Capital Efficiency Plan™ Update
Aquarion Water Company

DRAFT

Prepared by:

TATA & HOWARD

November 2014

TATA & HOWARD

November 21, 2014

Mr. John Walsh, Vice President, Operations
Aquarion Water Company
900 Main Street
Hingham, MA 02043

Subject: Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
T&H Project No. 3719

Dear Mr. Walsh:

In accordance with our agreement, Tata & Howard is pleased to present you with the Updated Capital Efficiency Plan™ for the Hingham/Hull Water System. The analysis and improvements in this report are based on the Three Circle Approach for optimum capital efficiency, which combines hydraulic and critical component considerations with an asset management rating system to evaluate the condition of the water mains in the distribution system.

In March 2011, Tata & Howard completed the original Capital Efficiency Plan™ for the Hingham/Hull system. For the Updated Capital Efficiency Plan™ the hydraulic model was updated to include improvements to the system since 2011. Hydraulic recommendations and critical areas of the system were updated. Finally, the asset management score for each segment of water main was updated based recent improvements, revised information, and new research. The results were combined to determine the water mains most in need of replacement and establish a prioritized set of improvements in the system. A detailed description of the improvements and estimated costs is presented in Section 7.

During the course of this project, Ms. Justine Carroll, P.E. served as Project Manager, Ms. Brooke Cotta served as Engineer, and the undersigned provided technical reviews.

At this time, we wish to express our appreciation to the Aquarion Water Company for their participation in this study and for their help in collecting information and data. We appreciate the opportunity to assist the Aquarion Water Company on this important project.

Sincerely,

TATA & HOWARD, INC.

Karen Gracey

Karen L. Gracey, P.E.
Vice President

Enclosures
cc: Kenneth Skov

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SECTION 1 – Executive Summary

1.1 General

Tata & Howard, Inc. was retained by Aquarion Water Company (Aquarion) to complete a Capital Efficiency Plan™ for the Hingham/Hull finished water system in 2011. The purpose of the study was to identify areas of the system in need of rehabilitation, repair, or replacement and prioritize improvements to make the most efficient use of the system's capital budget. Due to improvements in the distribution system and additional information on population projections, Aquarion retained Tata & Howard to update the original study. The update evaluates the existing water infrastructure including water transmission and distribution piping and appurtenances. In addition, water storage needs are evaluated and prioritized. The conditions of the system's above ground facilities, including water supply and chemical feed facilities and water storage tanks, were not evaluated as part of this study.

1.2 The Three Circle Approach

Tata & Howard evaluated the water distribution system using the Three Circle Approach. The Three Circle Approach includes the following evaluation criteria:

- System hydraulic evaluation,
- Critical component assessment,
- Asset management considerations.

Each circle represents a unique set of evaluation criteria for each water system component. From each set of criteria, system deficiencies are identified. System deficiencies from each circle are then compared. Any deficiency that falls into more than one circle is given higher priority than one that does not. Using the Three Circle Approach, recommended improvements will result in the most benefit to the system. In addition, the Three Circle Approach allows us to identify any situations that mitigate a deficiency in one circle while eliminating a deficiency in another circle. By integrating all three sets of criteria, the infrastructure improvement decision making process and overall capital efficiency is optimized.

Priority 1 hydraulic improvements included recommendations that would meet an ISO recommended fire flow or strengthen the transmission capabilities of the system. Priority 2 hydraulic recommendations were identified as part of a system wide evaluation and include improvements required at or near system extremities and in areas not included in the most recent ISO testing.

A critical component assessment was performed for the water distribution system to evaluate the impact of potential water main failures on the system. Critical components and critical water mains were identified based on input from Aquarion. Critical water mains include any water main within a 1,000 foot radius of an identified critical customer, transmission mains, water mains that are difficult to access, water mains that cross under a river, water body, or railroad, and water mains identified using the criticality feature in WaterGEMS.

An asset management assessment was completed for the system. A number of factors are considered in the ratings including; break history, material, water quality, age, size, soil conditions, and water hammer potential. These factors affect the decision to replace or rehabilitate a water main. Using our asset management rating approach, each main in the system was assigned a rating based on these factors. Water mains with a total rating of 30 or less are considered to be in good to excellent condition. Areas with a total rating between 31 and 60 are considered to be in fair to good condition, and areas with a total rating greater than 60 are considered to be in poor to fair condition.

Utilizing the Three Circles Approach, improvements were recommended and prioritized based on the aforementioned criteria of hydraulic deficiencies, criticality, and asset management rating. Phase I and Phase II Improvements are prioritized based on hydraulic needs, location in the distribution system, and the condition of the water main. In general, the Phase I Improvements include water mains that fall into all three of the circles. The total estimated probable construction cost of the Phase I Improvements is approximately $10,212,000. Phase II Improvements generally include water mains that fall into two of the three circles. These improvements strengthen the transmission grid, eliminate potential asset management concerns, and provide redundancy. The total estimated probable construction cost of Phase II recommended improvements is approximately $8,170,000. Phase III Improvements generally fall into one circle. These improvements have been divided into two sections; Phase IIIa and Phase IIIb. Phase IIIa Improvements include recommendations that represent the remaining hydraulic recommendations from Section 4. Phase IIIb Improvements include the water mains with high asset management ratings. The total estimated probable construction cost of the Phase IIIa recommended improvements is approximately $7,701,000. The total estimated probable construction cost of the Phase IIIb recommended improvements is approximately $48,367,000.

SECTION 2 – Existing Water Distribution System

2.1 General System Overview

Aquarion's Hingham/Hull finished water distribution system consists of approximately 186 miles of water mains ranging in diameter from two to twenty inches. Figure No. 2-1 shows a breakdown of the water main size distribution of the existing finished water system. Approximately six percent of the system is 14-inch diameter or larger water main, approximately 15 percent is 12-inch diameter water main, approximately one percent is 10-inch diameter water main, approximately 38 percent of the system is 8-inch diameter water main, approximately 30 percent is 6-inch diameter water main, and approximately 10 percent is 4-inch diameter or smaller water main. These mains are constructed of various materials including cement lined ductile iron, unlined and factory lined cast iron, galvanized steel, and asbestos cement. There are also small percentages of polyvinyl chloride (PVC) and prestressed concrete cylinder pipe (PCCP). Figure No. 2-2 shows the breakdown of material distribution of the existing finished water system. The system also includes seven active supply sources, one emergency supply source, two water storage facilities, and a water treatment facility. A map of the existing water distribution system is included in Appendix A.

2.2 Water Supply Sources

The Hingham/Hull water system is supplied by seven water supply sources and one emergency source. The supply system is comprised of six groundwater sources and one surface water source. The Accord Pond is the sole surface water source within the system and Free Street Well Nos. 2A, 4, 3/5, Downing Street Well, Prospect Street Well, Scotland Street Well and Fulling Mill Station are groundwater supply sources. Free Street Well No. 2 is currently listed as an emergency supply source.

Downing Street Well

Downing Street Well is a gravel packed well located off Downing Street (Lat 42^{o} 13' 25", Long 70^{o} 52' 50"). It was constructed in 1965 to a depth of approximately 66.5 feet. The well was cleaned and rehabilitated in March 2002. The Massachusetts Department of Environmental Protection (MassDEP) approved pumping rate for this well is 284 gallons per minute (gpm) or 0.41 million gallons per day (mgd). The Downing Street Well is the only supply source that pumps directly into the finished water system. All other sources are treated at the Hingham/Hull District Water Treatment Facility.

