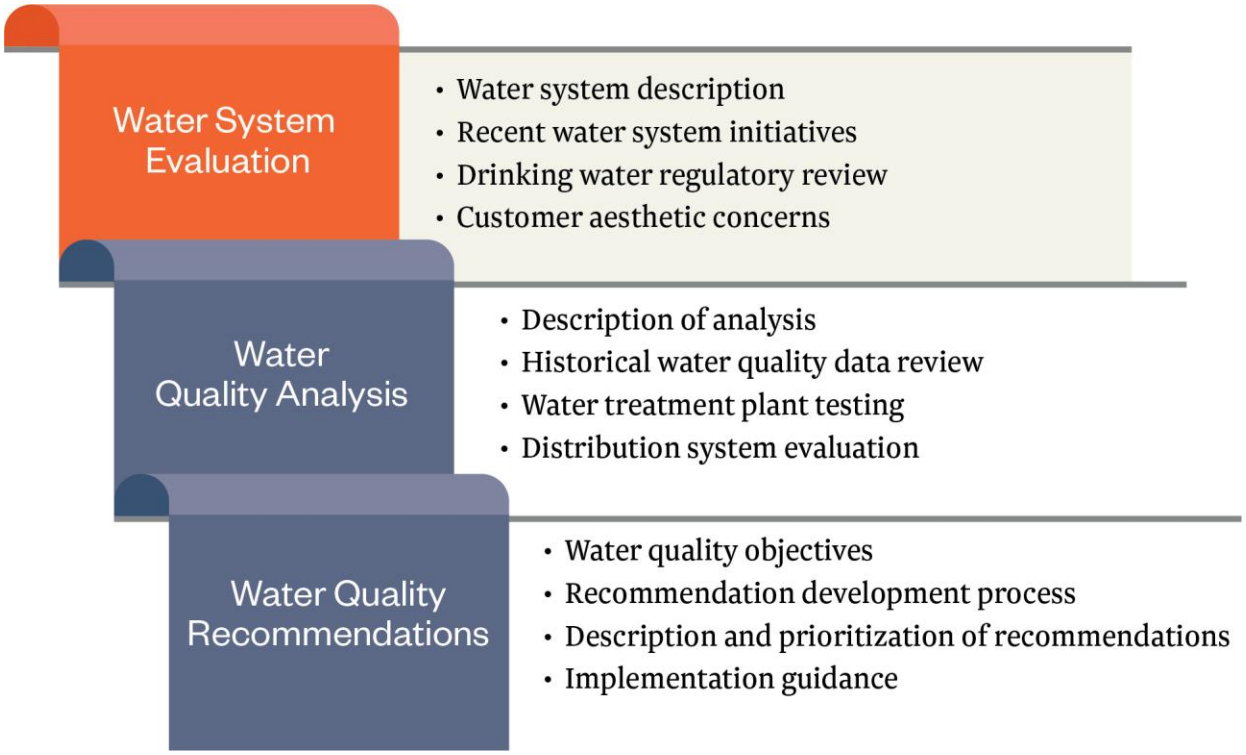

Figure 1-1. Summary of Water System Study Tasks and Objectives

This memorandum summarizes the results of the Water System Evaluation performed as part of the Water System Study. The objectives of the evaluation were as follows:

- To develop a comprehensive understanding of the Town's water system infrastructure and recent improvements.
- To benchmark the Town's system performance against the U.S. Environmental Protection Agency (USEPA) and Virginia Department of Health (VDH) regulatory standards.
- To catalogue and contextualize customer water quality concerns related to drinking water aesthetics (taste, odor, discoloration).

Results from the Water System Evaluation were used to prioritize objectives for the Water Quality Analysis and Water Quality Recommendations (Technical Memoranda 2 and 3).

1.1 Water System Evaluation Approach

The approach to the Water System Evaluationwas to review primary and secondary drinking water regulations and consumer reports regarding water quality. Findings from the evaluation were used to prioritize future steps for the subsequent Water Quality Analysis and Water Quality Recommendations.

To inform the Water System Evaluation, 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 present to facilitate the regulatory review. The Town 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.

1.2 Report Organization

This technical memorandum consists of the following sections:

- **Section 1** – Introduction: This section describes the purpose and approach of the Water System Evaluation.
- **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** – Recent Water System Initiatives: This section summarizes recent projects implemented by the Town to enhance the water system since the Town joined the American Water Works Association (AWWA) Partnership for Safe Water Program.
- **Section 4** – Town of Culpeper Drinking Water Regulatory Review: This section presents a review of the Town's compliance data for primary drinking water regulations.
- **Section 5** – Public Perception of Aesthetic Water Quality Concerns: This section catalogues and characterizes consumer concerns related to drinking water aesthetics (i.e., taste and odor, discoloration, hardness).
- **Section 6** – Conclusion: This section summarizes findings from the Water System Evaluation and presents the focus for Water Quality Analysis and Recommendations.

The following appendices referenced in the memo provide additional detail for the Water System Evaluation.

- Appendix A: Distribution System Maps
- Appendix B: Public Outreach Supporting Information

2. Town of Culpeper Water System

The Town of Culpeper is an unincorporated town located in Culpeper County, Virginia, with a population served by the water system of 17,411 according to the United Stated Environmental Protection Agency (USEPA). The Town's water supply system consists of a combination of surface water and groundwater supplies and provides approximately 2 million gallons per day to consumers. Until 2014, the Town water supply was exclusively sourced from surface water (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. Specifically, groundwater augments supply from the WTP and maintains system supply when the WTP is offline. Since 2015, the percentage of groundwater supply used to meet customer demands has increased annually.

As shown in **Figure 2-1,** surface water is obtained from Lake Pelham and treated at the Town's water treatment plant (WTP), which is typically operated daily over a single shift of approximately 12 hours. The WTP consists of a treatment process including 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, supplies 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 (72%-74%) and cast iron (26%) with smaller portions comprised of galvanized pipe (0.3-2%) and copper (0.2%). The distribution system is primarily comprised of ductile iron pipe, which is a corrosion resistant material that contains an internal cement lining and is accepted in industry standards.

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 the 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.

The review of the Town's Water System is organized as follows:

- Drinking Water Sources
- Drinking Water Treatment Facilities
- Drinking Water Distribution System

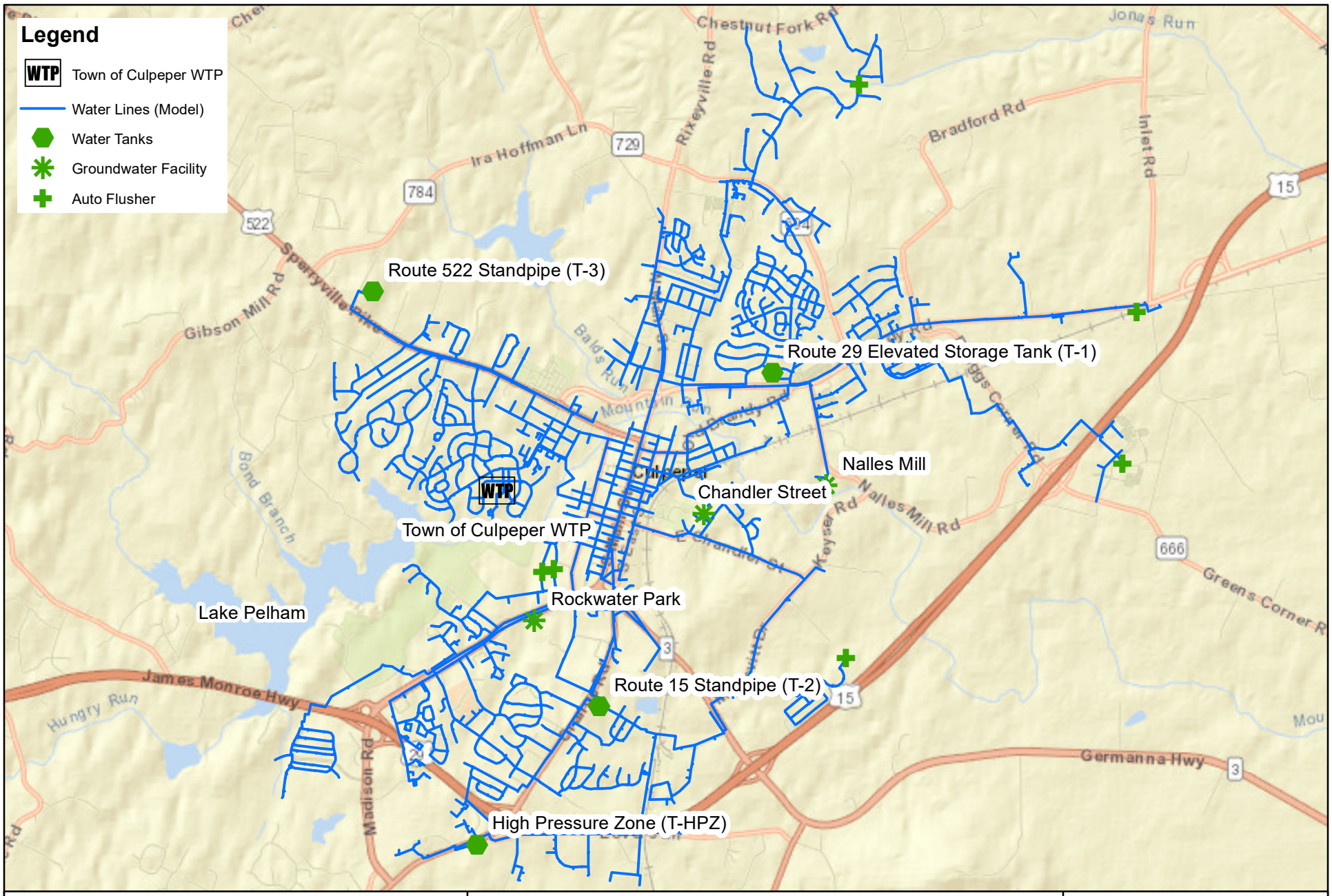

Figure 2-1: Town Water System Overview

Client: Town of Culpeper
Project: Town of Culpeper Water System Assessment
Location: Culpeper, Virginia
Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

2.1 Drinking Water Sources

Historically, the Town has primarily utilized surface water for their drinking water supply and introduced groundwater into the system starting in 2015. **Figure 2-2** 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. Starting in 2015, the percentage of groundwater supply in the system has increased to approximately 37% of overall production. The total average production was approximately 2.1 MGD in 2018.

According to the Town's FY18 Regional Water Supply Plan, the Town estimated that the system will need approximately 6.4 MGD of supply over the next 40-year period.

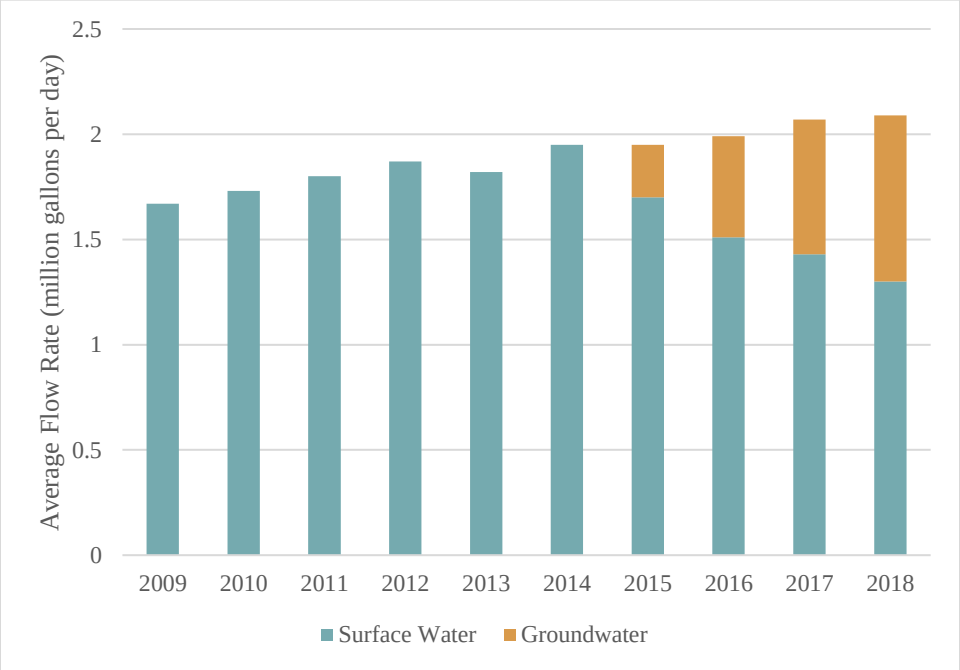

Figure 2-2. Town of Culpeper Water Sources

2.1.1 Surface Water Reservoirs

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. The withdrawal ports in the water intake structure are located at depths of approximately 4 to 6 feet below water surface.

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 labyrinthine spillway and a revised intake structure. Construction of the rehabilitation improvements was completed in December 2018.

Lake Pelham has a surface area of approximately 254 acres and stores approximately 1.3 billion gallons of water. The height of the earthen dam is approximately 38 feet. Currently the safe yield of Lake Pelham and Mt. Run Lake, as reported in the 2004 Water Supply Plan, is 5.1 MGD. However, the Town's FY10 and FY18 Regional Water Supply Plans indicated that the Town believes the effective safe yield to be closer to 4.0 MGD based on experiences in prior droughts.

Lake Pelham has a drainage area of 16,726 acres. The land cover characteristics of the drainage area, according to the United State Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) *Supplemental Watershed Plan No. 5 and Environmental Assessment*, are presented in **Table 2-1**. The drainage area consists primarily of woodland and pasture.

Table 2-1. Lake Pelham Drainage Area Characteristics (USDA NRCS)

Land Cover	Percent of Total
Developed	15.3
Cropland	0.4
Woodland	40.1
Pasture	40.2
Water	3.2
Wetlands	0.8
Other	<0.1

Lake Pelham experiences seasonal algae growth and applies a peroxide-based algaecide to the reservoir to control algae 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 a peroxyacetic acid concentration of 5.3% and a hydrogen peroxide concentration of 23%. GreenClean has NSF 60 certification for drinking water application and is registered with the US EPA under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) for use in reservoirs.

2.1.2 Groundwater Wells

Table 2-2 summarizes the Town's groundwater well sources. During planning of groundwater wells prior to introduction of groundwater into the system, groundwater was tested for numerous water quality parameters regulated by primary drinking and secondary drinking water standards by Emery and Garrett Groundwater Investigations and National Testing Laboratories. Test results showed that groundwater quality parameters were in compliance with Primary and Secondary Drinking Water Standards.

Table 2-2. Town of Culpeper Groundwater Facilities

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

2.2 Drinking Water Treatment Facilities

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

2.2.1 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 million gallons per day. Since its startup, the WTP has been operated for a portion of the day as needed to produce water to meet customer demands. For example, from January 2015 (when Chandler Street wells were introduced) through February 2019, the WTP has been operated 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 is presented in **Figure 2-3**.

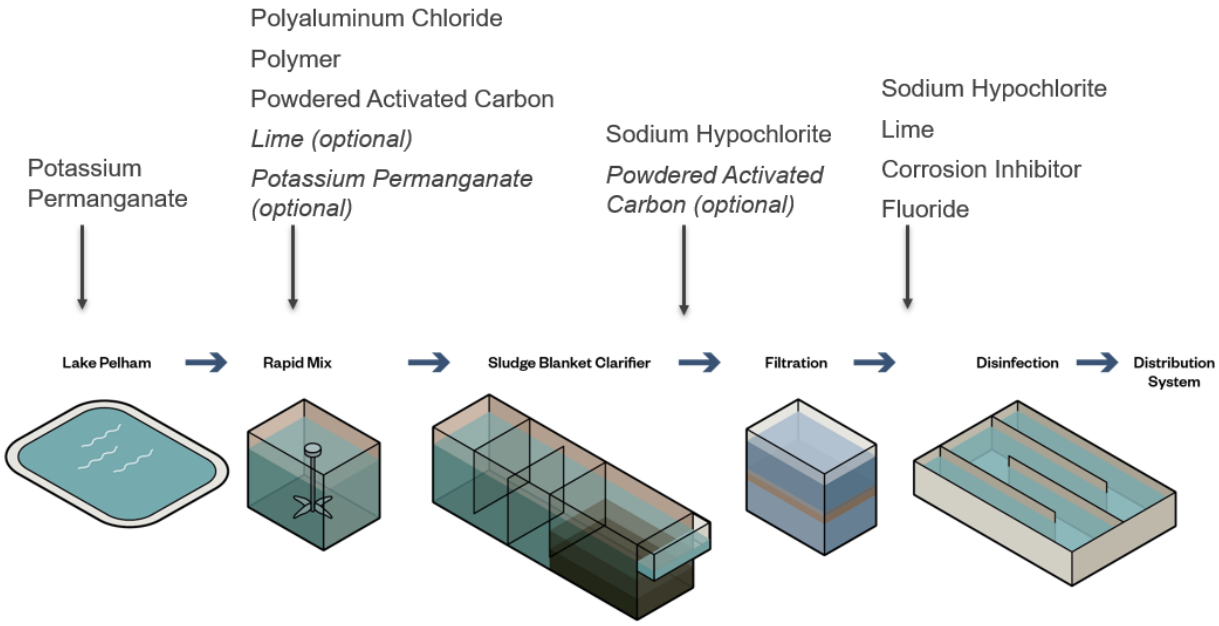

Figure 2-3. Town of Culpeper Water Treatment Plant Process and Chemical Addition

The treatment process includes the following chemicals:

- **Potassium Permanganate** – Permanganate is a strong oxidant and is added to raw water to oxidize dissolved iron and manganese without forming regulated DBPs in reactions with natural organic matter. The WTP can add permanganate to the raw water near Lake Pelham and at the WTP prior to the rapid mix. Potassium permanganate is delivered as a dry product, and batches of liquid solution are prepared on site.
- **Polyaluminum Chloride (PACl)** – Addition of PACl coagulant results in formation of aluminum hydroxide precipitates and enhances removal of particles during sedimentation. The

WTP historically utilized aluminum sulfate (alum) for coagulation and switched to PACl in June 2018, when the product was switched to DelPAC 1000 manufactured by USALCO, to improve consistency in solids removal. Coagulation is the WTP's primary treatment process for removal of DBP precursors from raw water, as NOM adsorbs to formed precipitates.

