YARMOUTH WATER SYSTEM MASTER PLAN

FOR

YARMOUTH WATER DIVISION
YARMOUTH, MA

KLEINFELDER PROJECT # 20193862.001A

DECEMBER 2019

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YARMOUTH WATER SYSTEM MASTER PLAN

FOR

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YARMOUTH, MA

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0 EXECUTIVE SUMMARY

The Yarmouth Water System is comprised of extensive infrastructure, including 24 pump stations, 17 corrosion control facilities, 3 tanks, and nearly 300 miles of water main. The condition of the existing infrastructure was assessed by inspection, flow testing, and hydraulic modeling. The purpose of this Water Management Plan is to present to the Town of Yarmouth a plan for water supply, storage, distribution, and operations which will correct existing deficiencies and meet requirements for projected future water system needs.

WATER SUPPLY (SECTION 2)

The Town of Yarmouth draws its water supply from 24 groundwater wells that are an average of 50 years old and with a total maximum pumping capacity of about 12 MGD. The Town has an excellent annual program for well and pump cleaning and rehabilitation which supports flexibility and resiliency for meeting elevated summer demand. Average daily demand (ADD) in 2018 was 3.78 MGD with a maximum day demand (MDD) of 8.56 MGD. Yarmouth has been selling water to Barnstable over the past several years, with the sold volume making up between 10 to 25% of total usage. The total Water Management Act Permit approved water withdrawal for the Town is currently 4.95 million gallons per day (MGD) on an average daily basis. Three water projection scenarios were developed: existing, best case, and worst case, and water sale to Barnstable was projected to continue through 2025.

Water Supply Findings:

- Average Daily Demand: The Town's current water supply is adequate to meet projected ADD through 2040.
- Maximum Daily Demand: The Town's current water supply is adequate to meet the Town's projected average daily demand through 2040, given that caveat that 'worst case' scenario (residential usage increase of 20%) is avoided while sales to Barnstable continue. This also assumes that Yarmouth's existing wells are maintained.
- In relation to its WMA Permit, Yarmouth's existing WMA Permit (plus registration) allocation (4.95 MGD) is adequate, with the exception of in the worst-case scenario in 2025, which assumes sale of water at current volume. Although the worst-case scenario

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is unlikely, this illustrates the need for the current Permit allocation to remain in place to allow for water sales to communities in need.

Water Supply Recommendations: In order to maintain and protect water supply adequacy, the following actions are recommended:

1. **Well Maintenance -** Maintaining wells through the Division's annual rehabilitation and maintenance program is critical for sustaining adequate supply for MDD and should be continued at its current investment level (approximately 5 wells per year).
2. **Demand Management & Water Loss –**
   - Leak detection and repair efforts appear to be highly effective at keeping water loss low and should be continued.
   - Enhanced water conservation programs should be considered.
3. **Watershed Land Protection** – Protecting existing wells from watershed contamination threats is critical. If suitable land for a potential well site is available for purchase, it is always prudent to consider land purchase for future wells and / or for watershed protection. As a reasonable rule of thumb, the Town should evaluate opportunities for purchase of available land within 1,000 feet of existing wells. MassDEP typically offers a grant program with awards of up to $250,000 for the purpose of purchasing watershed land.
4. **New Source Exploration** – Undeveloped land which is either owned by the Town, or potentially available for purchase (or conservation restriction) by the Town should be considered for test well exploration on a case by case basis. One such potential property is the Flax Pond property. The area north of the Flax Pond Recreation Area is owned by the Town and should be investigated for a possible future well site.

WATER QUALITY AND REGULATIONS (SECTION 3)

Existing and anticipated water quality regulations were reviewed against Yarmouth water quality historical results and watershed threats.

Water Quality Findings and Recommendations:

- Yarmouth was found to have water quality in compliance with the existing regulations. However, the following proactive monitoring is recommended for early identification of potential changes in treatment that may be needed to comply with anticipated regulations:

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- Secondary contaminants in all wells annually to track trends of raw water iron, manganese, and corrosivity. Manganese has been observed at levels close to the MassDEP health guidelines and is only required to be sampled once every 3 years.
- 1,4-Dioxane in finished water at CCFs 11, 21/22, 6-7-8 once annually to monitor levels which are near the existing MassDEP health guideline of 0.3 ug/L. 1,4-dioxane is not currently part of routine sampling requirements.
- Nitrate in Wells 4, 5, and 11 quarterly to evaluate trends in relation to the 10 mg/L regulatory limit. Nitrate sampling is currently required annually in these wells.

- PFAS is an emerging contaminant that is ubiquitous, linked to health effects, and likely to be regulated at 20 parts per trillion in drinking water during 2020. A watershed threat analysis was conducted. Numerous land uses of concern and potential PFAS sources were identified in the recharge zones of Yarmouth's wells including: septic tanks, golf courses (fertilizer application), industrial facilities, Route 6, the Town septage plant, and sources in Barnstable.
  - Proactive sampling for PFAS, either at a monitoring well network or of at least 7 entry points to the distribution system for high risk wells is recommended. An accompanying sampling training program and communications plan as part of this are also highly recommended.
  - Wastewater planning should carefully weigh the risks of potentially increasing discharge of wastewater effluent and/or septage to groundwater in Yarmouth. Wastewater can be a significant source of PFAS, as well as other emerging contaminants.
- Perchloroethylene (PCE) has been detected in Well 9 in prior years, causing it to be taken offline in 2013. A monitoring well network was installed in 2019 to look for patterns of a plume in the nearby aquifer. Only one detection at low levels was observed. It is recommended that monitoring for PCE be reduced in frequency and the network be tested for PFAS.
- Proposed revisions to the Lead and Copper Rule will require a publicly accessible inventory of all lead service lines, among other requirements. The Town should consider beginning to prepare for anticipated LCR changes.
- Beginning in October 2020, Consumer Confidence Reports will be required to be distributed and / or posted on the website twice annually.

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FACILITIES (SECTION 4)

Facilities Findings and Recommendations:

Pump Stations:

- A phased improvements program to address safety and structural issues at pump stations is underway. Phase 1 of 3 is currently in design. With 24 stations, the Town should budget for continuing to upgrade pump stations following the current 3-year program. A recommended annual budget placeholder of $1.5M is proposed.

Tanks:

- The three tanks recently underwent sanitary and security inspections and were found to be generally in good condition. Minor repairs are recommended, along with security fencing at German Hill and Prospect Hill.
- German Hill and Prospect Hill were painted in 2015 and 2011, respectively. Sandy Pond was painted in 2005. Although Sandy Pond coating has reached its recommended age for repainting, the recent inspection did not indicate serious concern. Given the priority of pump station and fire flow improvements, we recommend delaying the tank painting for 2 years. Spot painting and other recommended maintenance should be performed in FY21.

Wells:

- The Town has a total of 23 wells serving the distribution system and one well which is inactive. Since 2006, about 5 wells per year have undergone maintenance that typically includes general maintenance of the pumps, motors, and other associated components.
- The maintenance program has been successful in addressing continued routine maintenance and spacing out larger maintenance items such as pump replacements. Continuing this program will help ensure that Yarmouth's wells are operating efficiently, and that the system is able to meet the large seasonal demand increases.

SYSTEM MANAGEMENT (SECTION 5)

An assessment of System Management was conducted in 2018 (Tighe & Bond) and was not part of the scope of this Master Plan Update. However, this section presents recommendations reinforcing certain of the 2018 findings and identifying a new regulatory requirement. Investment

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in a range of operational and planning initiatives is recommended to maintain facilities and water quality, facilitate system maintenance, and aid in planning.

Management / Operational Recommendations:

Operations: If not already being implemented, the following operational programs should be implemented. These programs should be implemented with the assistance of the Division's work management software so that condition data and maintenance is tracked on a continual basis:

- Gate valve exercising
- Hydrant inspection and maintenance
- Unidirectional flushing
- Service line inventory (to support future compliance requirements of the Revised Lead and Copper Rule).

Planning & Regulatory Compliance:

- Asset Management Plan and Financial Planning: The 2017 Asset Management Plan GIS should be updated to develop a phased program of age and condition-based main replacement. Financial modeling scenarios should be developed to provide the Town with a sustainable way to fund needed improvements. Grants are available to continue funding this program.
- America's Water Infrastructure Act – Risk & Resiliency Assessment / Emergency Response Plan Update – this is a new Federal requirement with respective deadlines of June 30, 2021 and December 30, 2021. An RRA must be prepared that considers natural hazards and malevolent acts to infrastructure, and to computer systems. The ERP must be updated to incorporate RRA findings.

DISTRIBUTION SYSTEM (SECTION 6)

The Town's hydraulic model was updated and calibrated. Model scenarios were used to assess the ability of the Yarmouth distribution system to meet present and projected future maximum day demands, domestic pressure requirements, available fire flow requirements, and desired water age limits. Areas of need were identified and capital improvement upgrades to address them were recommended based on the results of the hydraulic analysis.

Distribution System Findings and Recommendations:

- No significant pressure, headloss, or velocity deficiencies were found.
- Several areas of fire flow deficiency were identified (approximately 9,000 LF).

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- The Town should implement water main improvement projects to increase 6-inch water mains to 8-inch and 8-inch to 12-inch in areas with deficient fire flow. The 9,000 LF of improvements should be implemented over a 2 to 4-year period beginning in FY21. Specific improvement projects are identified in Section 6.6.
- Water age (which can lead to degraded water quality) is elevated in the German Hill and Prospect Hill Tanks. Modeling indicated that a significant age reduction can be achieved without significant pressure loss by increasing tank daily drawdown by 5 feet over existing conditions.
- A large majority of the Town's water mains are assumed to be of similar age and material (ductile iron) based on historic growth patterns. The main material and age should be verified from record plans and a phased program of age and condition-based renewal replacement developed to begin following the fire flow improvements. Meanwhile, Yarmouth should track break history using work management software and record water main material and condition when breaks are observed or other system work allows. This program could also benefit from destructive and/or non-destructive testing to better assess condition and remaining useful life.
- For the time being, opportunistic main replacement should be considered whenever major roadway disturbance is planned for road improvements or installation of new sewer mains, such as the Route 6A project by MassDOT and the Route 28 sewer project.

BUDGET RECOMMENDATIONS (SECTION 7)

Estimated budgets were developed for the capital upgrades and additional initiatives which are recommended in this report. Table E-1 below lists recommendations that are projected to incur an expense to the Town over a 5-year period.

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Table E-1: Summary of Recommended Water System Improvements and Expenditures

Recommendation	System	Expense Type	Reason	Estimated Budget	Notes*
YEAR 1					
Pump Station Improvements Phase 1 (12 PS)	Facilities	One-Time	Deteriorating Stations	$ 2,000,000	$2.4M total Funds Avail after May TM
Route 6A Water Main Replacement 8" and 12" Water Mains (Design + Construction)	Distribution	One-Time	Opportunistic Water Main Replacement	$ 3,800,000	12" 5080 lf , 8" 4400 lf
PFAS Sampling and Communication	Wells	One-Time	Watershed Threats	$ 11,000	7 distribution entry points; comm plan, training
Update Asset Management Plan; Financial Plan / Rate analysis	Planning	One-Time	Develop pipe renewal program based on age, condition; Maintain adequate funding;	$ 70,000	Grant funding available
AWIA Risk and Resiliency Assessment	Planning	One-Time	Regulatory Requirement	$ 35,000	Due 6/30/21
Flax Pond Test Wells	Planning	One-Time	Proactive Supply Planning	$ 40,000	
Annual Activities	varies	Annual	varies	$ 520,000	See detail below
		Total FY2021		**$ 6,476,000**	
YEAR 2					
Pump Station Improvements Phase 2 (11 PS)	Facilities	One-Time	Deteriorating Stations	$ 2,000,000	Order of magnitude estimate for planning
1- Acorn Hill Drive and Sophie Ann Drive	Distribution	One-Time	Deficient Fire Flow Risk	$ 320,000	876 LF 8" Mains
2 - Driving Tee Circle	Distribution	One-Time	Deficient Fire Flow Risk	$ 270,000	738 LF 8" main
3- Williams Road	Distribution	One-Time	Deficient Fire Flow Risk	$ 350,000	960 LF 8 main
4 - Mocking Bird Lane	Distribution	One-Time	Deficient Fire Flow Risk	$ 260,000	716 LF 8" main
Route 28 Water Main Replacement Parker River to Dennis Town Line	Distribution	One-Time	Opportunistic Water Main Replacement	$ 5,810,000	13,540 lf 12" main
Route 28 Water Main Replacement Parker River to Barnstable Town Line	Distribution	One-Time	Opportunistic Water Main Replacement	$ 5,900,000	13,750 lf 12" main
AWIA Emergency Response Plan	Planning	One-Time	Regulatory Requirement	$ 40,000	Required by 12/30/21
Annual Activities	varies	Annual	varies	$ 535,600	See detail below. Inflation 3% annually
		Total FY2022		**$ 13,485,600**	
YEAR 3					
Pump Station Improvements Phase 3 (20 CCFs)	Facilities	One-Time	Deteriorating Stations	$ 3,200,000	Order of magnitude estimate for planning
Sandy Pond Tank Painting	Tanks	One-Time	Preserve steel integrity	$ 2,000,000	Order of magnitude estimate for planning
5 - Monterrey Lane (Curve Hill Road)	Distribution	One-Time	Deficient Fire Flow Risk; Water Age	$ 50,000	138 LF connection
6 - Green Teal Way (Gig Ln, Old Salt Lane)	Distribution	One-Time	Deficient Fire Flow Risk	$ 390,000	1060 LF
Begin Design for Water main renewal program	Distribution	One-Time	Main breaks, water quality	$ 350,000	Placeholder. Effort TBD in Yr 1 Asset Management Update
Lead Service Line Program Inventory / Development	Planning	2-year	Regulatory Requirement	$ 50,000	Placeholder. Effort TBD.
Annual Activities	varies	Annual	varies	$ 551,668	See detail below. Inflation 3% annually
		Total FY2023		**$ 3,391,668**	

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Table E-1: Summary of Recommended Water System Improvements and Expenditures (continued)

Recommendation	System	Expense Type	Reason	Estimated Budget	Notes*
YEAR 4					
Pump Station renewal	Facilities	One-Time	Facility renewal as needed	$ 1,500,000	Placeholder
Water Main renewal for age / condition	Distribution	One-Time	Main breaks, water quality	$ 2,000,000	Placeholder
Lead Service Line Program Inventory / Development	Planning	2-year	Regulatory Requirement	$ 50,000	Placeholder. Effort TBD.
Annual Activities	varies	Annual	varies	$ 568,218	See detail below. Inflation 3% annually
		Total FY2024		**$ 4,118,218**	
YEAR 5					
Pump Station renewal	Facilities	One-Time	Facility renewal as needed	$ 1,500,000	Placeholder
Water Main renewal for age / condition	Distribution	One-Time	Main breaks, water quality	$ 2,000,000	Placeholder
Annual Activities	varies	Annual	varies	$ 585,265	See detail below. Inflation 3% annually
		Total FY2025		**$ 4,085,265**	
Annual Activity Recommendations					
Unidirectional Flushing Program	Distribution	Annual	Water quality	$ 125,000	50% of system Annually
Proactive Water Quality Testing	Wells	Annual	Water quality	$ 5,000	Secondary, Mn, NO3, 1-4 Dioxane
Well & Pump Rehabilitation	Wells	Annual	Supply reliability	$ 200,000	Approx 5 annually
Tank Inspections	Tanks	Annual	Supply reliability	$ 7,500	
Asset Management	Distribution	Annual	Fiscal Sustainability	$ 25,000	Ongoing assistance / software
SCADA Maintenance	Facilities	Annual	Supply reliability	$ 15,000	
Tank Repairs / maintenance	Tanks	Annual	Supply reliability	$ 100,000	Placeholder
Meter Calibration	Facilities	Annual	Management	$ 7,500	
Groundwater Monitoring Program	Wells	Annual	Source protection	$ 35,000	PFAS and/or other contaminants
				$ 520,000	

Notes:

Water main costs per linear foot are in $2019 and include construction, engineering (20%), and contingency (10%). **Paving and other roadway improvement is not included in the unit costs**

Water main replacement cost based on unit costs 8" of $364/LF; 12" of $429/LF

Vertical construction bidding climate is extremely volatile. Estimates considered order of magnitude and suitable for planning only; subject to change

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1 INTRODUCTION

This report documents results of an evaluation of the Yarmouth water system infrastructure and procedures and identifies potential needs. This is an update to a previous water master plan. Decisions throughout the system evaluation process were made in the context of that previous plan, the stated purpose of this plan, and the defined scope of work. Water system best practice is to update water master plans approximately every 7 years, or more frequently if changing conditions warrant.

1.1 PRIOR MASTER PLAN

Kleinfelder conducted the previous water system planning study for the Yarmouth Water Department: *Water System Management Plan* dated October 2007. That plan included the following major elements:

- updated hydraulic modeling to assess distribution system deficiencies and capital needs
- updated water demand projections and supply adequacy assessment
- facilities condition review and recommended improvements
- assessment of water quality and regulatory compliance and recommendations
- evaluation of system management practices and identification of enhancements
- estimated project costs and provided suggested phased improvements plan

1.2 PURPOSE AND SCOPE OF PLAN UPDATE

The purpose of this Water Management Plan Update is to update the prior study to reflect changes in the community and water system and set a planning window through 2040. It builds on the prior study, addressing water supply and protection, water quality, regulatory compliance and facility condition in detail. This finished Plan is intended to provide a single reference that will assist Water Division and the Town Manager in their long-term capital planning and annual budget planning, document the adequacy of system elements, and help new staff members acquaint themselves with Yarmouth Water Division operations.

1.3 SCOPE OF WORK

The following is a summary of tasks performed in the preparation of this report.

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- Gathered distribution system, population, and pumping data for use in the analysis. Assessed the existing system carrying capacity and flow characteristics through on-site system flow testing.
- Developed updated demand projections for use with the distribution system model and for planning purposes.
- Assessed the adequacy of existing water supplies to meet projected future maximum day demands.
- Updated the existing computer hydraulic model of the water distribution system based on flow testing results over the past five years, new water main installation, updated pump curve data, and discussions with Division personnel.
- Calculated the system-wide available fire flow using the hydraulic model.
- Based on the water distribution system analysis, identified areas of deficiency and developed recommended improvements.
- Evaluated storage residence time and water age and made recommendations for operational improvements to reduce water age.
- Reviewed facility condition reports and recommended updates to individual components within these facilities as well as overall system improvements.
- Evaluated water quality results and watershed threats in relation to current and expected regulatory requirements and made recommendations to monitor and maintain water quality.
- Developed estimates of probable cost for recommended system capital improvements.
- Prepared a sequencing plan for system improvements based on cost and level of necessity.
- Documented findings, conclusions and recommendations in this report.

1.4 ACKNOWLEDGEMENTS

Kleinfelder would like to express our appreciation to the many Water Division staff members and Town officials who provided assistance in the preparation of this report. These include Jeff Colby, the Director of Public Works, Gary Damiecki, the Water Division Acting Superintendent, staff from the Town's Clerk's office, and staff from the Town Planning Department. We also wish to specifically thank the Water Division staff for their assistance during the field flow testing portion of the project. The knowledge and expertise of these individuals, their understanding of the water system, and the quality of their record keeping proved invaluable in performing this system evaluation.

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2 WATER SUPPLY

2.1 YARMOUTH WATER SOURCES

2.1.1 Water Supply Wells

Yarmouth has 22 active gravel-packed wells and one well field (1-M). All of the wells, pumps, and motors have been rehabilitated within the last ten years (see Section 4, Facilities). The well depths, pump makes and models, design flows, motor horse powers, and last year of maintenance are listed in Table 2-1. The design flows for the pumps of Wells 6, 7, 8, and 17 are unknown. The flow rates after the most recent maintenance activity are presented in the place of the unknown design flows.

Table 2-1: Summary of Yarmouth Water Supply Wells

Number	Address	Year Installed	Depth (ft)	Diameter (in)	Pump Make / Model	Pump Design Flow	Pump Last Service	Motor Hp	Motor Last Service	Well Last Redevelop
1-M	Union Street	1931	well field	well field						
1	Higgins Crowell Rd.	1953	66.9	24	Goulds / 9WHHC	225	2015	30	2015	2015
2	Higgins Crowell Rd.	1953	61.3	24	American-Marsh / 10KC	350	2015	30	2015	2015
3	Higgins Crowell Rd.	1953	60.5	24	Goulds / 9RCLC	400	2015	30	2015	2015
4	Long Pond Drive	1960	62.1	24	Goulds / 11RALC	350	2015	40	2015	2015
5	Long Pond Drive	1960	66.75	24	Goulds / 11RALC	350	2015	40	2015	2015
6	N. Main Street	1963	68.3	24	Goulds / 8RJLO	300	2014	25	2014	2014
7	N. Main Street	1963	66	24	Goulds / 8RJLO	300	2014	25	2014	2014
8	N. Main Street	1963	64	24	Goulds / 8RJLO	300	2014	25	2014	2014
9	N. Main Street	1969	72	24		600	INACTIVE			
10	Forest Road	1969	57.8	24	Goulds / 10WALC	300	2014	20	2014	2011
11	Kristin Path	1969	48	24	Goulds / 10WALC	300	2009	25	2009	
13	Chickadee Lane	1974	57.9	24	Goulds / 9RCHC	500	2011	30	2011	2011

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Number	Address	Year Installed	Depth (ft)	Diameter (in)	Pump Make / Model	Pump Design Flow	Pump Last Service	Motor Hp	Motor Last Service	Well Last Redevelop
14	Higgins Crowell Rd.	1974	67.2	24	Goulds / 9RCLC	350	2018	30	2018	2018
15	N. Dennis Road	1975	78	24	Goulds / 9RCHC	500	2019	50	2019	2019
16	N. Dennis Road	1975	72.5	24	Goulds / 10RJLC	500	2011	30	2011	2011
17	Horse Pond Road	1976	80	24	Goulds / 11CLC	600	2014	60	2014	2014
18	Chickadee Lane	1976	65	24	American Marsh / 9LC	450	2014	40	2014	2014
19	Chickadee Lane	1976	72.6	24	Goulds / 9RCLC	450	2019	30	2019	2019
20	Higgins Crowell Rd.	1979	67.6	24	Goulds / 10WAHC	350	2018	30	2018	2018
21	Setucket Road	1981	91	24	Goulds / 9RCHC	450	2018	40	2018	2018
22	Setucket Road	1981	81	24	Goulds / 11CLC	550	2019	40	2019	2019
23	Mid Tech Drive	1989	102	24	Goulds / 10RJLC	500	2019	40	2019	2019
24	Higgins Crowell Rd.	1989	67.2	24	Goulds / 10WAHC	350	2018	30	2018	2018

2.1.2 Water Management Act Permit

Twenty-two of Yarmouth's 24 wells are registered sources under the Water Management Act (310 CMR 36), with a collective registered volume of 3.03 MGD (1106 MGY). Yarmouth also has withdrawals for Wells 13, 14, 17, 18, 19, 23, and 24 which are subject to a WMA Permit (Permit #9P-4-22-351.01), which was initially issued in 1992 and last reissued in 2007. The 2007 WMA Permit approves withdrawal of an additional 1.92 MGD above the Registered volume, for a total of 4.95 MGD. This volume may be exceeded on individual days within the constraints of the Permit, but the annual total volume pumped divided by 365 must not exceed this volume.

Yarmouth submitted a WMA Permit renewal application in 2010 and in 2012. The 2007 Permit was extended in 2010 and again in 2012. MassDEP responded in April of 2015 with an Order to Complete requesting additional information and proposing to lower Yarmouth's maximum annual authorized withdrawal from 4.95 to between 3.57 and 3.88 MGD. A response by Yarmouth was submitted in 2017 requesting the 4.95 MGD limit remain, but a response has not yet been received from MassDEP.

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One of the 2007 Permit conditions includes the goal for the Town to operate its wells at an annual daily rate that does not exceed the Zone II rate assigned during the New Source Approval Process. Table 2-2 lists the approved Zone II rates for the Yarmouth wells in the 2007 Permit Although these rates are listed in the Permit 'Findings of Fact', the actual Permit Conditions (Special Condition 2), only specifies these rates for Wells 13, 14, 17, 18, 19, 23 and 24. The approved combined Zone II withdrawal rate is 10.39 MGD (with none assigned to four other wells, which can be presumed to operate at mechanical capacity).

Table 2-1:Yarmouth Water Source Approved Zone II Rates

Well Name	Average Daily Withdrawal (MGD)	Average Daily Withdrawal (gpm)	Applicable Permit Condition
Well #1M	0.64	444	N/A
Well #1	0.36	250	N/A
Well #2	0.35	245	N/A
Well #3	0.61	425	N/A
Well #4	0.43	300	N/A
Well #5	0.43	300	N/A
Well #6	None Assigned	None Assigned	N/A
Well #7	None Assigned	None Assigned	N/A
Well #8	None Assigned	None Assigned	N/A
Well #9	None Assigned	None Assigned	N/A
Well #10	0.40	278	N/A
Well #11	0.40	278	N/A
Well #13	0.48	333	Permit Special Condition 2
Well #14	0.50	350	Permit Special Condition 2
Well #15	0.64	444	N/A
Well #16	0.64	444	N/A
Well #17	0.58	400	Permit Special Condition 2
Well #18	0.43	300	Permit Special Condition 2
Well #19	0.43	300	Permit Special Condition 2
Well #20	0.50	350	N/A
Well #21	0.64	444	N/A
Well #22	0.64	444	N/A
Well #23	0.79	550	Permit Special Condition 2

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Well Name	Average Daily Withdrawal (MGD)	Average Daily Withdrawal (gpm)	Applicable Permit Condition
Well #24	0.50	350	Permit Special Condition 2

The 2007 Permit lifted certain wetland and vernal pool monitoring conditions, as well as operational restrictions. The 2007 Permit includes performance standards for unaccounted for water, water conservation, and residential per capita water use.