Free Street Well Nos. 2, 2A, and 4

Free Street Well No. 2 is a gravel packed well located off Free Street (Lat 42^{o} 13' 05", Long 70^{o} 52' 40"). It was constructed in 1952 to a depth of approximately 73 feet. The well was cleaned and rehabilitated in March 2006. Free Street Well No. 2A is a replacement well that was installed in 2007 to a depth of approximately 79.5 feet. Free Street Well No. 4 is a gravel packed well located off Free Street (Lat 42^{o} 13' 10", Long 70^{o} 52' 45"). It was constructed in 1983 to a depth of approximately 86 feet. In November 2008, the MassDEP approved a status change of Free Street Well No. 2 and 4. Free Street Well No. 2 was changed from an active

Figure No. 2-1
Water Main Diameter Distribution

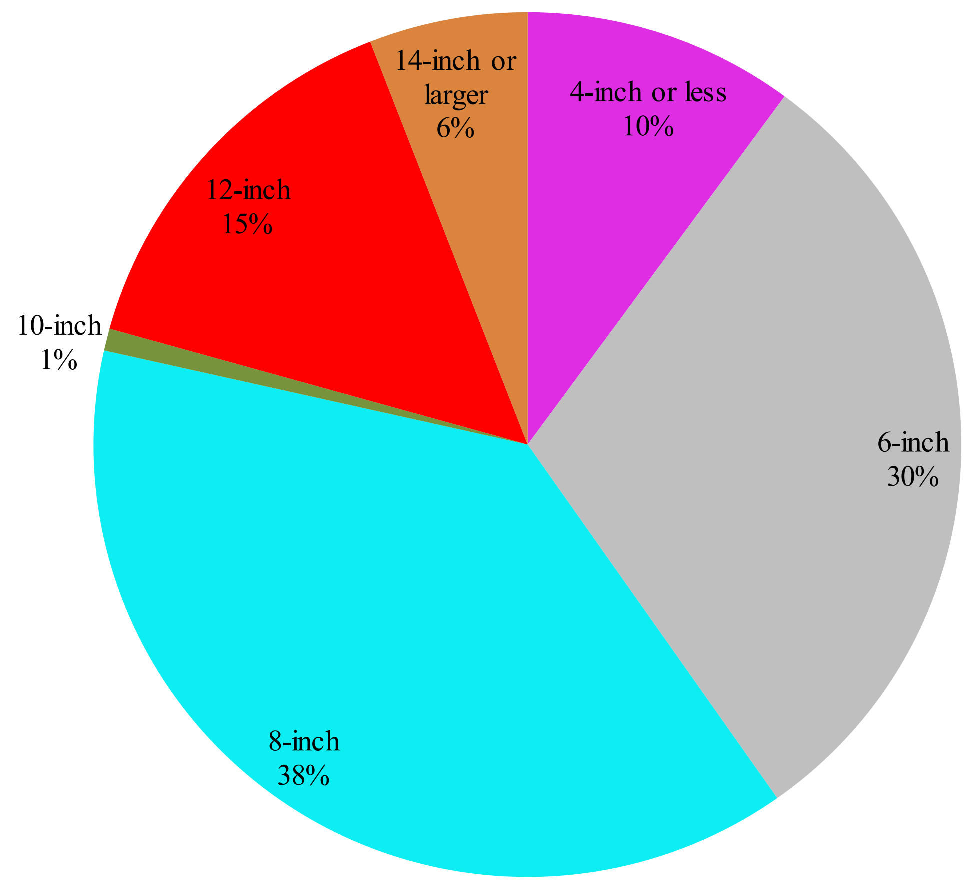
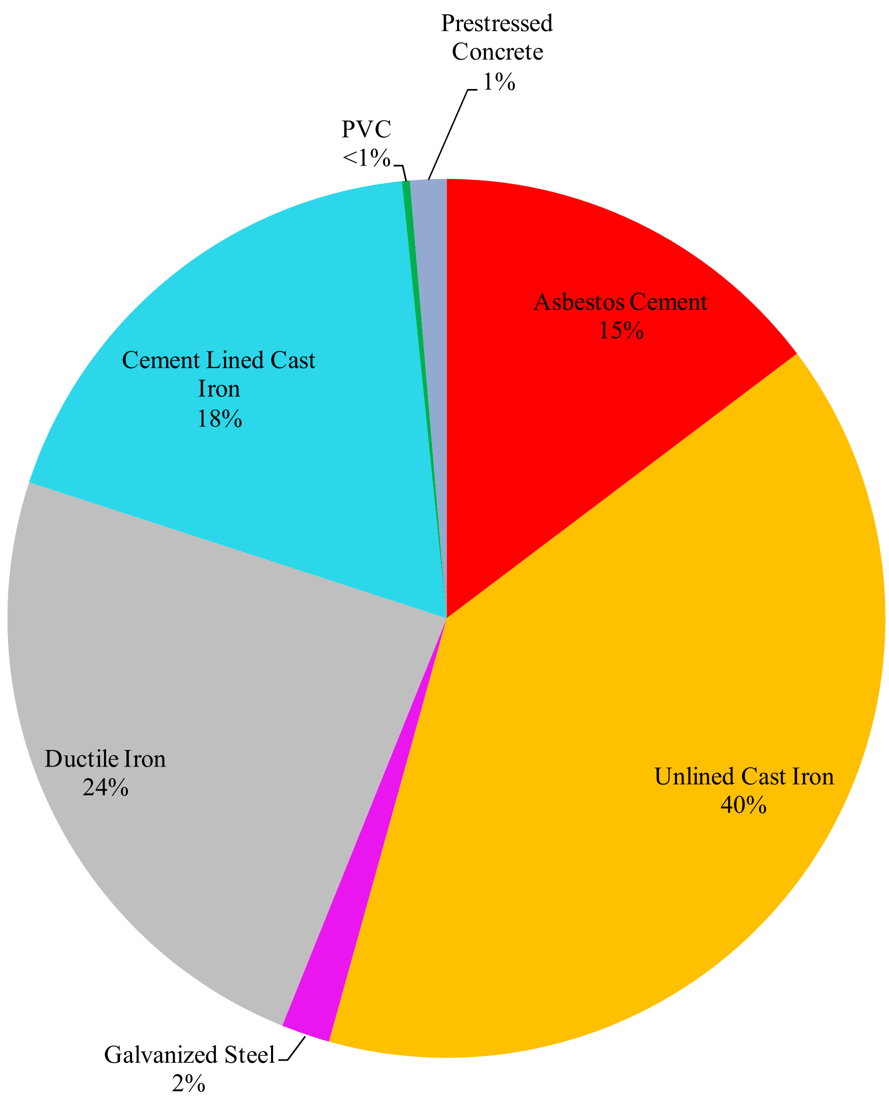


Figure No. 2-2
Water Main Material Distribution



source to an emergency source while Free Street Well No. 4 was changed to an active source. MassDEP has limited the total maximum daily withdrawal from Free Street Well No. 4 to 0.81 mgd. The total combined volume to be withdrawn from Free Street Well No. 2 and 4 cannot exceed 1.80 mgd.