- **Polymer** – A polymer is added to raw water to assist with clarification.
- **Powdered Activated Carbon** – Powdered activated carbon is added to assist with removal of taste and odor compounds in raw water. The WTP has the capability to add powdered activated carbon to the raw water near the rapid mix and to the proprietary sludge blanket clarifier effluent and typically feeds powdered activated carbon to raw water.
- **Lime** – Lime is added 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. The WTP was originally designed to feed soda ash (sodium carbonate) for pH adjustment and switched to lime in 2011.
- **Sodium Hypochlorite** – Sodium hypochlorite is dosed to the filter influent and to the filter effluent for free chlorine 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.
- **Corrosion Inhibitor** – The WTP adds a blended phosphate corrosion inhibitor containing 50% orthophosphate and 50% polyphosphate to the filtered water for corrosion control and for sequestration of iron and manganese.
- **Fluoride** – Fluoride is added to the filtered water using hydrofluorosilicic acid to promote dental health.

2.2.1.1 Clarification Process

The WTP has two Superpulsator® clarifiers, which are proprietary high-rate sludge blanket clarifiers equipped with plate settlers manufactured by SUEZ. In sludge blanket clarifiers, 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. The Superpulsator system includes a pulsation system to enhance floc formation and help to prevent blanket compaction. At a flow rate of 4 MGD, the sludge blanket clarifiers have an overflow rate of 3,125 gpd/SF and a detention time of approximately 51 minutes.

2.2.1.2 Filtration Process

The WTP utilizes a proprietary filtration system known as the Greenleaf filtration system as manufactured by SUEZ. This system provides filter backwash by gravity by reversing flow from the filter effluent weir chamber into the filter. Finished water is recycled into the filter effluent weir chamber during backwash to maintain the chamber full and to provide sufficient head and volume of water for backwash. The Greenleaf system is designed to reduce backwash pumping costs compared to a conventional filter system; however, the Greenleaf filter system does not provide the capability to control or measure the backwash flow rate. While some Greenleaf filters include adjustable filter weirs that allow the backwash

rate to be adjusted, the Culpeper WTP was designed with fixed weirs, and the backwash rate could only be adjusted by modifying the weirs, subject to confirmation of filter capacity impacts. The filters include an air scour system which introduces air into the filters to scour the media prior to water backwash. At a plant flow rate of 4 MGD, the filters have a hydraulic loading rate of approximately 3.3 gpm/SF.

The dual-media filters contain the following layers:

- Top Layer – 20 inches of anthracite with an effective size of 1.15 mm
- Bottom Layer – 20 inches of sand with an effective size of 0.5 mm

A filter rehabilitation design was completed in 2009, which included replacement of filter media, underdrain repairs, and other improvements.

2.2.1.3 Disinfection Process

The WTP uses free chlorine addition coupled with contact time in the onsite clearwells to achieve disinfection of the finished drinking water. Sodium hypochlorite is added to the filter effluent, which flows into the downstream clearwells. The WTP has two circular clearwells, each with an inner diameter of 55 feet. The clearwells contain spiral baffles to encourage plug flow through the clearwell and improve the baffle factor (i.e., reduce the potential for short circuiting). Finished water is pumped from the clearwells into the distribution system.

2.2.1.4 Process Solids

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 offsite.

2.2.2 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, 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.

2.3 Drinking Water Distribution System

Figure A-3 in **Appendix A** presents an overview of the Town's distribution system including the extent of different types of pipeline construction materials. The Town's distribution system includes 100 miles of pipe, four storage tanks and six automatic flushing stations.

In 2016, the Town created a high-pressure zone 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. **Figure A-2** in **Appendix A** shows the location of the high-pressure zone.

Table 2-3 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 during the period of analysis.

Table 2-3. Town of Culpeper Distribution System Storage Tanks

Tank	Year Built	Year Last Painted	Volume (MG)	Overflow Elevation (ft)	Diameter (ft)	Hydraulic Residence Time
Route 29 Elevated Storage Tank (T-1)	1961	2012	0.5	620	Variable	2 days
Route 15 Standpipe (T-2)	1967	2012	0.5	620	34	4 days
Route 522 Standpipe (T-3)	1993	2012	1	620	54	5 days
HPZ Elevated Storage Tank (T-HPZ)	2018	2018	0.4	689.5	Variable	3 days

Distribution system pipe materials include ductile iron, cast iron, copper and galvanized. **Figure A-3** in **Appendix A** presents the distribution system pipe materials. The Town provided a color-coded map of the distribution system pipe materials based on staff knowledge. Approximate percentages of pipe type is presented in **Table 2-4**. Pipe sizing is presented in **Table 2-5**. The date of pipe installation for all materials is not known.

Table 2-4. Distribution System Pipe Material

Material	Percent
Ductile Iron	74%
Cast Iron	26%
Copper	0.2%
Galvanized	0.3%

Table 2-5. Distribution System Pipe Sizes

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 as shown on **Figure A-1** in **Appendix A** to control water age in localized areas. The Town also performs conventional hydrant flushing throughout the distribution system.

The Town has 20 Bacti Sites that are monitored for pH, temperature, turbidity, chlorine, manganese, iron, alkalinity and hardness on a monthly basis. In March of 2019, the Town started monitoring orthophosphate and total dissolved solids. Bacti Site locations are shown in **Figure A-4** through **Figure A-7** located in **Appendix A**. Addresses for the 20 Bacti Sites are included in **Table 2-6**.

Table 2-6. Bacteriological Testing Site Locations

Site ID	Sample Site Locations (2019)	Site ID	Sample Site Locations (2019)
Bacti Site 10	612 Sperryville Pike	Bacti Site 110	1202 Orange Road
Bacti Site 20	307 Southgate Center	Bacti Site 120	129 East Locust Street
Bacti Site 30	13388 Lovers Lane	Bacti Site 130	302 East Davis Street
Bacti Site 40	13065 Orange Road	Bacti Site 140	584 Culpeper Town Square
Bacti Site 50	400 South Ridge Parkway, Suite 400B	Bacti Site 150	451 James Madison Highway
Bacti Site 60	779 Madison Road	Bacti Site 160	16113 Ira Hoffman Lane
Bacti Site 70	457 Madison Road	Bacti Site 170	15469 Brandy Road
Bacti Site 80	400 South Main Street	Bacti Site 180	15345 Creativity Drive
Bacti Site 90	101 E Davis Street	Bacti Site 190	16390 Brandy Road
Bacti Site 100	522 North Blue Rige Avenue	Bacti Site 200	1475 N Main Street

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 the owner's responsibility, and the portion of the service line on the public side of the meter is owned by the Town. Service lines owned by the Town are copper, plastic or galvanized iron. Specific service line materials at each customer connection in the Town and private service line materials are not known.

2.3.1 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.

The service pressure and fire flow capacity of the Town of Culpeper 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. These lower pressures were mainly due to the high ground elevations near the tanks. The northern portion of downtown experiences pressures higher than 100 psi due to the low ground elevation in the area. This evaluation verified the system can meet the current peak hour demand and provide all customers with adequate pressure.

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 Standards Office (ISO) minimum of 500 gpm (see **Figure 2-4**). The predicted available fire flow (AFF) for all 772 hydrants in the Town of Culpeper are illustrated in Figure using the ISO color scheme. The model predicted AFFs range between 539 gpm to more than 5,000 gpm and were calculated under a worst-case scenario of current maximum day demand with tank levels at their lowest operating limit while maintaining a minimum residual pressure of 20 psi throughout the service area.

It should be noted that the predicted AFF represents the maximum flow rate that the local pipe network can supply at 20 psi residual pressure, rather than the maximum possible flow out of a single hydrant. The actual flow out of a single hydrant may be restricted by the headloss through the hydrant valve and opening of hydrant port(s). As a general rule, 1,500 gpm is the maximum flow from a single hydrant. Fire flows above 1,500 gpm necessitate multiple hydrants.

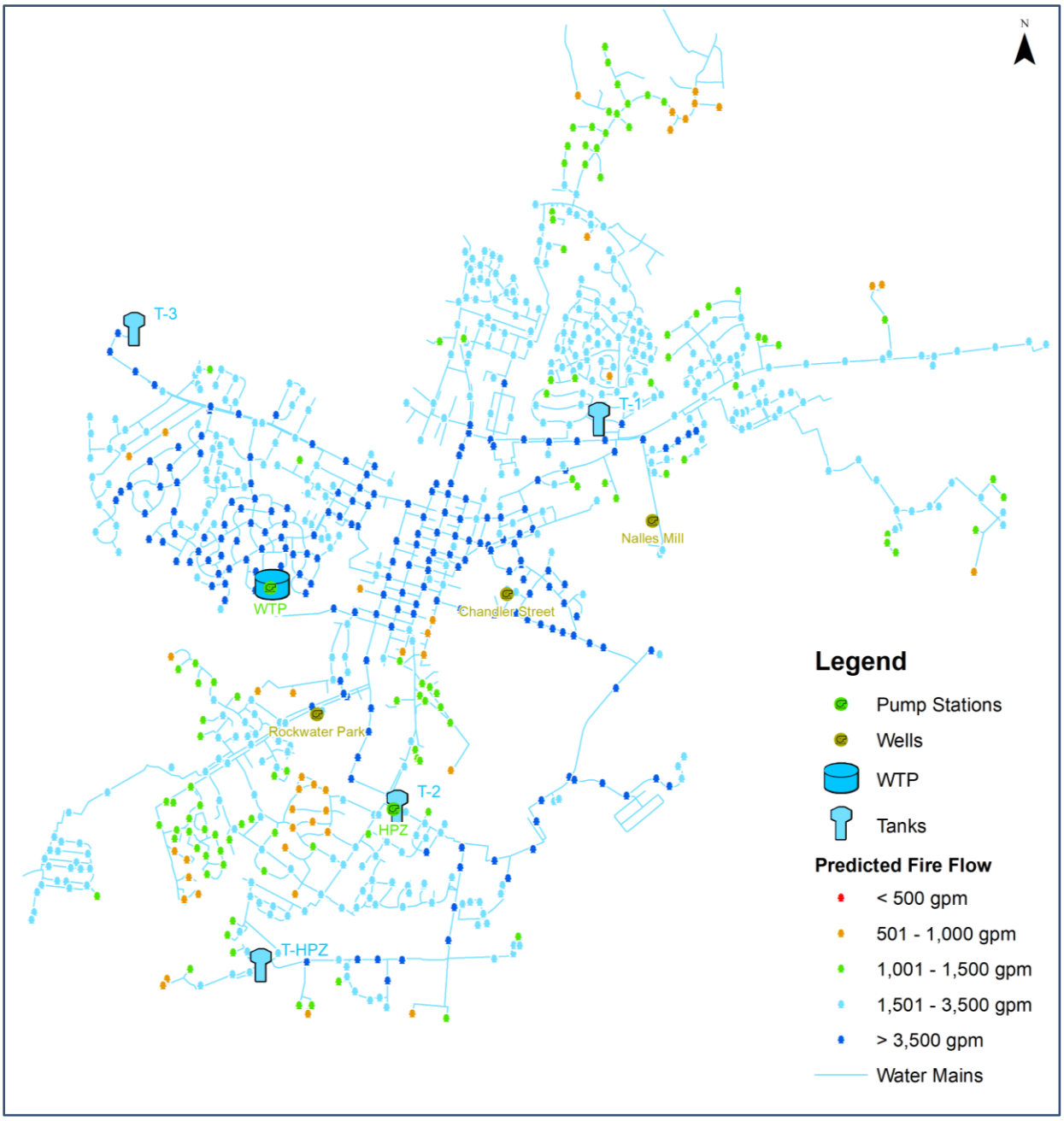

Figure 2-4. Predicted Fire Flows at Hydrants

3. Recent Water 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 program consists of treatment process optimization and distribution system optimization to voluntarily 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 a series of water system initiatives to improve water supply, system operations, and water quality. **Figure 3-1** presents a summary of select water system initiatives in the Town since 2008.

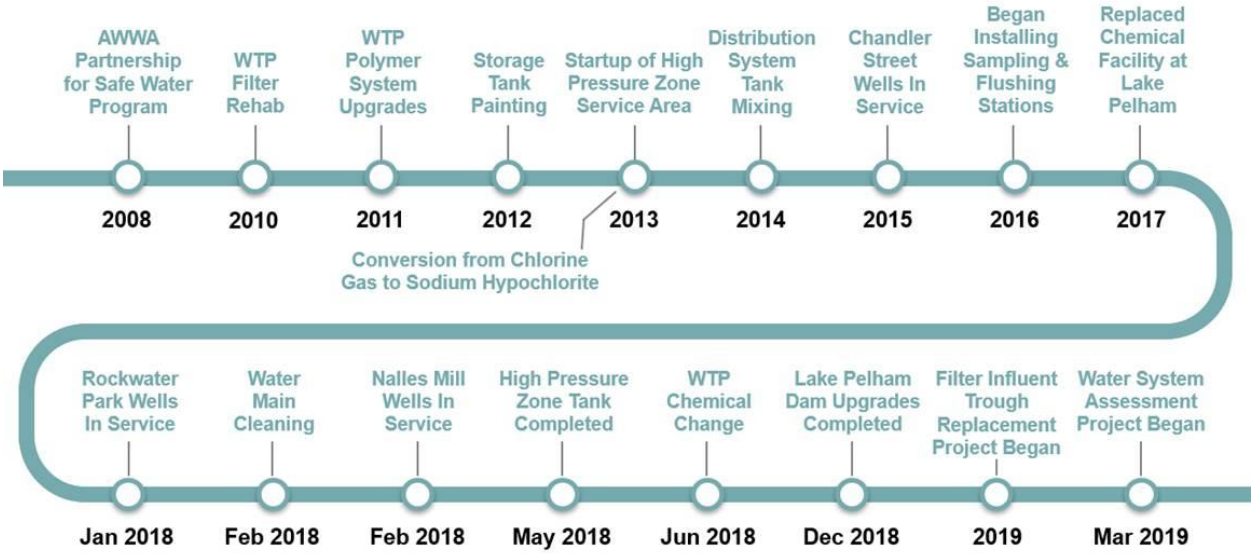

Figure 3-1. Timeline of Recent Town of Culpeper Water System Initiatives

Important 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 2011 Regional Water Supply Plan recommended development of an additional 3 MGD of capacity to meet the Town's growing needs and noted 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. Additionally, introduction of groundwater supply has provided benefits for reducing levels of disinfection byproducts in the distribution system.

- **Distribution System Operations** – The Town implemented several initiatives since 2012 to improve distribution system operations. These improvements included painting of storage tanks, installation of tank mixers, installation of dedicated sampling stations, and installation of 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 for managing the system, and automatic flushing stations can be beneficial for controlling water age in certain portions of the distribution system.

- **Treatment Process Optimization** – The Town has implemented a series of water treatment changes to improve 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, high flushing velocities 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. Although pigging and ice pigging can be an effective approach for distribution system cleaning, a water main break occurred in the Oaklawn neighborhood during ice pigging, which resulted in service interruptions and discolored water. The Town found that ice pigging was effective for cleaning of 18-inch and 12-inch diameter mains.

- **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.

4. Town of Culpeper Drinking Water Regulatory Review

The Town's water supply system is regulated by the United States Environmental Protection Agency (USEPA) under the Safe Drinking Water Act of 1974, as amended. These regulations 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 Drinking Water Standards established by the USEPA. The Primary Drinking Water Standards establish regulations for contaminants that may cause adverse health effects. The Town tests water quality at multiple locations in the water system as required by the Primary Drinking Water Standards to monitor compliance with these regulations.

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. **Table 4-1** summarizes the drinking water regulatory review for the Town. Details on each key regulation are presented in the following subsections.

Table 4-1. 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	✓

Guideline values are also established by EPA for certain non-health based aesthetic considerations, including iron, manganese, color, sulfate, and total dissolved solids. The Town's water quality has occasionally exceeded recommended levels for these parameters.

4.1 Long Term 2 Enhanced Surface Water Treatment Rule

The Surface Water Treatment Rule is a key federal drinking water regulation affecting the Town's surface water treatment plant. The purpose of the Surface Water Treatment Rule is to reduce illnesses caused by pathogens in drinking water, including *Giardia lamblia*, *Cryptosporidium*, and Legionella. The Surface

Water Treatment Rule requires all water systems to filter and disinfect surface water sources and has been amended on several occasions to improve requirements.

The Long Term 2 Enhanced Surface Water Treatment Rule was promulgated in 2006 and builds upon prior surface water treatment rules to further enhance control of the protozoan *Cryptosporidium*. Surface water sources have *Cryptosporidium* risks derived from animals in the watershed. Based on the land use surrounding Lake Pelham, the risk of *Cryptosporidium* exists, and effective treatment for turbidity removal and disinfection is needed to ensure *Cryptosporidium* removal. According to VDH compliance datasheets, the Town's surface water supply is classified as "Bin 1" for *Cryptosporidium*, which is the category with the lowest source water *Cryptosporidium* levels based on a single prior monitoring event The WTP meets required LT2 compliance by implementing EPA mandated treatment techniques, including dual-media filtration and chlorine disinfection. With Bin 1 classification, no additional treatment techniques are required for *Cryptosporidium* removal.