2.2 WATER USE AND RECENT TRENDS

Water use in Yarmouth was classified as residential, non-residential, municipal, sold, and unaccounted. Table 2-3 defines each class of water use.

Table 2-3: Water Use Classifications

Class	Definition
Residential	Water used in residential settings, including residential institutions, for drinking, cooking, bathing, sanitation, and outdoor use.
Non-Residential	Water used in retail business, restaurants, manufacturing, or agriculture
Municipal	Water used by Town buildings, Town process, and flushing programs
Sold	Water sold to neighboring communities
Unaccounted	Unmetered water used as a result of firefighting, wan main leaks, and inaccurate meters.

Yarmouth's water usage is categorized by the Town and reported to the MassDEP on Yarmouth's Annual Statistical Reports (ASRs). The past eight ASRs were summarized and used as the baseline for the water demand analysis. The data from the last eight years is summarized in Table 2-4.

Table 2-4: Yarmouth Annual Water Use

Year	Residential Water (MG)	Non-Residential Water (MG)	Municipal Water (MG)	Sold (MG)	Unaccounted For Water (MG)	Unaccounted For Water %	Total Water Use (MG)
2011	1,124	82	27	0	99	7.5%	1,333
2012	1,091	86	25	0	52	4.1%	1,253

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Year	Residential Water (MG)	Non-Residential Water (MG)	Municipal Water (MG)	Sold (MG)	Unaccounted For Water (MG)	Unaccounted For Water %	Total Water Use (MG)
2013	1,136	94	16	0	30	2.3%	1,276
2014	1,096	74	15	0	42	3.4%	1,228
2015	1,212	66	3	4	157	10.9%	1,442
2016	1,264	75	6	136	136	8.4%	1,617
2017	1,110	58	0	196	50	3.5%	1,414
2018	734	192	4	349	102	7.4%	1,381
Avg.	**1,096**	**91**	**12**	**86**	**83**	**6.1%**	**1,368**

Figure 2-1 shows the total annual water usage in Yarmouth by classification for 2011 to 2018. Residential water consumption is the largest category of water usage in Yarmouth. Since 2016, the amount of water sold by Yarmouth has been increasing. Water sold was the second largest

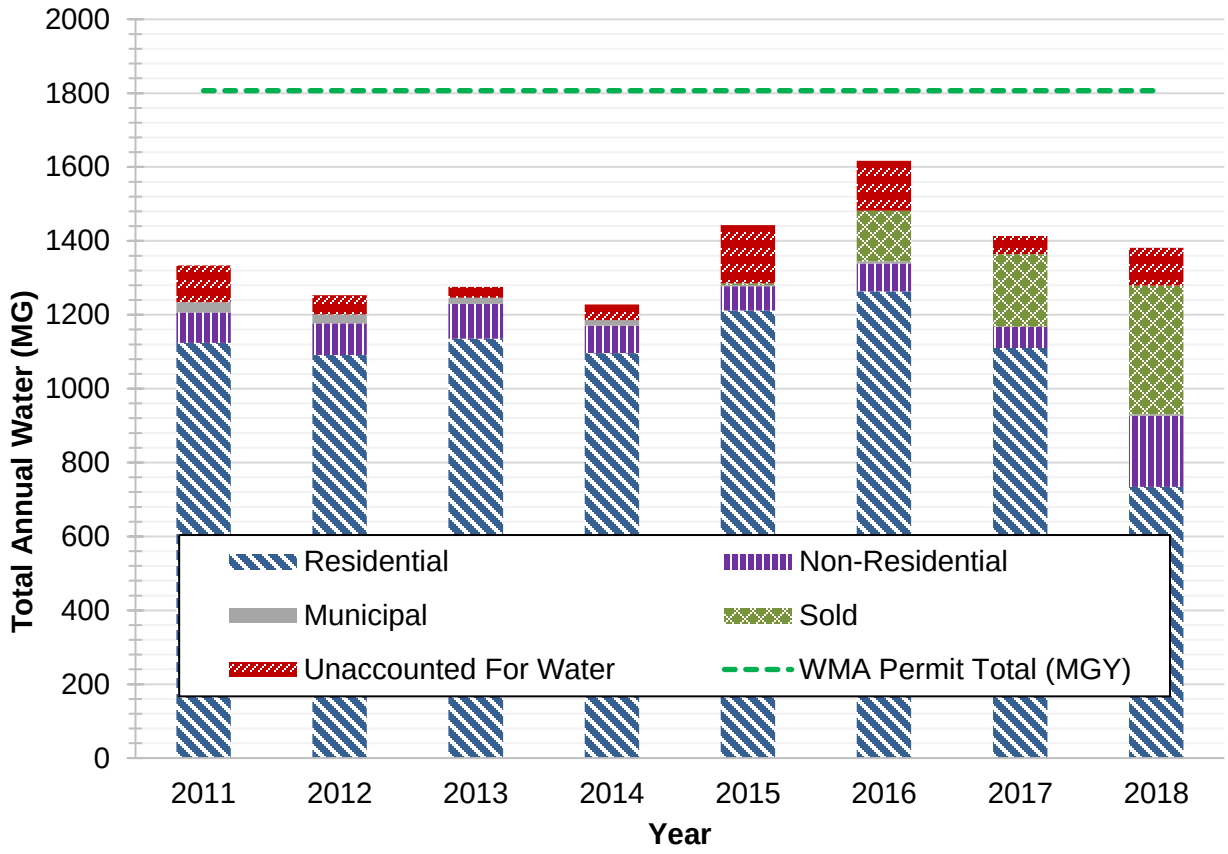

Figure 2-1: Total Annual Water Use by Type

water usage category in 2018, accounting for about one quarter of all water pumped by Yarmouth in 2018. This water has been sold to the Town of Barnstable which needs to supplement its supply

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while it designs and installs treatment over the next several years for wells impacted by contamination.

2.2.1 Average Daily and Maximum Daily Demand

The average daily demand was calculated by dividing the total annual water consumption by 365. The maximum daily demand is the volume of water consumed on the day with the highest demand. The maximum daily demand is used to determine the adequacy of the capacity of water supply sources. The highest demand days often occur consecutively so water supply systems should be capable of delivering the maximum daily demand without dependence on storage. If the combined pumping capacity from all wells is less than the maximum daily demand, the water level in the storage tanks will drop, which could potentially jeopardize system pressure and emergency storage. Table 2-5 shows the average daily demands and maximum daily demands from 2011 to 2018. Figures 2-2 and 2-3 display the average daily demand and maximum daily demand compared the WMA permit limits and maximum well output.

Table 2-5: Yarmouth Average Daily Demand and Maximum Daily Demand

Year	Average Daily Demand (MGD)	Maximum Daily Demand (MGD)	Maximum to Average Demand Ratio
2011	3.65	8.70	2.38
2012	3.43	9.20	2.68
2013	3.50	8.50	2.43
2014	3.36	7.94	2.36
2015	3.95	9.32	2.36
2016	4.43	9.81	2.21
2017	3.87	8.85	2.28
2018	3.78	8.56	2.26
Average 2011-2018	**3.75**	**8.86**	**2.37**

The average demand ratio of 2.37 is considered appropriate, considering the Town's large seasonal population. For the demand projections, the demand ratio was rounded to 2.4, and used to estimate the future maximum daily demands based on the projected average daily demands.

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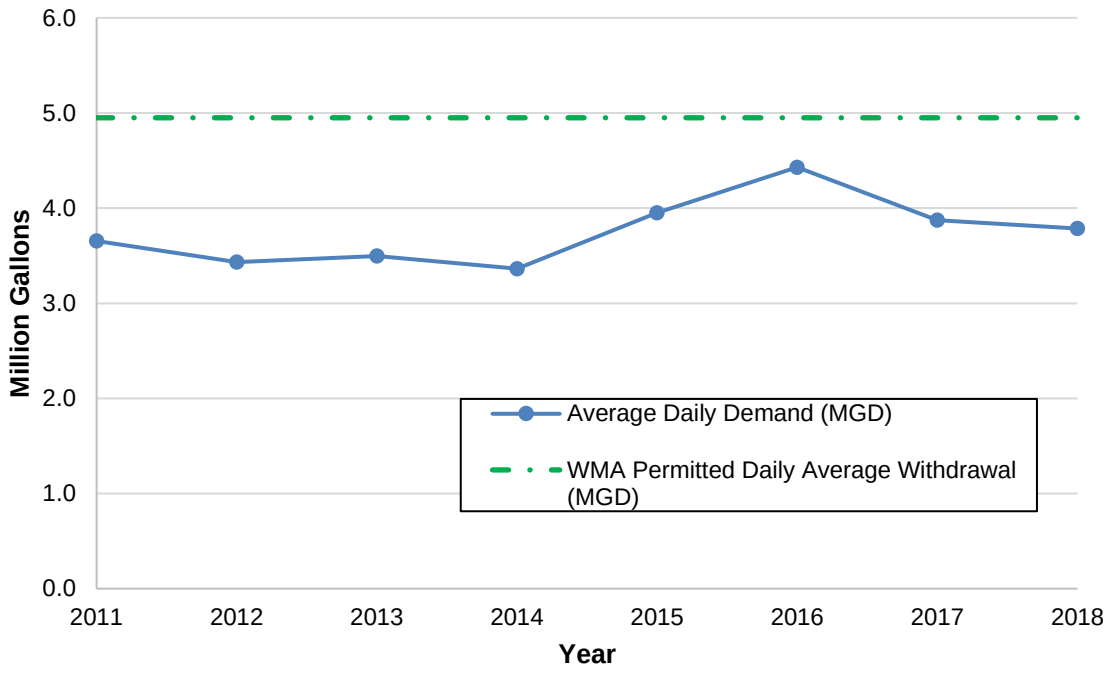

Figure 2-2: Yarmouth Average Daily Demand and WMA Permitted Daily Average Withdrawal

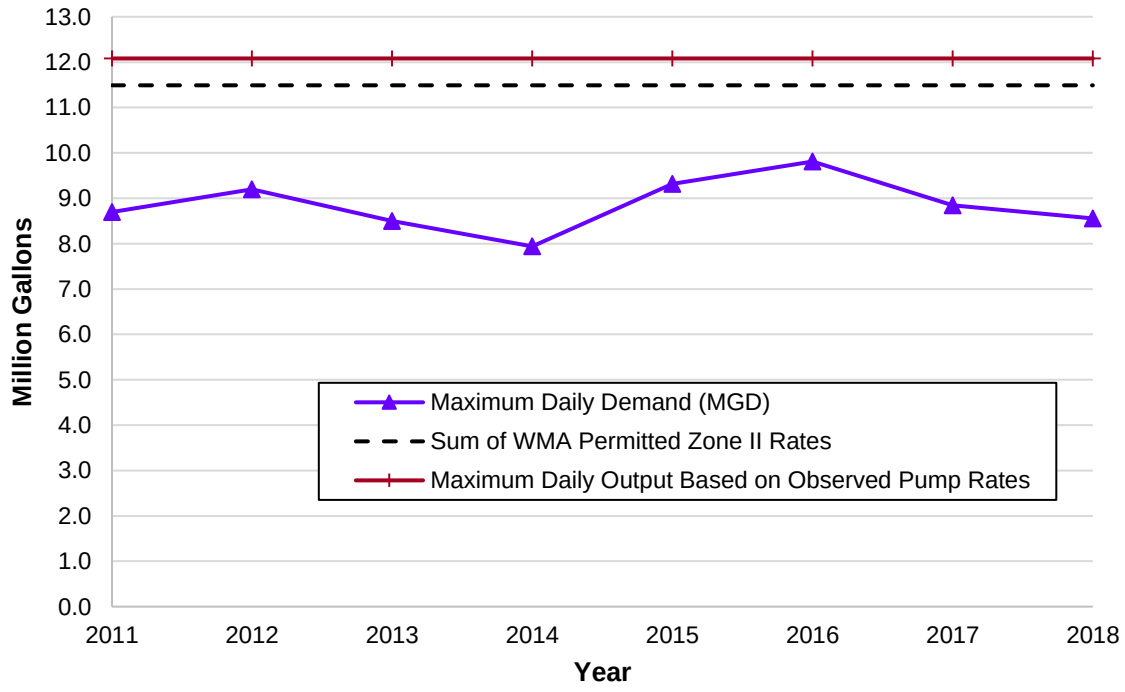

Figure 2-3: Yarmouth Maximum Daily Demand, Sum of WMA Zone II Rates, and Maximum Daily Outputs

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The average daily demand was below the WMA average daily withdrawal limit, and the maximum daily demand was below the sum of the WMA approved zone II rates. If all wells were operational, Yarmouth would have been able to meet its maximum daily demands without depleting the volume of water in storage tanks.

The peak hourly demand was estimated for use in the water distribution model, which is discussed in Section 6. The peak hourly demand was calculated by multiplying the 2017 average daily demand to maximum daily demand ratio by a factor of 1.5. The peak hour demand factor was calculated as 3.4.

2.2.2 Residential Per Capita Demand

Residential gallons per capita per day (RGPCD) is a measure of the average amount of water each resident uses each day. The MassDEP standard for RGPCD is currently 80 gallons per day for Yarmouth1. The calculation for RGPCD is fundamentally impacted by the transient summer population that is characteristics of municipalities on Cape Cod and the complexities involved with estimating the size of that population. This inherent uncertainty makes the use of RGPCD as a performance standard difficult to monitor and enforce. For this reason, MassDEP has indicated it intends to remove the RGPCD standard from future WMA Permit conditions.

Table 2-6 and Figure 2-4 display the estimated RGPCD in Yarmouth from 2011 to 2018.

Table 2-6: Yarmouth Residential Water Use Per Capita Per Day

Year	Population	Residential Water Use (MG)	Consumption Per Capita Per Day (gpd)
2011	31,714	1,124	97
2012	31,714	1,091	94
2013	31,714	1,136	98
2014	31,714	1,096	95
2015	31,714	1,212	105
2016	31,714	1,264	109
2017	31,714	1,110	96
2018	31,714	734	63

[1] *Yarmouth Water Management Act Permit, Massachusetts Department of Environmental Protection, March 2007*

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Year	Population	Residential Water Use (MG)	Consumption Per Capita Per Day (gpd)
		Average Per Capita Demand (gpd)	99
[1] Error in ASR, 2018 Residential Water Use excluded from Average Per Capita Demand			

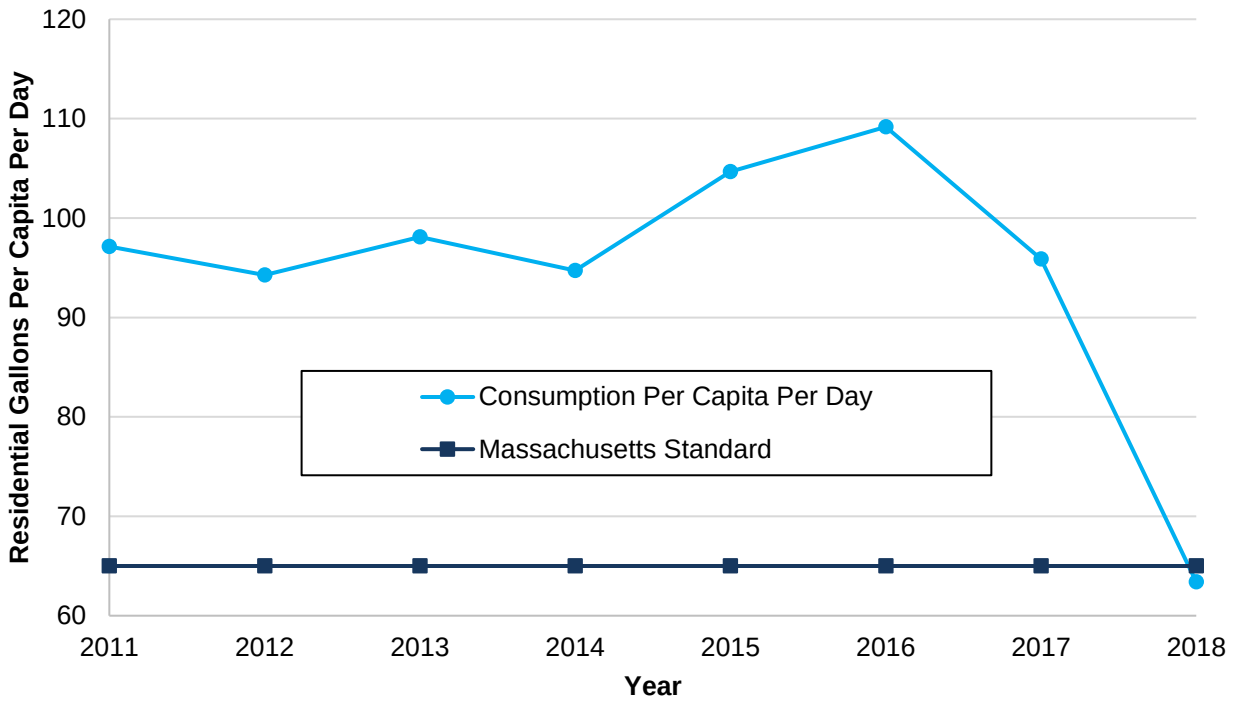

Figure 2-4: Yarmouth Residential Water Use Per Capita Per Day

NOTE: The residential water consumption reported in the 2018 ASR is believed to contain an error.

The residential consumption presented in Yarmouth's 2018 ASR is believed to contain an error, because the residential water usage decreased by one third from 2017 to 2018 without an explanation. The RGPCD calculated for 2018 is thus also believed to be erroneous. The 2018 RGPCD is presented in this report, but it was not used to calculate the average RGPCD.

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2.2.3 Unaccounted-For Water

The MassDEP standard for Unaccounted-for Water (UAW) for Yarmouth is 15% or less of the total water entering the distribution system[1]. Yarmouth has met the MassDEP standard for UAW. Considering that the average UAW from 2011 to 2018 was 6.1% and the Maximum UAW was 10.9%, Yarmouth is doing well with locating and repairing leaks. Figure 2-5 shows the Yarmouth UAW from 2011 to 2018.

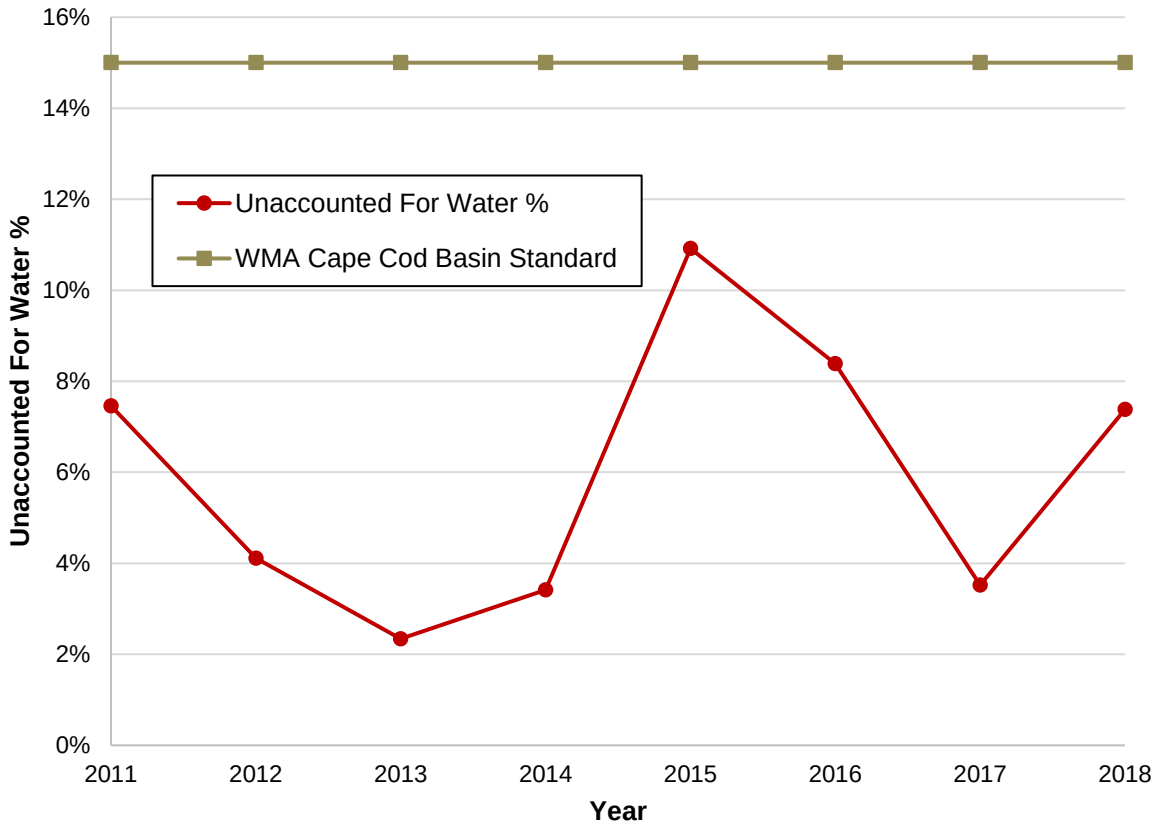

Figure 2-5: Yarmouth Unaccounted for Water (UAW) (%)

2.3 DEMAND PROJECTIONS

The future water demand in Yarmouth was projected based on estimated changes in population, economic development, per capita water use, UAW, and the current baseline water usage rates.

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Kleinfelder used the Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities[2] from the Water Resources Commission to prepare the water demand projections.

2.3.1 Population Projections

The MassDOT[3] and UMDI[4] population projections were used to estimate the future population of Yarmouth; a method consistent with industry standard and Massachusetts Water Resources Commission policy. The MassDOT and UMDI population projections, which were similar for Yarmouth, were averaged to calculate the estimated future population. The MassDOT data is projected for every 10 years, from 2020 to 2040. The UMDI data is projected for every 5 years, ending 2035. To determine the approximate MassDOT projection for 2025, the average of the 2020 and 2030 population projections was calculated. The same process was followed to calculate the MassDOT 2035 approximate projection using the 2030 and 2040 data. An average between two points could not be used to estimate the 2040 UMDI projection. To estimate the UMDI population projection for 2040, the second derivative of the UMDI projection was calculated and then applied to estimate the projection for 2040.

The U.S. census and population projections only account for permanent residents of Yarmouth. However, Yarmouth has a large seasonal population that needs to be considered for water demand projections. There is no official account of Yarmouth's seasonal population. Therefore, rough estimates of the summer population must be used to estimate the historic seasonal population and to predict the future population. According to the 2018 Annual Statistical Report (ASR), the summer population of Yarmouth is 39,635 people. The additional seasonal population is the summer population minus the year-round population.

Based on the 2018 ASR population data, the Yarmouth seasonal population is 15,842 people. To annualize the additional seasonal population, the seasonal population was multiplied by the number of months seasonal residents spend in Yarmouth and divided by 12 months. In the ASR, the seasonal population is reported from April through September. Following the ASR, the seasonal population spends 6 months of the year in Yarmouth. The additional seasonal

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[2] *Policy for Developing Water Needs Forecasts for Public Water Suppliers and Communities and Methodology for Implementation, The Commonwealth of Massachusetts Water Resources Commission, revised March 2017*

[3] *Socio-Economic Projections for 2020 Regional Transportation Plans, Massachusetts Department of Transportation, September 2018*

[4] *Long-term Population Projections for Massachusetts Regions and Municipalities, UMass Donahue Institute, March 2015*

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population was multiplied by 6/12, which equates to annualized seasonal population of 7,921. The additional seasonal population of Yarmouth was assumed to be constant in the future population projections.

The past population and the estimated future population of Yarmouth, based on the UMDI and MassDOT projections, are shown in Figure 2-6. Population is projected to decrease in Yarmouth by approximately 9% between 2020 and 2040.