Free Street Well No. 3/5

Free Street Well No. 3/5 are gravel packed wells located off Free Street (Lat 42^{o} 13' 05", Long 70^{o} 52' 52"). Free Street Well No. 3 was constructed in 1967 to a depth of approximately 88.5 feet. Free Street Well No. 5 was constructed as a satellite well to supplement lost capacity of Free Street Well No. 3. The satellite well pumps to Well No. 3 and is then pumped to the water treatment facility. The wells were cleaned and rehabilitated in 1998. The MassDEP approved pumping rate for these wells is 351 gpm or 0.51 mgd.

Prospect Street Well

The Prospect Street Well is a gravel packed well located off Elaine Road (Lat 42^{o} 11' 30", Long 70^{o} 52' 30"). It was constructed in 1971 to a depth of approximately 58 feet. The MassDEP approved pumping rate for this well is 269 gpm or 0.39 mgd.

Scotland Street Wells

The Scotland Street Well is a gravel packed well located off Scotland Street (Lat 42^{o} 11' 25", Long 70^{o} 52' 20"). It was constructed in 1956 to a depth of approximately 45 feet. A replacement well was installed in 2008 to a depth of 57 feet. The original well was cleaned and rehabilitated in March 2007. The MassDEP approved pumping rate for this well site is 1,078 gpm or 1.55 mgd.

Fulling Mill Station

The original Fulling Mill Station is a dug well fed by infiltration basins located at 93 South Pleasant Street (Lat 42^{o} 12' 10", Long 70^{o} 52' 30"). It was constructed in 1903 to a depth of approximately 21.5 feet. Two replacement wells were installed at the Fulling Mill Well site in 2008. The Fulling Mill Replacement Wells No. 1 and 2 have a capacity of 430 gpm and 265 gpm, respectively. The MassDEP approved pumping rate for this well site is 941 gpm or 1.36 mgd. The wells were last cleaned in 2011.

Accord Pond

Accord Pond is 100 acre pond located off Whiting Street (Lat 42^{o} 10' 30", Long 70^{o} 53' 30"). The total storage capacity of the pond is approximately 523 million gallons with a drainage basin area of 1.01 square miles. The intake pipe is a gravity line to the treatment plant. Accord Pond has an estimated sustainable yield of 3.0 mgd for 80 days as determined by a study completed in 1984 as reported in system's WMA Registration Application. The estimated safe yield of the pond is approximately 0.69 mgd.

2.3 Hingham/Hull District Water Treatment Facility

Aquarion operates a 7.7 mgd water treatment facility located in Hingham. The treatment facility, in operation since April 1996, receives water from all water supply sources except the Downing Street Well and satisfies the treatment requirements set forth by the United States

Environmental Protection Agency (US EPA). The Hingham/Hull District Water Treatment Facility treats raw water via rapid mix, Superpulsator clarifiers, deep-bed GAC filters and post-filtration disinfection, pH adjustment and fluoridation. The facility also has a large holding tank for treated water to improve water pressure in the system during high demand periods.

2.4 Water Storage Facilities

There are two water storage facilities located within the Hingham/Hull system. The Turkey Hill Tank is located on Turkey Hill Lane in Hingham. The welded steel standpipe is 70 feet in diameter, 70 feet tall and has a reported capacity of 2.01 million gallons (mg). It has an overflow elevation of 240 feet and is connected to the system with a 20-inch diameter water main. The Accord Tank is located on Whiting Street in Hingham. The elevated welded steel tank is 58 feet in diameter, 112 feet tall and has a reported capacity of 0.75 mg. Accord Tank has an overflow elevation of 282 feet and is connected to the system through a 16-inch diameter water main.

2.5 Hull Booster Pump Station

The Hull Booster Pump Station services the northern portion of Hull. The booster pump station provides domestic pressure only when high demands in Hull reduce pressures in the area.

2.6 Interconnections

Aquarion currently wheels up to 0.3 mgd of finished water from Cohasset to the Linden Pond development. Aquarion also has emergency connections with Weymouth and Cohasset.

SECTION 3 – Water Supply and Storage Evaluation

3.1 General

In accordance with the MassDEP, the supply sources of a water system must be capable of meeting existing and projected maximum day demand (MDD) conditions, existing and projected average day demand (ADD), and existing and projected summer average day demand (SADD) conditions with the largest source out of service. In this section, existing demand conditions were considered and demand projections completed by the Massachusetts Department of Conservation and Recreation (DCR) were reviewed. The safe yields of the supplies and permitted withdrawals of the existing supply sources were compared to current and future demand conditions.

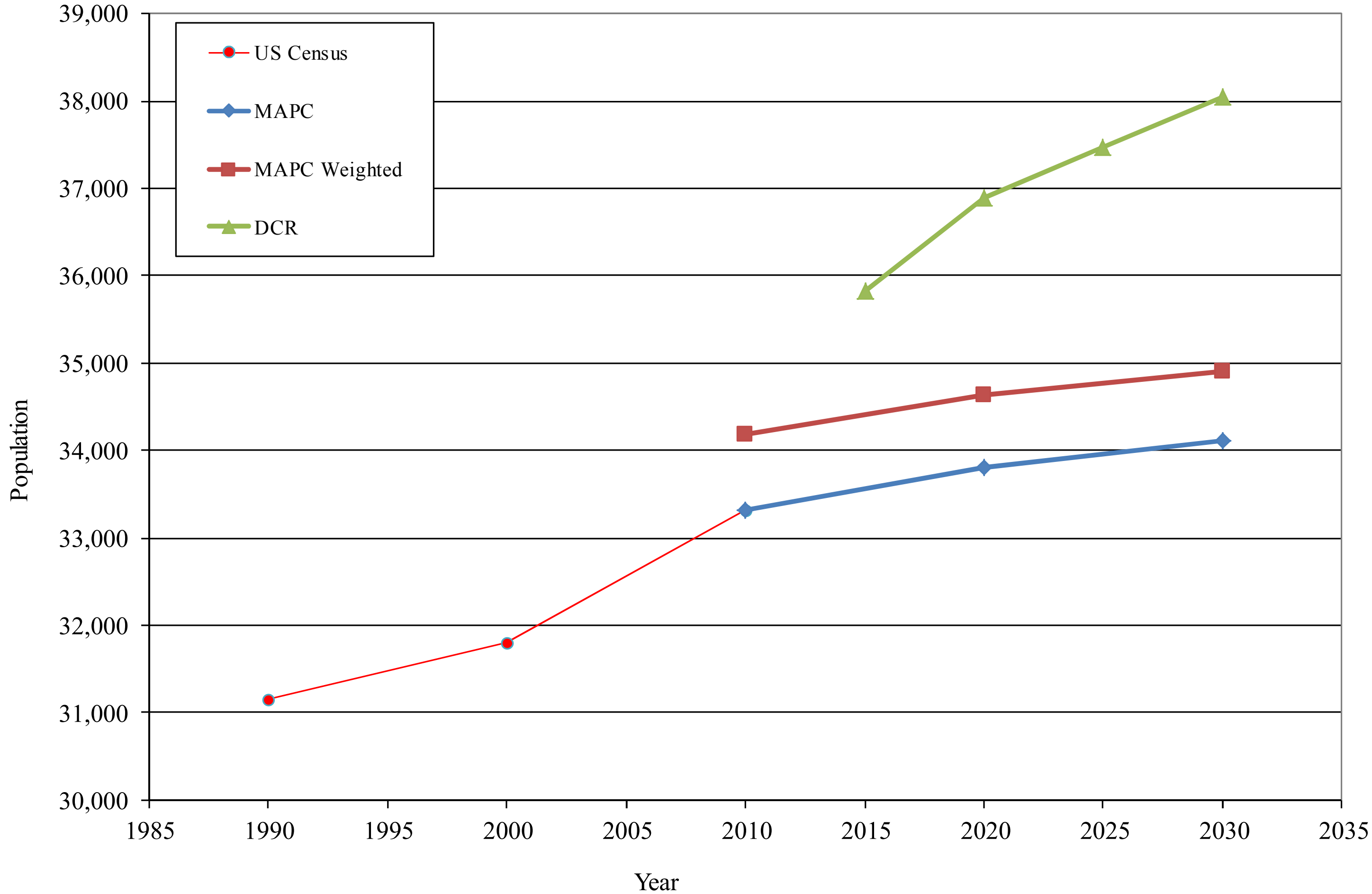
3.2 Population Projections

Because population has a direct correlation to water consumption, population projections from various sources were reviewed to reflect actual and planned growth within the Towns. The following section reviews historical population data and presents an estimated future population based on available information from the Towns, the United States Census, and Metropolitan Area Planning Council (MAPC).