In order to ensure treatment techniques are operating properly, EPA has set operational standards for filtration and disinfection. Applicable standards for the WTP include:

- Combined filter effluent turbidity in conventional and direct filtration plants must be less than or equal to 0.3 NTU in 95% of samples taken each month and must never exceed 1 NTU.
- Minimum free chlorine disinfection "CT credit" must be met at the treatment plant.

Figure 4-1 presents the historical combined filter effluent turbidity at the Culpeper WTP based on the Town's monthly operating reports. Daily average filter effluent turbidity has remained below 0.3 NTU. The data indicated that the combined filter effluent turbidity has steadily improved since 2008. Over the past several years, the filter effluent turbidity has been consistently below the AWWA Partnership for Safe Water goal of 0.1 NTU.

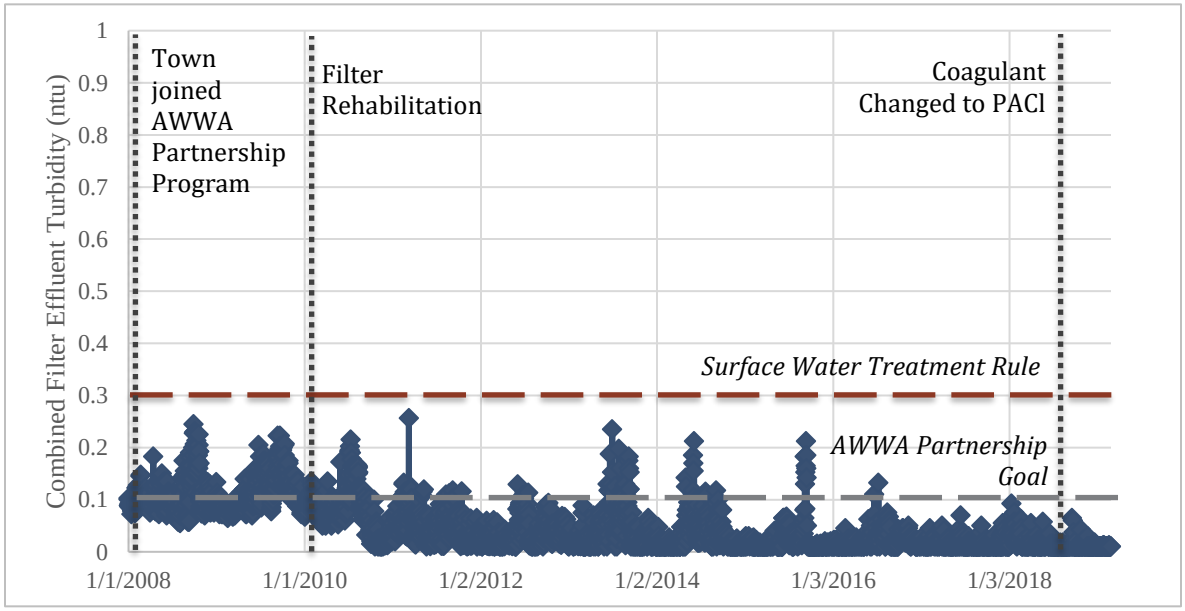

Figure 4-1. Culpeper WTP Combined Filter Turbidity

The WTP practices free chlorine disinfection. In order to ensure adequate disinfection is achieved, the Town submitted a disinfection profile to document the chlorine contact ("CT") credit for disinfection to VDH. Operationally, CT calculations are made multiple times daily during plant operation, based on measured chlorine residuals in the WTP clearwells and plant flow rates.

Additionally, the Surface Water Treatment Rule requires that a detectable chlorine residual be maintained in the distribution system to control biological growth. The Town monitors distribution system chlorine residuals at 20 locations in the distribution system on a monthly basis.

During the period of analysis from September 2016 to February 2019, the Town of Culpeper had detectable free chlorine residuals in all distribution system samples. Additionally, the AWWA Partnership for Safe Water Program recommends that a minimum free chlorine residual of 0.2 mg/L be maintained in at least 95% of distribution system samples. Free chlorine residuals were greater than 0.2 mg/L in 98.5% of distribution system samples, exceeding regulatory requirements and AWWA Partnership goals.

Sanitary surveys of the WTP have been performed annually by the Virginia Department of Health (VDH). VDH has provided 2 to 7 comments regarding the WTP in each annual inspection from 2015 through 2018, and the Town has responded and coordinated with VDH to resolve comments.

The Surface Water Treatment Rules also cover provisions for recycle of backwash water at WTPs for control of pathogens including *Cryptosporidium*. The WTP does not recycle backwash water at the plant and is not subject to the provisions of the Filter Backwash Recycle Rule.

4.2 Stage 2 Disinfectants and Disinfection Byproducts Rule

4.2.1 Background Regulatory Requirements

The Disinfectants and Disinfection By-Products (D/DBP) Rule was established to limit levels of total Trihalomethanes (TTHMs) and Haloacetic Acids (HAA5). The rule has been revised several times since it was first introduced as the 1979 Total Trihalomethane Rule, and currently exists as the Stage 2 D/DBP Rule that became effective in 2006. The Stage 2 D/DBP Rule revisions changed compliance from a system-wide running annual average to specific representative locational running annual averages, selected to reflect a combination of highest TTHM and HAA5 locations.

Under the Stage 2 D/DBP Rule, compliance with the TTHM and HAA5 MCLs of 80 μg/L for TTHM and 60 μg/L for HAA5 is determined through the use of *Locational* Running Annual Average (LRAA) values at each compliance monitoring site. With the LRAA approach, a violation occurs if the running annual average at any distribution system sampling site exceeds the MCL. Based on the LRAA, individual quarterly DBP samples above the MCL do not cause a violation of the MCL.

4.2.2 Town of Culpeper Compliance Data

The Town monitors quarterly for regulated DBPs at four locations in the distribution system. The DBP sampling locations are presented in **Figure A-8** in **Appendix A.**

Figure 4-2 presents historical LRAA values for TTHM. As shown, the values have been consistently below the MCL since 2014. The introduction of groundwater supplies with low levels of natural organic matter has allow the Town to further reduce DBP levels in the distribution system. The AWWA Partnership for Safe Water Program has a goal for DBP levels to remain below 75% of the MCL, or 60 ppb for TTHM. TTHM levels in the Town of Culpeper have generally met this goal since 2016. TTHM levels have increased at site DBP02 since 2017, and the Town should consider evaluating water age and water quality at this location to control TTHM formation. Site DBP02 is located near the Route 522 Standpipe Tank, and tank operations may influence observed DBP levels at this site. While TTHM levels at DBP02 have remained below the MCL, the Town is currently evaluating a tank aeration system to remove volatile TTHMs in the tank by air stripping.

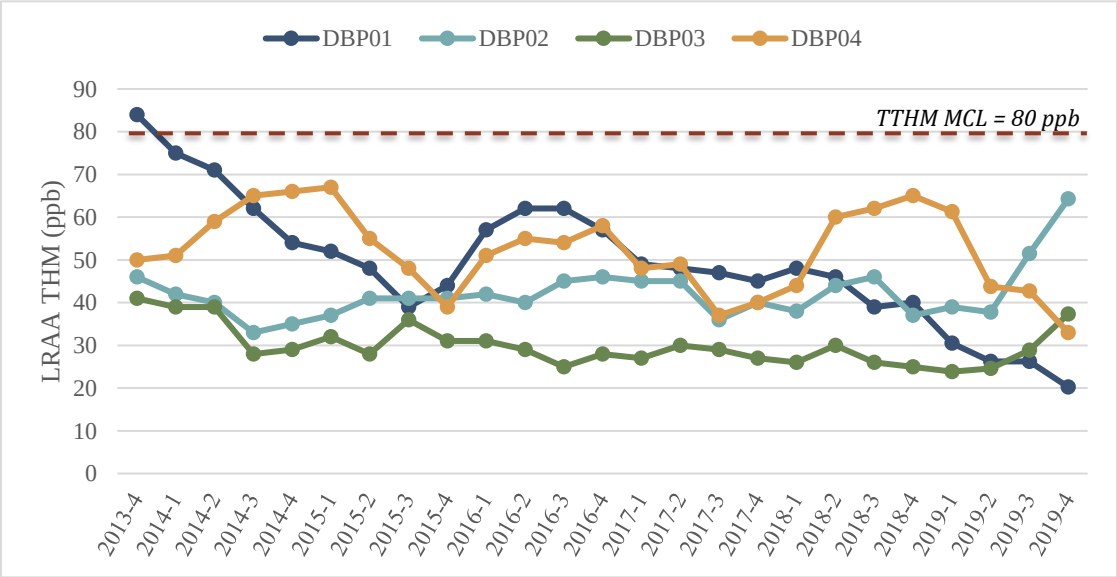

Figure 4-2. Town of Culpeper TTHM LRAA Values

Figure 4-3 presents historical LRAA values for HAA5. LRAA values have remained below the MCL throughout the period of analysis. In addition to meeting the primary MCL for HAA5, the HAA5 levels in the Town of Culpeper have also met the AWWA Partnership for Safe Water goal of 45 ppb (or 80% of the primary MCL).

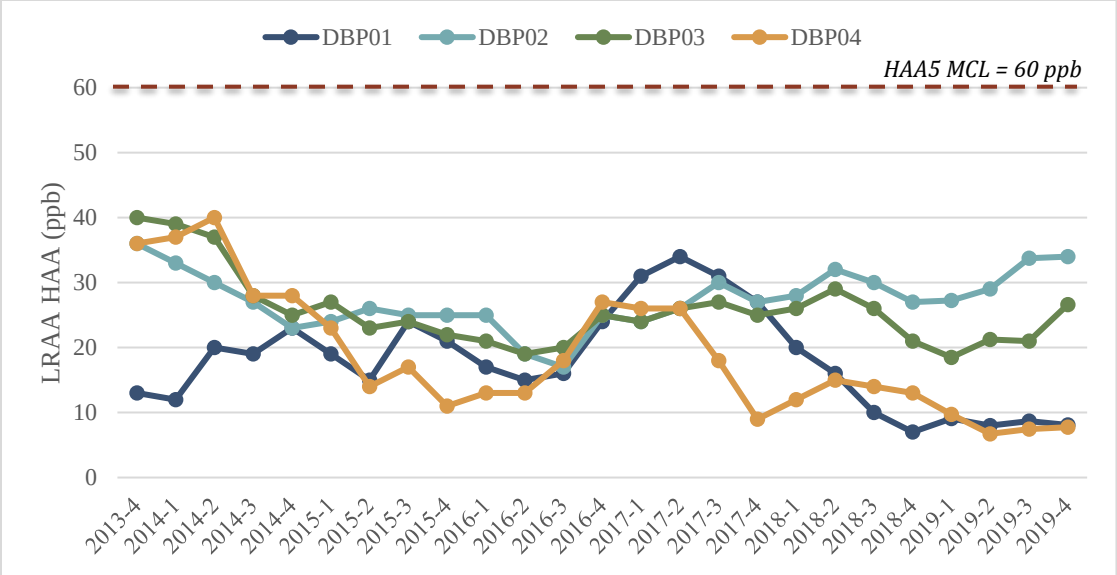

Figure 4-3. Town of Culpeper HAA5 LRAA Values

The introduction of groundwater supplies has allowed the Town to further reduce DBP levels in the distribution system. Groundwater contains lower levels of natural organic matter, which serves as a precursor for DBP formation. Blending of groundwater in the system has also reduced the water age of surface water supply in many portions of the distribution system, further reducing the potential for DBP formation in the Town.

The Stage 2 D/DBP Rule also requires systems that exceed an Operational Evaluation Level (OEL) to investigate system operational practices and identify opportunities to reduce DBP concentrations in the distribution system. The OEL value is determined for each DBP compliance monitoring location as the average of the two previous quarters' results for each site plus twice the current quarter's result. If the OEL is greater than the MCL for any site, an operational evaluation must be conducted to examine treatment and distribution system operational practices and identify strategies to reduce DBP formation. An OEL exceedance suggests that an MCL violation could occur during the following quarter unless operational changes are implemented. Operational Evaluation Levels (OELs) for TTHM and HAA5 were reviewed, and these levels have also remained below the OEL threshold in the Town since 2015.

The D/DBP Rule has established a treatment technique for DBP precursor removal. Conventional filtration systems are required to remove specified percentages of organic matter, measured as total organic carbon (TOC), based on monthly monitored source water TOC and alkalinity values, as shown in **Table 4-2**.

Table 4-2. Enhanced Coagulation TOC Removal Requirements

Raw Water TOC (mg/L)	Raw Water Alkalinity (mg/L as $CaCO_3$)		
	0-60	60-120	>120
2-4	35%	25%	15%
4-8	45%	35%	25%
>8	50%	40%	30%

Based on the average raw water alkalinity and TOC at the Lake Pelham WTP, the minimum TOC removal based on enhanced coagulation requirements is 45%. The Town measures total organic carbon removal on a monthly basis. **Figure 4-4** presents raw and finished water TOC data at the Culpeper WTP. As shown, the WTP effectively removes TOC which helps to minimize DBP levels in the distribution system. The average TOC removal at the WTP was approximately 59% over the period from 2013 through November 2018. The WTP changed the coagulant from aluminum sulfate to polyaluminum chloride in June 2018. The average reported TOC removal from July 2018 through November 2018 was approximately 64%.

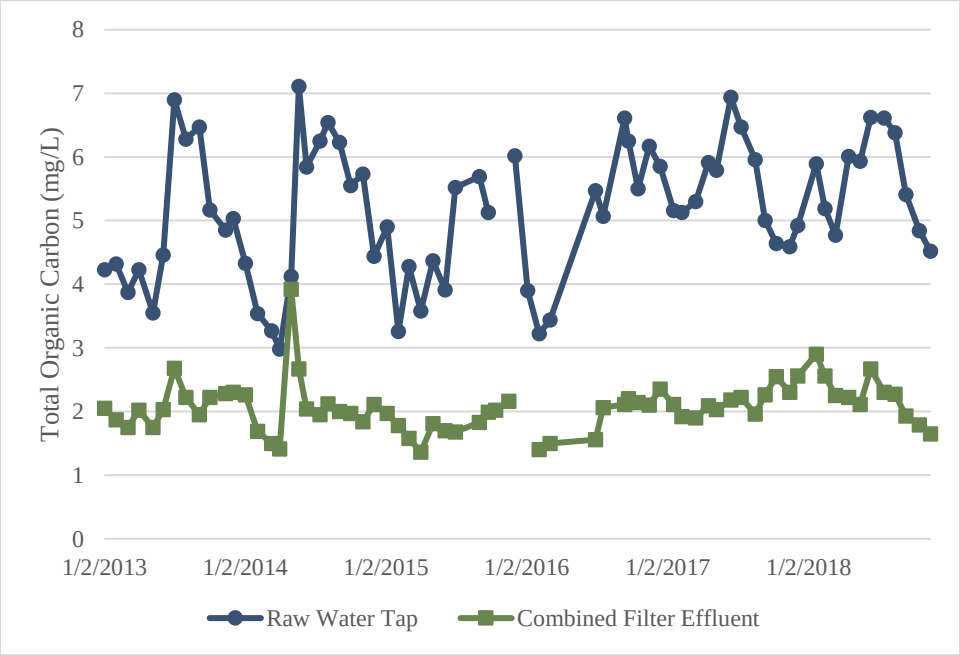

Figure 4-4. TOC Removal Compliance Monitoring at the Culpeper WTP

Overall, the Town has maintained TTHM and HAA5 levels below the respective MCLs and has achieved AWWA goals for control of DBP formation. The WTP has effectively removed natural organic matter from Lake Pelham to control DBP formation, and introduction of groundwater has further helped to maintain low DBP levels.

4.3 Lead and Copper Rule

The Lead and Copper Rule established requirements for monitoring of lead and copper in tap samples and implementation of corrosion control treatment to reduce lead and copper release into drinking water.

The Lead and Copper Rule (LCR) requires collection of tap samples from targeted locations throughout the distribution system. EPA established lead and copper Action Levels as a benchmark to establish when additional action is required to optimize corrosion control treatment. The Action Level is exceeded if the 90th percentile statistic of all samples collected in a given monitoring period exceeds 15 µg/L for lead or 1.3 mg/L for copper.

The Action Level is not a health-based standard. There is no safe level of lead in drinking water (USEPA, 2016), and while there are no regulatory limits or MCLs for lead or copper in drinking water, the USEPA has a stated non-enforceable goal of zero for lead.

The LCR defines corrosion control treatment, including pH/alkalinity adjustment or use of a corrosion inhibitor, to reduce the potential for release of lead and copper from building plumbing materials into drinking water. For water systems like Culpeper with a population less than 50,000, optimal corrosion control treatment is not required by the regulations unless an Action Level exceedance occurs. However, the Town of Culpeper proactively provides corrosion control treatment by adding a corrosion inhibitor at each water treatment facility and adjusting the finished water pH at the WTP.

For compliance monitoring, the Town coordinates with customers to collect first-draw tap samples as required by the LCR. **Table 4-3** summarizes the quantity of LCR compliance samples collected by the Town in prior monitoring periods (as reported by VDH Drinking Water Water).

Table 4-3. Quantity of LCR Compliance Samples

Date	Number of Samples
2019 Round 1	61
2018	60
2017	30
2016	30
2015 Round 2	60
2015 Round 1	60
2014	32
2011	30
2008	30
2005	30
2002	20

From 2002 to 2014, the Town was required to conduct triennial sampling in accordance with the LCR. In 2015, two 6-month rounds of LCR compliance monitoring were required by VDH due to the introduction of groundwater into the distribution system. During the first round of monitoring in 2015, the Town requested that VDH invalidate certain samples which were collected from hose bibs. These samples were

invalidated by VDH, and the Town collected additional tap samples and submitted the results to VDH for compliance purposes.