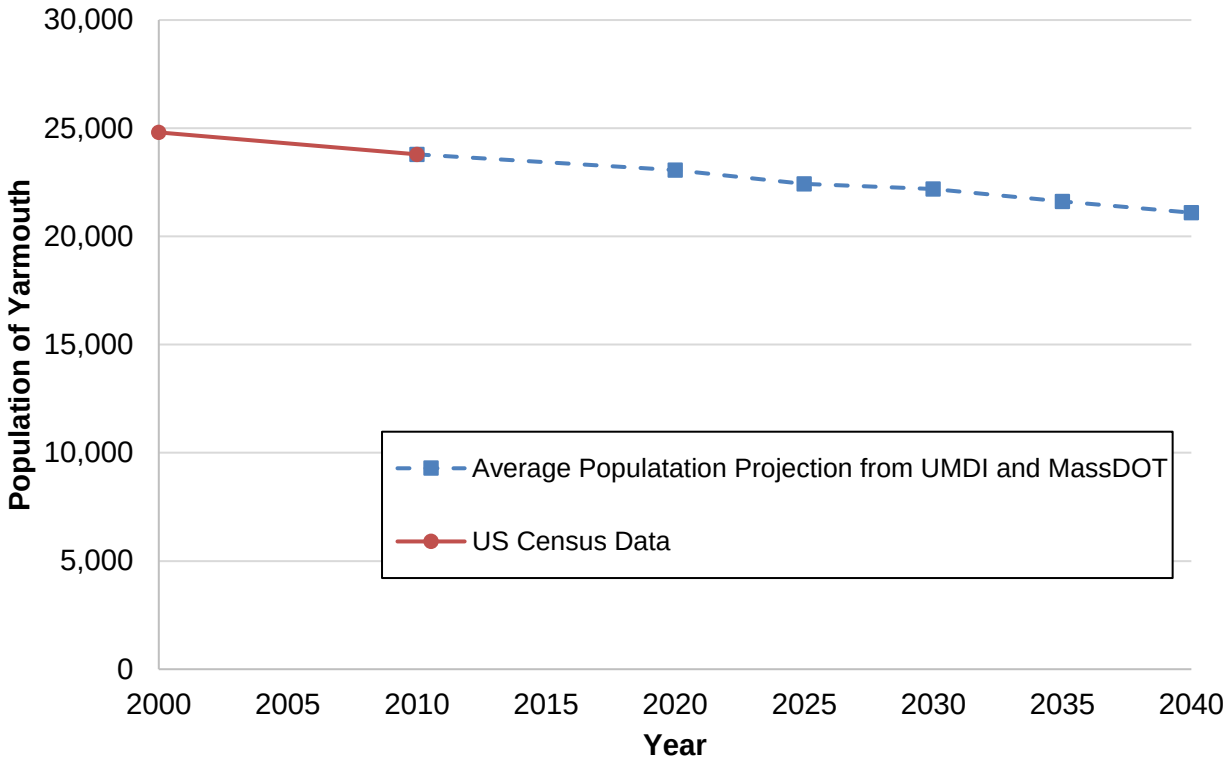

Figure 2-6: Past Population and Estimated Future Population of Yarmouth (Permanent Residents Only)

2.3.2 Employment Projections

The employment projections from MassDOT[1] and the Town's Build-Out Data from the Yarmouth Community Development Department[5] were reviewed. The employment projections from MassDOT were created as part of the Socio-Economic Projections for 2020 Regional

[5] *Wastewater Buildout Analysis, Yarmouth Community Development Department, August 5th 2019*

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Transportation Plans. MassDOT has estimated a decrease in employment in Yarmouth, at a rate of about a 4% decrease in employment every 5 years from 2020 to 2040. The MassDOT employment projections are shown in Figure 2-7. The projected changes in employment were used to estimate the future changes in non-residential water usage.

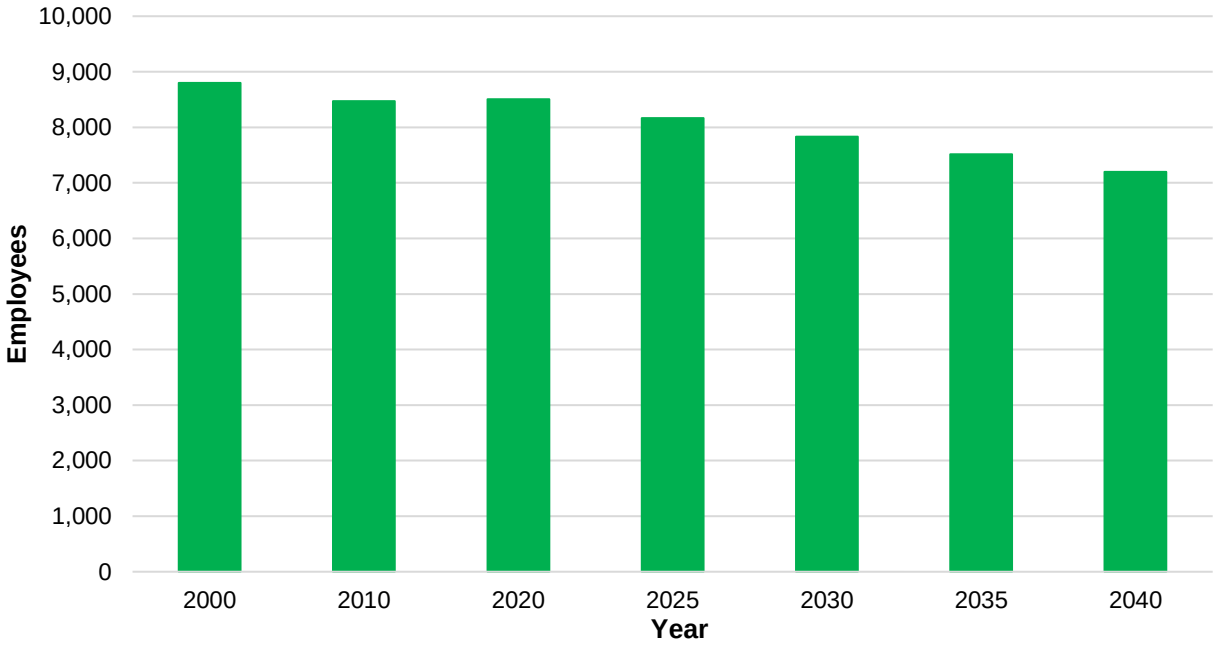

Figure 2-7: Yarmouth Employment Projections from MassDOT

2.3.3 Anticipated Development

Planned developments and large redevelopments reported in the Town of Yarmouth Wastewater Buildout Analysis[4] were reviewed and summed to estimate the anticipated development in Yarmouth due to building. To avoid double counting changes in population and employment that are already accounted for in the MassDOT socio-economic projections data, only planned new developments and large redevelopments were considered from the Build-Out data. These large developments represented growth and additional water-usage outside of the population and employment growth projections. The total water usage estimated to be added by these developments is about **0.09 MGD**. This 0.09 MGD was spread over 15 years, assuming one-third of the developments would be completed each 5 years.

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2.3.4 Projected Water Needs

The same population, non-residential usage, municipal usage, and water sold projections were used for all the scenarios. Only the residential gallons per capita per day (RGPCD) and the unaccounted-for water (UAW) rates were altered in each scenario. These factors were chosen to be altered, because they can be controlled or effected by Yarmouth's Water Department. Yarmouth can reduce the RGPCD by increasing education and encouraging water saving practices. Yarmouth can also prevent UAW by increasing leak detection activities and increasing the amount of capital investments made on the system.

Three different scenarios were used to project the future water needs of Yarmouth. The first scenario assumes the best case for consumption and water loss, the second scenarios assumes that consumption and water loss will continue as-is, and the third scenario assumes the worst case for consumption and water loss. A summary of each scenario is shown in Table 2-7.

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Table 2-7: Water Consumption Projections and Assumptions for Each Scenario

Scenario	Description	Population Projection	Population	Residential Use (RGPCD)	UAW (%)	Year	ADD (MGD)	MDD (MGD)
-	Baseline		31,714	99.1	6.1%	2011-2018	3.513	8.859
1	'Best Case' Future residential water use at 80 RGPCD and UAW at 4%	MassDOT & UMDI	30,345	80	4%	2025	3.795	9.107
		MassDOT & UMDI	30,111	80	4%	2030	2.839	6.814
		MassDOT & UMDI	29,543	80	4%	2035	2.814	6.753
		MassDOT & UMDI	29,017	80	4%	2040	2.760	6.624
2	Existing Conditions - Future residential water use at current RGPCD value and future UAW at current value (Avg 2011-18)	MassDOT & UMDI	30,345	99.1	6.1%	2025	4.468	10.723
		MassDOT & UMDI	30,111	99.1	6.1%	2030	3.508	8.419
		MassDOT & UMDI	29,543	99.1	6.1%	2035	3.470	8.329
		MassDOT & UMDI	29,017	99.1	6.1%	2040	3.405	8.172
3	'Worst Case' Future residential water use at 120 RGPCD and future UAW at 10%	MassDOT & UMDI	30,345	120	10%	2025	5.294	12.704
		MassDOT & UMDI	30,111	120	10%	2030	4.328	10.387
		MassDOT & UMDI	29,543	120	10%	2035	4.276	10.263
		MassDOT & UMDI	29,017	120	10%	2040	4.196	10.071

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The expected Average Daily Demand (ADD) for each scenario was calculated following equation 1.

$$ADD = (Pop * RGPCD + Non\ Resid. + New\ Devel. + Municipal + Sold\ ) * (1 + UAW) \qquad \textit{(eq. 1)}$$

Where: pop. is the population,
RGPCD is the assigned consumption rate,
Non Resid. is the non-residential water usage,
New Devel. is the expected water usage for new developments,
Municipal is the water usage for municipal purposes
Sold in the water sold to neighboring towns, and
UAW is the assigned water loss rate.

The RGPCD and UAW were assigned to each scenario to reflect different levels of capital investment in the water system.

The non-residential water usage rates were calculated based on the average non-residential rate for 2011-2018 and the employment data from MassDOT (Section 2.2). The average non-residential rate was multiplied by the percent change in the employment, as shown in equation 2.

$$Non\ Resid. = Average\ Non\ Residential\ * (1 + \%\ Employment) \qquad \textit{(eq. 2)}$$

The new development estimates were summed from Yarmouth's build-out data, which is explained in section 2.3.3 of this report. The build-out data was evenly divided between 2025, 2030, and 2035 to reflect different construction schedules and distribute additional water consumption over time.

The municipal water usages were held constant at the average rate for 2011-2018. The average municipal water usage of 0.033 MGD was assumed to be constant in the future for all scenarios, because it not significantly affected by population growth or development.

The amount of water sold was estimated assuming that the amount of water sold in 2025 would be the same as the amount sold in 2018. It was also assumed that no water would be sold after 2025.

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Based on the ADDs and Maximum Daily Demands (MDD) reported in the 2011-2018 ASRS, the average ratio for ADD:MDD is 1:2.4. Thus, the estimated MDD for each scenario was calculated following equation 3.

$$MDD = ADD * 2.4 \qquad \textit{(eq. 3)}$$

2.4 ASSESSMENT OF WATER SUPPLY ADEQUACY

To assess the adequacy of Yarmouth's water supply, the maximum daily well output, the reliable well output, annual WMA permitted withdrawal limits, and the WMA zone II rates were compared to the average daily demand and maximum daily demand. Table 2-8 below shows the definitions for the different measures of water supply.

Table 2-8: Definitions for the Different Measures of Water Supply

Measure of Supply	Definition
Maximum Daily Output	The maximum amount of water that the pumps could supply within a 24-hour period. The maximum daily output was calculated by summing the maximum flow rates that were observed on SCADA from 7/8/19.
Reliable Daily Output	The reliable daily output was calculated by assuming conservatively that 1/3 of Yarmouth's wells could be offline for maintenance or repairs. The reliable daily output was calculated by multiplying the maximum daily output by 2/3.
Annual WMA Permitted Withdrawals	The maximum amount of water that Yarmouth can withdrawal per a year according to the 2007 WMA permit.
Daily Average WMA Permitted Withdrawal	The average amount of water that can be withdrawn each day to meet the WMA annual maximum withdrawal.
WMA Zone II Rates	The approved rate of pumping in each well, which each well can sustain without excessive drawdown. The zone II rates were assigned by MassDEP in the 2007 permit, and the maximum daily rates at each well should not exceed the zone II rate for that well.

The annual WMA permitted withdrawals, reliable daily output, historic ADD data, and the estimated ADD for each demand projection scenario are shown in Figure 2-8. The maximum daily output, sum of WMA zone II rates, historic MDD data, and the estimated MDD for each demand scenario are shown in Figure 2-9.

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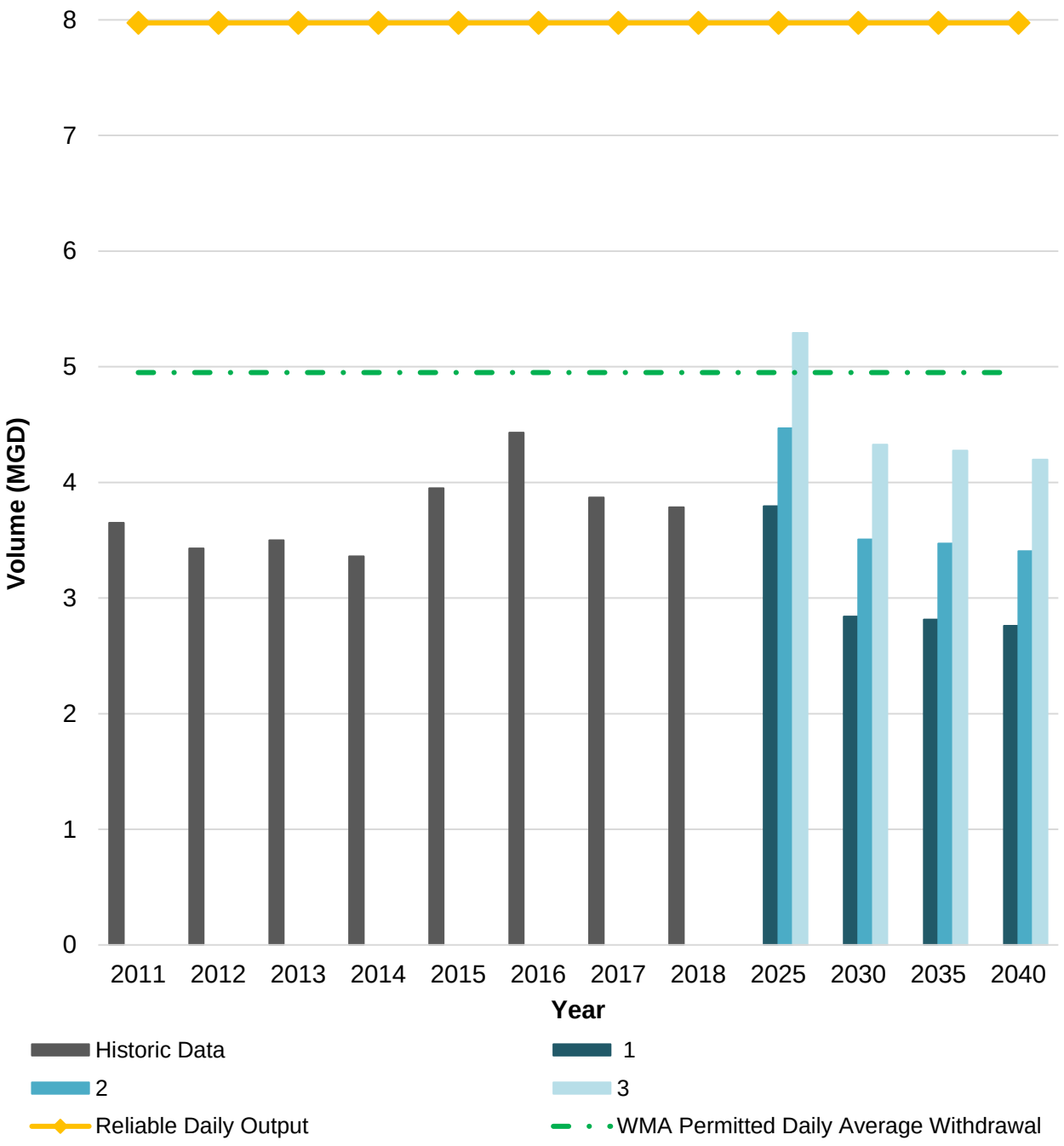

Figure 2-8: Average Daily Demand of Historic Data and Projected Scenarios, with WMA Permitted Daily Average and Reliable Daily Output

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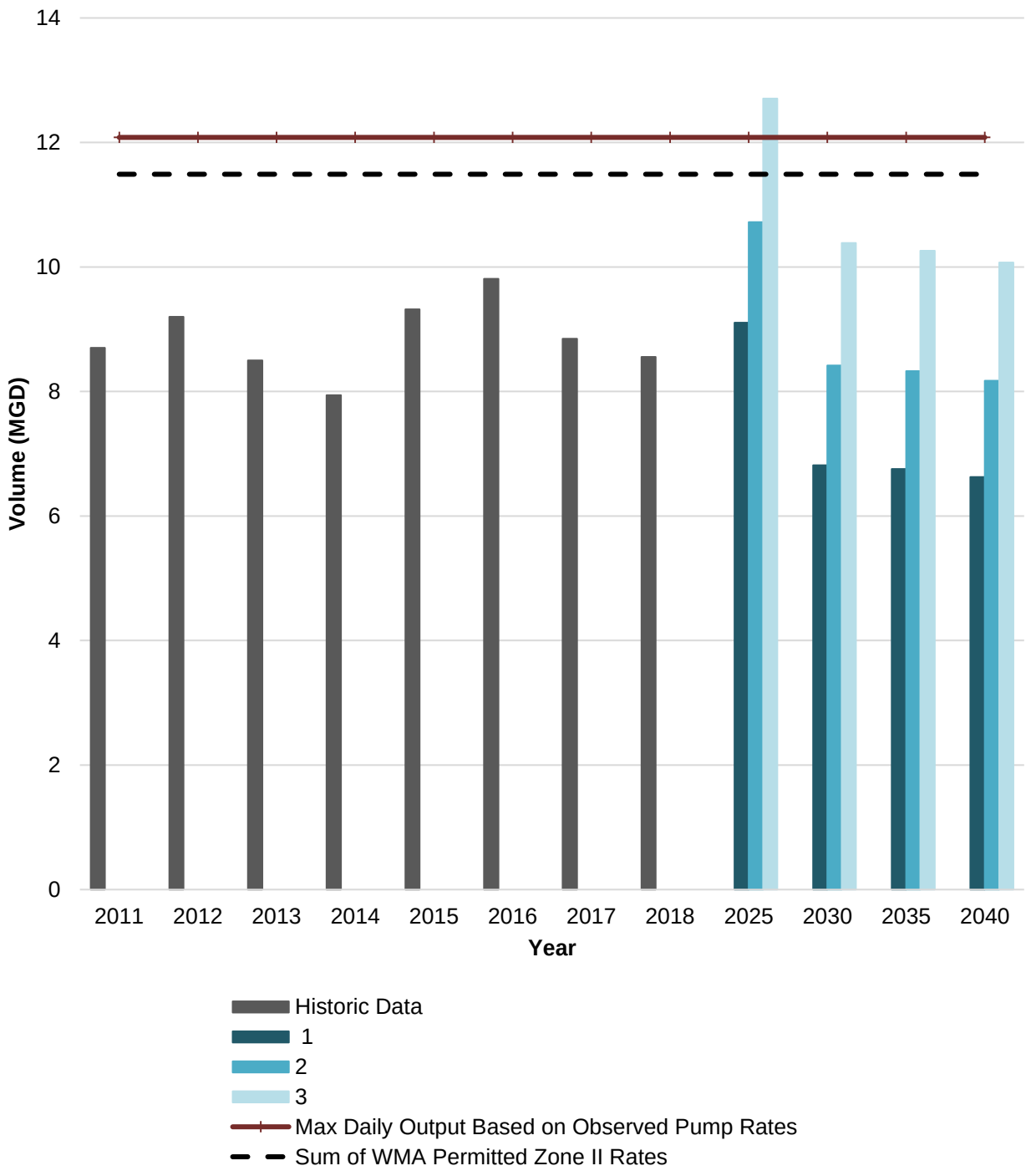

Figure 2-9: Maximum Daily Demand of Historic Data and Projected Scenarios, with Maximum Possible Pumping Rate and the Sum Permitted Zone II Rates

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2.4.1 Adequacy for Meeting Average Daily Demands

Yarmouth's permanent resident population is projected to decrease slightly, and its supply remains robust. Under all projection scenarios, Yarmouth is well positioned to meet its future average daily demand through 2040, even with several of its sources off-line.

In relation to its WMA Permit, Yarmouth's existing WMA Permit (plus registration) allocation (4.95 MGD) is adequate, with the exception of in the worst-case scenario in 2025, which assumes sale of water at current volume. Although the worst-case scenario (UAW increase to 10% and RGCPD increase to 120 gpd) is unlikely, this illustrates the need for the current Permit allocation to remain in place to allow for water sales to communities in need.

2.4.2 Adequacy for Meeting Maximum Daily Demands

The Town's current water supply is adequate to meet the Town's projected average daily demand through 2040, <u>provided that 'worst case' scenario (residential usage increase of 20%) is avoided while sales to Barnstable continue</u>.

The maximum daily output exceeds the future maximum daily demand, except for the worst-case scenario in 2025. During peak demand periods, the current pumping rate of all the wells combined may present issues for the Town, if a significant number of wells are out of service. The maximum daily demands in the future scenarios are above or near the reliable daily output of 8MGD. When the pumping rates of all the wells is less than the demand, the volume of water stored in the system will be depleted on that day. If there are multiple high demand days, with the volume of water consumed exceeding the amount pumped, the water levels in the system tanks could be significantly reduced. Lowered water levels in system tanks would reduce the pressure in the system and the amount of emergency water stored in the system.

For example, if the daily water demand is 9.5 MG per day for 4 days straight, but the pumping capacity is only 8MG for those 4 days, then 6MG will be consumed from system storage. Assuming that the tanks started completely full, with water elevations at 189ft in all three tanks, by the end of the 4th day all of the tanks would have a water elevation of about 152ft. The Sandy Pond Tank would be effectively empty, and the remaining water in the Prospect and German tanks would be insufficient for maintaining adequate pressure and emergency water. The calculations for the scenario are shown below:

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To avoid depleting the water stored, jeopardizing system pressure, and consuming emergency storage, Yarmouth should maintain well capacity and avoid well and pump maintenance during the summer and maintain high tank levels before expected peak demands.

In addition, given the potential threat of watershed contaminants, Yarmouth should take steps where possible to 1) to identify potential new well sites and 2) protect existing wells through land acquisition, as discussed below.

2.5 WATER SUPPLY RECOMMENDATIONS

In order to maintain and protect water supply adequacy, the following actions are recommended:

5. **Well Maintenance -** Maintaining wells through the Division's annual rehabilitation and maintenance program is critical for sustaining adequate supply for MDD and should be continued at its current investment level.
6. **Demand Management & Water Loss –**
    - Leak detection and repair efforts appear to be highly effective at keeping water loss low and should be continued.
    - Enhanced water conservation via the programs described in Section 2.5.1 should be considered.
7. **Watershed Land Protection** – Protecting existing wells from watershed contamination threats is critical. If suitable land for a potential well site is available for purchase, it is always prudent to consider land purchase for future wells and / or for watershed protection. As a reasonable rule of thumb, the Town should evaluate opportunities for purchase of available land within 1,000 feet of existing wells. MassDEP typically offers a grant program with awards of up to $250,000 for the purpose of purchasing watershed land.
8. **New Source Exploration** – Undeveloped land which is either owned by the Town, or potentially available for purchase (or conservation restriction) by the Town should be considered for test well exploration on a case by case basis. One such potential property is the Flax Pond property. The area north of the Flax Pond Recreation Area is owned by the Town and should be investigated for a possible future well site.

2.5.1 Water Conservation

Maintaining water usage near current levels is important for maintaining supply adequacy. Additional water conservation measures are available which would reduce demand and, in so

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doing, would essentially have the effect of making more water available in the event of drought, loss of wells due to contamination or maintenance. The programs likely to provide the greatest volume of water savings typically require a formalized program on the part of the Town or Water Division. Significant water savings tend to be especially viable through reduction of lawn irrigation. Examples of programs the Water Division can evaluate to reduce system demand include:

- Increasing seasonal block rate structure to discourage high volumes of water use
- Mandate limited watering days (e.g. three days per week) and/or times (morning and evening hours only)
- Bylaw that requires moisture sensors on automatic irrigation systems
- Bylaw limiting the amount of land clearing to create lawns
- New construction to include water-efficient fixtures and appliances
- Water-efficient fixture and appliance rebate program
- Low impact development regulations

In addition to demand reduction methods for achieving water conservation, water rates are another potential mechanism for conservation that should be considered. Increasing block rate structures that charge higher rates for water use beyond normal indoor use levels can reduce non-essential outdoor water use. The Town's implementation of automated meter reading (AMR) also offers the opportunity to issue more frequent billing (such as monthly) and/or adjust rates between the summer use season and low use winter season.

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3 WATER QUALITY

A fundamental function of the Yarmouth Water Division is to provide an adequate and safe drinking water source. Regulatory compliance is a major element of protecting Town residents and providing a safe, high quality potable water supply. MassDEP issues a compliance monitoring schedule to every public water system (PWS) in the state on a rolling three-year basis. The current three-year compliance cycle is between 2017 and 2019. Sampling results reviewed between 2009 and 2019 indicate that Yarmouth has been compliant with primary and secondary drinking water standards, apart from isolated sampling events for microbiological contaminants in May 2018.

3.1 REGULATORY OVERVIEW

This section reviews Federal and State drinking water quality regulations and their applicability to the Yarmouth Water supply. Both existing regulations (Section 3.1.1) and those anticipated in the future (Section 3.1.2) are detailed.

3.1.1 Existing Regulations

3.1.1.1 Groundwater Rule

The Environmental Protection Agency (EPA) promulgated the Groundwater Rule (GWR) in October 2006. The intent of the GWR is to monitor and control microbial contaminants in groundwater. It establishes an approach to identify water sources at a high risk of fecal contamination and specifies when corrective action is required. The primary GWR requirements for public water suppliers include:

- Massachusetts must conduct periodic sanitary surveys to assess significant deficiencies in groundwater systems.
- Source water monitoring to test for the presence of *E. coli*, enterococci, or coliphage. Sampling for Yarmouth, as a system that does not currently provide 4-log treatment for viruses, would be triggered by a positive routine sample under the Revised Total Coliform Rule or by DEP direction.

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- Corrective action for systems with significant deficiencies or source water fecal contamination. Corrective options include elimination of the contamination source or the addition of treatment. Treatment systems must be monitored to ensure at least 4-log virus removal is being achieved.

Assessment: This new rule is applicable to Yarmouth. The most recent sanitary survey conducted by DEP on April 03, 2019 revealed no major system deficiencies.