According to the United States Census, the population in Hingham remained constant from 1990 to 2000 and experienced a growth of approximately 1.1 percent per year from 2000 to 2010. The population in Hull experienced a growth of approximately 0.6 percent per year between 1990 and 2000 but the population in Hull decreased by approximately 0.7 percent per year between 2000 and 2010. The population recorded during each decennial census has been plotted in Figure No. 3-1. According to the US Census, the total population in Hingham was 22,157 and Hull was approximately 10,293 people in 2010.

The MAPC published updated population projections for Hingham and Hull in the Population and Housing Demand Projections for Metro Boston Regional and Municipal Forecasts in January 2014. The population projections were estimated using two scenarios. The Status Quo scenario is based on existing rates of births, deaths, migration, and housing occupancy. Based on the Status Quo scenario, the population in Hingham is expected to continue to increase through 2030 and the population in Hull is expected to continue to decrease through 2030. The Stronger Region scenario considers changing trends resulting in lower growth in Hingham and a slower rate of population decline in Hull. The population projections are shown in Figure No. 3-1. To be conservative, the scenario which yielded a higher population for each community was considered. Therefore, the Status Quo Scenario was used for Hingham and the Stronger Scenario was used for Hull, respectively. Based on the combination of scenarios, the estimated 2034 population for Hingham and Hull is 34,211. Aquarion also serves approximately 870 people in North Cohasset. The population served in North Cohasset is not anticipated to change in the planning period.

Figure No. 3-1
Population Projection



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A list of the approved and pending subdivisions in Hingham and Hull was obtained from each Town's Building Department. Currently, there are six subdivisions under construction in Hingham. The proposed subdivisions include one permit for Weathervane at Chestnut Farms, five permits for the Backriver Project, one permit for Christina Estates at Baker Hill, 25 permits for Lennar Hingham Holdings Shipyard, and six permits for Black Rock. In addition, there are 20 permits for single family homes. There is one subdivision currently under construction in Hull. The proposed subdivision includes 11 townhouse permits. In addition, there is one permit for a single family dwelling.

The 2010 US Census reported that the average household size in Hingham was 3.0 people per house and Hull to be 2.34 people per house. Based on the average household size, the current permits in Hingham (58 housing units) would result in an increase in population of approximately 174 people and in Hull (12 housing units) would result in an increase in population of approximately 28 people. These housing increases are based on the current building permits. The Building Departments did not have any information on project completion dates. Also, it is unknown if the new townhouses being installed in Hull are being constructed in empty space or if the new structures replace or update any existing residential homes. While the existing building permits suggest there may be a slight increase in population in Hingham and Hull in the near future, the overall population is expected to follow the trends determined by the MAPC.

According to the Town of Hull, the population more than doubles from the winter to summer months. Seasonal population estimates for Hull have historically involved doubling Hull's residential population for five months of the year. Based on information provided by the US Census, Hull's estimate of the population doubling in the summer is likely not all residential homes. The summer population estimates includes additional visitors to Hull's hotels, restaurants, and beaches. The 2010 US Census reported that approximately 14 percent of the total housing units were considered seasonal housing units. The population numbers reported in the US Census were assumed to be full time residents. Based on the average household size and the number of seasonal housing units, it is estimated that the residential population increases by approximately 20 percent in the summer months. A weighted population was determined for Hull to be used in demand projections. The weighted population is based on using the winter population for seven months and the summer population for five months. Based on the weighted population for Hull, the estimated 2034 population for Hingham, Hull, and North Cohasset is approximately 35,081.

3.3 Water System Demands

DCR follows specific guidelines while projecting the water usage for communities in conjunction with the MassDEP Water Management Act (WMA). These guidelines incorporate trends in the use of water conservation devices in homes and industry, and emphasize the importance of monitoring the distribution system through water audits and leak detection surveys to reduce unaccounted-for water. It is important to note that the DCR has a key role in the water management approval process. Water demand projections through the year 2030 were completed for Aquarion by the DCR in 2009 as part of the WMA permitting process. Any alternative demand projections must be approved by the DCR before the MassDEP will approve development of a new water supply source or authorize the withdrawal of additional volume from existing sources. The DCR based their projections on population and employment projections developed by the MAPC for Hingham and Hull prior to 2008. DCR also included the population served in North Cohasset and a weighed seasonal population. The weighted seasonal population was based on the population in Hull doubling in the summer months. The estimated 2030 service population based on the DCR projections is 40,900. Compared to the estimate from the MAPC Projections, this number is relatively high due to a calculation difference in seasonal population. The additional demands associated with increased population at hotels, beaches, and restaurants would be accounted for in the non-residential water usage.

Based on recent developments, the Massachusetts Water Resource Commission (MWRC) has adopted new Water Management Standards for all registered and permitted withdrawals. The policy includes performance standards and conditions for all registered and permitted public water suppliers in the following areas:

- Maximum residential consumption of 65 gallons per capita per day (gpcd).
- Maximum of 10 percent unaccounted-for water.

DCR used a residential population of 40,900 and the MWRC performance standards to estimate a 2030 ADD of 4.17 mgd with their allowable five percent buffer. This ADD is based on the higher residential summer population. Also, there were many large developments in the planning stage before 2009 that were not constructed due to changes in the economy.

Residential Consumption

Residential consumption is calculated by dividing water supplied to residential connections by the reported population. MassDEP has developed standards for all Public Water Suppliers to meet 65 gpcd. Public Water Suppliers currently meeting 65 gpcd will be required to develop a Seasonal Demand Management Plan to manage non-essential outdoor water usage. Public Water Suppliers who have not consistently met the 65 gpcd will be required to develop and implement MassDEP approved Compliance Plans, including the use of Best Management Practices to meet the residential consumption standard. The 2009 through 2013 MassDEP Performance Standards for Public Water Supplies indicate that the system has an average residential consumption of approximately 58.2 gpcd. The residential consumption has ranged from approximately 50 to 66 gpcd between 2009 and 2013.

Non-residential Consumption

Non-residential water usage includes commercial, industrial, municipal, and recreational water use. The 2009 through 2013 Annual Statistical Reports suggest that the non-residential consumption remains consistent from year to year. The average non-residential consumption within the system between 2009 and 2013 was approximately 16 percent of total consumption. Commercial, industrial, and municipal water use is not expected to increase significantly in Hull over the next 20 years; however, there is potential for additional development in the South Shore Industrial Park (SSIP) south of Route 3 in Hingham. A South Shore Industrial Park Demand and Supply Evaluation was completed in June 2013. This evaluation determined that buildout of the SSIP could result in an additional ADD of 0.14 mgd. It is not anticipated that there will be significant changes to the non-residential usage in the rest of Hingham. An average non-residential usage of 16 percent was used for the non-residential usage and then an additional 0.14 mgd was added to the total 2034 ADD demand for the SSIP.