As shown in **Figure 4-5** and **Figure 4-6**, the 90th percentile lead and copper concentrations in compliance monitoring have been below the respective Action Levels. Individual sample results were reviewed, and the maximum concentration in any single sample is also presented. For 2015 Round 1, individual sample results were not available for review, and the 90th percentile value is presented.

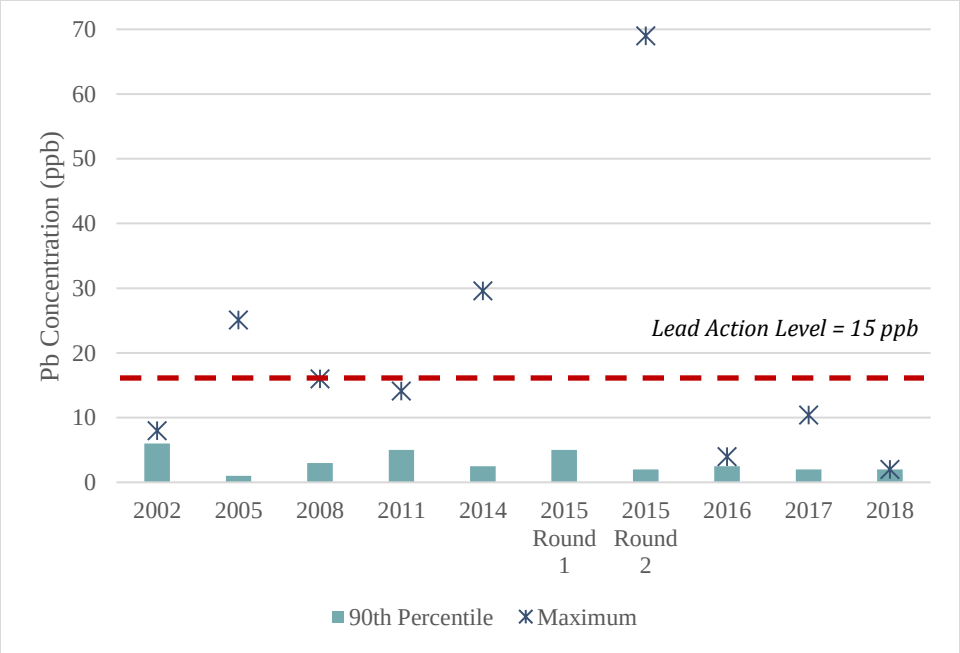

Figure 4-5. Lead Levels in LCR Compliance Monitoring

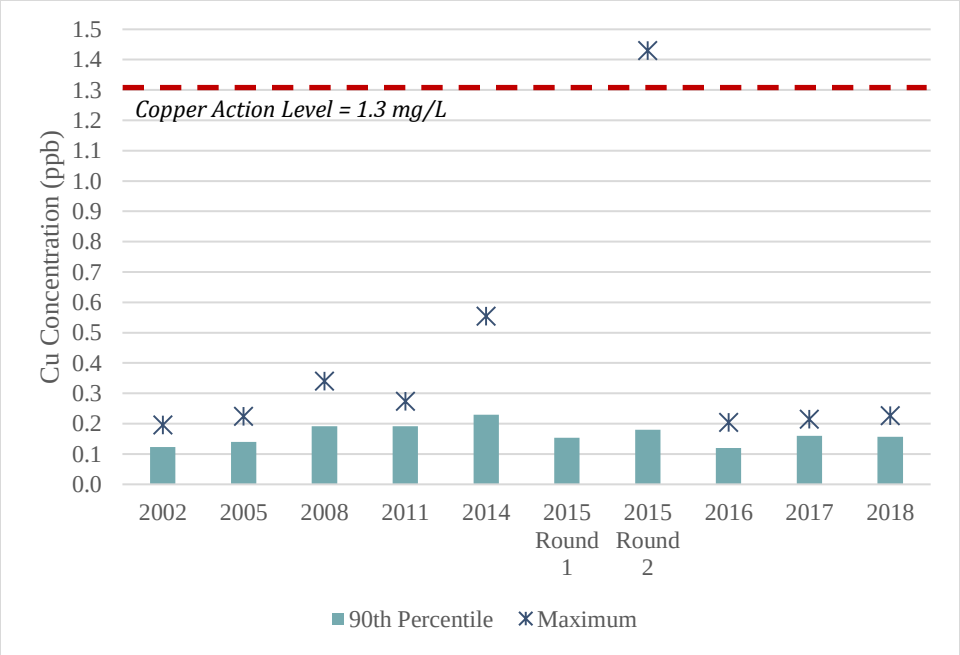

Figure 4-6. Copper Levels in LCR Compliance Monitoring

As part of revisions and clarifications to the LCR (effective December 2008), systems are required to provide advance notification and receive approval from the primacy agency for any proposed treatment or source water changes that could affect corrosion control. The Town of Culpeper was required to conduct additional monitoring as a condition of approval for introducing groundwater in 2015 and changing coagulants at the WTP in 2018. The Town complied with these sampling requirements and observed 90th percentile lead and copper levels below the LCR Action Levels.

4.4 Revised Total Coliform Rule

In order to determine the adequacy of water treatment and the integrity of the distribution system, EPA requires distribution system monitoring for total coliform, through the Revised Total Coliform Rule (RTCR). Compliance requires distribution system monitoring for total coliform. Any total coliform-positive routine sample must be tested for the presence of E. coli. If any total coliform-positive sample is also E. coli-positive, then the sample result must be reported to the state by the end of the day that the PWS is notified.

The RTCR establishes a maximum contaminant level (MCL) for E. coli and uses E. coli and total coliforms to initiate a "find and fix" approach to address fecal contamination that could enter into the distribution system. It requires public water systems to perform assessments to identify sanitary defects and take action to correct them. The RTCR specifies two levels of assessments (i.e., Level 1 and Level 2) based on the severity or frequency of the problem.

In accordance with RTCR requirements, the Town performs bacteriological monitoring of the distribution system in accordance with the sampling plan approved by VDH. Bacteriological sample results were

reviewed from May 2017 through August 2019 (as reported on VDH Drinking Water Watch), and all samples were reported absent for total coliform. VDH performs annual sanitary surveys of the distribution system, and VDH provided 2 to 3 comments regarding the distribution system in annual inspection in 2015 through 2017. The Town responded and coordinated with VDH to resolve comments.

4.5 Groundwater Rule

The Groundwater Treatment Rule requires monitoring and disinfection for protection against microbial contaminants in groundwater. Groundwater systems that use chemical disinfection and serve more than 3,300 people must continuously monitor their disinfectant concentration.

The Town adds sodium hypochlorite at each groundwater treatment facility for disinfection and uses an online analyzer and routine testing of grab samples to confirm that free chlorine residuals are maintained at the point of entry.

Sanitary surveys of the groundwater facilities are performed annually by VDH. VDH provided a comment regarding the groundwater facilities in annual inspections in 2017 and 2018, and the Town has responded and coordinated with VDH to resolve comments.

4.6 Primary Drinking Water Standards

Other contaminants are regulated by primary MCLs. The Town has tested numerous potential chemical contaminants in accordance with the Chemical Contaminant Rules, which regulates inorganic contaminants, volatile organic contaminants (VOCs), and Synthetic Organic Contaminants. There have been no reported violations of the Maximum Contaminant Levels for these chemical contaminants.

The 2016 annual report by Emery and Garrett Groundwater Investigations noted that the presence of VOCs, including tetrachloroethylene, may be a concern for the Chandler Street wells under long-term pumping conditions. The report presented results of three rounds of VOC testing for the wells. Tetrachloroethylene was detected in a July 2016 composite sample of Chandler Street wells at a concentration of 0.6 ppb, below the MCL of 5.0 ppb. VOCs were not detected in January 2016 and February 2017 samples of raw water from each well. Emery and Garrett Groundwater Investigations recommended on-going semi-annual testing of each well for VOCs. VOCs were not detected in subsequent testing of well C-1 in August 2017 and August 2018.

4.7 VDH and USEPA Documentation

Additional documentation from VDH and USEPA summarize the Town's regulatory status and indicate that the Town is in compliance with regulatory requirements.

VDH performs annual sanitary surveys of the Town's waterworks. A brief summary of information from the 2018 VDH Compliance History Report for the Town of Culpeper is as follows:

- **Total Coliform Rule** – Distribution system sampling for total coliforms is performed in accordance with the Town's approved plan.

- **DBP Rule** – The Town's Stage 2 monitoring plan was approved in July 2016, and the required monitoring frequency is quarterly.
- **Surface Water Treatment Rules** – An approved disinfection profile was submitted. Required *Cryptosporidium* monitoring was performed and resulted in a classification of Bin 1 indicating low *Cryptosporidium* risk in Lake Pelham.
- **Consumer Confidence Reports** – The Town has issued public consumer confidence reports in accordance with regulatory requirements.
- **Lead and Copper Rule** – A materials survey and sampling plan was approved in 2018. The Town did not exceed the Action Level.
- **Cross Connection Control** – The Town has an approved and active cross connection control program.
- **Operation Reports** – The Town submits monthly operation reports to VDH for all required data.
- **Emergency Management Plan** – The Town has a current emergency management plan with verification submitted in 2010.
- **Source Water Assessment** – The Town performed a source water assessment of Lake Pelham in 2010.
- **Enforcement** – VDH reported that the Town had no current administrative or consent orders, violations, or enforcement actions.

The USEPA Safe Drinking Water Information System (SDWIS) tracks information and regulatory violations for all public water systems. The Town of Culpeper has public water system identifier VA6047500. SDWIS indicates that the Town of Culpeper had one "monitoring and reporting" violation for total organic carbon in 2016, which is not a health-based violation. Since 2010, no other regulatory violations or primary MCL violations are reported in SDWIS, indicating that the Town of Culpeper has maintained compliance with applicable regulatory requirements.

4.8 Secondary Drinking Water Regulations

The USEPA has established National Secondary Drinking Water Regulations (NSDWRs), also known as secondary standards, which are non-mandatory guidelines regulating contaminants that may cause aesthetic effects 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 at the SMCL. Testing for SMCL constituents by public water systems is voluntary. The USEPA established SMCLs based on the following potential non-health-based impacts:

- **Aesthetic effects** – Effects include undesirable colors, tastes or odors; SMCLs for aluminum, chloride, color, copper, foaming agents, iron, manganese, pH, sulfate, threshold odor number, and total dissolved solids were established based on potential aesthetic effects.

- **Cosmetic effects** – These effects on the body are not harmful but are undesirable; an SMCL for silver was established due to potential skin discoloration, and an SMCL for fluoride was established based on tooth discoloration; there is also a health-based MCL for fluoride of 4 mg/L.
- **Technical effects** – Corrosivity may cause damage of equipment, staining of household fixtures and reduced water flow, and can also cause aesthetic effects due to corrosion of iron. SMCLs for chloride, copper, corrosivity, iron, manganese, pH, total dissolved solids, and zinc were established due to potential technical effects.

Table 4-4 summarizes the USEPA NSDWRs and presents references levels for water quality the Town of Culpeper.

Table 4-4. Summary of USEPA Secondary Standards

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL (per USEPA)	Town of Culpeper Observed Levels
Aluminum	0.05 to 0.2 mg/L	colored water	Below detection level in 2019 samples
Chloride	250 mg/L	salty taste	Below SMCL
Color	15 color units	visible tint	Occasional distribution system samples above SMCL
Copper	1.0 mg/L	metallic taste; blue-green staining	1 customer tap sample above SMCL
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining	Not quantifiable
Fluoride	2.0 mg/L	tooth discoloration	Below SMCL
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor	N/A
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining	Occasional distribution system samples above SMCL
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste	Occasional point-of-entry and distribution system samples above SMCL
Odor	3 threshold odor number	“rotten-egg”, musty or chemical smell	Not quantified
pH	6.5 – 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits	Point-of-entry values within SMCL range
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye	Below SMCL at Rockwater Park and Nalles Mill; no data available at other sites
Sulfate	250 mg/L	salty taste	282 mg/L at Chandler Street in July 2019
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste	46.7% of daily values at Chandler Street above SMCL; 0.7% of daily average values at Rockwater Park SMCL
Zinc	5 mg/L	metallic taste	Below SMCL at Rockwater Park and Nalles Mill

Water quality in the Town of Culpeper generally meets the national SMCLs. As indicated in **Table 3-4** above, levels exceeding the SMCL have been observed for the following parameters:

- **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 of distribution system mains and premise plumbing.
- **Total Dissolved Solids** – 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.

5. Public Perception of Aesthetic Water Quality Concerns

The Town initiated the Water System Assessment in response to public concerns about water quality within the Culpeper System. As a result, an objective of the Water System Evaluation was to catalogue, characterize, and provide context for customer concern data. To do so, Hazen performed the following:

- An analysis of water system customer reports documented by the Town to characterize customer water quality concerns.
- Implementing an online Customer Reporting Tool in 2019 to collect additional information from water system customers on water quality concerns.
- Public contact through outreach for specific customer reports and public meetings.

Data from these sources were evaluated to provide context for prioritization of aesthetic water quality improvements for further analysis.

5.1 Town of Culpeper Customer Concern Data

Data to inform the assessment of customer concerns was compiled from: (1) historical consumer complaint data received by the Town; and (2) data that was solicited from consumers via an online tool. This data was used to characterize consumer experiences with water quality and aesthetics. As is common for most 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 perception 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 Appendix B 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. Consumer complaint data was analyzed to develop an understanding of water aesthetic issues reported by a minority of the Town's customers.

5.1.1 Town of Culpeper Customer Complaint Documentation

The Town started tracking consumer complaints in 2016 and provided the Town Work Order (WO) System Listing of Complaints from 2016 to January 2019. The Town also provided Consumer Complaint Documentation Forms that included consumer information, water quality information based on a 1000 mL water sample collected from the meter jumper, actions during investigation and follow-up actions. Of the Town's 7,324 metered customers, the Town received a total of 190 complaints from 2016 to January 2019. Of the 190 complaints, 75 had addresses associated with them in the Town's records. **Figure B-1** in **Appendix B** shows the locations of the complaints with available addresses and the type of water quality complaint for each location. Approximately 60% of the complaints were for discolored water. **Figure 5-1**

summarizes the number of complaints received by the Town per month and the number that were associated with discolored water.

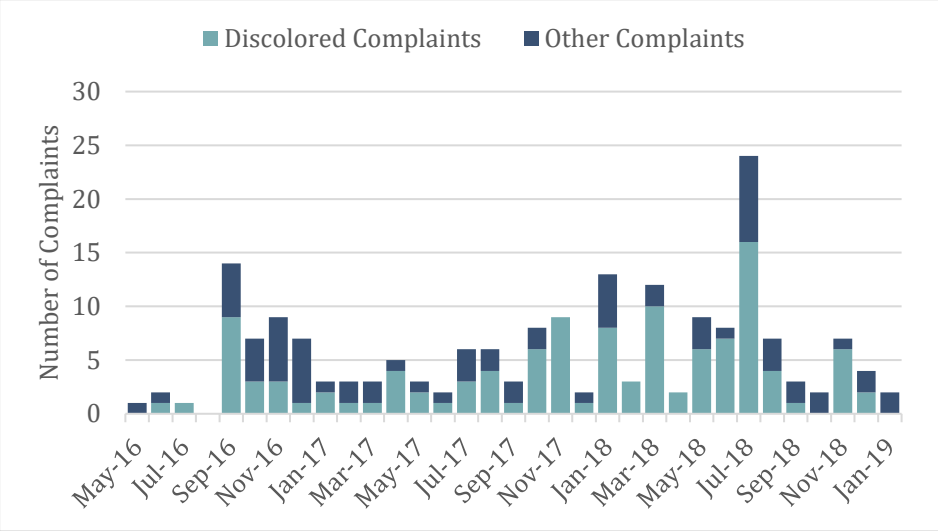

Figure 5-1. Town WO System Listing of Complaints

The Town performed ice pigging of the 18-inch finished water main and nearby water mains in February 2018, as flushing is not effective for cleaning of large diameter pipes due to limited flushing velocity. 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 implemented this technology to remove pipe deposits and improve the water quality in the neighborhood. A water main break occurred during the ice pigging in Oaklawn, which resulted in service interruptions and discolored water. In March, following the completion of the ice pigging, the Town recorded 12 customer complaints. Ten of the twelve complaints were due to discolored water.

5.1.2 2019 Customer Water Quality Complaint Data Collection

The Town of Culpeper mailed flyers, **Figure 5-2,** with information and a link to the Online Customer Reporting Tool. The tool was available for customer input through August 31, 2019.

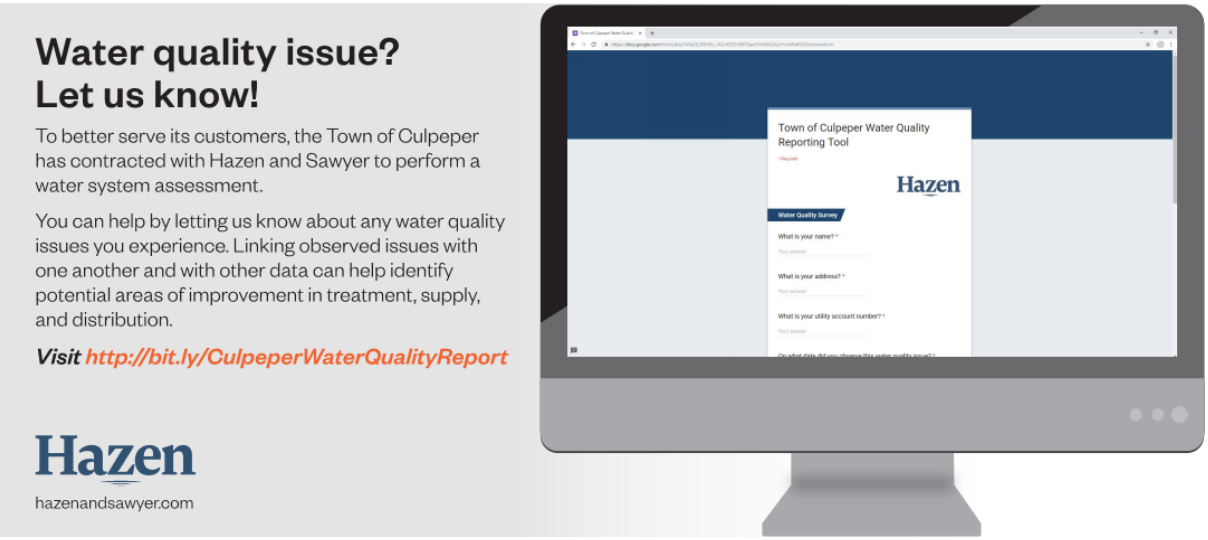

Figure 5-2. Customer Online Reporting Tool Flyer

The tool received a total of 48 responses from June 3 to August 31. Three customers responded multiple times with different water quality concerns. A total of 44 customers of the 7,324 metered customers responded to the tool with water quality concerns. The online tool listed selections for the type of water quality issue or concern including the following categories:

- Water Discoloration
- Unusual Taste or Odor
- Water Hardness
- Water Pressure
- Water Leak
- Other:_____

The other category allowed the customer to fill in any information, comments, or feedback about the Town's water system. The results for the type of water quality issue or concern are presented in Figure 5-3.