3.1.1.2 Revised Total Coliform Rule

The Revised Total Coliform Rule (RTCR) was promulgated in 2013 and went into full effect in on April 01, 2016. The Total Coliform Rule (TCR) established an MCL for total coliform bacteria present in drinking water and resampling requirements from positive samples. The RTCR provides updates to the TCR and established a new "find and fix" approach with defined pathways for addressing positive total coliform hits through system assessments.

Yarmouth has had some instances where the monthly sampling results exceeded the maximum contaminant limit (MCL) for total coliform. A high count of total coliforms has been addressed in the past by activating temporary liquid chlorine feed systems for disinfection at several of the existing corrosion control facilities..

Assessment: Yarmouth is typically in compliance and has made changes to remain in compliance.

3.1.1.3 Lead and Copper Rule

The Lead and Copper Rule (LCR) was promulgated in June 1991. It governs lead and copper in the distribution system, the source of which is primarily from household plumbing fittings and poorly performing corrosion control programs. Its primary requirements include:

- The LCR establishes an Action Level of 0.015 mg/L for lead and 1.3 mg/L for copper. Action levels are based on the 90th percentile level of samples collected from the distribution system.
- Monitoring requirements are set by population, and the number and frequency of monitoring reduced over time upon receipt of low lead and copper results.

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Yarmouth currently samples every three years at 30 approved locations (defined by the rule) and two taps within two schools for lead and copper. The number of locations and frequency of sampling are based on previous results below the LCR action levels.

High levels of copper were encountered in the first years after the rule was promulgated (1990's). The construction of corrosion control facilities proved effective in bringing both lead and copper levels below the action levels. This performance has been maintained following a change in the corrosion control approach which was adopted in 2005. The 2016 sampling event demonstrates results meet the lead and copper rule drinking water standards. Proposed revisions to the LCR have recently been published. Implications for the Revised LCR and Yarmouth are described below in Section 3.1.2.2.

Assessment: The current corrosion control process is achieving results below the action levels. Yarmouth is in compliance but should keep abreast of and plan for the upcoming changes in the proposed Revised LCR.

3.1.1.4 Drinking Water Standards

There are enforceable drinking water standards for numbers of contaminants, including broad classes like volatile organic chemicals (VOCs), synthetic organic chemicals (SOCs), and inorganic chemicals. These chemicals are regulated by EPA under the National Primary Drinking Water Regulations. There are also secondary standards for aesthetic water quality, as well as Health Advisories. Massachusetts has in some cases adopted standards, guidelines, and health advisories that are more stringent than EPA's. Sampling and analytical requirements for the drinking water standards can be found in Code of Massachusetts Regulations 310 CMR 22.07.

Assessment: Routine sampling shows Yarmouth is in compliance with these standards.

3.1.1.5 Perchlorate Standard

This contaminant is primarily a result of improper disposal of solid rocket propellent. It is not currently regulated on a national level, but Massachusetts adopted a standard late in 2006 of 2 µg/L. The EPA is reviewing a proposed rule to set a maximum contaminant level (MCL) for Perchlorate and should it be passed, MassDEP may revise its current standard to adhere with any other requirements set forth by the federal standard. Yarmouth has sampled for Perchlorate since 2016. Results have typically been non-detected, with some instances of detection between

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the Minimum Detection Limit (0.05 µg/L) and the Minimum Reporting Limit (1.0 µg/L). Table 3-1 demonstrates all detectable concentrations found since Perchlorate sampling was initiated.

Table 3-1: Test Perchlorate Detections in samples between 2016 and 2018

Yarmouth Well Number	Sampling Date	Detection (µg/L)
GP WELL # 11 KRISTIN'S POND (12G)	05/15/2016	0.1
GP WELL # 13 CHIKADEE LANE (13G)	08/30/2016 09/20/2016	0.11
WELL 15 AND 16	9/15/2016	0.074
WELL 2 AND 3	08/30/2018	0.19
WELL 21 AND 22	09/15/2016	0.12
WELL 4 AND 5	09/15/2016	0.099
WELL 6,7 AND 8	09/15/2016	0.1

Assessment: Yarmouth is in compliance.

3.1.1.6 Perchloroethylene (PCE)

PCE has been detected in Well 9 at levels above the maximum contaminant level of 5 micrograms per liter (ug/L). Well 9 was taken offline in August 2013 after an exceedance was measured of 7 ug/L. Subsequent samples ranged from 3 ug/L to 9 ug/L. After evaluating potential blending of Well 9 with other sources (6, 7, and 8), YWD made the decision to monitor the aquifer to gather a database that could inform future decisions about Well 9, and potentially provide early warning of contaminant levels that could impact nearby Wells 6, 7, or 8. During 2019, a monitoring well network of six wells was installed and three rounds of samples were collected. To date, only one sample had a detection, at a concentration of 0.55 ug/L. It is recommended that the PCE groundwater sampling frequency be reduced. However, it may be useful to resample the production well. Also, this monitoring well network may be valuable for monitoring for emerging contaminants such as PFAS (see Section 3.2.2 and 3.2.3.) that could be associated with septic systems or industrial / commercial / agricultural land uses.

Assessment: Yarmouth is in compliance as Well 9 is still offline. Reassessing the groundwater monitoring network is recommended.

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3.1.1.7 Stage 1/Stage 2 Disinfectants and Disinfection By-Product Rule

The Stage 1 Disinfectants and Disinfection By-Product Rule (Stage 1 D/DBPR) was promulgated on December 16, 1988. It applies to water systems that add a disinfectant to drinking water in any part of the treatment process. Its primary requirements include:

- Reduced allowable concentration of disinfection by-products in the distribution system and established minimum monitoring requirements. It set a standard of 80 ppb running annual average of total trihalomethanes (THMs) in the distribution system and a standard of 60 ppb running annual average of total halo-acetic acids (HAAs).
- It also set several additional standards for other DBPs and for disinfectants.

The Stage 2 rule is a new rule that builds on the Stage 1 rule by selectively identifying distribution sampling points. It applies the 80 ppb THM limit and 60 ppb HAA limit as a specific locational running annual average, instead of across the distribution system.

Assessment: The current Yarmouth treatment process does not routinely include the addition of a disinfectant, so the rule <u>not applicable</u> at this time. However, chlorine is added to the water on an as-needed basis in response to positive total coliform test results. If total coliform positive results become more frequent or the decision in made to activate chlorination on a full-time basis, the Water Division would need to comply with this rule.

3.1.1.8 Surface Water Treatment Rule

The Surface Water Treatment Rule (SWTR) sets requirements for the inactivation or treatment of microbial contaminants including giardia and viruses at water treatment plants treating surface water or groundwater under the direct influence of surface water. None of the Yarmouth sources are classified as under the direct influence of surface water.

Flooding risks associated with climate change and the increased frequency of extreme precipitation events in the region could potentially affect several wells within close proximity to streams, wetlands and other water bodies or in known FEMA flood zones. Flooding events have the potential to alter local hydrogeologic conditions and affect water quality in wells and is therefore important to document. The following wells identified are potentially at risk due to these events:

- <u>Well 10 and Well 11</u> – both wells are located within 200-feet of an un-named stream that flows south and discharges to Plashes Pond. FEMA has identified the pond and portions of the upstream wetlands as “Zone X” (0.2% chance of annual flooding). Extreme

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precipitation events could temporarily flood the associated wetlands upstream towards the wells.

- Well 18 – is located adjacent to the associated wetlands north of Horse Pond. FEMA has identified the pond and portions of the upstream wetlands as "Zone X" (0.2% chance of annual flooding). Extreme precipitation events could temporarily flood the associated wetlands upstream towards the well.

Assessment: This regulation is not applicable to Yarmouth. It would only become applicable if a current or new groundwater source was found to be under the direct influence of surface water.

3.1.1.9 Regulatory Summary Table

A summary of drinking water regulations that are applicable to Yarmouth is presented in **Table 3-2**. This table is developed based on the current treatment approach. Adjustments to treatment may result in the Water Division being required to comply with additional regulations.

Table 3-2: Existing Water Quality Regulatory Summary - Yarmouth

Regulation	Key Requirements	Yarmouth Status
Groundwater Rule	• Sanitary survey • Source water sampling, as required	In Compliance
Revised Total Coliform Rule	• Monthly total coliform sampling • Assessment and corrective actions following samples positive for Total Coliform	Typically In Compliance
Lead & Copper Rule	• Action levels (90th Percentile) set at: 0.015 mg/L for lead 1.3 mg/L for copper	In Compliance
Drinking Water Standards	• VOC MCLs • SOC MCLs • Inorganic Compound MCLs • Secondary (aesthetic) MCLs • MassDEP health-based guidelines	In Compliance
Perchlorate Standard	• MCL of 2 µg/L	In Compliance

3.1.2 Anticipated Regulations

3.1.2.1 Unregulated Contaminant Monitoring

UCMR3: The Unregulated Contaminant Rule (UCMR) 3 was published in May 2012; the rule issued a list of currently unregulated contaminants to be monitored by PWSs' with the anticipation

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of collecting data that will inform the development of future drinking water standards. The selected 21 contaminants from the Contaminant Candidate 3 list moved onto assessment monitoring between 2013 and 2015. The list included six Per-and Polyfluorinated Substances (PFAS) congeners, 1,4-Dioxane, chromium, hexavalent chromium, and strontium among others.

Two rounds of sampling were conducted in March and September 2015 at each of the Yarmouth corrosion control facilities. Some facilities had multiple samples collected. Table 3-3 presents the contaminant concentration averages for the number of detection locations. Both sampling events detected various levels on strontium, chromium, hexavalent chromium, and 1,4-Dioxane. Although these contaminants are currently not regulated with drinking water standards, it is important to keep in mind these detections should future regulations be promulgated; in particular, attention should be paid to 1,4-Dioxane as it is a probable human carcinogen (EPA) and already is subject to a MassDEP health-based guideline of 0.3 ug/L and detections were close to this level in CCF 11 and CCF21/22.

Table 3-3: Yarmouth UCMR 3 Contaminant Detections

Contaminants	March & September 2015	
	Maximum	# Detections
Strontium *(µg/L)*	82	*25*
Chromium *(µg/L)*	0.60	*12*
Hexavalent Chromium *(µg/L)*	0.59	*23*
1,4-Dioxane[(1)] *(µg/L)*	0.17	*4*
Total Samples	16 (March 2015) 25 (September 2015)	

[(1)] Massachusetts has set a health-based guideline for 1,4- Dioxane of 0.3 ug/L

PFAS were not detected in Yarmouth during UCMR3, however, PFAS have become a subject of increasing regulation at parts per trillion levels in the teens which are significantly lower than the detection limits achieved in UCMR 3 sampling (up to 90 parts per trillion). The subject of PFAS pending regulations and potential watershed sources is addressed in detail below in Section 3.2.2.

<u>UCMR4 and Manganese:</u> The Unregulated Contaminant Rule 4 was published in December 2016 and will require sampling of 30 chemicals between 2018 and 2020. According to the EPA the list is comprised of two metals, eight pesticides plus one pesticide manufacturing byproduct, three alcohols, and three semi-volatile organic chemicals (SVOCs). Included UCMR4 is <u>manganese</u>, a contaminant that Yarmouth currently tests for on a tri-annual basis. Currently, manganese has a secondary maximum contaminant (SMCL) of 0.05 mg/L. In Massachusetts, the MassDEP has already set the following health-based guidelines for manganese:

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- For general population: 0.3 mg/L (lifetime exposure);1 mg/L no more than 10 days
- For infants < 1 year old: 0.3 mg/L (limit exposure above 0.3 mg/L to no more than 10 days)

Development of a manganese MCL may have widespread implications especially in Massachusetts and New England where groundwater frequently has elevated levels and may require the design and installation of filtering treatment systems.

Analysis of the MassDEP database for Yarmouth shows that finished water from Well 1 and Wells 6, 7, & 8 have manganese concentrations exceeding the SMCL, and approaching the MassDEP health guideline of 0.3 mg/L. According to the MassDEP 2017 – 2019 Compliance Monitoring Schedule, manganese is sampled for on a tri-annual basis for each well. It would be prudent in anticipation of the UCMR sampling to collect manganese samples on a semi-annual or quarterly basis to establish trends in at least the wells exceeding the SMCL, although it is recommended that all wells be sampled.

Table 3-4: Yarmouth Manganese Levels

Contaminant	2014 - 2015		MassDEP health-based guideline
	Maximum	# Detections	
Manganese (mg/L)	0.11	*23*	0.3

3.1.2.2 Lead and Copper Rule Long Term Revisions

The EPA is in the process of revising the Lead and Copper Rule originally promulgated in 1991. Proposed revisions to the rule were published in October 2019. Key changes to the rule more specifically define sample site selection, sample collection procedures, and treatment requirements. The rule also takes a “find and fix” approach similar to the RTCR for addressing site specific exceedances and establishes an action level for lead concentrations between 10 and 15 ug/L. Other key provisions are: the mandatory system-wide inventory of all lead service lines, specific lead service line replacement goals, and a ban on partial lead service line replacement. Community water systems will also be required to sample schools. Overall the revisions are intended to strengthen the rule with the goal of increased and enhanced protection of public health. If the draft revisions are accepted and put into law, Yarmouth will need to take action to update their lead and copper rule sampling plan to fully comply. Yarmouth will also need to

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implement (if not already in place) a lead service line inventory (that is publicly available) and replacement program.

3.1.2.3 Chromium

The national primary drinking water regulation MCL for total chromium is 0.1 mg/L (100 ug/L) and was promulgated in 1991. The EPA initiated a reassessment of the health risks associated with chromium in March 2010 and did not revise the limits at that time. The EPA is currently assessing Hexavalent Chromium through monitoring (UCMR 3) and determination of health effects. Upon issuance of the final human health assessment, the EPA will then make a decision on whether to pursue any standards. Currently, chromium samples from Yarmouth's UCMR 3 sampling in 2015 demonstrate that Yarmouth is currently in compliance with the current MCL of 100 ug/L. Should regulations change in the next few years, they should pay close attention if a new standard develops.

3.2 WATERSHED THREATS AND WATER QUALITY TRENDS

3.2.1 Nitrates

Three wells in Yarmouth have demonstrated consistently elevated levels of nitrate over the past 25-years. Nitrate is regulated by the EPA and MassDEP with an MCL of 10 mg/L. In many communities relying on septic systems for sanitary wastewater disposal, elevated levels of nitrates typically above 3 mg/L, although not an exceedance, can be indicative of the septic systems treated discharge influencing water quality. Where agricultural land use is significant, runoff containing plant fertilizers and/or animal waste can leach into the groundwater and contribute to elevated nitrate. The elevated concentrations also cause harmful algal blooms in surface water bodies. The use of fertilizers on golf courses or other recreational fields may also contribute.

The 25-year sampling history for each of Wells 4, 5, and 11 are depicted in **Figures 3-1, 3-2 and 3-3** and show consistently elevated nitrate levels over 3 mg/L. In **Figure 3-1**, Well 4 shows consistent concentrations over 4 mg/L, with an overall slowly increasing trend. In **Figure 3-2**, Well 5 more stable conditions are observed, averaging around 4 mg/L, however a larger gap in data between 2008 and 2013 may be skewing the trend slightly downward. In **Figure 3-3**, Well 11 demonstrated a strong increasing trend with results since 2017 consistently above 5.3 mg/L.

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The area surrounding these wells consists of primarily high-density residential neighborhoods with individual septic tanks. It is most likely that due to the high density of septic tanks in close proximity to the wells, septic tank recharge to the aquifer is responsible for the elevated concentrations of nitrates in each of the wells. While concentrations are under the MCL, Yarmouth should increase monitoring these wells to quarterly and continue to work with the Board of Health on implementing watershed protection measures. Solutions specific to reducing nitrate loading include, reduction in nitrate-based plant fertilizers in gardens and on crop lands, and replacement of traditional septic tanks with denitrifying septic systems (innovative alternative, or I/A systems), or sewering.

Figure 3-1:

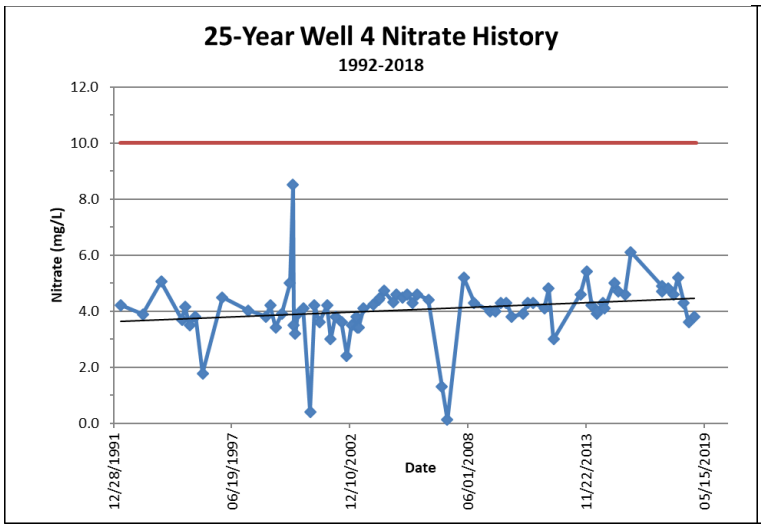


Figure 3-2:

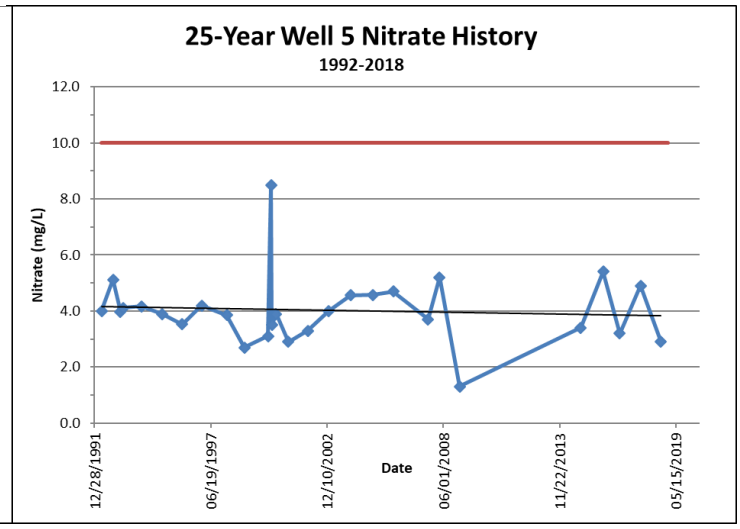
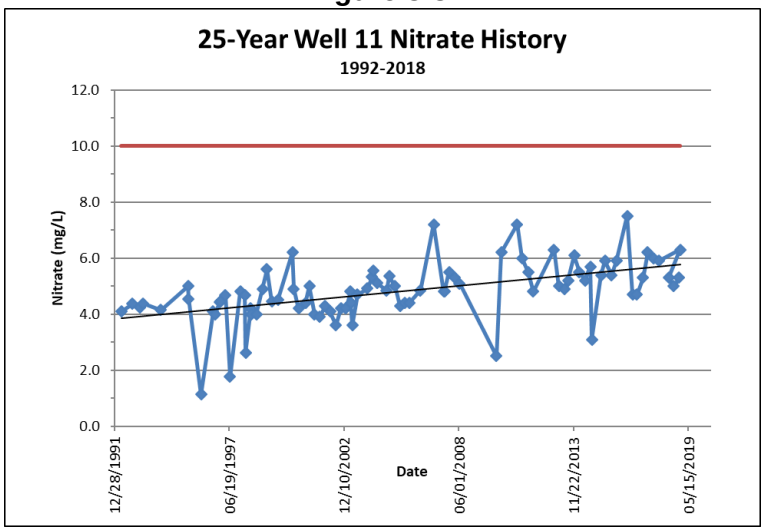


Figure 3-3:



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The Towns of Yarmouth, Dennis, and Harwich are currently in the process of developing a community partnership to evaluate the implementation of a regional wastewater treatment plant and sewer system. The program currently envisioned by the Towns includes a phased buildout of a sewerage system aimed at balancing water quality goals as well as economic and community development goals. The primary driver for this effort is the reduction of nutrients in coastal water quality to meet Total Maximum Daily Loads. In addition, the Town of Yarmouth is considering a partnership to receive treated effluent from Barnstable for infiltration within Yarmouth.

A centralized wastewater plant would discharge effluent to groundwater at one or more locations. If carefully designed to avoid impacts to groundwater, the wastewater system can improve the overall water quality of water resources across the towns including groundwater, ponds, rivers and estuaries that are relied upon on for not only drinking water, but recreation and tourism that support the communities' economic status and future development. However, because wastewater treatment technology lags behind emerging contaminants, there is potential risk to groundwater (and as a result to Yarmouth's drinking water. These factors must be carefully considered in the planning process. PFAS is an emerging contaminant of concern, discussed in the following section.

3.2.2 Per and Polyfluoroalkyl Substances (PFAS)

Per-and Polyfluoroalkyl Substances (PFAS) are group of large complex chemicals typically consisting of chains of carbon and fluorine. These man-made chemicals are widely used in industrial applications such as firefighting foams, as well as everyday products such as in non-stick coatings like Teflon, and personal care products and makeup. The most concentrated sources are typically associated with chemical manufacturing, airports or military bases, and fire training facilities. However, lower levels have been found associated with septic systems, municipal wastewater, and land application of biosolid or sludge fertilizers. This group of chemicals has come under recent scrutiny because they are found to be widespread, persistent in the environment, and with the ability to bioaccumulate in people. Current toxicology research suggests that bioaccumulation of certain PFAS congeners may cause negative health effects.

Under the 2015 UCMR 3, six PFAS congeners were sampled and have proven to be widespread amongst drinking water systems across the United States. The EPA established a health advisory in May 2016 limiting concentration to less than 70 ppt for the sum of Perfluorooctane Sulfonic Acid (PFOS) and Perfluorooctanoic Acid (PFOA). The EPA has recently stated its intent to propose an MCL by the end of 2019. Massachusetts, and many other states in the Northeast,

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are rapidly moving towards developing their own MCLs. Currently, the Massachusetts Office of Research and Standards Guidance (ORSG) has strengthened the EPA Health Advisory Limit by requiring concentrations for the sum of the following five PFAS congeners to be less than 70 ppt: Perfluorooctane Sulfonic Acid (PFOS) Perfluorooctanoic Acid (PFOA) Perfluorohexane Sulfonic Acid (PFHxS) Perfluorononanoic Acid (PFNA) Perfluorohepatanoic Acid (PFHpA). **Table 3-5** illustrates the current status of PFAS analytical reporting limits and their regulatory limits.

Table 3-5: PFAS Analytical Detection Limits and Regulatory Outlook

Contaminant		2015 UCMR MRL*	MassDEP LCMRL**	2016 EPA Health Advisory	2018 MassDEP ORSG Level	2020 Anticipated MassDEP MCL
		ng/L				
Perfluorodecanoic Acid	PFDA	n/a	3.8	n/a	n/a	20
Perfluoroocatane Sulfonate	PFOS	40	6.5	70	70	
Perfluorooctananoic Acid	PFOA	20	5.1			
Perfluorohexanesulfonic Acid	PFHxS	30	8.0	---		
Perfluorononanoic Acid	PFNA	20	5.5			
Perfluoroheptanoic Acid	PFHpA	10	3.8			
Perfluorobutanesulfonic Acid	PFBS	90	3.7		---	---

** 2015 UCMR MRL – Minimum Reporting Level*
*** LCMRL – Lowest Concentration Minimum Reporting Level is the lowest true concentration for which the future recovery is predicted to fall, with high confidence (99%), between 50 and 150% recovery.*

Yarmouth sampled for six PFAS congeners in **Table 3-5** as part of the 2015 UCMR3 sampling event as mentioned in **Section 3.1.2.1**. None of the six PFAS congeners sampled for were detected at the 2015 UCMR minimum reporting levels (**see Table 3.5**). <u>However</u>, these reporting levels are all significantly higher than the MassDEP LCMRL. Outside of the UCMR, MassDEP does not currently require PFAS to be sampled, although it is highly encouraged and will likely change as MassDEP intends to promulgate an MCL in 2020 that would require PFAS sampling. The Town may wish to consider resampling some or all of its wells according to the MassDEP LCMRL and to assure that both the 2016 EPA Health Advisory Limit and the 2018 MassDEP ORSG levels are being met. The following section below looks at the Yarmouth watershed in relation to potential PFAS sources.