Unaccounted-for Water

Unaccounted-for water consists of unmetered water used for street cleaning, water main flushing, meter inaccuracy, unauthorized water uses, firefighting, and leakage in the distribution system. This term is typically expressed as a percentage of the total water supplied to the system. Unaccounted-for water can be estimated by taking the difference between the total amount of water supplied and the total water billed and dividing by the total water supplied.

The MassDEP allows communities to calculate a confidently estimated municipal use volume. To obtain credit as confidently estimated municipal usage, communities must present calculations and documentation for each estimated use. In 2009 through 2013, Hingham and Hull's estimated municipal water use ranged from 4 percent to 14 percent, and averaged 7 percent of the total available finished water. However, the MassDEP recorded unaccounted-for water from 2009 to 2013 was between 16 and 23 percent. Aquarion will either need to provide additional documentation to prove the unaccounted-for water is less than 10 percent, or if the unaccounted-for water remains high, reducing the unaccounted for water will result in decreases in projected demands.

Average Day Demand

Average day demand (ADD) is the total water supplied to a community in one year divided by 365 days. This term is commonly expressed in millions of gallons per day (mgd). This demand includes all water used for domestic (residential), commercial, industrial, agricultural, and municipal purposes. The municipal component includes water used for system maintenance such as hydrant flushing and fire flows. In addition, the ADD includes unaccounted-for water attributed to unmetered water uses and system leakage.

According to the 2009 through 2013 Annual Statistical Reports (ASRs), the ADD supplied for Aquarion ranged from 3.11 mgd to 3.34 mgd.

The following criteria was used to develop the 2034 ADD

- Residential consumption of 65 gpcd
- Year 2034 service population of 35,081
- Maximum of 10 percent unaccounted for water.
- 16 percent non-residential water use
- 0.14 mgd SSIP buildout demands (2034 demand only)

Using the stated criteria, the projected 2034 ADD is approximately 3.22 mgd.

Summer Average Day Demand

MassDEP guidelines recommend that a system consider a projected summer ADD (SADD). The current SADD is estimated by averaging demands from the three maximum months for the past five years. As shown in Table No. 3-1, the SADD ranged from 3.73 mgd to 4.34 mgd. The SADD peaking factor is determined by dividing the SADD by the annual ADD for each of the past five years. These peaking factors are averaged to estimate the future summer peaking factor. Based on the 2009 through 2013 monthly demand data, the average summer peaking factor is 1.28. Based on the projected ADD of 3.22 mgd, the estimated 2034 SADD is approximately 4.12 mgd.

Maximum Day Demand

Maximum day demand (MDD) is the maximum one-day (24-hour) total quantity of water supplied during a one-year period. This term is typically expressed in mgd. According to the 2009 through 2013 ASRs, the MDD supplied ranged from 4.95 mgd to 5.67 mgd.

MDD is a critical factor to be considered when determining the adequacy of a water supply system. The distribution system must be capable of meeting maximum day demands with coincident fire demands at a minimum pressure of 20 pounds per square inch (psi). Estimates of the projected maximum day demand and an allowance for the estimated recommended fire flow are used to evaluate or design pumping, transmission and storage facilities.

Table No. 3-1
Historic and Projected Water Use

Year	ADD (mgd)	SADD (mgd)	Peaking Factor (SADD/ADD)	MDD (mgd)	Peaking Factor (MDD/ADD)	Peak Hour (mgd)
2009	3.11	3.73	1.20	4.95	1.59	*
2010	3.11	4.01	1.29	5.76	1.85	*
2011	3.23	4.25	1.31	5.60	1.73	*
2012	3.31	4.34	1.31	5.70	1.71	*
2013	3.34	4.22	1.26	5.26	1.57	*
2024	3.05	3.90	1.28	5.64	1.85	9.15
2034	3.22	4.12	1.28	5.96	1.85	9.66

*Peak hour information for 2009 through 2013 is not available.

The projected MDD can be estimated by the MDD/ADD ratio. The MDD/ADD ratio provides a relationship between the two demands that can be used to estimate future demands. Historical MDD to ADD ratios ranged from 1.57 to 1.85. To be conservative, the highest historical peaking factor was used to estimate future MDD. The resulting projected MDD for year 2034 is estimated to be 5.96 mgd based on the projected 2034 ADD of 3.22 mgd.

Peak Hour Demand

Peak hour demand is the maximum total quantity of water supplied in a single hour over a one-year period typically expressed in mgd. These demands are typically met by distribution water storage facilities.

Since system records of peak hourly demands are not available, the peaking factor for the current usage and design year 2034 was estimated based on typical historical consumption for communities of similar size. The MDD/ADD ratio for a community can be used to estimate the peak hour/ADD peaking factor. Using a MDD/ADD ratio of 1.85, the corresponding peak hour peaking factor for the system is approximately 3.0. Using an ADD of 3.22 mgd, the projected peak hour flow for the year 2034 is estimated at 9.66 mgd.

3.4 Adequacy of Existing Water Supply Source

In 1987, the Water Management Act (WMA) program was implemented by MassDEP to regulate withdrawal of water from the state's watershed basins. Under this program, all new sources withdrawing more than 100,000 gallons per day (gpd) and existing sources exceeding their registered withdrawal volume by 100,000 gpd are required to obtain a withdrawal permit under the WMA. The registered withdrawal volume for a public water system was based on that system's historical pumping rate of the water supply source(s) between 1981 and 1985. However, permits can be renewed and amended as system demands increase and additional supply sources are utilized. The WMA program considers the need for the withdrawal, the impact of the withdrawal on other hydraulically connected water suppliers, the environmental impacts of the withdrawal, and the water available in the river basin or subbasin (the basin safe yield) prior to issuing a permit. It is important to note that the basin safe yield is different from the safe yield of a supply. In accordance with the WMA permit application instructions, the basin safe yield is the total water available to be withdrawn from a river basin or subbasin, whereas the safe yield of a well is the volume of water the well is capable of pumping under the most severe pumping and recharge conditions that can be realistically anticipated.

The sources of water supply in the Hingham/Hull system are listed in Table No. 3-2. The table provides the maximum withdrawal rates for each source based on the Zone II analysis, which defines the recharge area of the wells. The table also shows the withdrawal capacity of Accord Pond. Accord Pond has an estimated sustainable yield of 3.0 mgd for 80 days as determined by a study completed in 1984 as reported in system's WMA Registration Application. The total estimated safe yield of the pond is approximately 0.69 mgd. It should be noted that for some of the sources, the withdrawal volume is limited by the hydraulic capacity of the piping system that runs from the sources to the water treatment plant (WTP). Aquarion is planning to address these hydraulic restrictions.

MassDEP guidelines recommend that a system have adequate supply to meet (1) the projected MDD and (2) the projected SADD with the largest source offline. The system's total combined maximum pumping rate of all active supply sources is 9.02 mgd. Based on the 2034 MDD of 5.96, Aquarion can meet the projected MDD with the existing water supplies. Accord Pond is the largest source; therefore, the available pumping rate with the largest source offline is 4.37 mgd. The Aquarion Water Company can meet the existing and projected SADD of 4.12 with the largest source offline. Figure No. 3-2 provides a comparison of the current available water supply versus the projected demands.