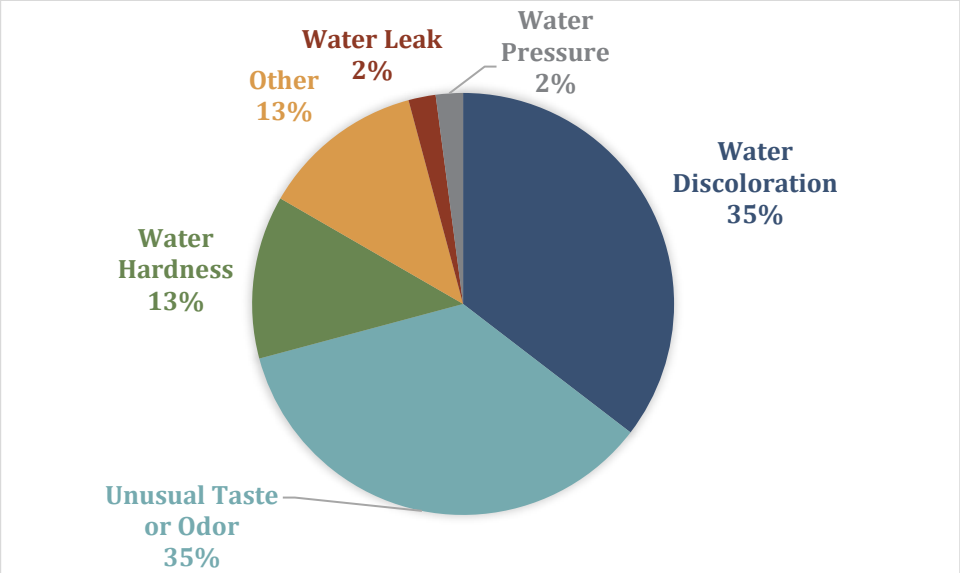

Figure 5-3. Results of Customer Online Reporting Tool

Water discoloration and unusual taste or odor were the most common selection and accounted for 70% of responses. Inputs into the other category included sediment, dark brown gritty, black or red mold and silt. **Figure B-2** in **Appendix B** presents a map of the tool results by category of water quality issue or concern.

Customers that selected water discoloration were asked to describe the color of the water at their tap. The tool listed options for selection of water color that included: red water, brown water, yellow water, black water, particles in the water and other. Based on the survey responses, the discoloration categories were revised slightly to include yellow, brown, red/orange stains, and mold/sediment. **Figure 5-4** presents the results of customer reports related to water color. The most common response was for brown water at 48% followed by mold/sediment at 39%. **Figure B-3** in **Appendix B** presents a map of the water discoloration type by location.

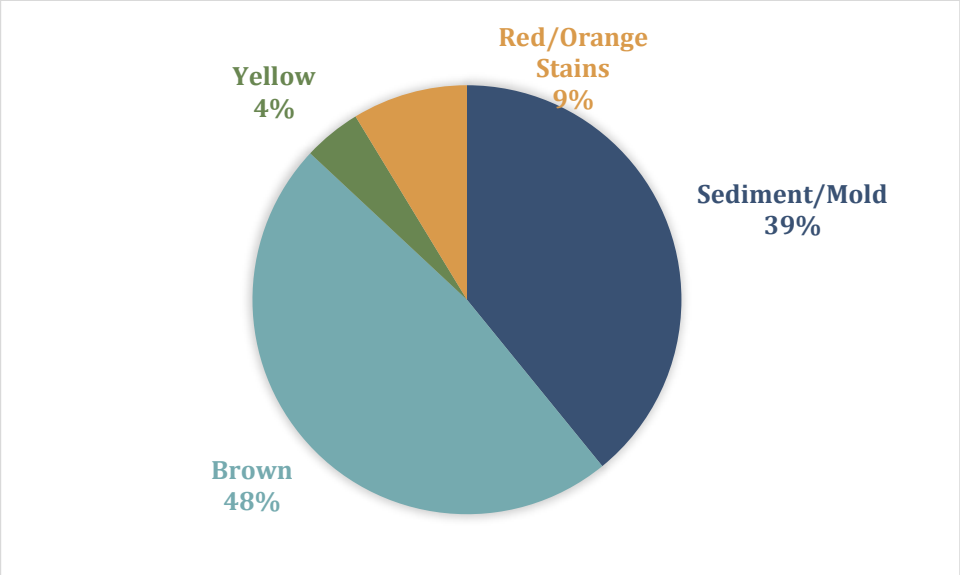

Figure 5-4. Results of Discoloration Appearance from Customer Online Reporting Tool

Customers that selected unusual taste or odor were asked to describe the taste or odor. The tool listed options for selection of taste or odor that included: earthly/musty/moldy, strong chlorine taste or odor (chlorinous), sulfurous, metallic taste, salty, chemical/hydrocarbon or other. The results from this are summarized in **Figure 5-5.** The most commonly reported taste and odor was earthly/musty/moldy, followed by a strong chlorine taste or odor (chlorinous). **Figure B-4** in **Appendix B** presents a map of the taste or odor type by location.

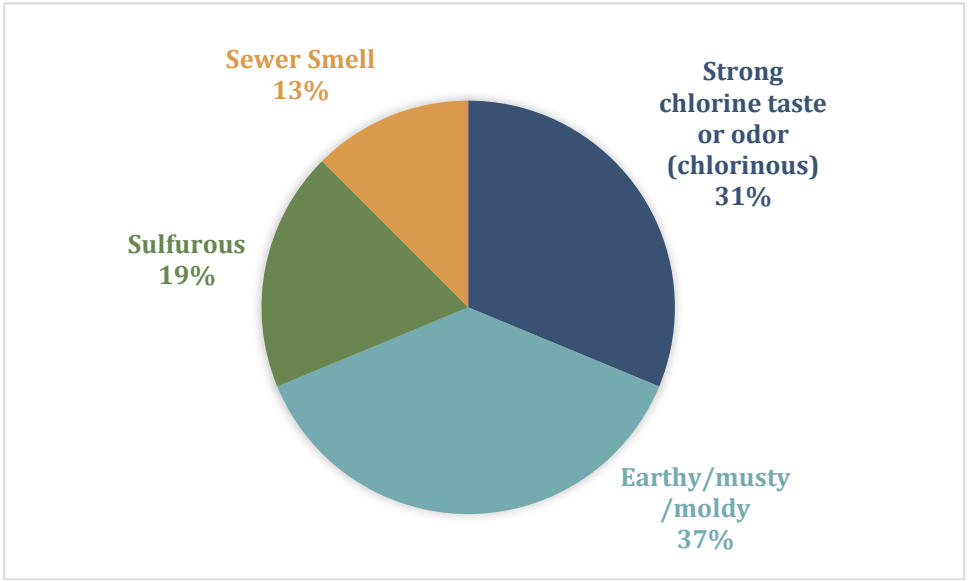

Figure 5-5. Results of Taste or Odor Type from Customer Online Reporting Tool

Two public meetings were held to inform the public of the project and to gain public input and comments. The Initial Public Meeting was held on April 11, 2019 to present an overview of the Water System Assessment project approach and to obtain public input and comments. The meeting was advertised by the Town through a press release and posting of information on social media. Approximately 8-10 community members attended. Comments from the initial public meeting focused on the following primary topics: discolored water concerns, water impacts on appliances, filters, and clothing, taste and odor issues, water pressure and fire flow and inquiries about water sources.

An Interim Public Meeting was held on August 20, 2019 to present the findings from recent progress on the Water System Assessment project approach and to obtain public comments and questions. The Town advertised the meeting in advance by issuing a press release describing the meeting. Approximately 16-18 community members attended. Public meeting summaries and presentations are included in **Appendix B**.

5.2 Summary of Public Reports

Water quality complaints were reported by a small 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 primary water quality concerns reported by the public were associated with water discoloration, taste and odor, and water hardness. Water discoloration and taste and odor are reported to be the most common causes of customer complaints in water systems across the country and affect water aesthetics, customer end uses, and public perception of the water quality. The reported aesthetic issues in the Town of Culpeper are associated with non-enforceable Secondary Drinking Water Standards, which do not present public health concerns at the SMCL.

As part of the customer complaint data analysis, customer reports were reviewed to determine if the origin of these episodic aesthetic water quality issues could be identified. As documented customer complaints were only available for analysis since 2016, customers were asked about the history and duration of reported water quality issues. Anecdotal reports from customers at public meetings and during phone conversions suggest that these issues have occurred for more than 4 years, and multiple customers residing in the Town for up to 30 years noted that these issues had occurred throughout their period of recollection. Thus, an origin or precipitating event affecting the reported aesthetic issues could not be determined. Public descriptions suggest that the reported aesthetic issues are a long-term yet episodic occurrence.

6. Conclusion

The Town operates a large water system, comprised of both surface and groundwater sources, a surface water treatment plant, 3 groundwater treatment facilities, and 100 miles of pipe, four storage tanks and six automatic flushing stations. The Town has consistently provided high quality water to their customers, and has implemented several key initiatives to improve efficiency, resiliency, and water quality since joining the AWWA Partnership for Safe Water in 2008.

The Culpeper Water System has consistently been in compliance with all federal and state primary drinking water regulations over the period of review (2008 – present). In response to several aesthetic concerns raised by customers, the Town has engaged in outreach and information gathering efforts, to catalogue, characterize, and contextualize public concerns regarding aesthetic water quality. An examination of historical water quality complaints and current outreach efforts determined that water discoloration, unusual tastes and odors, and hardness were the most frequently identified public concerns. Further efforts in the Water Quality Study (Water Quality Analysis and Water Quality Recommendations) are focused on identifying potential causes of these aesthetic concerns and providing the Town with achievable short- and long- term strategies to improve drinking water aesthetics and continue to provide high quality reliable drinking water service to their customers.

Appendix A: Distribution System Maps

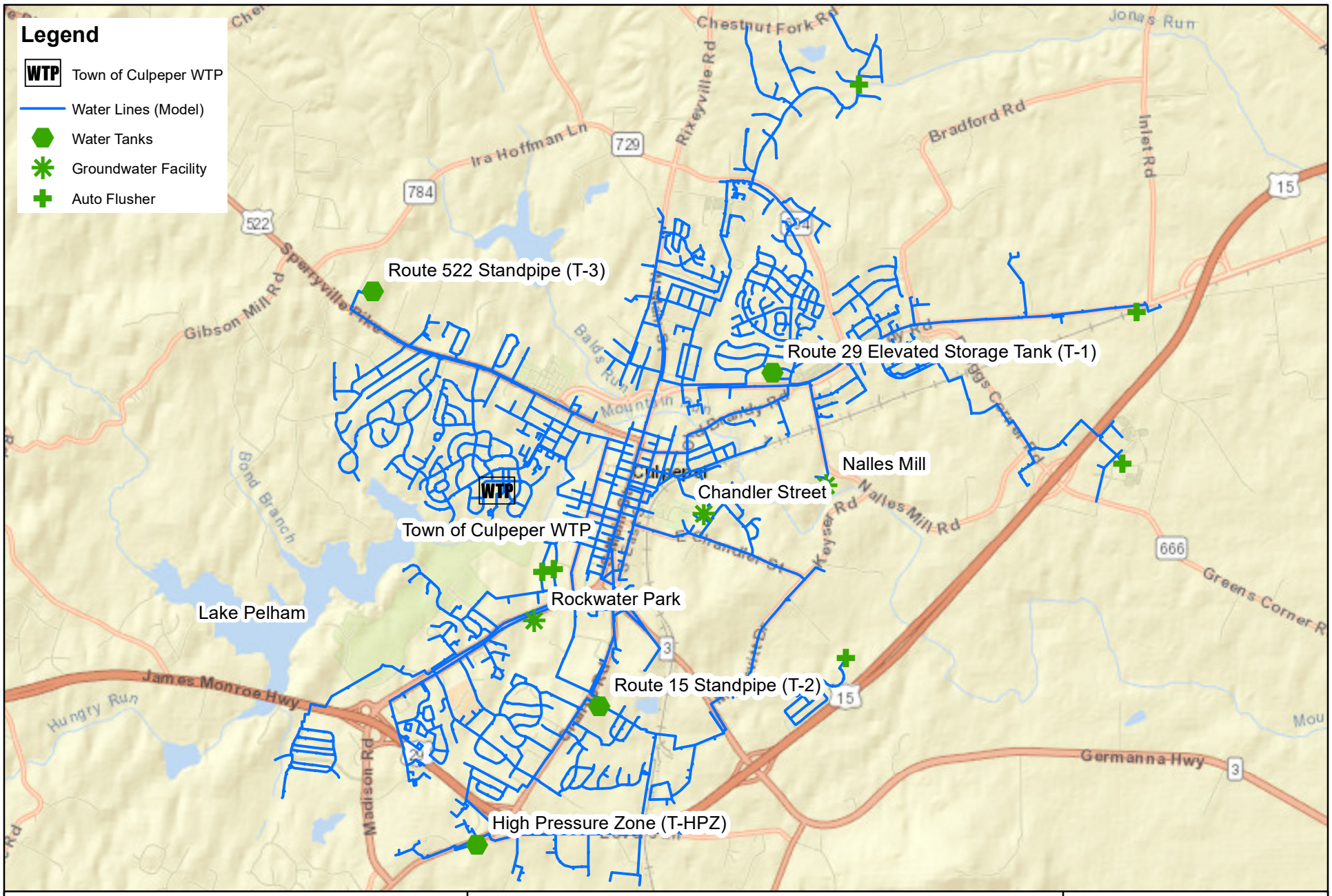

Figure A-1: Town Water System Overview

Client: Town of Culpeper
Project: Town of Culpeper Water System Assessment
Location: Culpeper, Virginia
Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