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3.2.3 PFAS Watershed Threat Analysis

Potential sources of PFAS contamination include airports, firefighter training facilities and highways which have been known to use aqueous film-forming foams (AFFFs) to put out fires. Other facilities which may be significant sources of PFAS include industrial areas, wastewater discharge from septic systems, sewage or septage plants, and landfills/transfer stations. **Figure 3-4** depicts the central section of Yarmouth with callouts to some of the Wells and their associated Zone I's and II's, and potential PFAS contaminant threats. Zone I and II are defined by MassDEP as follows: Zone I is the 400-foot wellhead protection area surrounding an overburden well with a daily withdrawal over 100,000 gpd; and Zone II is the area of an aquifer which contributes to a well under the most severe pumping and recharge conditions. There are multiple, significant potential PFAS contaminant threats in the recharge areas of the Town's wells, as shown on Figure 3-4 and described below:

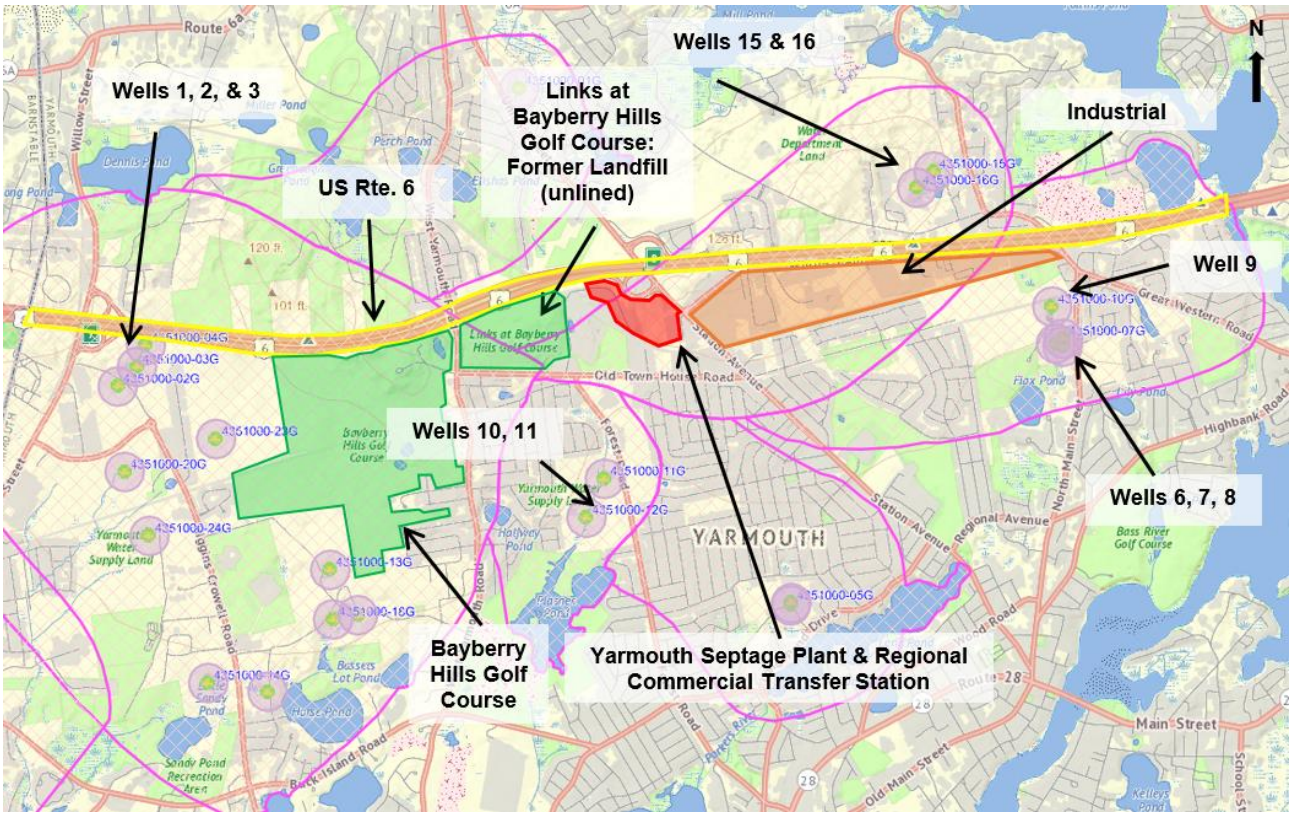

Figure 3-4: PFAS Potential Contaminant Threats to Yarmouth Wells and Zone IIs (*source MassGIS Oliver*)

- <u>Yarmouth Septage Plant / Commercial Transfer Station / Septage Discharge Facility</u> – This facility is located almost in the geographical center of town and along U.S. Route 6

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at the point of highest groundwater elevation. Septage collection systems can potentially concentrate sources of PFAS that leach out untreated into groundwater sources. Transfer stations could be susceptible to contaminants collected in runoff. The Zone II for Wells 15 and 16 encompasses these facilities. Septage effluent is periodically pumped to the Town-owned land on Buck Island Road and discharged by spray irrigation to the vegetated fields. Although this discharge is outside of any existing Zone IIs, it is approximately 2,000 feet from the Zone II for Wells 13, 14, 17 and 18.

- Golf Courses – The Bayberry Hills Golf Course has a WMA permit that includes the use of reclaimed wastewater for irrigation, which could contribute a source of PFAS to the groundwater. In addition, recent research indicates that many commercially available fertilizers originating from municipal sludge or other biosolids may contain significant concentrations of PFAS. PFAS in fertilizers is not yet regulated by Massachusetts.
- Yarmouth Landfill – The Bayberry Links Golf Course is situated on top of the capped Yarmouth Landfill. Although the landfill is capped, it is reportedly unlined. While precipitation can no longer percolate into the waste material, the existing contamination may potentially migrate into groundwater through the base of the landfill.
- Industrial Area – The historically industrial area running along White's Path on the south side of U.S. Route 6 could have companies that have used PFAS chemicals in the past. The Zone II for Wells 15 and 16 encompasses most of the industrial area. Additionally, a known contaminated site currently exists on the eastern most portion of the Industrial area and is encompassed by the Zone II of Wells 6-9. Well 9 is currently offline as Tetrachloroethylene (PCE) was discovered in the early 2000's and exceeded primary drinking water standards in 2013. The Town is currently monitoring the area for PCE with a surrounding network of observation wells. The Corrosion Control Facility serving Well 9 is not currently operational and was not sampled during the 2015 UCMR. No PCE or degradation products have been detected in Wells 6, 7, or 8. Due to the known impact of industrial chemicals sampling either the supply wells or the existing monitoring network for PFAS is recommended.
- U.S. Route 6 – Route 6 lies generally along the elevated ridge running through the center of Cape Cod. The topographic high represents a groundwater divide; shoulders slope away from the roadway and could potentially carry PFAS contaminants associated with firefighting towards the adjacent grassy and wooded areas and infiltrate into the aquifer. Many of the Yarmouth wells are located along the central ridge of the Cape near U.S. Route 6 with their Zone IIs encompassing almost the entire length of U.S. Route 6 that transects the town. Wells with Zone IIs overlapping the highway could be at risk for PFAS.

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- Septic Tanks – most of Yarmouth's buildings are served by individual septic systems. Some dense neighborhoods have high concentrations of septic tanks located near wells that have affected their water quality (as discussed in **Section 3.2**). Personal care products and makeup have been found to be sources of PFAS and because all residential buildings in Yarmouth have septic systems, wells that may influenced by septic recharge should be sampled. The Yarmouth Wells 4, 5, & 11 have all demonstrated elevated concentrations of nitrate, suggesting that they are the most strongly influenced by septic tank recharge.
- Known Barnstable PFAS Contamination - One of the major sources of PFAS drinking water contamination is through the use of aqueous film-forming foams (AFFF) used by firefighting units and training facilities. Firefighting units typically use the foams to put out fires at airports or on highways. The Town of Barnstable is currently evaluating long-term treatment options for a PFAS contaminated wellfield just north of the Barnstable Municipal Airport and east of the Barnstable County Fire/Rescue Training Academy. The Training Academy is currently the suspected source of contamination; it is also possible that the airport and/or Barnstable's municipal wastewater facility could contribute. Barnstable's contaminated well field is located approximately 1 mile west of Yarmouth's Wells 1, 2, 3, 20, and 24. **Figure 3-5** depicts the proximity of the western Yarmouth wellfields to the PFAS contaminated Barnstable wellfield; also shown are the Zone IIs for these wellfields which border and potentially overlap each other. Because of the proximity, and the

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ongoing development of the issue, Yarmouth should consider sampling the wells in closest proximity.

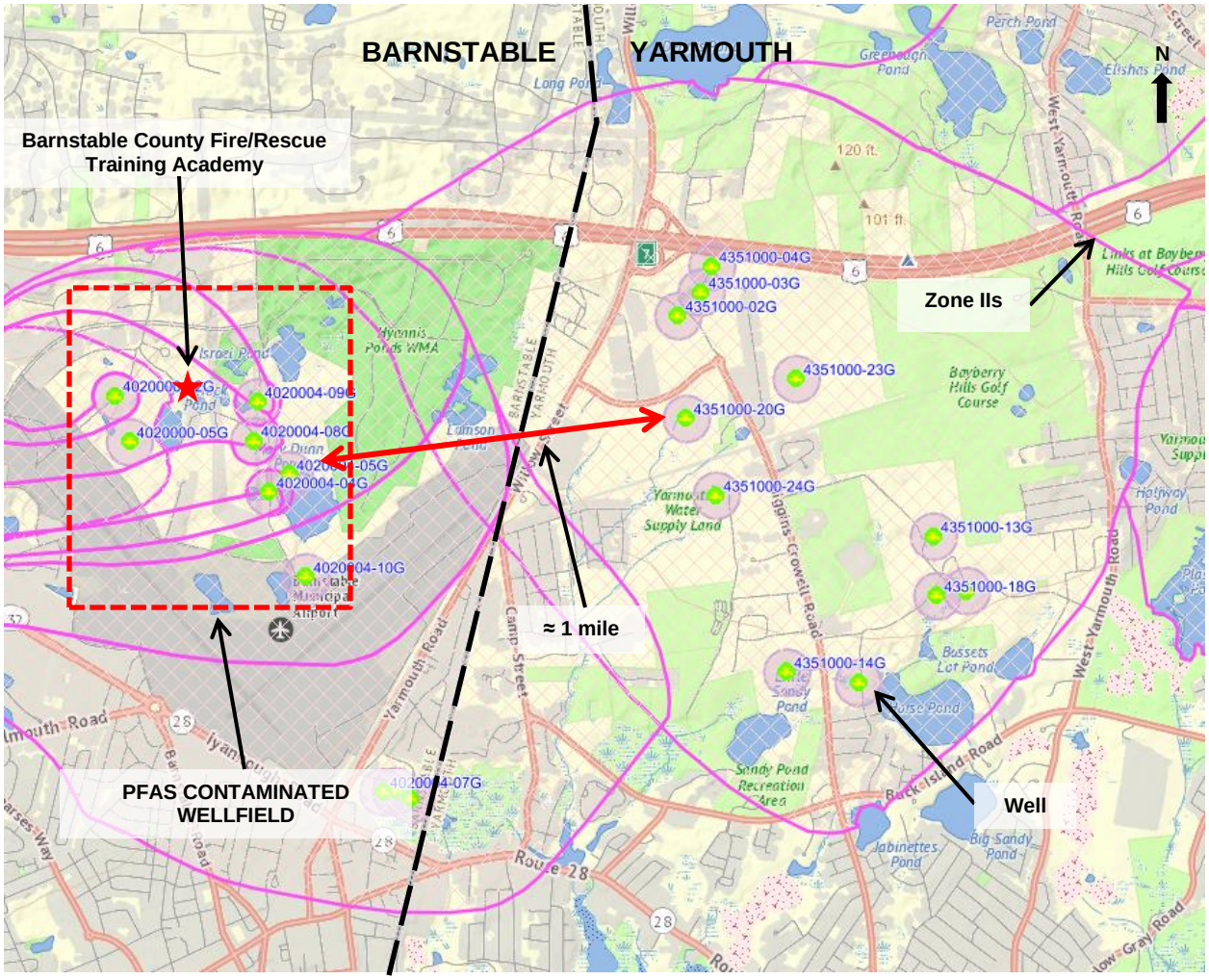

Figure 3-5: Proximity of Yarmouth Wells to PFAS Contaminated Barnstable Wellfield (source MassGIS Oliver)

Based upon all of the above potential PFAS contaminant threats, and the regulatory outlook for PFAS, it is recommended that Yarmouth sample (at a minimum) high risk wells for PFAS. In order of priority, these include: Wells 10 and 11; Wells 15 and 16; Wells 1, 2 and 3; Wells 6, 7, and 8; and Wells 4 and 5. Alternatively, adjacent monitoring wells could be sampled, if their condition is satisfactory and if they are first redeveloped. However, the results would not be as accurate a measure of the levels of PFAS in the distribution system, if any.

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3.3 SUMMARY OF WATER QUALITY RECOMMENDATIONS

Based upon the review of all the routine compliance monitoring sampling results, operation records, and the other water quality data, the Yarmouth water system is in good regulatory standing; meeting all federal and state primary and secondary drinking water standards. A number of forthcoming regulations, and the threat of potential contaminants in the Town's watershed drive the following recommendations:

Secondary Contaminant Monitoring:

Yarmouth's compliance monitoring plan does not currently require raw water testing for secondary contaminants from each well. The latest sampling of secondary contaminants (aside from pH which is consistently measured at Corrosion Control Facilities) occurred in 2015, however the results were lost. The only complete sampling of raw water from wells prior to the 2015 sampling occurred in 2003. Secondary contaminants are important to assessing water quality from a treatment standpoint, and particularly important from a corrosion control standpoint. Because Yarmouth relies on pH adjustment for corrosion control, pH in addition to other parameters that drive corrosion should be monitored on an annual basis. Groundwater quality does change over time, and with the latest results from 2003, there may be changes in the groundwater chemistry that could merit operational adjustments and changes to the corrosion control treatment system. This may help assist Yarmouth with continued compliance with the Revised Lead and Copper Rule. Sampling for secondary contaminants will also help to identify increasing trends in iron and manganese, if any. **It is recommended that Yarmouth sample raw water for secondary contaminants from each well on an annual basis.**

Proactive PFAS Monitoring:

As mentioned in Section 3.3, PFAS is becoming a high-profile issue for public drinking water systems. MassDEP is aggressively moving towards the establishment of an MCL and may soon require all public water systems to sample their raw water sources. Several contaminant threats that could potentially be a source of PFAS have been identified within the town in close proximity to some of its wells. Additionally, the known PFAS contamination in Barnstable and its proximity of several Yarmouth wells warrants caution. **It is recommended that Yarmouth proactively sample raw water for PFAS at certain higher risk wells noted above. It is important to note that due to the ubiquitous presence of PFAS in common household products, great care must be taken when collecting samples to avoid cross contamination and false positives**. **Due to the intense media focus on PFAS, it is further recommended that a Yarmouth-specific communication plan be implemented** prior to publishing the test results so that the

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public can be provided with clear, understandable information and that Town staff provide consistent information to customers so that the public maintains trust in the water system.

Proactive Monitoring for Manganese and 1,4 Dioxane:

As described above, several wells experience levels of manganese and 1,4- dioxane approaching the Massachusetts health guidelines. Proactive monitoring is recommended to identify trends can help Yarmouth prepare for future treatment needs, if any.

Lead and Copper Rule Updates:

When the revisions to the Lead and Copper Rule are passed and go into effect, Yarmouth will need to comply with any and all changes. It is likely that the provision for mapping all lead service lines will be included in the rule change as the sample site selection will include collection of samples at all these locations. It would therefore be prudent for the system to start accounting for and mapping the locations (if any) of all lead service lines.

Updated Digital Records System:

All sampling and operational records were provided in paper format with some records not accounted for. An electronic database may be useful for keeping track of sampling, as well as making data manipulation and analysis faster and easier.

Consumer Confidence Reports:

The Town has Consumer Confidence Reports posted on the Department of Public Works website. Beginning in October of 2020, CCR changes will be required, including posting or delivering updates CCRs twice annually.

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4 FACILITIES

This section summarizes the condition of the Yarmouth water system infrastructure based on facility inspections either by Kleinfelder (pump stations) or others (wells, tanks, VFDs). Based on the evaluation results, a series of upgrade recommendations are presented. Recommended expenditures are presented in Section 7.

4.1 PUMP STATIONS

In May 2019, Kleinfelder prepared a facilities improvement plan for all of Yarmouth's Pump and Corrosion Control Stations. The improvements identified focused on specific needs areas identified by Yarmouth, including: roofs and roof hatches, asbestos interior ceiling tiles, and accessibility of below grade vaults. Kleinfelder inspected the 24 pump stations and 21 corrosion control facilities for these deficiencies and put forth specific recommendations for each. In addition, major deficiencies or improvements to electrical systems were provided. Recommendations included:

1. Remediate asbestos ceiling tiles in nine Pump Stations.
2. Replace roofs in all Pump Station and Corrosion Control Facilities.
3. Replace Pump Station roof hatches to allow remote operation from the ground floor of the building.
4. Pump Station vaults are currently permit-required confined spaces. Upgrade vaults to either a) non-permit required confined spaces or b) provide a second egress (not confined space). The vault egress option has been presented as an alternate in the phased plan below.
5. Make selected upgrades to electrical and HVAC systems.

Due to the number of facilities, the proposed changes will be implemented in at least three phases. In general, these recommended phases address the most critical issues in the oldest facilities first.

- Phase 1 involves removing the asbestos ceiling tiles in the 9 impacted pump station buildings: PS 4, PS 5, PS 6, PS 7, PS 8, PS 9, PS 10, PS 11 and PS 13 as well as implementing the other upgrades to those buildings: roof replacement, hatch replacement, ceiling replacement, and vault upgrades or vault egress (alternate). It also includes roof and hatch replacement and vault upgrades at PS 1, 2, and 3.

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- Phase 2 involves implementing the upgrades to the other 11 Pump Station buildings with roof replacement, hatch replacement and ceiling replacement. These buildings do not require asbestos removal and do not have vaults. This phase includes buildings with a medium level of deterioration in need of repair/replacement.
- Phase 3 involves implementing the upgrades to Pump Station 1M and the 20 Corrosion Control buildings which require roof replacement. With exception of PS 1M, there are no hatches, vaults, asbestos, or ceilings in need of replacement. PS 1M includes an extensive roof with damaged gutters and a roof hatch. Phase 3 could also be split into a fourth phase depending on funding availability.

The Phase 1 improvements are currently being designed. As the design is progressing, electrical deficiencies are being identified which were not previously known. Electrical upgrades may need to be incorporated and the budget and phasing plan updated accordingly.

Table 4-1: Pump Station and Corrosion Control Facilities Improvements Plan Phased Cost Estimates (in 2019 Dollars)

Phase/Description	Estimated Cost
Phase 1	$782,000- $1,247,000
Phase 2	$947,000 - $996,000
Phase 3	$2,060,000
Total:	$3,789,000 - $4,303,000

4.2 WATER STORAGE TANKS

The size and capacity of each Yarmouth water storage tanks is summarized in **Table 4-2**.

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Table 4-2: Yarmouth Water Storage Tank Characteristics

Tank	Height (ft)	Diameter (ft)	Overflow Elevation[1] (ft)	Storage	Useable Storage
German Hill[2]	60.5	101	189.6	3.75 MG	2.00 MG
Prospect Hill[2]	68.2	100	189	4.00 MG	1.94 MG
Sandy Pond[3]	160	86	189	1.50 MG	1.43 MG
			TOTAL	**9.25 MG**	**5.37 MG**

[1] Based on USGS Datum
[2] Welded Steel tank
[3] Elevated welded steel hydropillar

Not all of the available storage capacity is useable. A portion of the total storage must be held in reserve to maintain a minimum pressure of 35 psi at all service connections. Based on the overflow elevations of the storage tanks (±189 feet MSL) and the ground elevation of the highest customer (±75 feet MSL), the 5.37 million gallons stored above an elevation of ±156 feet MSL can be considered useable storage.

4.2.1 2019 Tank Sanitary and Security Inspections

All tanks recently underwent sanitary and security inspections on September 29, 2019. Underwater Solutions, Inc., a contractor specializing in municipal drinking water storage tank inspections and maintenance carried out the inspections for each tank. All tanks appear to be in good condition with some recommendations for continued maintenance and upgrades to comply with all applicable standards. A summary of the inspection findings for each tank is presented as follows:

<u>German Hill Tank:</u>

- The German Hill Tank appears to be in sound condition and remains free of obvious forced entry or vandalism.
- The protective coatings applied to the welded steel surfaces appear to have good adhesion providing adequate protection.
- Mildew has accumulated across much of the exterior wall surfaces reducing the overall aesthetics.
- It is recommended that a non-corrodible 24-mesh screen be installed over the end of the overflow pipe to protect the existing 4-mesh screen on the interior of the pipe.

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- Exposed surfaces on the concrete foundations appear sound. Tight surficial cracks were observed on approximately 5% of the exposed surfaces. The cracks remain free of obvious voids and spall.
- The German Hill Tank site does not currently have security fencing. It is recommended that the town install security fencing around the tank that is at least 6-feet in height with 12-inches of barbed wire and a lockable gate.

Prospect Hill Tank:

- The exterior steel wall panels and welds appear sound and remain free of obvious fatigue or failures of the steel.
- Mildew has accumulated across much of the exterior wall surfaces reducing the overall aesthetics.
- Non-destructive graffiti on the lower rows of panels indicated unwanted access to the site and is consistent with Underwater Solutions, Inc's October 30, 2018 Sanitary and security inspection.
- The steel roof dome panels and associated welds demonstrate isolated areas of secondary coating adhesion loss and have resulted in exposure of the primary coating. This has led to surface corrosion in some locations. The corroded areas appear sound and free from fatigue and deterioration at this time.
- It is recommended that a non-corrodible 24-mesh screen be installed over the end of the overflow pipe.
- It is recommended that the overflow pipe be modified (by extending pipe or excavating under pipe) to allow a gap of at least 12 to 24-inches above grade to be consistent with MassDEP regulations.
- Exposed surfaces on the concrete foundations appear sound. Tight surficial cracks were observed on approximately 5% of the exposed surfaces. The protective coating applied to the concrete foundation appears to no longer seal the tight cracks observed throughout the surface.
- The Prospect Hill Tank site does not currently have security fencing. It is recommended that the town install security fencing around the tank that is at least 6-feet in height with 12-inches of barbed wire with a lockable gate.
- It is recommended that a 24-mesh non-corrodible metal screen be installed around the circumference of the roof vent.

Sandy Pond Tank:

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- The Sandy Pond Tank appears to be in sound condition and remains free of obvious forced entry or vandalism.
- The exterior surfaces on the lower support pedestal demonstrate isolated areas of coating fatigue and steel exposure. Mild surficial corrosion of the surfaces was observed however, no evidence of pitting corrosion was found.
- Mildew has accumulated across much of the exterior wall surfaces reducing the overall aesthetics.
- Several areas of the secondary coating have worn due to weathering and have exposed areas of the primary coating and isolated areas of steel exposure with surficial corrosion on approximately 5% of the steel panels and welds.
- It is recommended that the overflow pipe be modified (by extending pipe or excavating under pipe) to allow a gap of at least 12 to 24-inches above grade to be consistent with MassDEP regulations. Also installation of a splash-plate or rip-rap to prevent erosion around the pipe during overflow events.
- It is recommended that a non-corrodible 24-mesh screen be installed over the end of the overflow pipe.
- It is recommended that a 24-mesh non-corrodible metal screen be installed around the circumference of the roof vent.

4.2.2 Maintenance Recommendations

Based upon the results from the 2019 Sanitary and Security Inspections, continued maintenance will improve the aesthetic quality of the tanks, protect against corrosion or degradation, and ensure longevity of the tanks. **Table 4-3** summarizes the continued maintenance recommended by the 2019 Sanitary and Security Survey:

Table 4-3: Water Storage Tank Recommended Maintenance

Recommended Maintenance	German Hill	Prospect Hill	Sandy Pond
1. Install 24-mesh on outflow pipe	X	X	X
2. Overflow pipe airgap modifications		X	X
3. Install 24-mesh on vent		X	X
4. Exterior tank painting (spot painting)			X
5. Concrete base painting	X	X	
6. Security fencing around tank	X		X

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It is also recommended that the tanks get periodically drained and cleaned in order to maintain water quality and inspect the complete interior.

4.2.3 Tank Painting

Periodic tank painting is a critical maintenance element for steel water storage tanks. Typical rule of thumb best practice is to plan for tank painting every 15 years. The most recent dates of painting for Yarmouth's tanks are listed below. Yarmouth is doing well at keeping up with tank painting.

Table 4-4: Recent Tank Painting Summary

Tank	Most Recent Exterior Painting	Most Recent Interior Painting	Notes
German Hill	2015	2015	Mixing system also installed
Prospect Hill	2011	2011	Mixing system installed
Sandy Pond	2005	2005	

The next tank that is due for painting is Sandy Pond. The recent 2019 inspection indicated that the coating systems is in good condition, with only isolated areas of corrosion. This tank painting could be deferred a couple of years to prioritize funds for pump station repairs.

4.3 WELLS

The Town has a total of 23 wells serving the distribution system and one Well (No. 9) that is inactive. Since 2006, about 5 wells per year have undergone maintenance that typically includes general maintenance of the pumps, motors, and other associated components. The wells screens are inspected through a camera survey and then redeveloped through acid treatment, surging, and pumping. The selection of specific wells is based upon the inspection and/or if a significant drop in yield has been observed since the last maintenance year. **Table 4-5** summarizes the well maintenance performed since 2006. Overall the maintenance program has been successful in addressing continued routine maintenance and spacing out larger maintenance items such as pump replacements. This program ensures that Yarmouth's wells are operating efficiently, and that the system is highly resilient and able to meet the large seasonal demand increases.

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Table 4-5: Well Maintenance Summary

	Year											
Well	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012/ 2013**	**2014**	**2015**	**2016/ 2017**	**2018**	**2019***
1-Main								x				
1			x						x			
2					x				x			
3			x						x			
4			x						x			
5			x						x			
6	x							x				x
7	x							x				x
8	x							x				x
9			x									
10						x		x				
11				x								x
13						x						
14				x						x		
15				x							x	
16						x						x
17	x							x				
18	x							x				
19						x					x	
20				x						x		
21				x				x		x		
22						x					x	
23						x					x	
24				x						x		

** 2019 well maintenance is scheduled for the wells displayed in column*

4.4 SCADA AND VFD SYSTEMS

Industrial Technical Services (ITS) currently maintains the SCADA system for the Town. The systems were inspected on November 06 and 07, 2019. The company that manufactures the programmable logic controller (PLC) for each of the wells has been bought out and consequently the lead time on replacement components has increased to the point that ITS recommends replacing each PLC with a different brand at the end of their expected service life. In addition, the company that currently provides the radio antennas and associated components no longer exists

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and new replacement parts can no longer be reliably acquired. ITS has therefore recommended that the radio components be replaced at the end of their service life with a new system.
ITS will provide brief summary of recommendations under separate cover.