Figure No. 3-2
Current Available Supply and Projected Demands

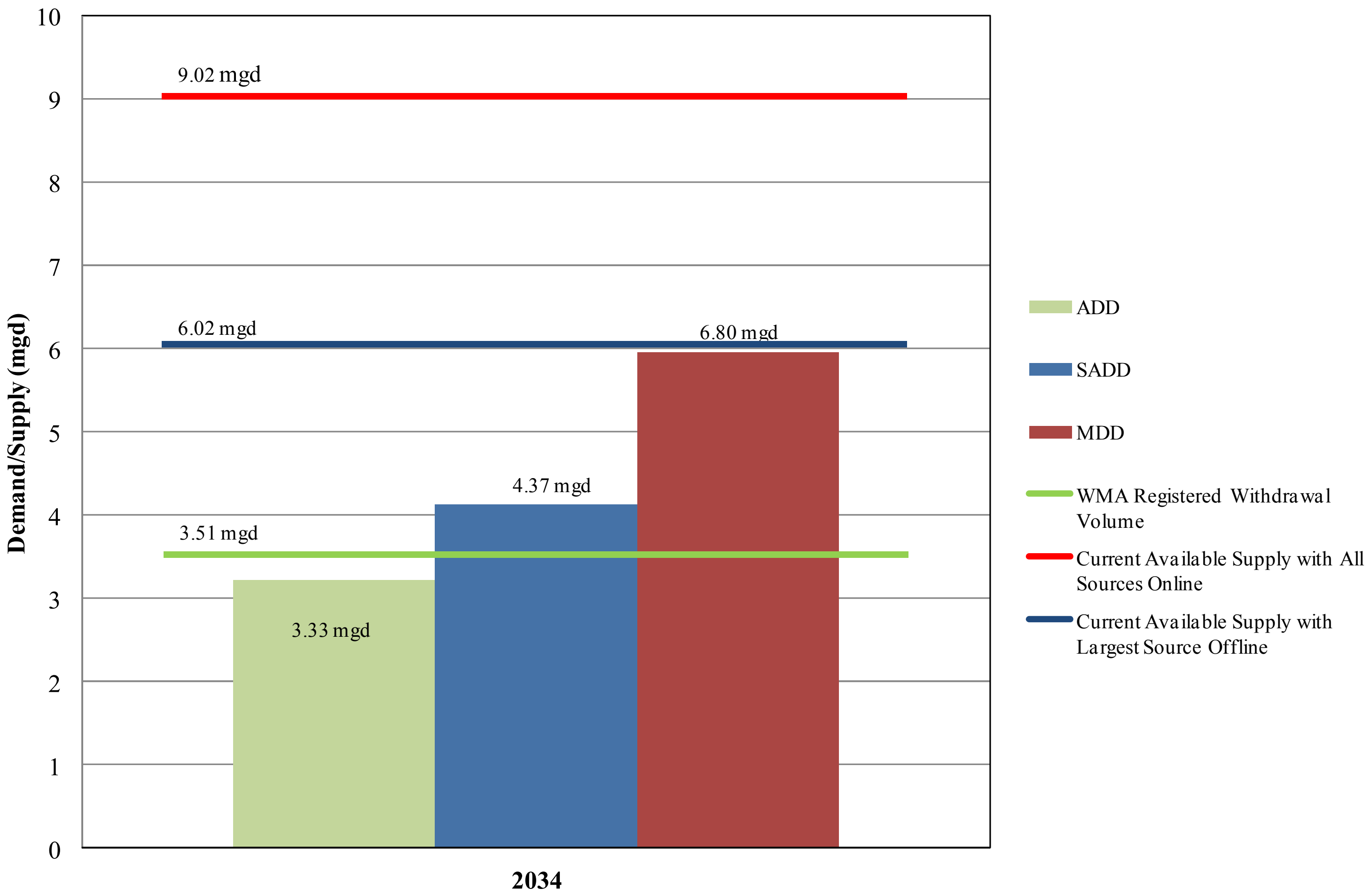

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Table No. 3-2
Approved Withdrawal Volumes

Groundwater Source Name	Zone II Maximum Daily Withdrawal Volume (mgd)	Zone II Maximum Daily Withdrawal Volume (mgd)
Downing Street Well	0.41	0.41
Free Street Wells 2A and 4(b)	1.80	1.80
Free Street Wells 3/5	0.51	0.51
Fulling Mill Wells 1 and 2	1.36	1.36
Prospect Street Well	0.39	0.39
Scotland Street Wells 1 and 1A	1.55	1.55
Free Street Well 2	Emergency source	Emergency source
Surface Water Name	**Maximum Yield (mgd)**	**Safe Yield (mgd)**
Accord Pond (largest source)	3.0	0.69
Total:	**9.02**	**6.71**

*Free Street No. 4 has a maximum withdrawal rate of 0.81 mgd. The total combined withdrawal rate from Free Street No. 2A and 4 is 1.80 mgd.

3.5 Water Management Act Registration

The Aquarion Water Company has a WMA Registration to withdraw water from the Boston Harbor Basin. In accordance with the WMA Registration for water withdrawal from the Hingham/Hull supply sources (Registration No. 41913101), the system is authorized to withdraw an average daily volume of 3.51 mgd and a total annual volume of 1,281.15 million gallons per year (mgy). According to the Water Management Act, a water system is allowed to pump up to 0.1 mgd on average over one calendar year over the registered volume prior to applying for a permit.

Based on the ASRs, the 2009 through 2013 ADDs were below the registered allowable withdrawal volume. Based on the demand projections, the estimated projected demands for Hingham/Hull do not exceed the registered volume. Figure No. 3-2 provides a comparison of the current available water supply versus the projected demands.

3.6 Adequacy of Existing Storage Facilities

Distribution storage is provided to meet peak consumer demands such as peak hour demands and to provide a reserve for firefighting. Storage also serves to provide an emergency supply in case of temporary breakdown of pumping facilities, or for pressure regulation during periods of fluctuating demand.

There are three components that must be considered for evaluating storage requirements. These components include equalization, fire flow requirements, and emergency storage. The three components of the storage evaluation were calculated under current and future demand conditions.

Equalization storage provides water from the tanks during peak hourly demands in the system. Typically, this quantity is a percentage of the maximum day demands. The percentages can range from fifteen to twenty-five percent, with fifteen percent used for a large system, twenty percent for a mid-sized system and twenty five percent used for a small system. A system is considered small if it has less than 3,300 customers, while a system is considered large if it has more than 50,000 customers. The Hingham/Hull system would be considered a mid-sized system. As a result, twenty percent of maximum day demand was used for the equalization storage calculations. The system was evaluated separately for the Main Service Zone and the High Service Zone.

The fire flow storage component is based on the basic fire flow requirement multiplied by the required duration of the flow. The basic fire flow is defined as a fire flow indicative of the quantities needed for handling fires in important districts, and usually serves to mitigate some of the higher specific flow. Within the Hingham/Hull system, a basic fire flow of 2,000 gpm for two hours was used for the storage evaluation.

The emergency storage component is typically equivalent to an ADD. However, if there is emergency power available at the sources, capable of supplying at least an ADD, the emergency storage component can be waived.