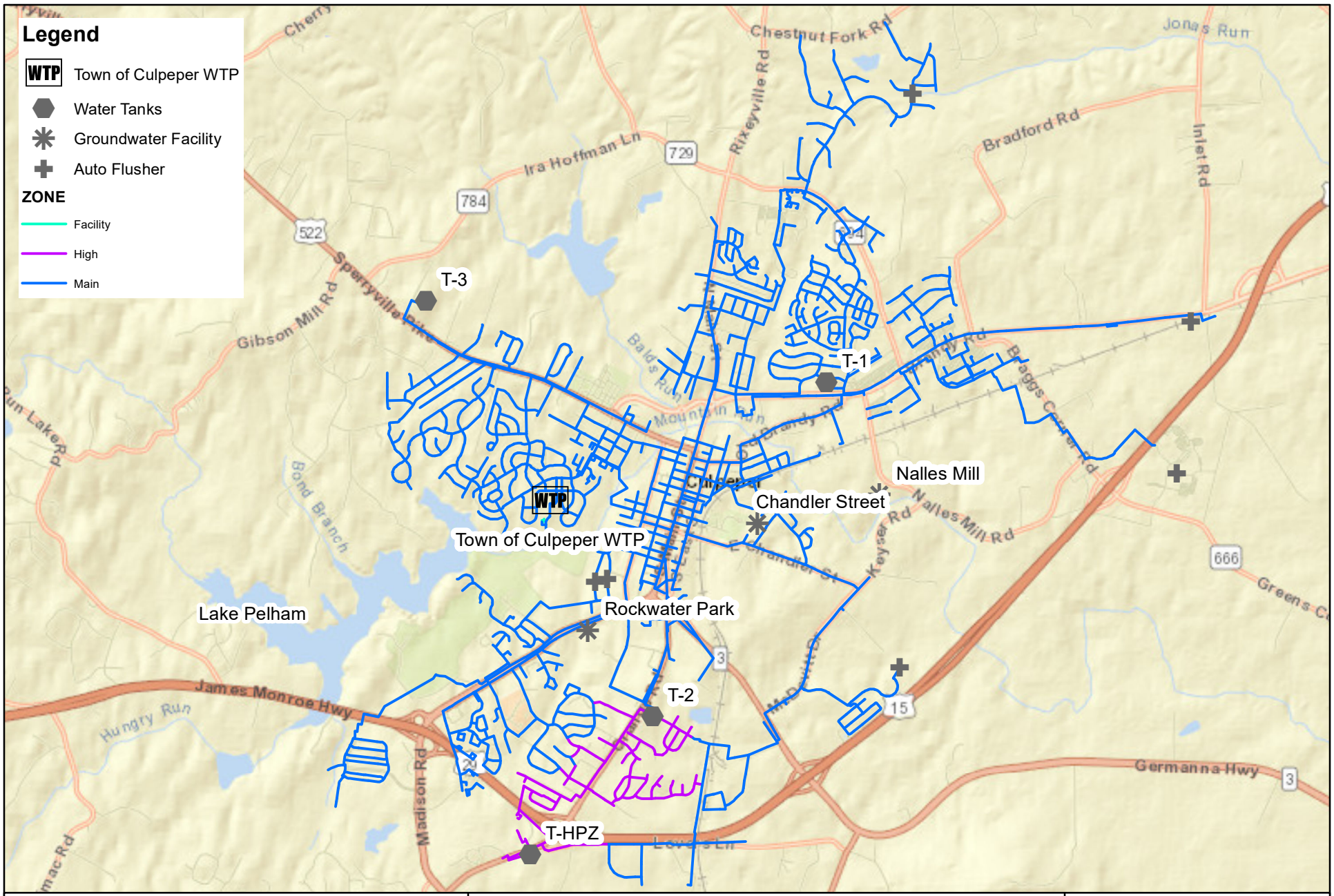

Figure A-2: High Pressure Zone

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

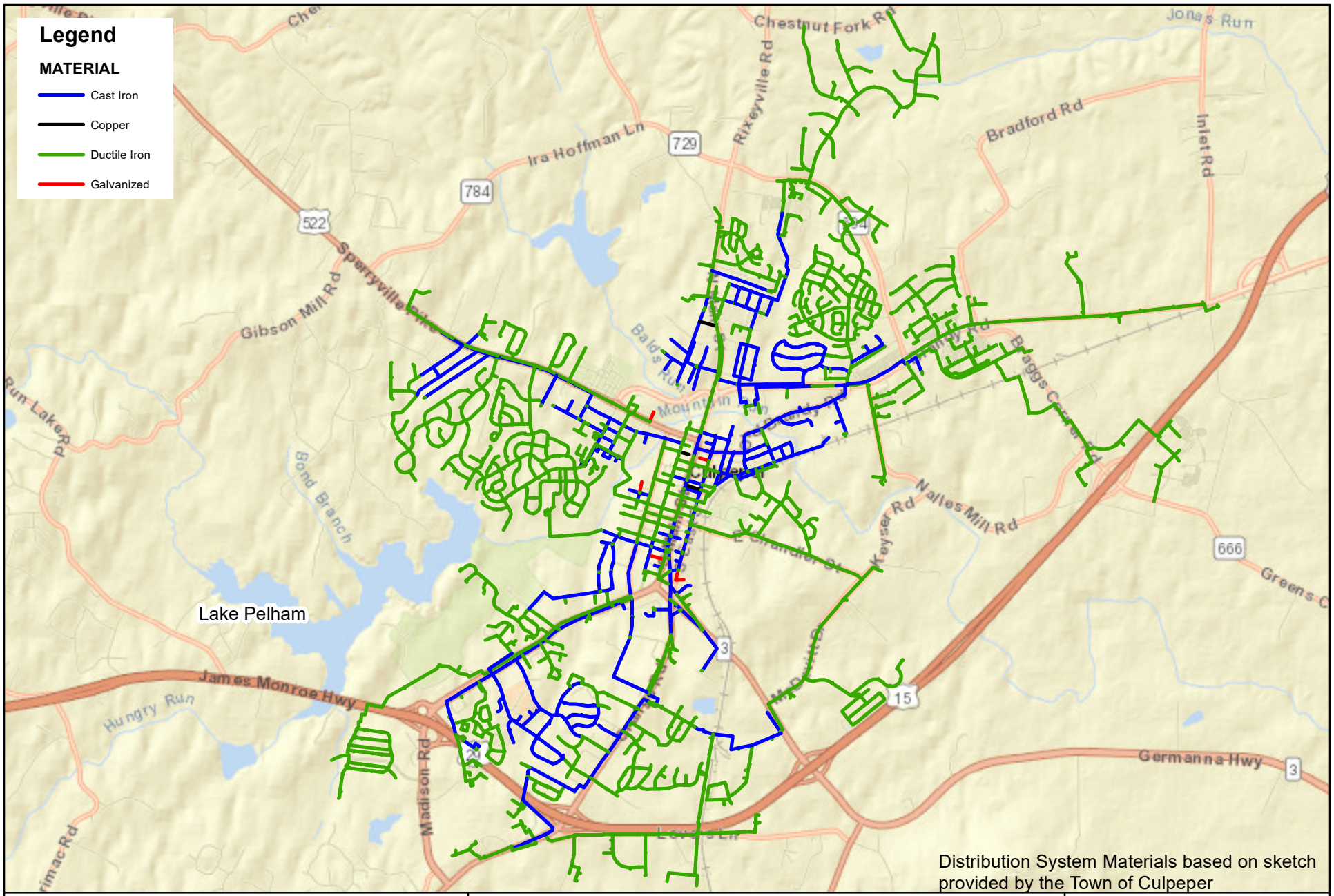

Figure A-3: Distribtuion System Pipe Materials

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

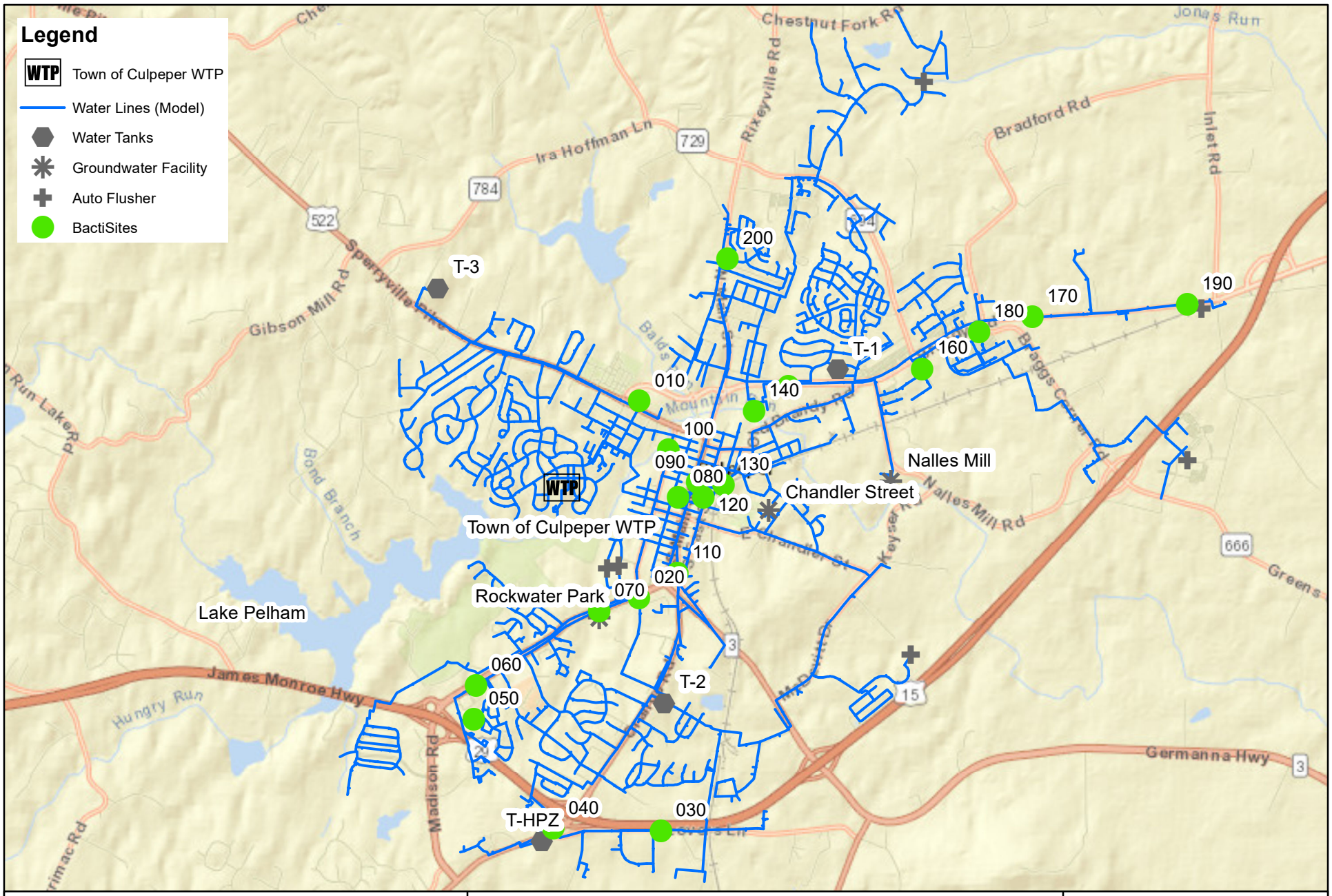

Figure A-4: 2019 Bacti Sites

N

0 0.35 0.7 1.4 2.1 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

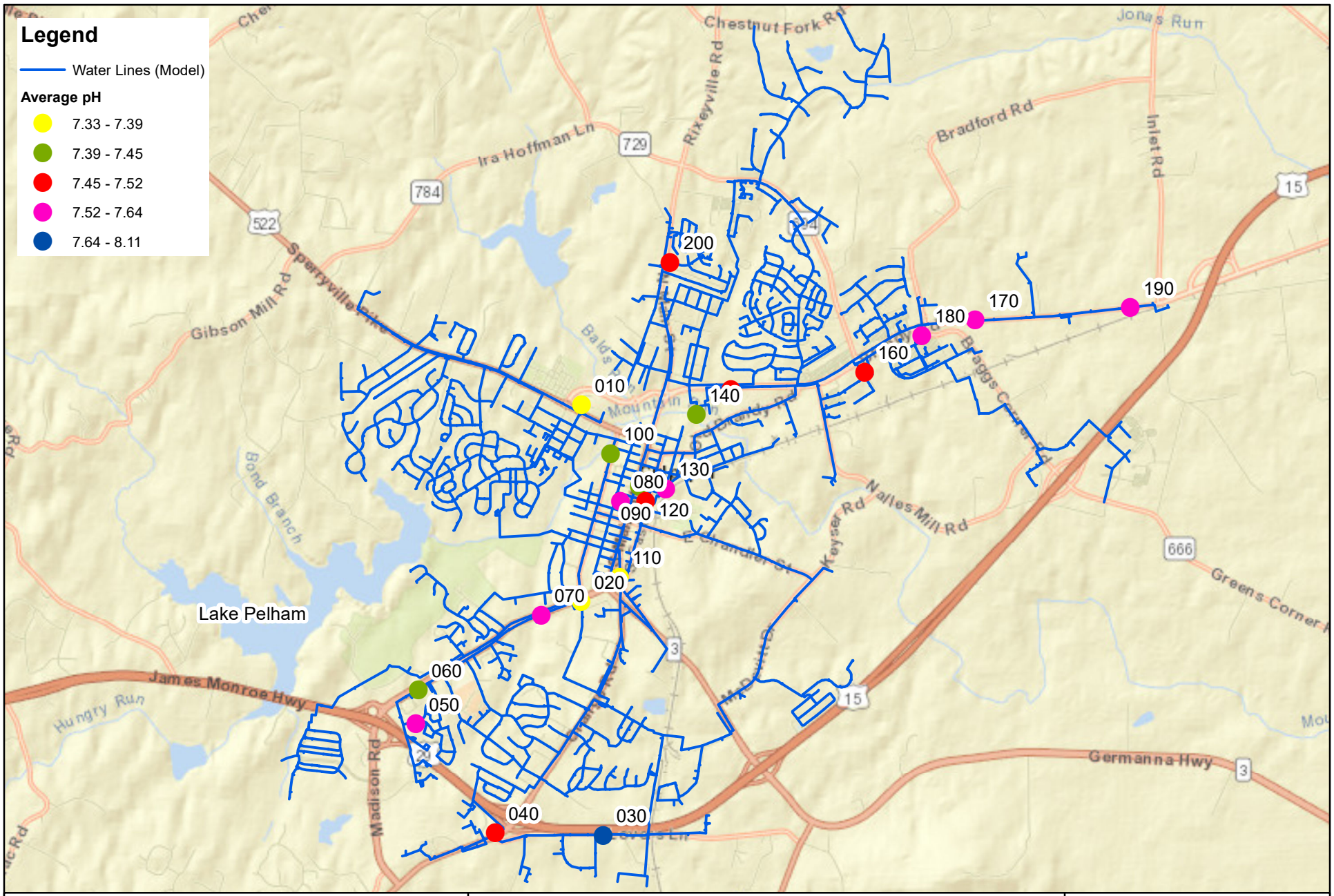

Figure A-5: Distribution Average pH

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

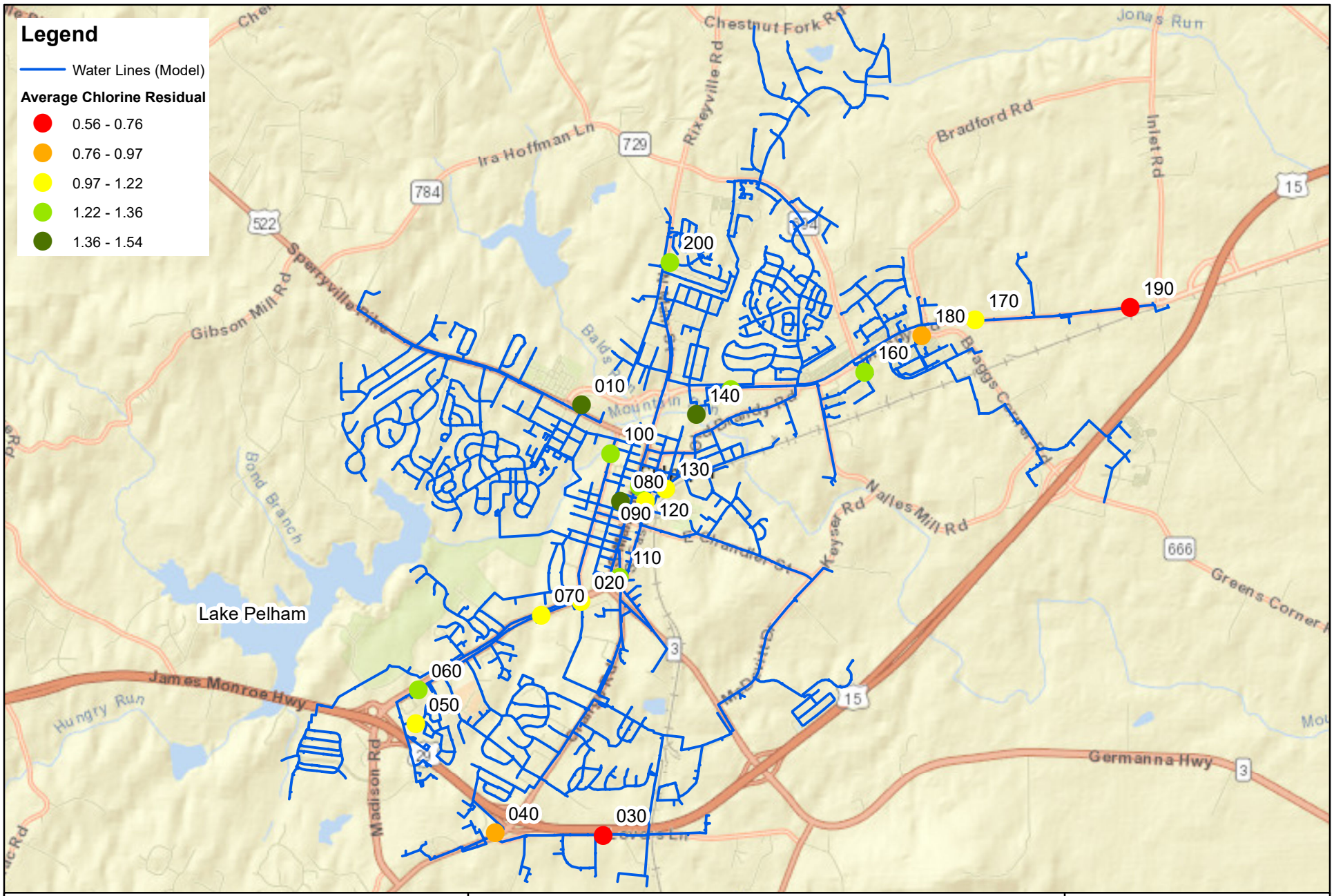

Figure A-6: Distribution System Free Chlorine Residuals

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

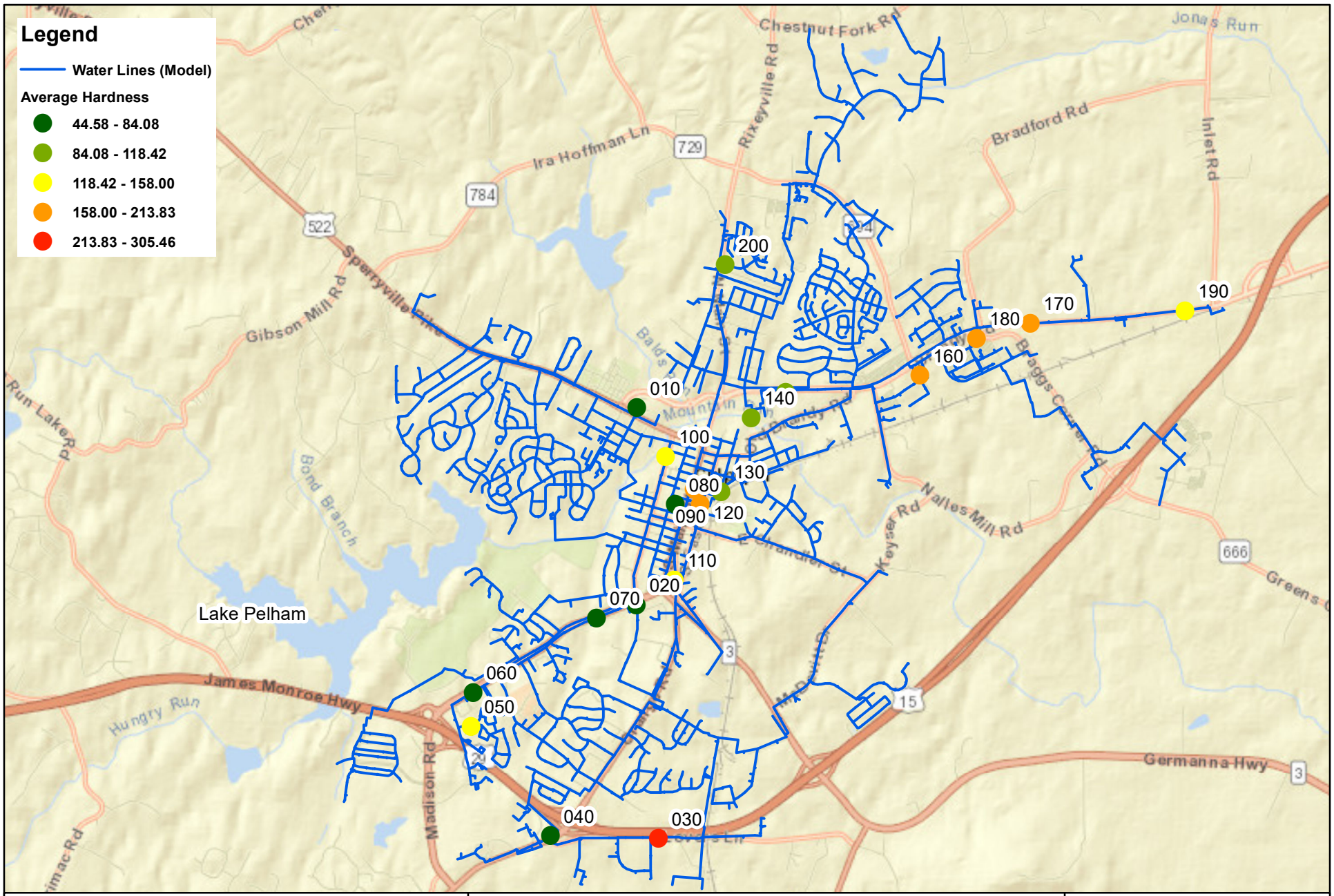

Figure A-7: Distribution System Hardness

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

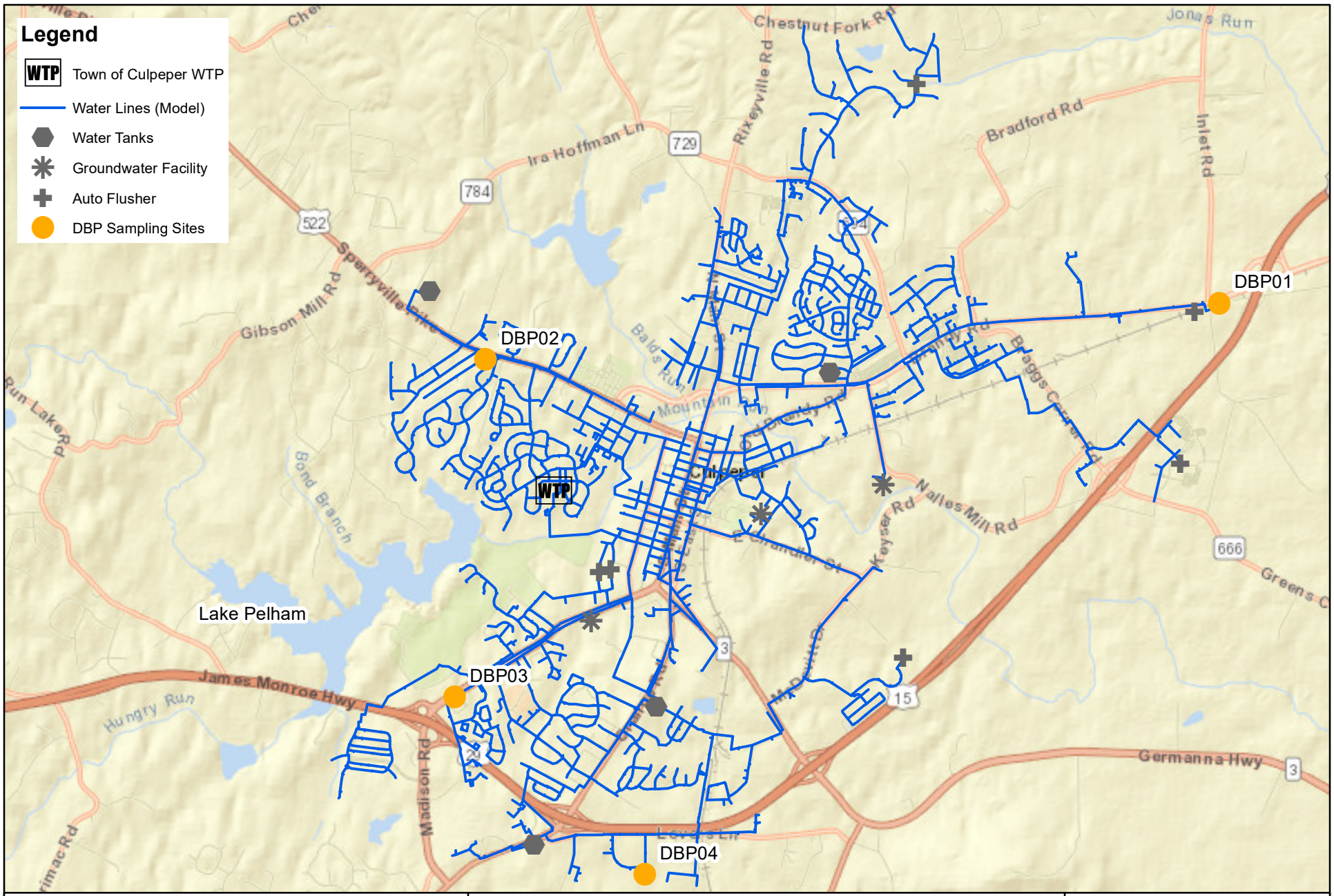

Figure A-8: DBP Sampling Locations

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

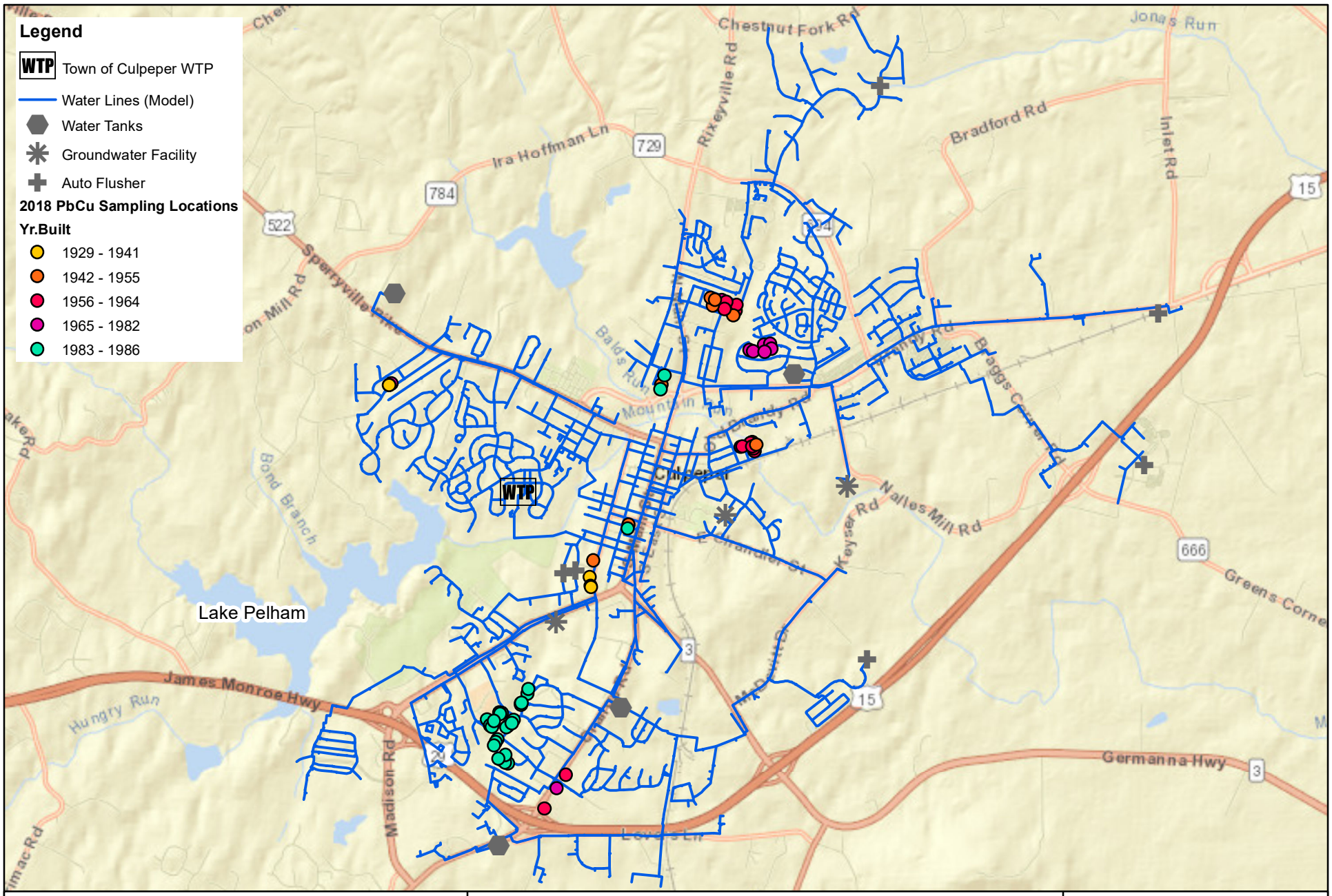

Figure A-9: LCR Sampling Locations

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

Appendix B: Public Outreach Supporting Information

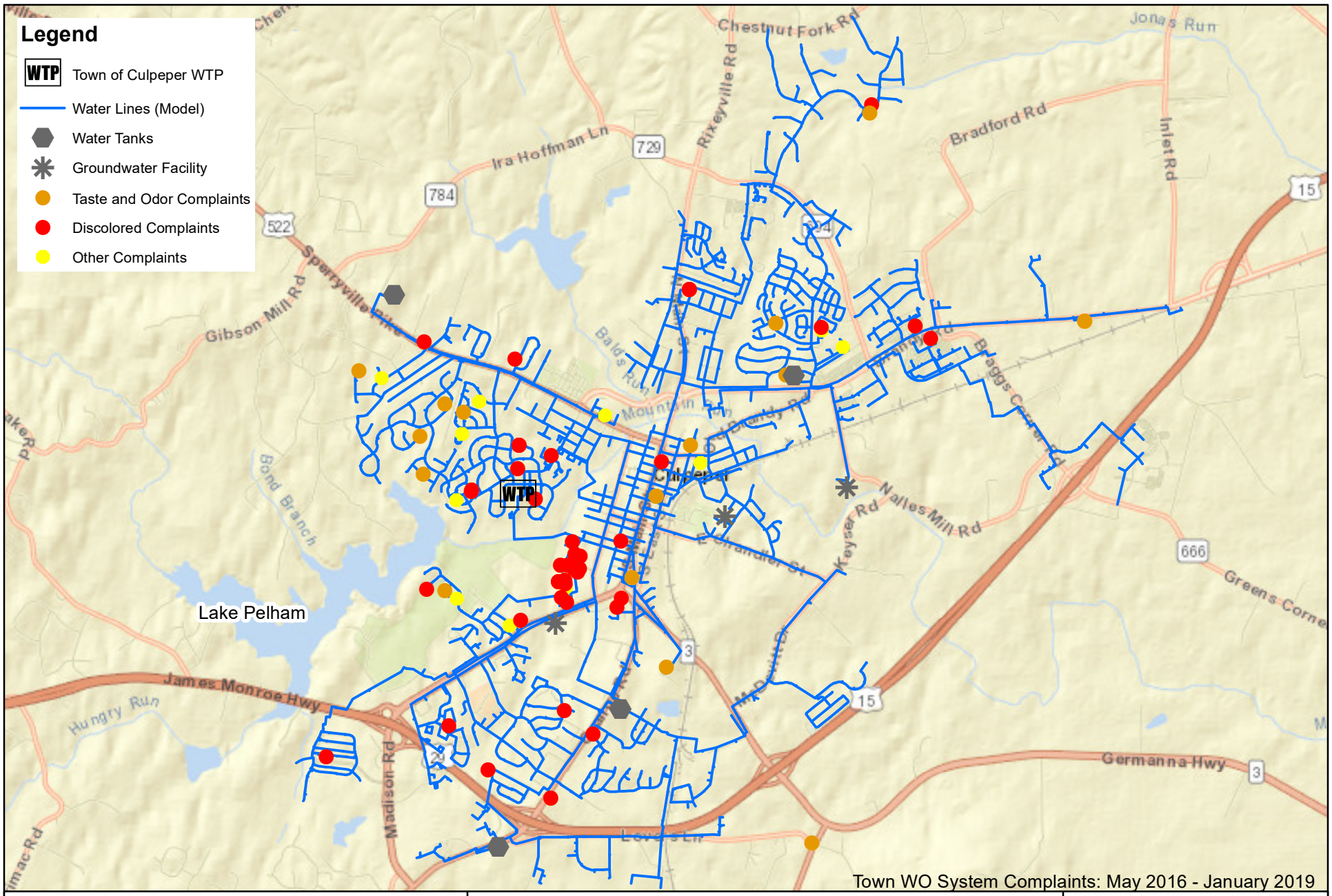

Figure B-1: Town WO System Complaints

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

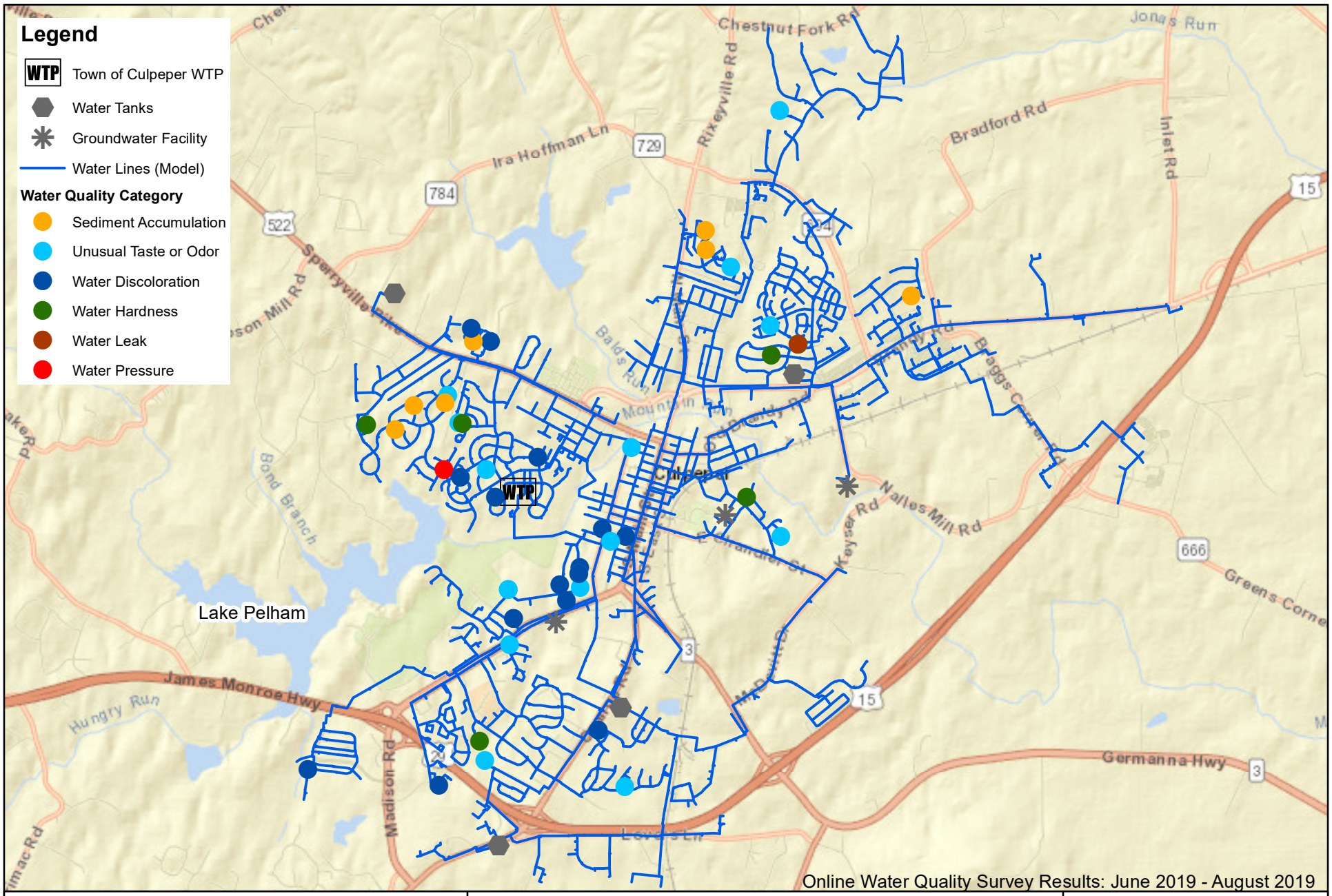

Figure B-2: Community Water Quality Survey Results

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

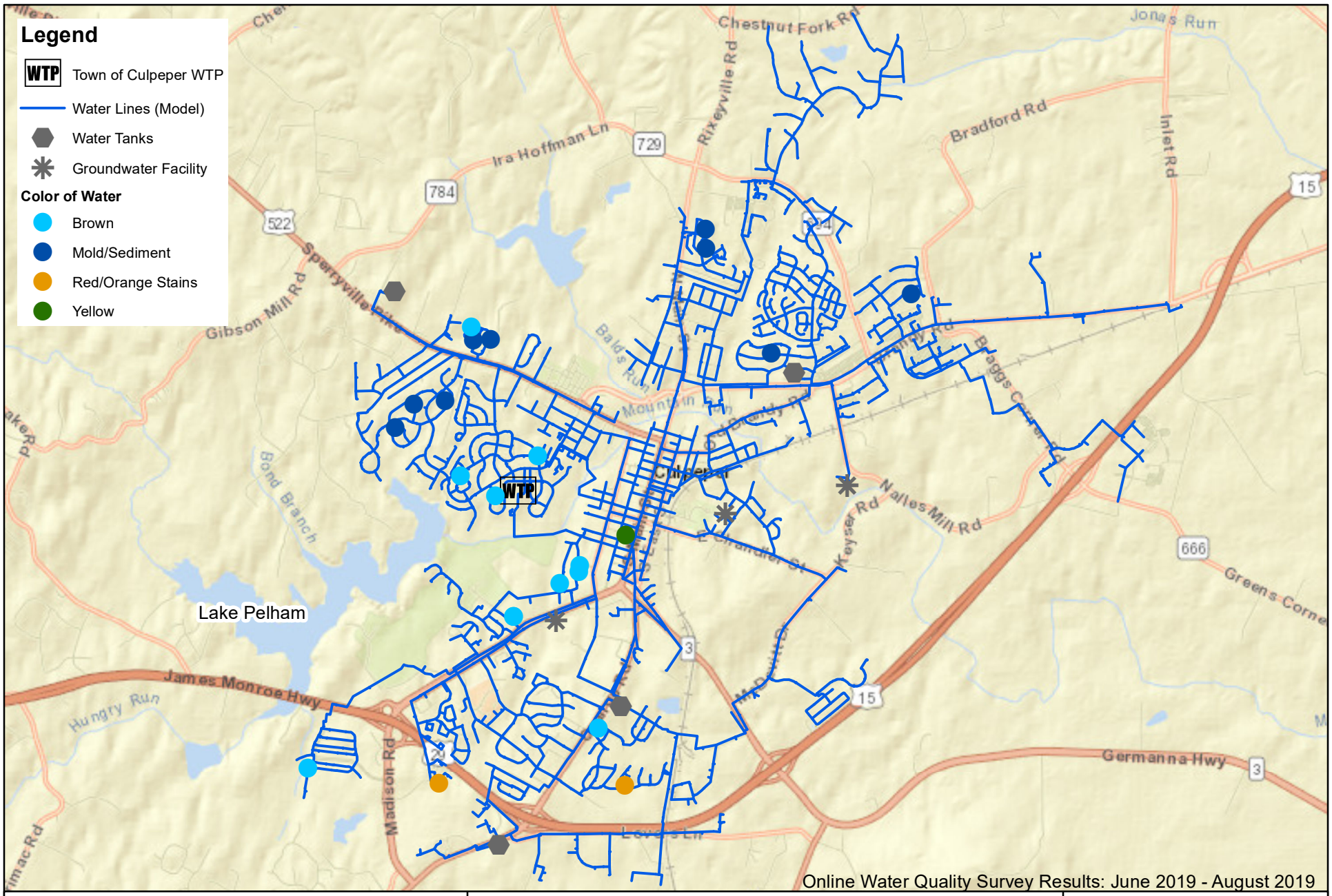

Figure B-3: Community Water Quality Survey Results (Water Color)

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen
4035 Ridge Top Road
Fairfax, VA 22030

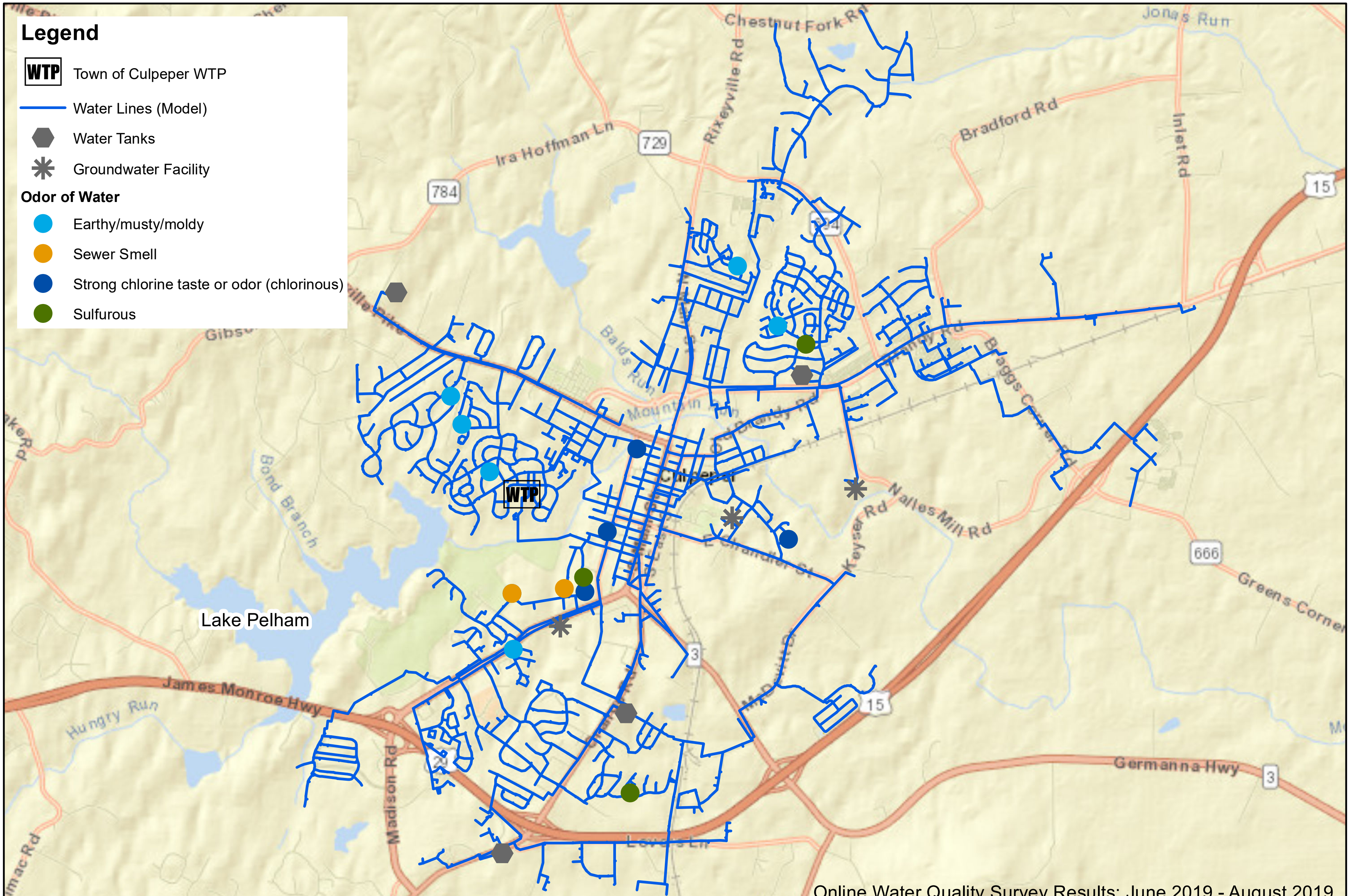

Figure B-4: Community Water Quality Survey Results (Water Taste or Odor)

N

0 0.4 0.8 1.6 2.4 Miles

Client: Town of Culpeper

Project: Town of Culpeper Water System Assessment

Location: Culpeper, Virginia

Date: January 2020

Hazen

4035 Ridge Top Road
Fairfax, VA 22030

Hazen *Meeting Summary*

Subject: **Town of Culpeper Water System Assessment – Initial Public Meeting Summary**

Location: Town of Culpeper Police Department Community Room

Date: April 11, 2019

An initial public meeting was held to present an overview of the Water System Assessment project approach and to obtain public input and comments related to the Town's water system.

An initial public meeting for the Water System Assessment project was held on April 11, 2019 at the Police Department Community Room. An introduction and welcome was delivered by the Town of Culpeper Director of Public Services, Jim Hoy. Hazen and Sawyer delivered a brief presentation about the Water System Assessment project, which described the project purpose, the project scope, and the project schedule. Following the presentation, community members attending the meeting had the opportunity to offer questions and comments about the project and the Town's water system.

The Town advertised the initial public meeting in advance by issuing a press release describing the meeting and by posting information about the meeting on social media.

Approximately 8-10 community members attended the initial public meeting, and members of the Town's staff were also in attendance.

Comments from initial public meeting participants were received in verbal and written form and were focused on the following primary topics:

- Discolored water concerns
- Water impacts on appliances, filters, and clothing
- Taste and odor issues
- Water pressure and fire flow
- Inquiries about water sources

Hazen

Public Comments – Verbal

Community members in attendance provided verbal comments and questions during the meeting. Questions regarding the presentation and the project were as follows:

- How far will the financial rate study go?
- Has Hazen and Sawyer performed similar projects in other places? Have there been quantifiable results in each study?
- How much latitude will Hazen and Sawyer have in developing a report for the Water System Assessment project? How much will the Town be able to edit the report?
- Will the Town share the presentation from the initial public meeting?
- What is the source of the Town's water? Does the water come from lakes, ponds, wells, or rain runoff?

Verbal comments about the Town's water system included the following:

- A resident of the Oaklawn neighborhood expressed concerns about the capacity of the fire hydrants in the Town when needed for firefighting due to variability in flow test results for hydrants.
- A participant shared comments from staff at All Smiles Dental who were not able to attend the meeting. The dental office has experienced brown rusty water, which has required them to use bottled water. The office was recently remodeled and the plumbing was replaced, but the office still has discolored water.
- A resident of the Lakeview neighborhood shared photographs of discolored water in the household, including brown water in the bathtub, stained clothing, damaged appliances, brown water filters, and a section of pipe removed from the Oaklawn neighborhood. The participant provided filter cartridges removed from a whole-house filter which were a brown color. The whole-house filter is located where the waterline enters the home in a 5.5 year old house. The participant emphasized the severity of the water quality issues and explained that the water has caused community members to frequently replace appliances, hot water heaters, and stained clothing. Several dentist's offices cannot use the Town's water. The participant expressed concerns about past responses from the Town when water quality issues were reported and explained that the Town provided potential causes of the discolored water, including: broken private service line, filling swimming pools, hot water heater problem, or internal home plumbing problem.