Variable Frequency Drive (VFD) inspection results conducted by others were not available at the time of preparation of this report.

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5 SYSTEM MANAGEMENT

Yarmouth's 2007 Water Master Plan included an assessment and recommendations related to System Management. A review of Water System management was recently conducted by others during 2018. The reader is referred to the following document for a more detailed discussion of system management practices and recommendations: *Organization and Operational Assessment, June 2018, Tighe & Bond.*

Based on our familiarity with the Yarmouth Water System, we reinforce the recommendations of the Tighe & Bond 2018 document, in particular the following items which are key to supporting the operational upkeep and capital investment in maintenance and renewal of the water system:

- Implementing routine maintenance programs if not already underway
  - valve exercising
  - unidirectional flushing
  - hydrant inspection and maintenance
- Staff training, certifications, and guidance (SOP) programs
- Data and work management tracking
- Evaluating and modifying rates and financing to accommodate cost of system upkeep and investment.

<u>Operations:</u> If not already being implemented, the following operational programs should be implemented. These programs should be implemented with the assistance of the Division's work management software so that condition data and maintenance is tracked on a continual basis:

- Gate valve exercising
- Hydrant inspection and maintenance
- Unidirectional flushing
- Service line inventory (to support future compliance requirements of the Revised Lead and Copper Rule).

<u>Planning / Regulatory Compliance:</u>

- Asset Management Plan and Financial Planning - The Asset Management Plan GIS should be updated to develop a phased program of age and condition-based main replacement. Financial modeling scenarios should be developed to provide the Town with a sustainable way to fund needed improvements. Grants are available to continue funding this program.

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- America's Water Infrastructure Act – Risk & Resiliency Assessment / Emergency Response Plan Update – this is a new Federal requirement with respective deadlines of June 30, 2021 and December 30, 2021. An RRA must be prepared that considers natural hazards and malevolent acts to infrastructure, and computer systems. The ERP must be updated to incorporate RRA findings.

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6 DISTRIBUTION SYSTEM EVALUATION

Yarmouth's distribution system consists of (approximately)[6] 282 miles of water main, 2,110 hydrants and 3,430 gate valves. The water system GIS locational data is fairly complete and was previously updated in 2017 and again verified for this Master Plan and model update.

For this Master Plan update, the Town's hydraulic model was updated and calibrated. Model scenarios were used to assess the ability of the Yarmouth distribution system to meet present and projected future maximum day demands, domestic pressure requirements, available fire flow requirements, and desired water age limits. Areas of hydraulic need were identified and capital improvement upgrades to address them were recommended based on the results of the hydraulic analysis.

Record drawings have not been provided or reviewed to establish actual year installed and material for water mains. Year installed and material have been estimated based on operator institutional knowledge, town historic population growth, and water main material historic production[6]. Water main improvements based on age or condition have therefore not been identified in this Plan. However, a future age-based main renewal / replacement program is discussed in Section 6.6.

6.1 HYDRAULIC MODEL

The Yarmouth Water Division owns a hydraulic model of the water system that was originally developed in 2001. Kleinfelder used an updated version of this model for this analysis. First, Kleinfelder calibrated the model using pressure and flow testing data collected at various points in the distribution system. Once calibrated, the hydraulic model is an effective means of evaluating the distribution system and can be used to simulate the system's capacity to meet projected future demands, pressure requirements, and calculate fire flow availability and water age. The hydraulic model can also be used to simulate and evaluate potential capital upgrades and operational changes.

[6] *Yarmouth Water Division Asset Management Plan, Kleinfelder, 2017*

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6.1.1 Model Description

The hydraulic model of the Yarmouth water distribution system was initially created in 2001 using the EPANET 2.0 software as developed by the United States Environmental Protection Agency. In 2007, Kleinfelder imported the hydraulic model into WaterCAD 4.1 (Haestad Methods, Inc.) for fire flow modeling. The 2007 computer model was a simplified version of the actual water distribution system network. The model consisted of a series of line segments (representing pipes), nodes (representing pipe intersections with assigned demands), storage tanks, and well pumping stations. The most important pipes, on a hydraulic basis, were included in the model, but some smaller, less hydraulically significant pipes were left out to improve the model run time.

For the 2019 model, Kleinfelder used the modeling software WaterGEMS by Bentley software. Each of these programs solve for the distribution of flows and hydraulic grades using the gradient algorithm. This gradient algorithm method for solution of pipe networks is an iterative process. This method of analysis is based on two principles:

1. The total flow entering the junction of two or more pipes must equal the flow leaving the junction.
2. The pressure difference between any two points in the system must remain the same regardless of what path is used to connect the points.

The computer software applies these two principles by assuming an initial flow pattern through the distribution system. Based on the assumed flow pattern, the software calculates headlosses between the supply sources and the points of distribution. These headlosses are compared and recalculated on an iterative basis until the above stated principles are satisfied.

6.2 2019 UPDATES TO INPUT DATA

6.2.1 Updates to Model Pipes

Due to increases in computing power, it is no longer necessary to operate a skeletonized model of the water distribution system as was done in 2007. Therefore, Kleinfelder imported the Yarmouth GIS pipes layer updated in 2017 for the Asset Management Plan into the model to simulate the pipe network in its entirety.

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6.2.2 Demand Allocation

Changes in Yarmouth population and demand trends required revised demand figures in the hydraulic model. The average day demands for the top 20 users in 2017 were provided by Yarmouth and were assigned to the nodes closest to those addresses. The remaining demand was allocated evenly to the other nodes throughout the model.

The maximum day demand was created using the demand allocation from the average day demand with a factor of 2.288 applied to achieve the 2017 ASR maximum day demand. For the 2017 peak hour demand, a factor of 1.5 was applied to the maximum day demand. The estimated future demand for 2035 was modeled by applying a factor of 1.187 to the 2017 maximum day demand allocation based on demand projections discussed in Section 2. The large consumers simulated in the model are reported in Table 6-1.

Table 6-1: Addresses for Top 20 Water Users

Address	2017 Average Demand (gpm)
0 Bayview Street (Hospital)	27.69
210 Station Avenue	6.98
241 Willow Street	6.82
182 Baxter Avenue	6.70
0 Bayview Street	6.46
265 North Main	6.10
1199 Route 28	5.94
291 South Shore Drive	5.89
822 Route 28	5.30
55 Long Pond	3.65
822 Route 28	3.54
100 Heatherwood at Kings Way #5000	3.18
688 Willow Street	2.92
134 Old Main Street	2.44
100 Heatherwood at Kings Way #3000	2.34
100 Heatherwood at Kings Way #2000	2.23
100 Heatherwood at Kings Way #1000	2.16
48 Captain Besse Road	1.82
32 Old Townhouse Road	1.07

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6.2.3 Well Pump Curves

Best available updated pump curve information was input into the model for each supply well based on SCADA data provided by Yarmouth for each pump station. A single point design curve was created based on the pressure and flow rates recorded on each SCADA record provided by Yarmouth Water.

6.3 MODEL CALIBRATION

The hydraulic model was calibrated using data collected during fire flow testing and SCADA data provided by Yarmouth for the days of flow testing. The model is initially calibrated for steady-state static pressure based on static pressures recorded prior to flow tests, the tank levels at the time of the flow test, and whether the pumps were on or off.

6.3.1 Flow Testing

Field flow testing data provides the most direct measurement of distribution water main condition. The calibration of the model was completed using the results of seventeen flow tests completed on May 8th and 9th, 2018. These flow test results were supplemented by additional flow testing data from 2007. Flow testing gives insight into how much water can be drawn from a hydrant before reducing the residual pressure below 20 psi. This measure is called Available Fire Flow at 20 psi residual pressure (AFF).

By recreating the test using the same system conditions within the hydraulic model, the accuracy of the hydraulic model can be tested. The degree of roughness inside a pipe (Hazen-Williams C-Factor) is then adjusted to calibrate the model until the simulated results match the results observed in the field. New pipe has an average C-Factor value of 130. In older unlined cast-iron distribution systems, C-Factor values as low as 30 can be encountered. No unlined cast iron pipes are thought to exist in the water distribution system, however, the 2017 Yarmouth Water Asset Management Plan acknowledged that water main material data was poorly documented. C-Factors within the calibrated model range from 95 to 140. Fire flow calibration results are discussed in section 6.3.3.

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6.3.2 Tank Level Fluctuations

Changes in the water level in water storage tanks provide valuable information about water system performance over time. Tank level data was provided by YWD through SCADA trends for each of the three Yarmouth tanks for the dates of May 8th and 9th, 2019. These dates correspond to the field flow testing program executed for this project. The well pumps that were operating during those days, and the time and duration of their operation, were also recorded. The pump operation data was input into the model and an extended period simulation was conducted setting tank levels at the levels observed at 12:00 AM. A two-day simulation provided results for each tank on each of those days, which was compared to the actual tank levels recorded. Tank calibration results are discussed in section 6.3.3.

6.3.3 Calibration Results

The results of the calibration process indicate the model is a well-calibrated representation of present-day hydraulic conditions in the Yarmouth water system except for two areas of the system that were unable to reach acceptable levels of calibration in the model. Fire flow calibrations results are presented below in Figure 6-1. A discussion of the results follows below.

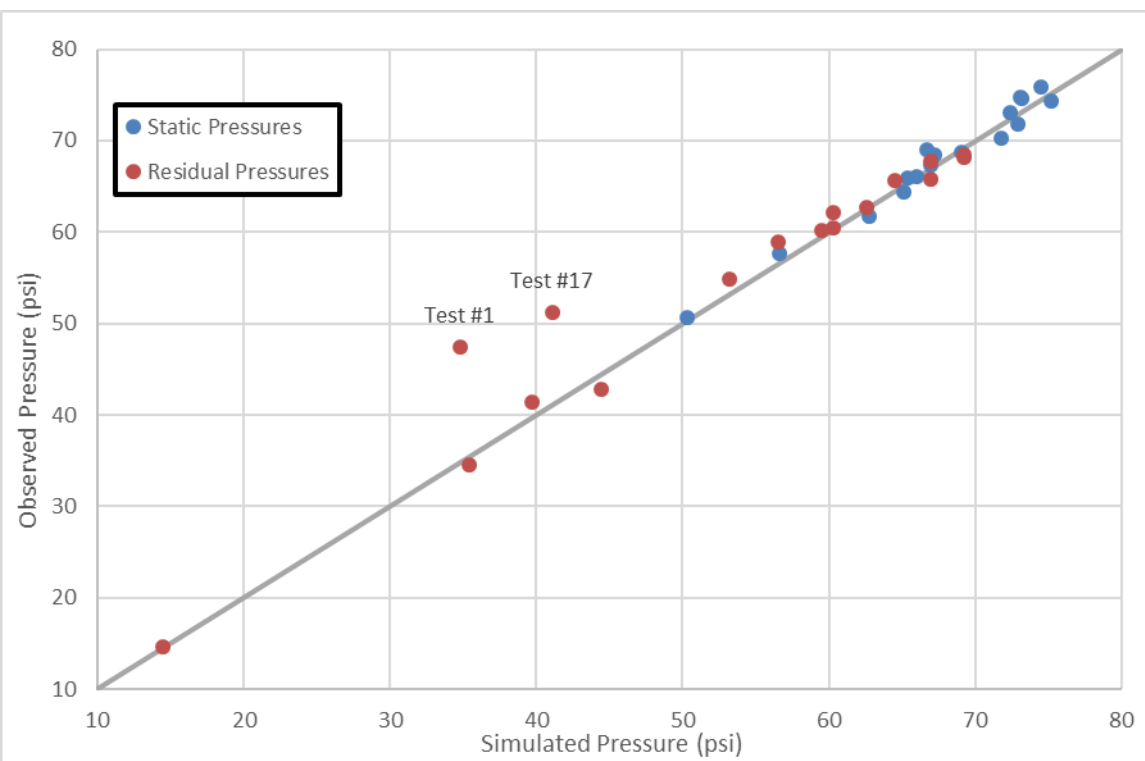

Figure 6-1: Fire Flow Calibration Results

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The static pressures predicted by the model during calibration runs were compared against the static pressures measured in the field. The predictions of a well-calibrated model will closely match the observed field conditions. A close match is typically defined as a difference of less than 5 psi. The static pressures for 17 locations were recorded during field-testing and checked against model results during the calibration process. Results showed all predicted static pressures were within 5 psi of the field-measured static pressures. The average difference between the predicted and actual static pressures for all nodes was 1.0 psi and the largest difference was 2.3 psi, which is within the margin of error for the SCADA tank levels average.

Hydrant flows measured in the field were entered into the model and the field measured residual pressures were compared against the model-predicted values to calibrate the model for pipe roughness. A difference of 5 psi or less between the actual and model residual pressures was achieved for 15 of the 17 hydrant flow tests. The average difference between predicted and actual residual pressures for those 15 tests was 1.1 psi and the largest difference was 2.4 psi, which is within the margin of error for the SCADA tank levels screenshot average. A brief description of the circumstances surrounding each of the two outlier points where model results differed from field conditions by more than 5 psi is presented below.

Flow Test #1: This flow test was conducted at Balsam Way. The model simulated a residual pressure 10.0 psi greater than was observed in the field. Due to the magnitude of this difference, 2007 flow test data in the area were referenced that confirmed the field test as valid. The 2007 flow test was also simulated to check if C-Factor adjustments would cause both tests to become calibrated. Lowering C-Factors significantly brought the 2019 flow test into acceptable calibration range, but not the 2007 test. **This error mostly likely is the result of one or more closed valves in the area causing the Yarmouth system to underperform compared to the model**.

Flow Test #17: This flow test was conducted at Gingerbread Lane. The model simulated a residual pressure 12.6 psi greater than was observed in the field. Due to the magnitude of this difference, 2007 flow test data in the area was referenced that confirmed the field test as valid. The 2007 flow test was also simulated to check if C-Factor adjustments would cause both tests to become calibrated. Lowering C-Factors significantly brought the 2019 flow test into acceptable calibration range, but not the 2007 test. **This error mostly likely**

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is the result of one or more closed valves in the area causing the Yarmouth system to underperform compared to the model.

Note regarding Flow Test #18: This flow test was conducted at Minnetuxet Way. The model simulated a residual pressure 94.4 psi greater than was observed in the field. Kleinfelder investigated this difference and concluded that a valve is likely closed on Old Church Street between Damaris Drive and Main Street. By simulating this pipe as closed in the model and rerunning the flow test, the model simulated a residual pressure only 0.2 psi greater than was observed in the field. **This valve should be investigated and opened**

Extended period simulation provides an indication that the temporal variation in model results reasonably reflects actual conditions. The results show that simulated tank level results for two tanks reflect actual conditions while one tank does not. The German Hill Tank is filling too quickly and to too high of a level in the model compared to SCADA information. This is most likely due to unaccounted for headloss somewhere at the German Hill Tank. It was found that decreasing the C-Factor of the 363-foot 20-inch pipe at the German Hill Tank from 100 to 15 and raising the base elevation of the German Hill Tank by 5 feet caused the tanks to match the SCADA information. This change was only used in the model for water age simulations where matching the tanks to the observed SCADA information is important.

Yarmouth Water has stated that to its knowledge, there are no valves purposely being throttled at the German Hill Tank. **Further investigation at the German Hill Tank and the surrounding valves should be conducted to determine the source of the headloss and the SCADA level should be verified to be accurate.** Tank level data recorded and modeled is presented below in Figure 6-2, Figure 6-3, and Figure 6-4.

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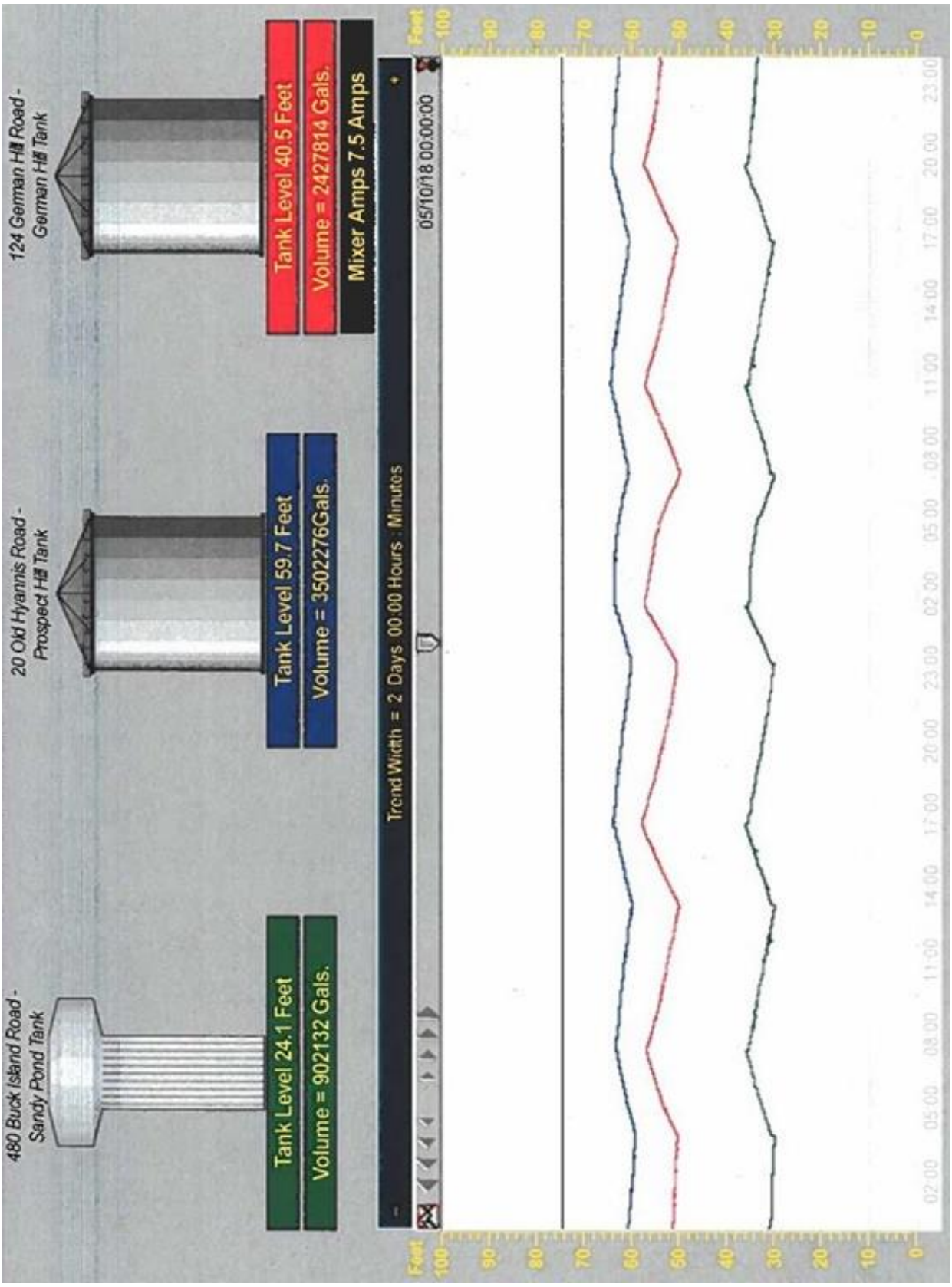

Figure 6-2: Tank Level SCADA Data

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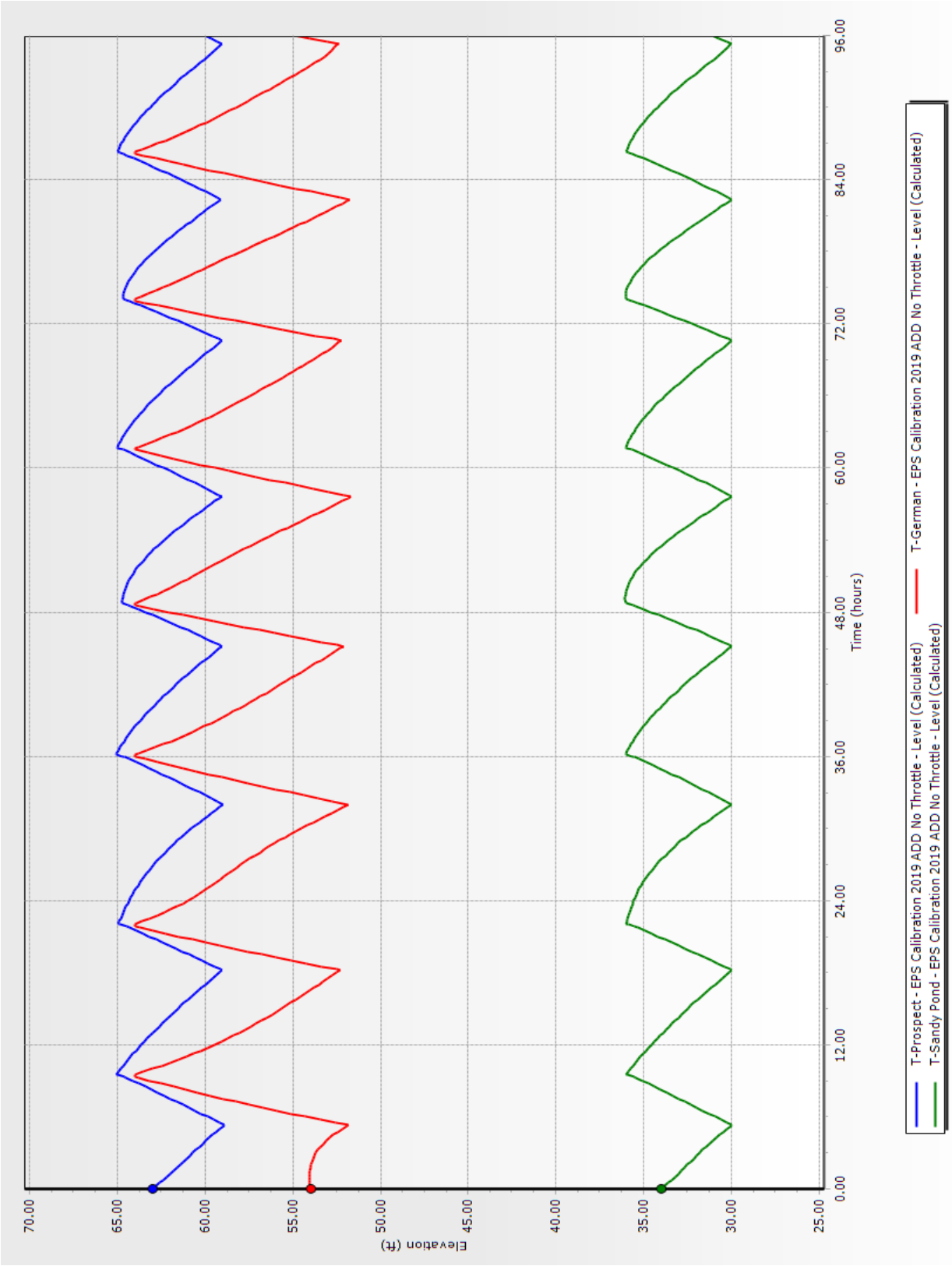

Figure 6-3: Tank Level Model Data

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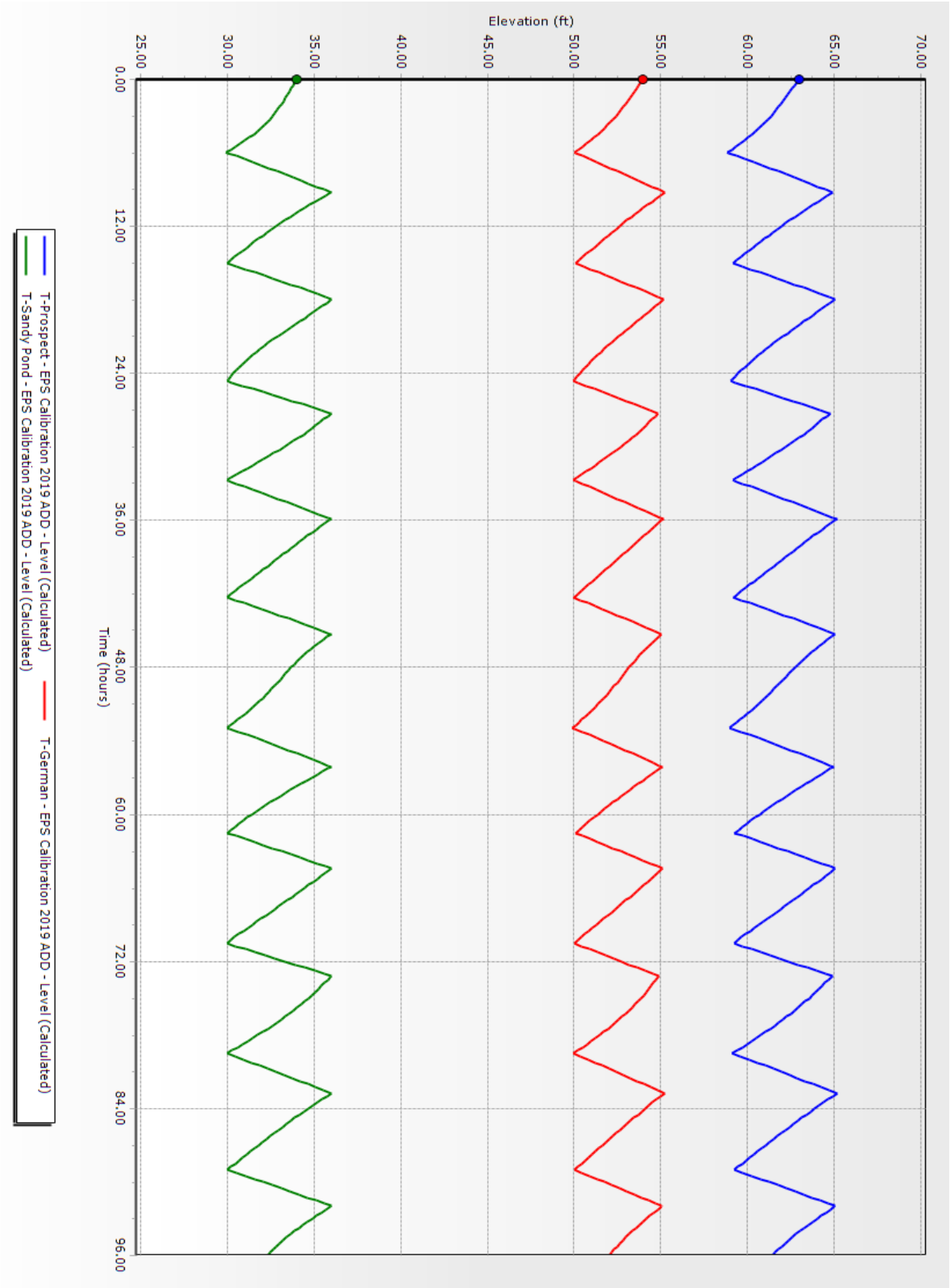

Figure 6-4: Tank Level Model Data with German Hill Tank Adjusted for Water Age Simulations

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6.4 MODELING SCENARIOS

The hydraulic performance of the distribution system was evaluated for a variety of operational conditions, each represented by individual modeling scenarios. The system was tested under future maximum day and 2017 average day demand conditions to identify areas in the system that showed inadequacies in pressure and available fire flow, as well as pipes with large headlosses. The results of the modeling scenarios are described below in Section 6.5.