1. Water Distribution System Equalization
- Mid-sized system = 20 percent of the Maximum Day Demand
- Maximum Day Demand in year 2013 = 5.76 mgd
- Estimated Maximum Day Demand in year 2034 = 5.96 mgd

- Equalization (2013) = 0.20 x 5.76 = 1.15 million gallons (mg)
- Equalization (2034) = 0.20 x 5.96 = 1.19 mg

2. Basic Fire Flow Requirement
- Representative fire flow for Hingham/Hull = 2,000 gpm
- Duration of 2 hours or 120 minutes.

- Basic Fire Flow Requirement = 2,000 gpm x 120 min = 0.24 mg

3. Emergency
- Waived

The total required storage for any given year is the equalization component plus the basic fire flow requirement plus the emergency component. Therefore, the existing and projected (year 2034) total required storage for the system is as follows:

- Total Required Storage (2013) = 1.15 + 0.24 = 1.39 mg
- Total Required Storage (2034) = 1.19 + 0.24 = 1.43 mg

Under existing and projected ADD, MDD, and peak hour demands, a minimum pressure of 20 psi should be maintained throughout the distribution system. A minimum pressure of 20 psi should be maintained under the projected MDD with fire flow. The highest customer in the main service area of the distribution system is at an elevation of approximately 131 feet. To maintain a pressure of 20 pounds per square inch (psi) at this elevation, the tank can drop to an elevation of approximately 177 feet. The Turkey Hill Tank has a base elevation of 170 feet. Therefore, in order to maintain 20 psi throughout the system, the Turkey Hill Tank level cannot drop below 63 feet. This reduces the usable storage in the Turkey Hill Tank to 1.81 mg.

In the high service area, the highest customer is at an elevation of approximately 175 feet above sea level and in order to maintain a pressure of 20 psi at this elevation, the Accord Tank can drop to an elevation of approximately 221 feet. Based on this scenario, the entire Accord Tank (0.75 mg), at a base elevation of 244 feet, is usable. The total usable storage in the water distribution system is approximately 2.56 mg. Based on the projected total required storage of mg, Hingham/Hull have a surplus storage of 1.13 mg.

SECTION 4 – Hydraulic Model Verification and Evaluation

4.1 General

In the 2007 Water Supply and Distribution System Study, Tata & Howard, Inc. used a hydraulic model to evaluate the Hingham/Hull water distribution system and as a basis for recommending water distribution system improvements. At the time of the study, a hydraulic computer model was created using WaterGEMS modeling software, allowing the user to conduct hydraulic simulations. The computer model is represented by the node, pipe and tank information provided in Appendix B. A color-coded junction map of the water distribution system model can be found in Appendix B. The node map provides information on storage facilities, water supply sources, sizes of water mains, and a general layout of the distribution system. The hydraulic input data in Appendix B provides data on system demands, length and diameter of water mains, roughness coefficient or "c-value" of water mains, elevations, pumping rates of water supply sources, and overflow elevations at storage facilities

WaterGEMS allows the user to conduct hydraulic simulations using mathematical algorithms while in an ArcGIS environment. The fire flow tests and information pertaining to the sources and storage facilities were used for model verification under steady state conditions. The hydraulic model was updated as part of the 2011 Capital Efficiency Plan™. As part of this project, the model was updated to address all system improvements completed since 2011. Recommendations set forth by the ISO for water storage necessary for fire protection, fire flows, and peak demands were utilized to analyze the distribution system under steady state conditions.

4.2 Evaluation Criteria

The hydraulic evaluation facet of the Three Circle approach evaluates the system's ability to meet varying demand conditions. In general, a minimum pressure of 35 psi at ground level is required during average day, maximum day, and peak hour demand conditions. During MDD with a coincident fire flow, a minimum pressure of 20 psi is required at ground level throughout the system. To evaluate the system's ability to meet these criteria, the following hydraulic simulations were run in the model:

Minimum/Maximum Pressures

During a projected year 2034 ADD, MDD, and peak hour demand condition (no coincident fire flow), a minimum pressure of 35 psi is recommended throughout the distribution system at street level. The ground elevations in the Main Service Zone in the areas of Talbot Road and Summit Drive in Hingham are approximately 125 feet. Pressures in these areas are close to the recommended 35 psi, with the largest pressure concerns occurring during peak hour conditions. Individual pumping systems should be recommended to customers in this area. If Aquarion wishes to expand the distribution system into areas currently not served by the water system in the future, areas with ground elevations greater than approximately 125 feet in the Main Service Zone would require booster pump stations.

Pressure in the area of Winfield Road in the High Service Zone in Hingham is close to the recommended 35 psi, having the largest pressure concerns occurring during peak hour conditions. The ground elevation in this area is approximately 170 feet. Individual pumping systems should be recommended to customers in this area. If Aquarion wishes to expand the distribution system into areas currently not served by the water system in the future, areas with ground elevations greater than approximately 170 feet in the High Service Zone would require booster pump stations.

An upper limiting pressure of 120 psi is generally recommended, as older fittings in the system are generally rated at 125 to 150 psi. Pressures above this level can result in increased water use from fixtures and increased leakage throughout the distribution system. In addition, plumbing code states that water heaters in homes can be affected by pressures greater than 80 psi.

Based on the overflow elevation of the water storage tanks, any building or structure in the Zone with a ground elevation less than approximately 10 feet could experience pressures greater than 120 psi. However, the pressure does not exceed 120 psi in the Hingham/Hull system, therefore no pressure reducing valves (PRVs) are necessary.

Insurance Services Office (ISO) Fire Flow Requirements

The recommended fire flow in any community is established by the ISO. The ISO determines a theoretical flow rate needed to combat a major fire at a specific location by taking into account the building structure, floor area, the building contents, and the availability of fire suppression systems. In general, the flows recommended for proper fire protection are based on maintaining a residual pressure of 20 psi. This residual pressure is considered necessary to maintain a positive pressure in the system to allow continued service to the customers and avoid negative pressures that could introduce groundwater into the system.

ISO data was available from December 2006. The results of the ISO testing for Hingham, Hull, and Cohasset are shown in Table No. 4-2, 4-3, and 4-4, respectively. The test results indicate the available flow and estimated recommended fire flow in various sections of the distribution system at the time of the tests. The estimated recommended fire flows established by ISO varied from 750 to 6,000 gpm, depending on the location and the structure. It should be noted that a water system is only required to provide a maximum of 3,500 gpm at any point in the system.

Additional Flow Recommendations

A review of the distribution system was completed to identify larger buildings that were not identified in the latest ISO evaluation. Examples include condominiums, apartment complexes, schools, and commercial or industrial buildings. Recommended flows were estimated for these areas using the ISO published Guide for Determination of Needed Fire Flow. The guide uses factors including building size, material, location, and contents. These factors were estimated based on aerial photos and street level observations. Estimated needed fire flows are for the analysis of the water system only, and are not intended to be used for any other purpose.