- A participant explained that he is currently running for Town Council and has found that water is the primary issue of concern for community members, although he has not personally experienced any water quality issues. He commented that water quality is a volatile issue in the Town because it has caused community members to frequently replace appliances. He explained that community members don't like to drink the water because of a strong chlorine taste and that some residents have experienced slow water with low pressure. He emphasized the need for

transparency in addressing water quality concerns. He provided a list of addresses with water quality concerns including: 829 Fox Den, 845 Fox Den, 846 Fox Den, 799 Woodcrest Loop, 869 Woodcrest Loop, and 879 Woodcrest Loop.

- A resident of the Oaklawn neighborhood commented that the water quality has significantly impacted home appliances and required frequent replacement of a whole-house filter. He observed that the water discoloration issues started in 2013. The participant explained that the water quality has caused him to replace 3 washing machines, 3 hot water heaters, and new refrigerator filter. His home has a 10 micron filter that must be changed every 23-26 days and appears brown when changed. The water in the toilets is brown. He commented that the Town should start to find and prioritize the problems.
- A participant commented that he wants to make sure the Town is using the right water distribution system pipe materials. He inquired if other utilities are using new PVC pipe and connecting PVC to steel pipe.
- The Deputy Chief of the Fire Department commented that the Town has been working to improve hydrant pressure and the Fire Department typically has adequate pressure for firefighting. The Fire Department has observed that hydrants produce clear water after flushing for approximately 30 seconds. He also operates the SWIFT data center on McDevitt Drive that has an on-site water treatment system. The data center receives water from the Town's groundwater wells and has observed high silica levels that cause problems at the facility.
- A participated commented that there is silt in the water.
- A participant described that that the water had a strong chlorine taste and odor.
- A participant described that the water had a mossy bouquet odor and smelled like grass or dirt.

Public Comments – Written

Comment cards were available for attendees to provide written comments during the meeting. Additionally, some community members provide pre-developed written documents about the Town's water system. Written comments received at the initial public meeting in addition to the verbal comments are summarized as follows:

- A written comment explained that two locations on S. East Street have experienced the following water quality issues for at least 3 years, and similar problems were reported throughout the neighborhood: sediment in the bottom of glasses, foul water odor, discoloration, grit left on dishes, film on clear glassware, problems with dishwashers, washing machines, etc., hardness of water. This has caused residents to purchase bottled water and water filtration systems. The comment noted that water costs have continued to increase despite the problems.
- A pre-developed written comment was provided by a resident of the Lakeview neighborhood. The residents moved into a new home in 2004, and in 2012 they began to notice brown water from all the faucets. Water discoloration was the worst in the Jacuzzi bathtub and in the hot water. They noticed that dirt from the water was collecting in the washing machine. They also

experienced an "extremely potent" chlorine odor in the shower. The comment expressed concerns about the potential impacts of water quality on skin health. The comment requested clean, clear water to be distributed to the Town.

- A pre-developed written comment was provided by a resident of the Lakeview neighborhood with additional background information on the history of water quality issues in the Town. Key written comments included:
    - At a meeting in October 2016, residents complained of sulfur smells, raw sewage smells, strong chlorine odors, black sludge, and brown discoloration that started around 2011.
    - A resident in Cardinal View had the water tested, and the iron and manganese concentrations were above the Secondary Maximum Contaminant Levels.
    - The wells were originally planned for emergency purposes only but were used as a main source of water. There were supposed to be underground waterlines from the wells to the water treatment plant.
    - The groundwater is so hard, it's interfering with the chemical feed into the water.
    - Distribution system was routinely performed prior to 2011 but was stopped. Flushing was resumed by 2017.