6.5 RESULTS OF DISTRIBUTION SYSTEM HYDRAULIC ANALYSIS

The hydraulic model was run to assess the condition of the Yarmouth distribution system. The assessment of the system condition was performed by examining four measurable areas of performance.

1. Service Pressure
2. Flow Velocity and Headloss
3. Fire Flow Availability
4. Water Age

The hydraulic analysis results presented assumes the distribution system is accurately represented in the model and there are no unexpected conditions in the system. Unknown complications in the system, such as partly or fully closed valves, blockages in the pipes, or disconnections, would affect the accuracy of the analysis results.

6.5.1 Service Pressure

The service pressure is the static pressure available to system customers. The generally desired range for static pressures is 50-80 psi. Pressures below 35 psi should be minimized to ensure adequate pressure for multi-story structures. Pressures should never be allowed to drop below 20 psi at the water main. Pressures over 100 psi should be avoided to prevent undue stress on water mains and increased risk of water main breaks and leakage.

For the high static pressure model simulation, pumps were turned on, tanks were set at their highest level according to SCADA information, and 2017 average day demand was used. The highest

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pressure in the system was 86 psi, indicating that high pressures are not an issue in the Yarmouth water system.

For the low static pressure model simulation, pumps were turned off, tanks were set at their lowest level according to SCADA information, and future maximum day demand was used. A graphical example of the distribution of pressures is presented in Figure 6-5.

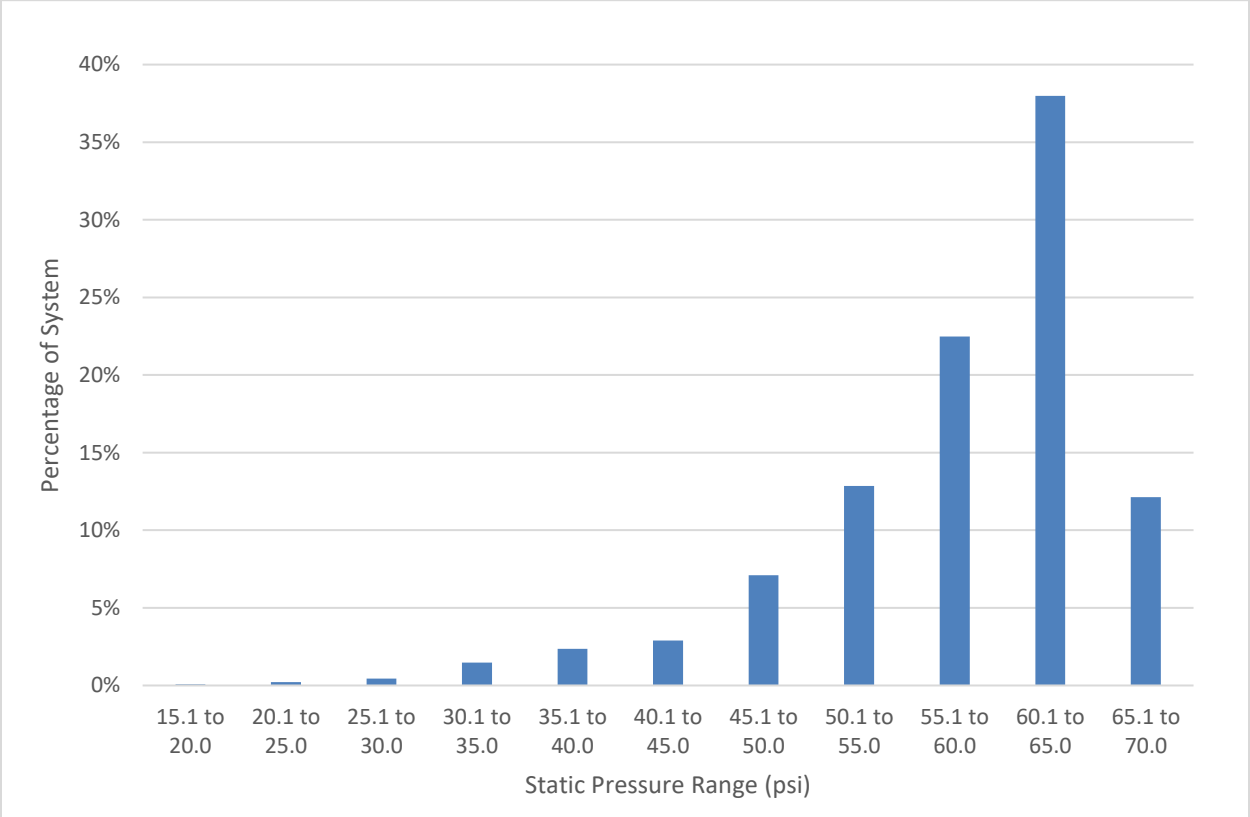

Figure 6-5: Simulated Static Pressure Distribution for Future Maximum Day Demand Conditions

Only one area in the model located adjacent to German Hill Tank registered a static pressure below 20 psi. Several other areas near the German Hill Tank, one area at Old Town House Road, and a large area in the north-east of the town, north of Main Street, registered a static pressure below 35 psi. The results of the pressure analysis are shown below in Figure 6-6.

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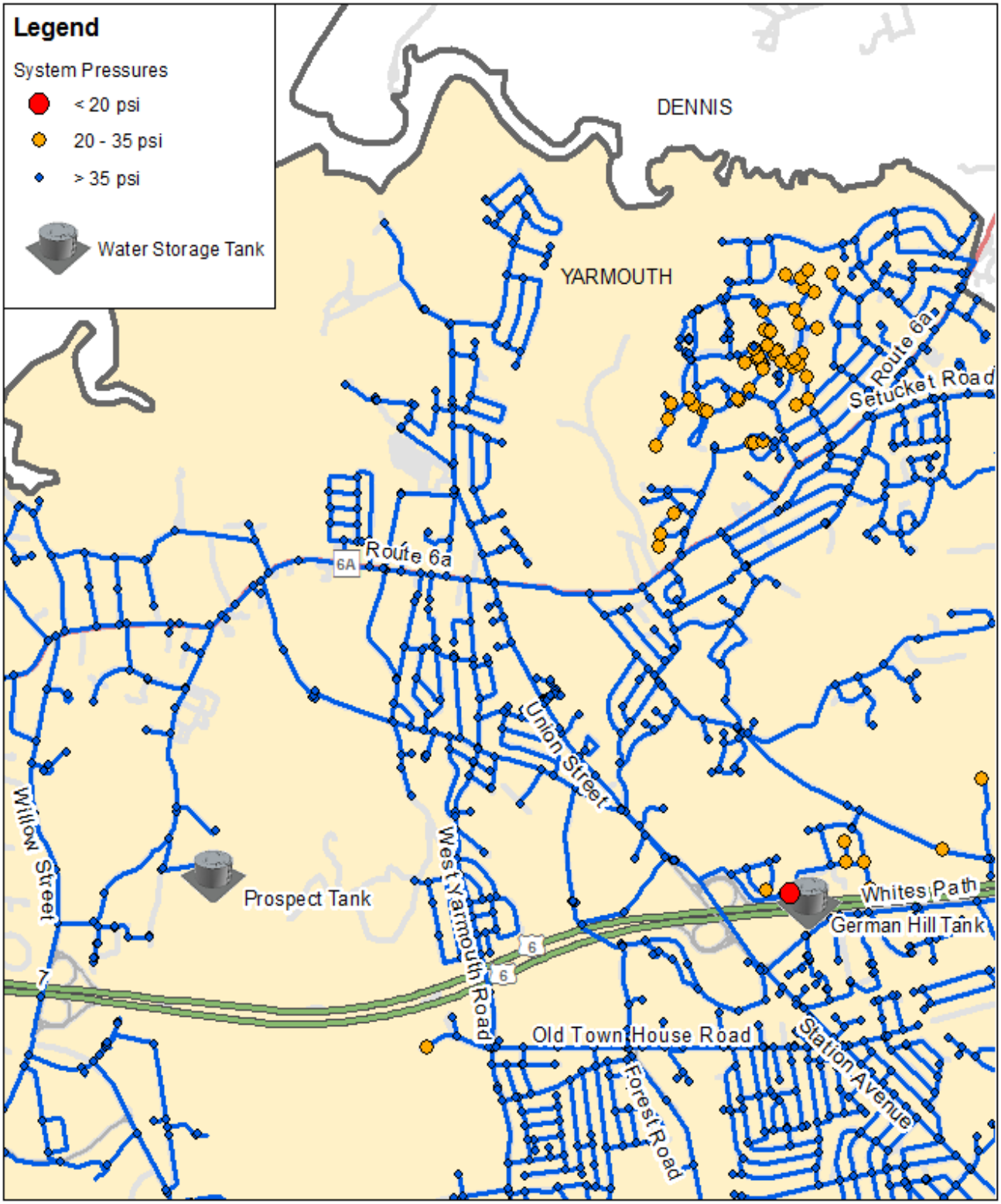

Figure 6-6: Low Pressure Areas for Future Maximum Day Demand Conditions

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6.5.2 Flow Velocity and Headloss

Excessive flow velocity through a pipe can be an indicator of an undersized pipe. The flow velocity of each pipe in the model was evaluated to determine if it was excessive. When flow velocity is doubled, headlosses increase by a factor of 4. The desired range of values for velocity is 2-6 ft/sec. The future maximum day demand flow velocity results indicate that the only pipe that has a flow velocity above 6 ft/sec is the Town of Barnstable interconnection with a flow velocity of 8 ft/sec. Overall, the system exhibits acceptable pipe velocities through the full planning period of this report.

Headloss is a measure of the pressure lost as water travels through a pipe. The headloss thorough every pipe in the model was calculated to identify areas with excessive pressure loss. The headloss was quantified based on headloss gradient (feet pressure lost / thousand feet of pipe) to normalize for pipe length. Headloss below 8 ft/1000 ft was considered acceptable based on experience with similar systems. The future maximum day headloss results show that only 5 locations have pipes over 8ft/1000 ft.

The five pipes that registered headloss in excess of 8 ft/1000ft were: Barnstable Interconnection, the pipe leaving the Sandy Pond Tank, the Mariah Drive connection to the German Hill Tank, and a short 10-inch pipe on German Hill Road that connects the parallel 10-inch and 20-inch mains. These pipes are important for the water system but are each so short in length that they do not cause substantial headloss for the overall water system.

6.5.3 Available Fire Flow

The distribution system model was evaluated for fire flow availability under future maximum daily demand conditions. Available fire flow was evaluated as the amount of flow that can be drawn without the residual pressure reducing below 20 psi. The basis for evaluation of fire flow adequacy was the requirements set forth by the Insurance Services Office (ISO). The typical ISO required fire flow for single family and two-family residential dwellings are based on the separation between structures, as summarized below in Table 6-2.

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Table 6-2: ISO Required Fire Flow (One- and Two-Family Dwellings)

Distance Between Dwellings (feet)	Required Fire Flow (gpm)
Greater than 100	500
31-100	750
11-30	1,000
10 or Fewer	1,500

ISO required fire flows for commercial and industrial buildings are determined on an individual basis and are typically greater than those for residential areas. A needed fire flow of 3,500 gpm was assumed in general commercial areas. Seven potential capital improvements were identified due to inadequate available fire flow and are discussed in Section 6.6 below.

6.5.4 Water Age

A water age simulation was run to calculate the age of water throughout the system. For this simulation, the German Hill Tank headloss and base elevation were adjusted to match the turnover rate and period observed in the SCADA information as described in Section 6.3.3. Desirable water age is 6 days or less in order to prevent water quality degradation. Table 6-3 below lists the results of the water age simulation. Figure 6-7 below shows the max water age throughout the system under average day conditions.

Table 6-3: Water Age at Tanks

Tank	Water Age
German Hill Tank	21 days
Prospect Hill Tank	18 days
Sandy Pond Tank	6 days

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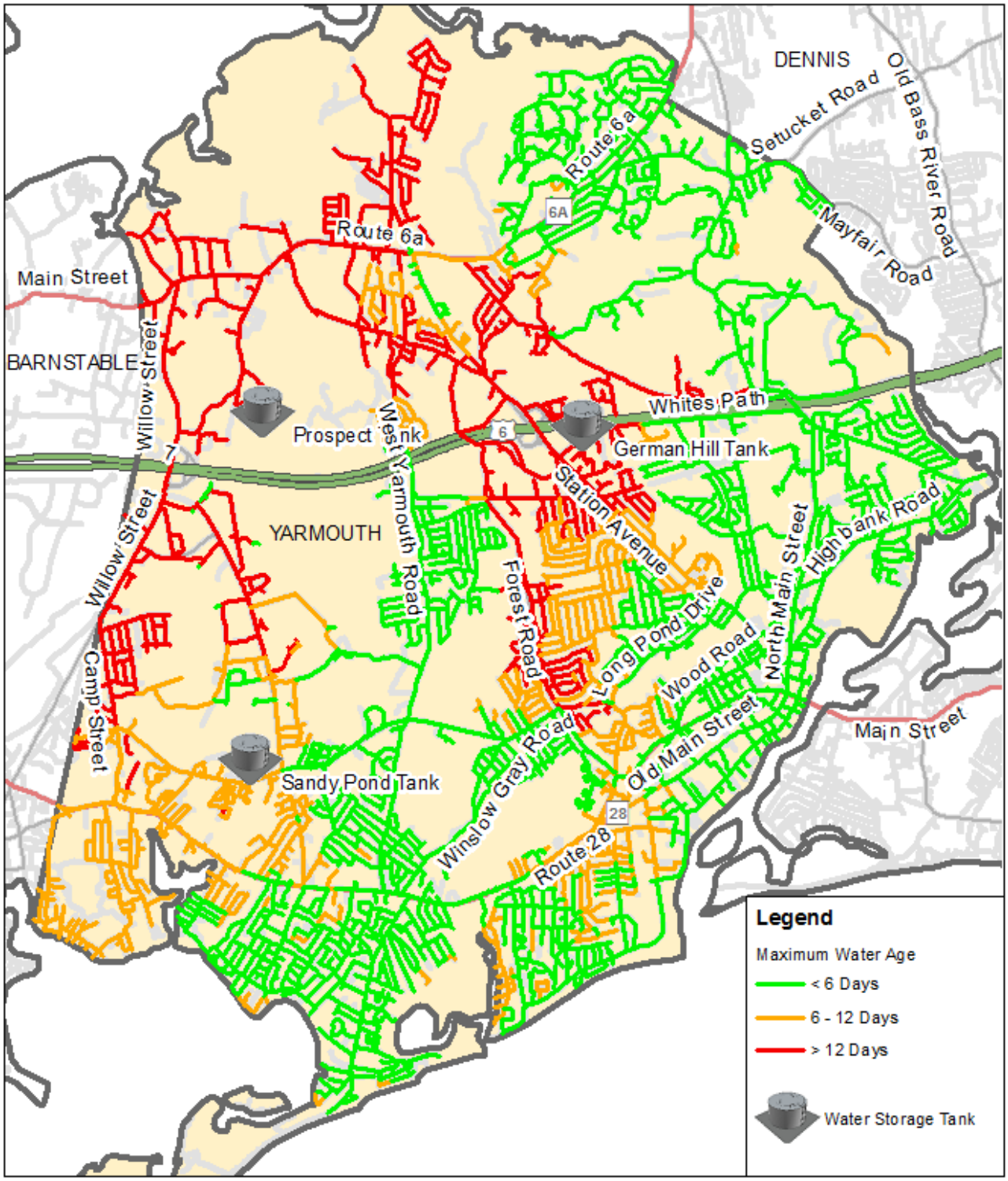

Figure 6-7: Maximum Water Age for Average Day Demand Conditions

Water age increases closer to the Prospect Hill and German Hill Tanks and generally on the western side of the water system. Water age over 15 days was observed in the northwestern part of the

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system and water ages over 20 days were observed around the German Hill Tank and some dead-end mains in the northwest of the water system. Water age on the eastern side of the water system was generally at an acceptable level of 6 days or less.

In order to improve water age within the German Hill and Prospect Hill Tanks, several scenarios were modeled and evaluated based on their improvements to water age as well as other impacts on the water system performance. Looping of dead-end mains and installing low flow bleeders are potential solutions for improving water age but are more suited for situations where low demand is the cause of high water age. In these cases, simply clearing the old water from the mains, or allowing other areas to also draw water from the main will decrease water age.

However, for the Yarmouth water system, the sources of the high water age are the 100-foot diameter Prospect Hill and German Hill Tanks whose current turnover is not high enough to maintain low water age. Looping dead end mains and installing low flow bleeders will not substantially affect the high water age in the tanks themselves.

Taking either the Prospect Hill Tank or the German Hill Tank offline were simulated but did not substantially improve the water age in the other tanks. Taking the Sandy Pond Tank offline did improve the water age in the German Hill and Prospect Hill Tanks by a few days, but the reduction in AFF associated with taking the Sand Pond Tank offline was too much. Allowing the tanks to cycle at a greater range did have a substantial impact on the water age in the German Hill and Prospect Hill tanks, but this does come at the cost of slightly reduced domestic pressures and lower AFF during certain times of the day. Tables 6-4 and 6-5 below show the reduction in water age achieved by allowing the tanks to cycle an additional 5 feet and 10 feet respectively before the well pumps are activated.

Table 6-4: Water Age at Tanks with 5 Feet Lower Well Pump Activation

Tank	Water Age
German Hill Tank	13 days
Prospect Hill Tank	13 days
Sandy Pond Tank	6 days

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Table 6-5: Water Age at Tanks with 10 Feet Lower Well Pump Activation

Tank	Water Age
German Hill Tank	10 days
Prospect Hill Tank	11 days
Sandy Pond Tank	6 days

Figures 6-8 and 6-9 below show the increase in low pressure and fire flow, respectively caused by allowing the tanks to drop an additional 5 feet and 10 feet before the pumps are activated. Figures 6-10 and 6-11 below show the reduction in AFF caused by allowing the tanks to drop an additional 5 feet and 10 feet respectively before the pumps are activated.

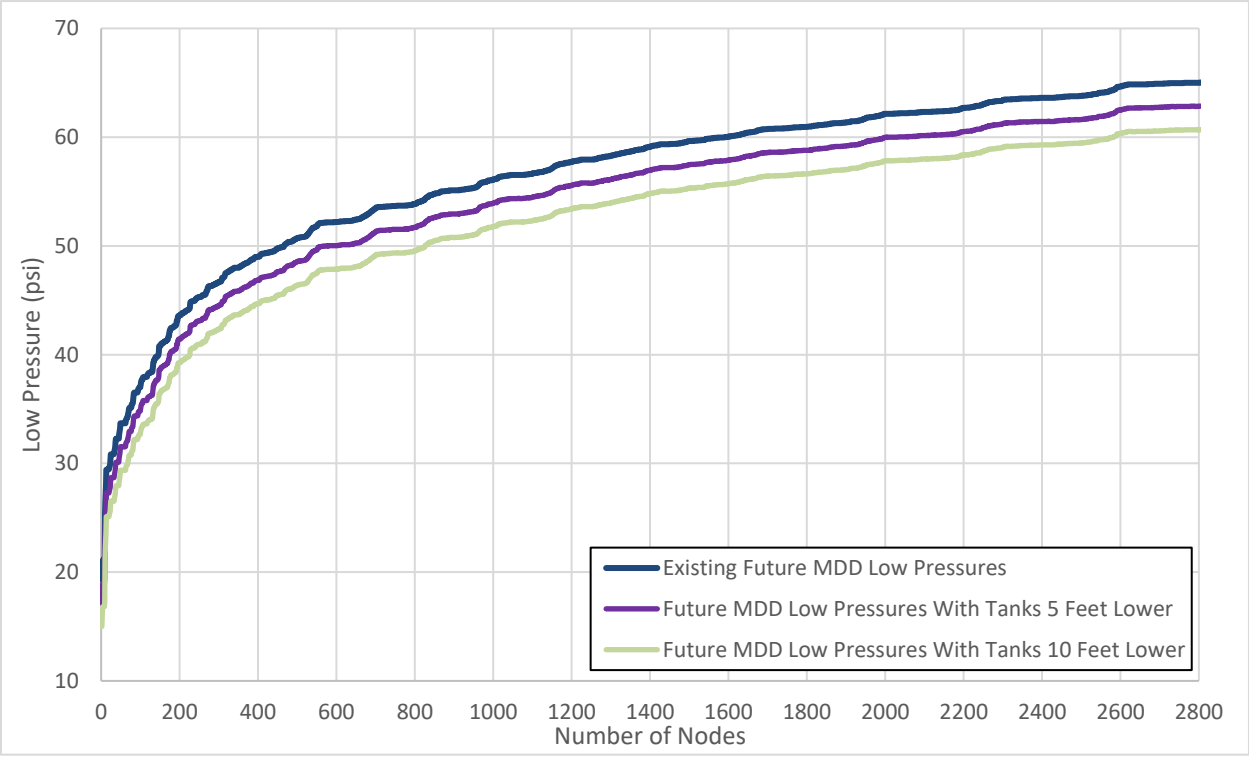

Figure 6-8: Lower Well Pump Activation Effect on Low Pressures

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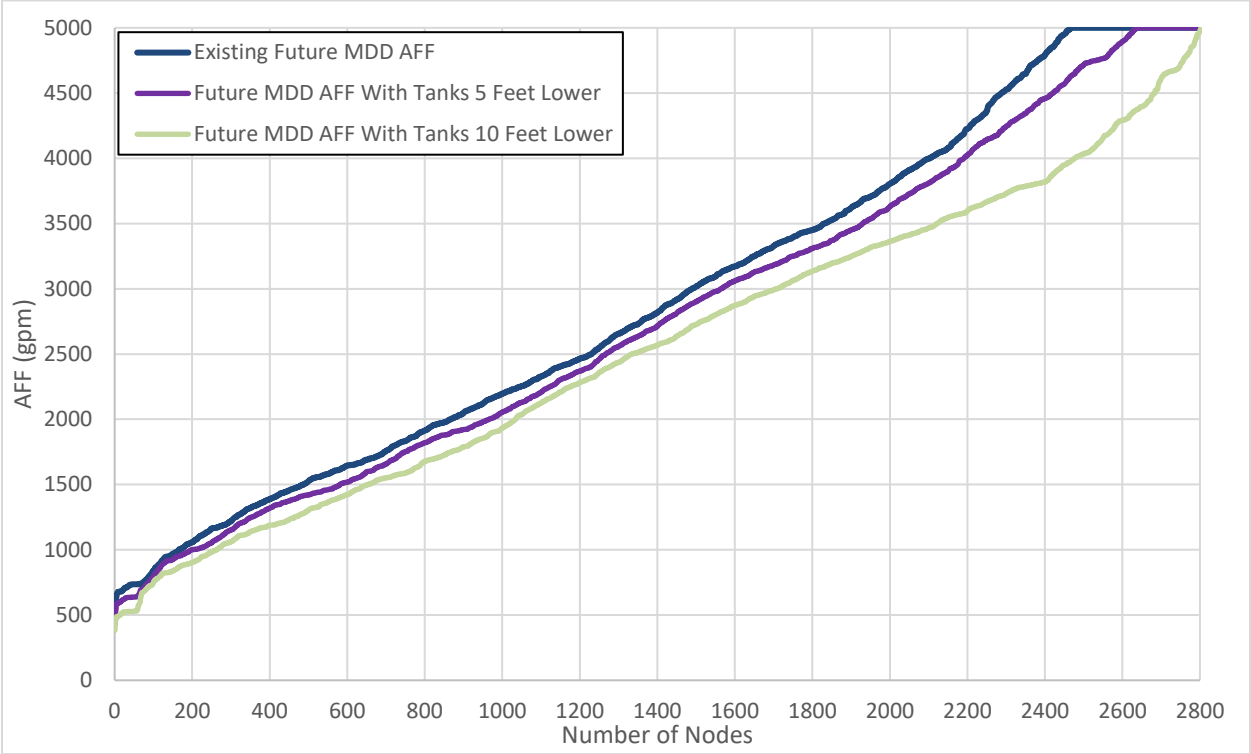

Figure 6-9: Lower Pump Activation Effect on Available Fire Flow

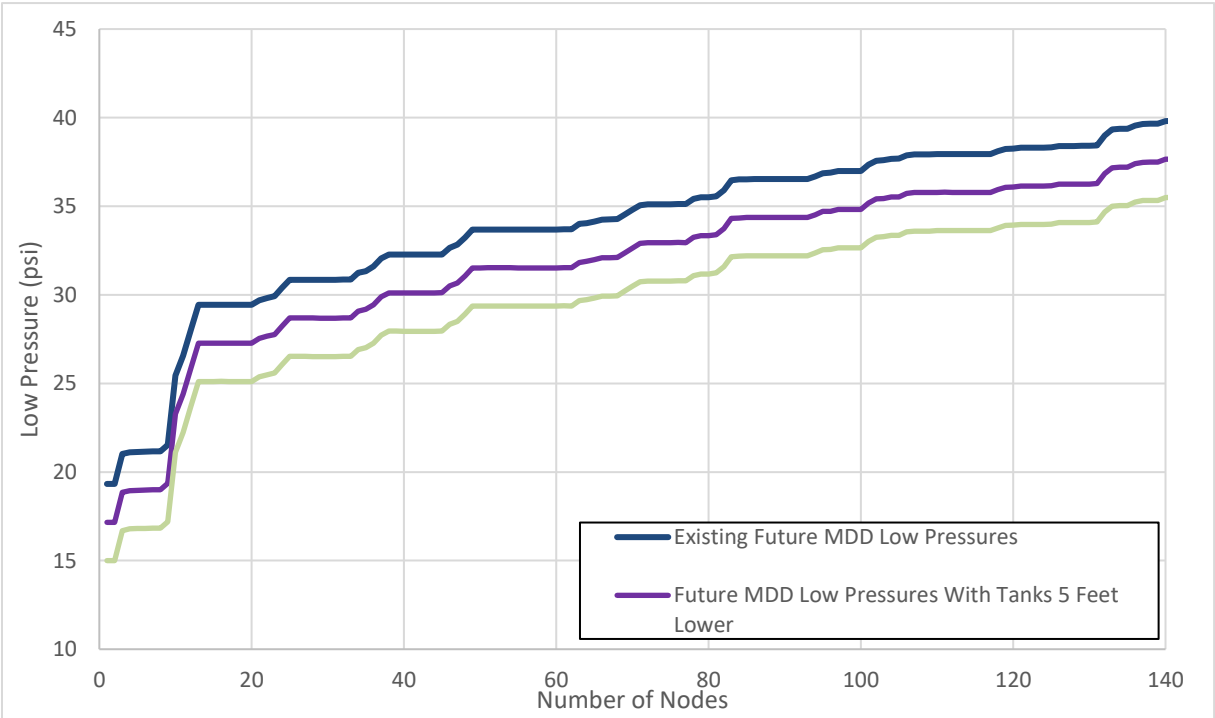

Figure 6-10: Lower Pump Activation Effect on Low Pressures (Lowest 140 Pressure Nodes)

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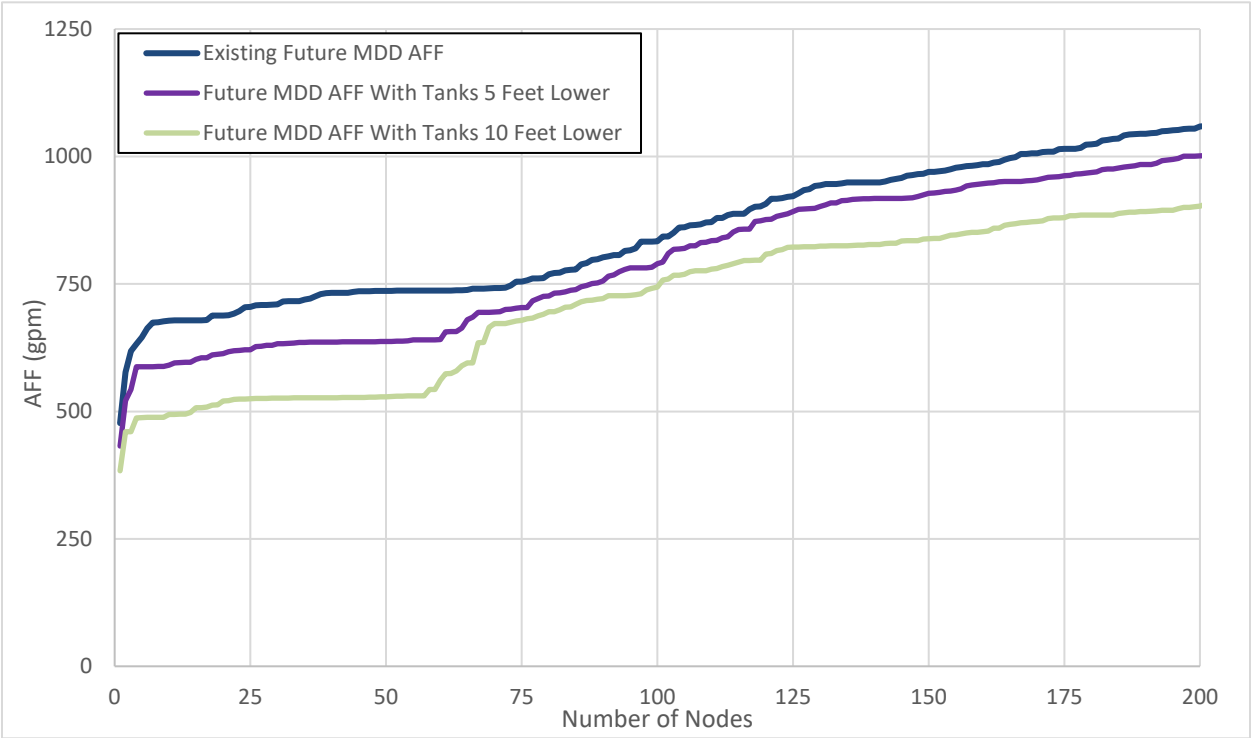

Figure 6-11: Lower Pump Activation Effect on Available Fire Flow (Lowest 200 AFF Nodes)

Under future MDD, allowing the tank levels to cycle further than they currently do reduces more areas of the water system below the minimum allowable pressure of 20 psi, specifically at Old Town House Road and at the base of the German Hill Tank itself. However, the pressures at the base of the German Hill Tank only reduced to between 17 and 19 psi with the tanks cycling 5 feet more than today. This may be acceptable because no customers are connected here and therefore 35 psi is not needed. However, other locations are being reduced below the recommended guideline of 35 psi.

Figure 6-12 below shows system low pressures under future MDD with the tanks lowered 5 feet. It is recommended that this operational change be implemented because it will significantly decrease water age in the German Hill and Prospect Hill Tanks by 5 to 8 days without negative impact on fire flow or pressure.

In the future, if Yarmouth is considering replacing one of the tanks, an elevated storage tank should be considered over a traditional standpipe tank. Elevated storage tanks maintain pressure and fire flow by storing the required volume of water at the proper elevation, but without the large column of unusable water below that leads to high water age within the tank.

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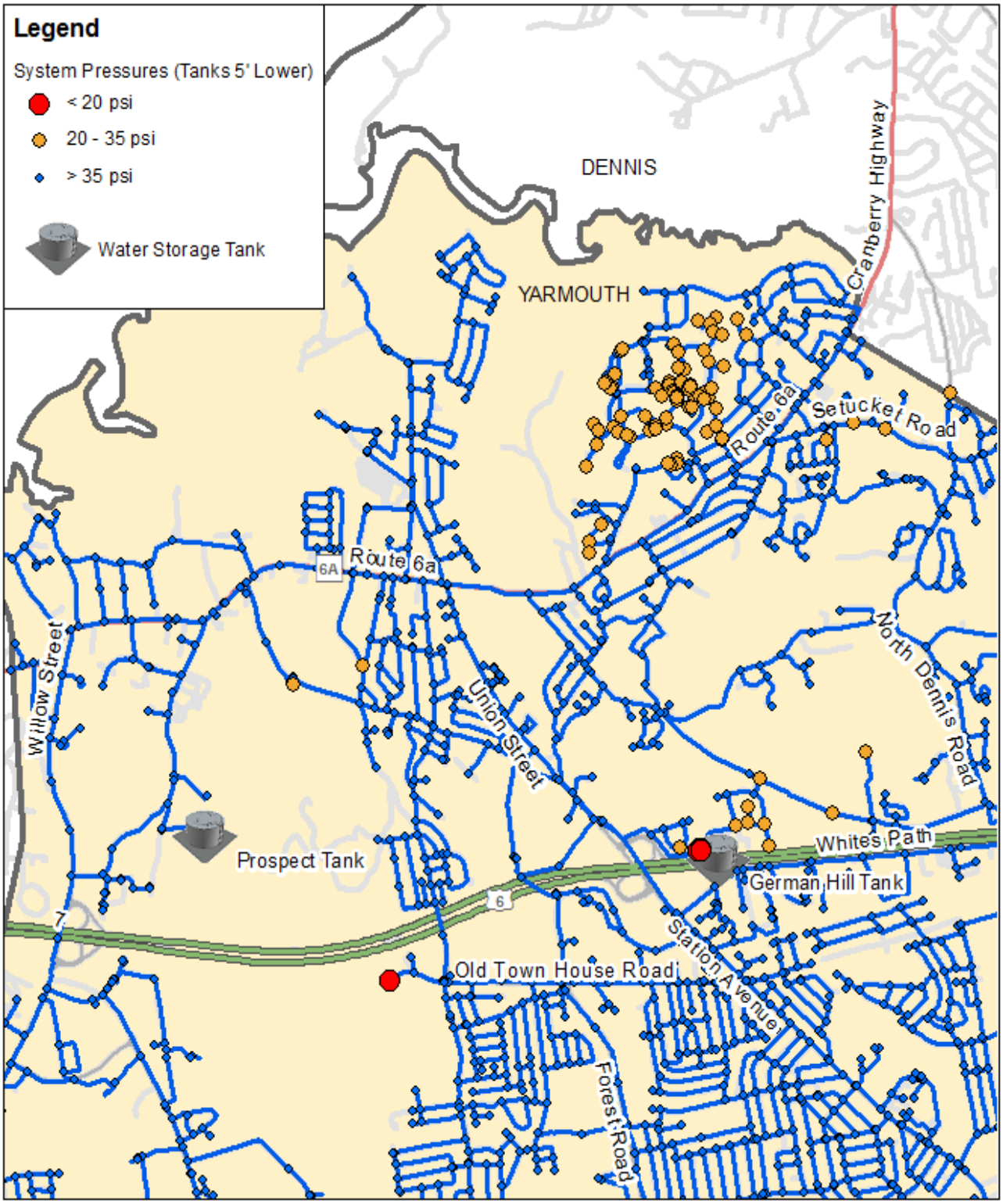

Figure 6-12: Low Pressure Areas for Future Maximum Day Demand Conditions and Tanks 5' Lower

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6.6 DISTRIBUTION SYSTEM RECOMMENDED CAPITAL UPGRADES

Recommended distribution system upgrades fall into three categories:

1. Upgrades to correct fire flow deficiency or other hydraulic needs
2. Opportunistic upgrades associated with major roadway or utility projects
3. Upgrades due to water main age or break history
4. System expansion

Fire Flow Deficiency: Several distribution system improvements were identified and are recommended to address the inadequate fire flows described in Section 6.5. These improvements were simulated in the hydraulic model to quantify the available fire flow improvements they would provide. General estimates of probable construction cost were established for the potential water distribution system improvements based on recent water main construction bids. **These projects are prioritized on Table 6-7 below.**

Opportunistic Upgrades: Where the Town or Commonwealth has planned major roadway improvements and/or other utility projects, Yarmouth should design water main upgrades to be incorporated into these projects. Two such upcoming examples include MassDOT projects on Route 6A (from Barnstable Town Line to Union Street) and Route 28. In general, it is recommended that water mains be replaced.

- **Route 6A** - Kleinfelder evaluated water main sizing for the Route 6A project. Any existing 6-inch diameter water mains that serve fire hydrants should be increased to 8-inch diameter. Any 8-inch diameter mains should be replaced with the same diameter. Upsizing 8-inch mains in this area of Town will not improve fire flow but will increase water age. The Town also needs to investigate possible valve closures in this area, as described in Section 6.3.3.

Upgrades Due to Water Main Age or Condition: As described previously, although GIS information on year installed is largely missing, much of the Yarmouth water system was built out after 1960[6]. Therefore, the system is largely assumed to consist of ductile iron pipe, which has an estimated service life of between 50 and 100 years. Therefore, most of the system may be reaching the end of its service life between 2020 and 2070. **As most of Yarmouth's system is similarly aged, a program of age-based renewal or replacement should be developed following the correction of fire-flow deficiencies**. For the time being, opportunistic main replacement should be implemented whenever major roadway disturbance is planned for road improvements or installation

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of new sewer mains. Meanwhile, Yarmouth should track break history using work management software and record water main material and condition when breaks are observed or other system work allows.

System Expansion: Yarmouth asked Kleinfelder to evaluate potential improvements that would extend service to a small number of Yarmouth residents in the Cummaquid Heights Area who are currently served by Town of Barnstable water. In order to serve this area, railroad tracks would need to be crossed. Alternatives and costs were developed assuming a trenchless crossing via horizontal directional drilling. **Cummaquid Heights expansion costs are presented below in Table 6-7**.

Table 6-7 lists the identified potential fire flow upgrades, in order of decreasing priority. The estimates for probable construction costs are based on awarding of construction contracts through competitive bidding under MGL Chapter 30, with all work performed under resident engineering observation. These costs also include a percentage allowance for engineering and contingencies. All costs are current as of October 2019, using an ENR Construction Cost Index (CCI) of 11,326. Future use of this cost data should be adjusted accordingly. The linear foot cost estimates for new water main construction includes cost for pipe design and engineering, installation, valves, hydrants, and appurtenant items required for a complete job. Estimates for this work were developed by Kleinfelder based on conservative bid results from water main replacement projects in other cities and towns in Massachusetts adjusted for inflation using the ENR CCI. Table 6-6 establishes the budget estimates for new cement-lined ductile iron water main on a linear foot basis. Please note these costs to do not include paving or other roadway improvements.

Table 6-6: Estimated Unit Costs for Water Main Construction

Main Size	Construction ($/ft)	Engineering, Design and Resident Observation (20%)	Contingencies (10%)	Total ($/ft)
8-inch	$280.00/ft	$56.00/ft	$28.00/ft	$364.00/ft
12-inch	$330.00/ft	$66.00/ft	$33.00/ft	$429.00/ft

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Table 6-7: Prioritized Potential Water Main Capital Improvement Projects

Priority	Area	Type of Development	Available Fire Flow in Model (gpm)	Target Flow (gpm)	Reason for Recommendation	CIP Recommendation	Post Improvement Available Fire Flow (gpm)	Pipe Footage	Approximate Cost
Recommended Fire Flow Improvements									
1	Acorn Hill Drive	Residential	435	750	Deficient Modelled Fire Flow	Option 1: Replace existing 6" mains in Sophie Anne Drive and Acorn Hill Drive with 8" DI.	855	876 LF	$320,000
						Option 2: Connect the dead end 6" main at Acorn Hill Drive to the 8" main at Whistler Lane with 8" DI.	1,045	175 LF (cross country)	$65,000* does not include easement costs
2	Driving Tee Circle	Residential	660	1,000	Deficient Modelled Fire Flow	Replace existing 6" main in Driving Tree Circle with 8" DI.	1,050	738 LF	$270,000
3	Williams Road	Residential	685	1,000	Deficient Modelled Fire Flow	Replace existing 6" main in Williams Road with 8" DI.	1,040	960 LF	$350,000
4	Mockingbird Lane	Residential	770	1,000	Deficient Modelled Fire Flow	Replace existing 6" main in Mockingbird Lane with 8" DI.	1,745	716 LF	$260,000
5	Monterey Lane and Surrounding Area	Residential	800	1,000	Deficient Modelled Fire Flow	Connect existing 8" and 6" mains in Curve Hill Road. This will also improve water age in the area.	1,010	138 LF	$50,000
6	Green Teal Way (Gig Lane, Old Salt Lane)	Residential	680	750	Deficient Modelled Fire Flow	Option 1: Replace existing 6" main in Gig Lane with 8" DI.	765	443 LF	$160,000
						Option 2: Replace existing 6" mains in Gig Lane and Old Salt Lane with 8" DI.	1,095	1,060 LF	$390,000
Potential System Expansion									
7	Cummaquid Heights: Sisters Circle/Desert Sands Lane	Residential	NA	NA	Extend service to Yarmouth Residents currently on Barnstable Water	550 LF HDD under RR, 3,000 LF new 8" DI	NA	3,000 LF	$1,600,000* does not include easement costs
8	Cummaquid Heights: Congressional Drive, Midpine Road	Residential	NA	NA	Extend service to Yarmouth Residents currently on Barnstable Water	200 LF HDD under RR, 2,100 LF new 8" DI	NA	2,100 LF	$1,250,000* does not include easement costs
9	Cummaquid Heights: Alt 2 including Augusta National connector pipe	Residential	NA	NA	Extend service to Yarmouth Residents on Barnstable Water	750 LF HDD under RR, 8,100 LF new 8" DI	NA	8,100 LF	$3,500,000* does not include easement costs

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6.7 DISTRIBUTION SYSTEM OPERATIONAL RECOMMENDATION SUMMARY

Tank Operation: As described in Section 6.5.4, the tanks should be allowed to each drop by an additional 5 feet. It is recommended that this operational change be implemented because it will significantly decrease water age in the German Hill and Prospect Hill Tanks by 5 to 8 days without negative impact on fire flow or pressure.

Possible Closed Valves: Investigate and remedy potential closed valves as identified in Section 6.3.3.

Other: Keeping the distribution system functional is important to maintaining a high level of service. If not already being implemented, we recommend the following operational programs. These programs should be implemented with the assistance of the Division's work management software so that condition data and maintenance is tracked on a continual basis:

- Gate valve exercising
- Hydrant inspection and maintenance
- Unidirectional flushing
- Service line inventory (to support future compliance requirements of the Revised Lead and Copper Rule).

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7 BUDGET RECOMMENDATIONS

7.1 SUMMARY OF RECOMMENDATIONS AND PHASED 5-YEAR PLAN

This report has detailed a series of capital and annual recommendations with associated budget figures. Those recommendations are summarized in this Section. The recommendations have been divided between those entail Town expenditures and those which do not represent direct additional outlay, to facilitate review by Division administrators.

A recommended approach and budget cost estimate was provided for each identified need in Section 2 through Section 6. Table 7-1 below summarizes the recommendations, the estimated budget, and whether the expense is considered a one-time expense or a recurring annual expense. Estimated budget figures reflect the estimates developed in the previous sections and include design, construction, and contingency.

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Table 7-1: Summary of Recommended Water System Improvements and Expenditures

Recommendation	System	Expense Type	Reason	Estimated Budget	Notes*
YEAR 1					
Pump Station Improvements Phase 1 (12 PS)	Facilities	One-Time	Deteriorating Stations	$ 2,000,000	$2.4M total Funds Avail after May TM
Route 6A Water Main Replacement 8" and 12" Water Mains (Design + Construction)	Distribution	One-Time	Opportunistic Water Main Replacement	$ 3,800,000	12" 5080 lf , 8" 4400 lf
PFAS Sampling and Communication	Wells	One-Time	Watershed Threats	$ 11,000	7 distribution entry points; comm plan, training
Update Asset Management Plan; Financial Plan / Rate analysis	Planning	One-Time	Develop pipe renewal program based on age, condition; Maintain adequate funding;	$ 70,000	Grant funding available
AWIA Risk and Resiliency Assessment	Planning	One-Time	Regulatory Requirement	$ 35,000	Due 6/30/21
Flax Pond Test Wells	Planning	One-Time	Proactive Supply Planning	$ 40,000	
Annual Activities	varies	Annual	varies	$ 520,000	See detail below
		Total FY2021		**$ 6,476,000**	
YEAR 2					
Pump Station Improvements Phase 2 (11 PS)	Facilities	One-Time	Deteriorating Stations	$ 2,000,000	Order of magnitude estimate for planning
1- Acorn Hill Drive and Sophie Ann Drive	Distribution	One-Time	Deficient Fire Flow Risk	$ 320,000	876 LF 8" Mains
2 - Driving Tee Circle	Distribution	One-Time	Deficient Fire Flow Risk	$ 270,000	738 LF 8" main
3- Williams Road	Distribution	One-Time	Deficient Fire Flow Risk	$ 350,000	960 LF 8 main
4 - Mocking Bird Lane	Distribution	One-Time	Deficient Fire Flow Risk	$ 260,000	716 LF 8" main
Route 28 Water Main Replacement Parker River to Dennis Town Line	Distribution	One-Time	Opportunistic Water Main Replacement	$ 5,810,000	13,540 lf 12" main
Route 28 Water Main Replacement Parker River to Barnstable Town Line	Distribution	One-Time	Opportunistic Water Main Replacement	$ 5,900,000	13,750 lf 12" main
AWIA Emergency Response Plan	Planning	One-Time	Regulatory Requirement	$ 40,000	Required by 12/30/21
Annual Activities	varies	Annual	varies	$ 535,600	See detail below. Inflation 3% annually
		Total FY2022		**$ 13,485,600**	
YEAR 3					
Pump Station Improvements Phase 3 (20 CCFs)	Facilities	One-Time	Deteriorating Stations	$ 3,200,000	Order of magnitude estimate for planning
Sandy Pond Tank Painting	Tanks	One-Time	Preserve steel integrity	$ 2,000,000	Order of magnitude estimate for planning
5 - Monterrey Lane (Curve Hill Road)	Distribution	One-Time	Deficient Fire Flow Risk; Water Age	$ 50,000	138 LF connection
6 - Green Teal Way (Gig Ln, Old Salt Lane)	Distribution	One-Time	Deficient Fire Flow Risk	$ 390,000	1060 LF
Begin Design for Water main renewal program	Distribution	One-Time	Main breaks, water quality	$ 350,000	Placeholder. Effort TBD in Yr 1 Asset Management Update
Lead Service Line Program Inventory / Development	Planning	2-year	Regulatory Requirement	$ 50,000	Placeholder. Effort TBD.
Annual Activities	varies	Annual	varies	$ 551,668	See detail below. Inflation 3% annually
		Total FY2023		**$ 3,391,668**	

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Table 7-1: Summary of Recommended Water System Improvements and Expenditures (continued)

Recommendation	System	Expense Type	Reason	Estimated Budget	Notes*
YEAR 4					
Pump Station renewal	Facilities	One-Time	Facility renewal as needed	$ 1,500,000	Placeholder
Water Main renewal for age / condition	Distribution	One-Time	Main breaks, water quality	$ 2,000,000	Placeholder
Lead Service Line Program Inventory / Development	Planning	2-year	Regulatory Requirement	$ 50,000	Placeholder. Effort TBD.
Annual Activities	varies	Annual	varies	$ 568,218	See detail below. Inflation 3% annually
		Total FY2024		**$ 4,118,218**	
YEAR 5					
Pump Station renewal	Facilities	One-Time	Facility renewal as needed	$ 1,500,000	Placeholder
Water Main renewal for age / condition	Distribution	One-Time	Main breaks, water quality	$ 2,000,000	Placeholder
Annual Activities	varies	Annual	varies	$ 585,265	See detail below. Inflation 3% annually
		Total FY2025		**$ 4,085,265**	
Annual Activity Recommendations					
Unidirectional Flushing Program	Distribution	Annual	Water quality	$ 125,000	50% of system Annually
Proactive Water Quality Testing	Wells	Annual	Water quality	$ 5,000	Secondary, Mn, NO3, 1-4 Dioxane
Well & Pump Rehabilitation	Wells	Annual	Supply reliability	$ 200,000	Approx 5 annually
Tank Inspections	Tanks	Annual	Supply reliability	$ 7,500	
Asset Management	Distribution	Annual	Fiscal Sustainability	$ 25,000	Ongoing assistance / software
SCADA Maintenance	Facilities	Annual	Supply reliability	$ 15,000	
Tank Repairs / maintenance	Tanks	Annual	Supply reliability	$ 100,000	Placeholder
Meter Calibration	Facilities	Annual	Management	$ 7,500	
Groundwater Monitoring Program	Wells	Annual	Source protection	$ 35,000	PFAS and/or other contaminants
				$ 520,000	

Notes:

Water main costs per linear foot are in $2019 and include construction, engineering (20%), and contingency (10%). **Paving and other roadway improvement is not included in the unit costs**

Water main replacement cost based on unit costs 8" of $364/LF; 12" of $429/LF

Vertical construction bidding climate is extremely volatile. Estimates considered order of magnitude and suitable for planning only; subject to change

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