    - The written comments included a list of "questions to consider", and several of these comments included:
        - What was the original intent of the wells?
        - Is the water supply being over-chlorinated due to the turbidity of the water?
        - From March 2019 to April 2019, the water quality seems to have improved. What is different now compared to the years from 2011 to 2018, and will the improvement in water quality be permanent?
- A written document was provided and indicated that complaints to the Town and the Department of Health Office of Drinking Water have occurred since 2013 and included photographs of discolored water, excavated distribution system pipes, and damaged appliances.
- A written copy of a community member's presentation about the Town's water from August 14, 2018 was provided.
- A written comment indicated that the Town's water is the number one complaint in the community.

Hazen *Meeting Summary*

Subject: **Town of Culpeper Water System Assessment – Initial Public Meeting Summary**

Location: Town of Culpeper Police Department Community Room

Date: August 20, 2019

An interim public meeting was held to present the findings from recent progress on the Water System Assessment project approach and to obtain public comments and questions related to the Town's water system.

An interim public meeting for the Water System Assessment project was held on August 20, 2019 at the Police Department Community Room. The Town advertised the initial public meeting in advance by issuing a press release describing the meeting. Approximately 16-18 community members attended the initial public meeting, and members of the Town's staff were also in attendance. An introduction and delivered by the Town of Culpeper Director of Public Services, Jim Hoy.

Hazen and Sawyer delivered a presentation about the Water System Assessment project. The presentation included an update on the public outreach results and findings from the project. Public comments analyzed in the study have focused primarily on water discoloration and water taste and odor issues.

Hazen presented results from the water system study and analysis of water quality data. Hazen presented background information on how naturally occurring iron and manganese can contribute to water discoloration, including: source water and treatment, distribution system legacy deposits, and corrosion of iron pipes in the distribution system and building plumbing. The US Environmental Protection Agency has secondary standards for iron and manganese due to aesthetic issues and does not have health-based regulations.

Hazen presented results from the fire flow analysis and hydrant testing conducted in the Town. Hydraulic model calibration agrees with the fire flow testing results. Model fire flow simulations are consistent with observed testing results. Fire flow analysis results for the Town indicate that available fire flows are favorable.

During and after the presentation, community members attending the meeting had the opportunity to offer questions and comments about the project and the Town's water system.

Hazen

Public Comments and Questions

Verbal comments about the Town's water system included the following:

- A community member inquired how many citizens of the Town had been contacted about the study. Hazen indicated that an online survey was conducted to obtain public input on the project. Approximately 43 reports were received in the online portal by the end of July.
- A community member inquired why the water discoloration continued on a daily basis if the Town was working on improvements since 2008. The presentation described factors contributing to water discoloration.
- A community member inquired if graphs the Town's data over time would be presented. Detailed data graphs were not presented in the interim public meeting and will be presented in the final report. Hazen indicated that a table would be prepared to summarize the Town's data analyzed for the study.
- A community member inquired why water in the home was discolored after the home was unoccupied for an extended period. Hazen indicated that corrosion of iron plumbing or service lines at the home may contribute to localized discoloration especially after extended stagnation.
- A community member inquired what is a hydraulic disturbance that can cause release of legacy deposits. Hazen indicated that hydraulic disturbances can be caused by main breaks, flushing, large demands, flow reversal, or other sudden flow changes.
- A community member inquired if more information on water tastes and odors would be provided at another meeting.
- A community member inquired if control of iron and manganese needed to be improved at the water treatment plant and if filter upgrades are needed.

Written Comments and Questions

- A community member inquired why the public meetings were not better publicized.
- A community member inquired why the Town pays for studies if they know what the problem is and could instead use the money for new pipes and better treatment, and asked how safe the Town's water is to drink.
- A community member commented that the water has a metallic taste and small pieces of sediment in the water. They have replaced many appliances and water heaters. Development in the area occurred in the early 2000's.