According to the American Water Works Association (AWWA), the minimum recommended fire flow in residential areas with homes greater than 100 feet apart is approximately 500 gpm. The recommended fire flow for homes between 31 feet and 100 feet apart is

Table No. 4-2
ISO Required and Available Fire Flow for Hingham
April 2007

Test Location	Static Pressure (psi)	Residual Pressure (psi)	Needed Flow at 20 psi (gpm)	Available Flow at 20 psi (gpm)
Mast Hill Road & Charles Street	61	27	750	950
Pinegrove Road & Rosemary Lane	65	55	4,500/3,000	2,100
Recreational Park Drive & Keith Way	52	42	3,000	2,000
Industrial Road & Commerce Road	50	35	2,250	1,700
Colonial Road & Hancock Road	91	62	750	1,700
Stanford Drive & Camelot Drive	70	26	3,000	800
French Street & Manatee Street	73	17	750	700
West Beal Street & Hillside Terrace	87	80	2,000	3,400
Beal Street & Terry Street	84	74	5,000/3,500	2,000
Bulow Road & Lincoln Street	84	45	6,000/3,500	1,200
Downer Avenue & Planters Field Lane	87	68	3,000	2,500
Malcom Street & Standish Street	80	77	750	3,800
Main Street & Elm Street	88	84	2,500	5,000
Eldridge Court & Water Street	90	87	2,250	4,600
Geo. Washington Boulevard	86	83	2,000	6,700
Jerusalem Road & Hull Street	87	82	1,000	5,200
Last Hydrant on East Gate Lane	71	66	3,000	4,500
Pleasant Street & Downing Street	66	64	3,000	5,700

Table No. 4-3
ISO Required and Available Fire Flow for Hull
April 2007

Test Location	Static Pressure (psi)	Residual Pressure (psi)	Needed Flow at 20 psi (gpm)	Available Flow at 20 psi (gpm)
Main Street near Helen Street	84	34	3,500	1,100
Harbor View Road near Battery Road	66	17	3,000	950
Nantasket Avenue & T Street	90	54	4,500/2,250	2,000
Central Avenue & L Street	90	50	3,000	2,100
Nantasket Avenue &@ Bay Street	92	70	3,000	3,200
Nantasket Avenue & Kenberma Street	92	64	3,000	2,700
Nantasket Avenue & Park Avenue	90	60	2,500	3,200
Atlantic Avenue & School Street	79	79	2,000	2,900
Spring Street near Main Street	92	40	1,750	1,900
Pt. Allerton Avenue near Glover Avenue	82	55	2,500	1,800
Nantasket Avenue & Eastman Road	88	80	2,000	2,500
Salisbury Street & Barnstable Street	92	52	2,000	1,200
Manomet Street & Lewis Street	94	60	1,750	2,200
Nantasket Avenue & Westminster Avenue	92	62	2,500	3,200
Highland & Newton Street	48	1	1,500	950
Bay Avenue & A Street	92	58	1,500	2,100
Summit Avenue & Driftway Avenue	92	20	1,000	750
Mayflower Road & Hampton Circle	92	10	1,000	750

Table No. 4-4
ISO Required and Available Fire Flow for Cohasset
April 2007

Test Location	Static Pressure (psi)	Residual Pressure (psi)	Needed Flow at 20 psi (gpm)	Available Flow at 20 psi (gpm)
Elm Street & Border Street	90	8	3,000	600
Jerusalem Road & Hull Street*	90	84	1,500	1,800
Border Street & Parker Avenue	90	48	1,500	550
Atlantic Avenue & Lothrop Lane	84	50	750	600
Atlantic Avenue & Nichols Road	90	52	750	450
Jerusalem Road & Linden Drive	76	18	750	400
Jerusalem Road & Black Rock Road*	95	78	2,250	950
Hull Street & Lamberts Lane*	68	38	750	800
Surrey Drive & Forrest Avenue*	58	15	750	350

*Served by Aquarion.

approximately 750 gpm. Based on a review of the system, much of Hingham and most of the areas served by Aquarion in North Cohasset fall within these categories. The exceptions to this are several homes along Jerusalem Road. These homes are significantly larger than typical residential homes and would have higher needed fire flows due to the size and building material. Several of these homes are included in Cohasset's ISO testing results. An estimated fire flow of 750 gpm was used for most residential areas of Hingham and North Cohasset. Areas with homes between 11 feet and 30 feet have a recommended fire flow of 1,000 gpm. Based on a review of the system, much of the Hull system generally falls within this category. An estimated fire flow of 1,000 gpm was used for most residential areas of Hull. A fire flow of 1,500 gpm is recommended for homes closer than 10 feet apart.

4.3 Hydraulically Deficient Area

The estimated recommended fire flows were simulated on the computer model. All scenarios were run using projected 2034 MDD conditions and typical tank operating levels. Areas where the available fire flows did not meet the ISO recommended fire flow or estimated recommended fire flow were considered hydraulically deficient. Recommendations were developed to alleviate these deficiencies.

Priority 1 recommendations are intended to strengthen the transmission capabilities or provide the recommended ISO fire flows. Priority 2 recommendations were identified as part of a system wide evaluation and include improvements required at or near system extremities and in areas not included in the most recent ISO testing. A map depicting areas with hydraulic deficiencies can be found in Appendix C.

Priority 1 Recommendations

1. To increase transmission to the northern portion of Hull and to improve the estimated available fire flow, a new 12-inch diameter water main is recommended on Lewis Street from Nantasket Avenue, on Beach Avenue from Lewis Street to W Street, W Street from Beach Avenue to X Street, X Street from W Street to Y Street, and on Y Street from X Street to Nantasket Avenue. The existing water main on Beach Avenue from L Street to W Street is located within the sand dunes along the beach. This increases repair costs, inhibits substantial maintenance efforts, and causes concern with the Hull Conservation Commission. The new water main will be installed along an abandoned railroad bed adjacent to Beach Avenue. Services will have to be transferred to the new water main.

2. It is recommended that the existing Hull Booster Pump Station be upgraded to include fire pumps. The fire pumps would provide additional fire flow to all services north of the pump station.

3. To provide the inherent capacity for the ISO recommended fire flow on Main Street at Rosemary Lane in Hingham and to improve transmission capabilities in the water distribution system, a new 12-inch diameter water main is recommended on Main Street from Whiting Street to Scotland Street.

4. A new 12-inch diameter water main is recommended on Downer Avenue, North Street and Thaxter Street from the existing 12-inch diameter water main at Otis Street to the existing 12-inch diameter water main at South Street. This improvement would provide the inherent capacity for the ISO recommended fire flow on Downer Avenue and improve transmission capabilities in the water distribution system in Hingham.

5. Based on discussions with Aquarion Water Company and the Town of Hingham, there is a potential for development in the South Shore Industrial Park (SSIP). As a result, a study of the existing and proposed water system in the SSIP was completed. To meet existing ISO recommended fire flows as well as potential recommended fire flows, a new water storage tank was recommended. The water storage tank would provide the existing ISO recommended fire flow on Recreational Park Drive at Keith Way and on Industrial Road at Commerce Road. This will also improve the available fire flow throughout the SSIP. The tank would also help maintain adequate pressures throughout the SSIP during peak demands and allow for adequate pressure and estimated available fire flow as growth occurs in the SSIP. The water storage tank would have a capacity of approximately 750,000 gallons and constructed to an overflow of 282 feet to match the existing hydraulic gradeline of the Accord Tank. Aquarion does not currently own property in the SSIP. The Town of Hingham owns property within the SSIP area; however, the ground elevations in these areas are approximately 125 feet. To provide a tank with an overflow elevation of 282 feet on these Town parcels, a tank with a height of more than 150 feet tall would be required. The area along Commerce Way area, not owned by the Town, has an elevation of approximately 170 feet, which would allow for a tank of with an approximate height of 110 feet. If the SSIP is not developed as anticipated, an additional evaluation

should be conducted to determine a cost effective improvement to meet the existing recommended fire flows in the area.

6. A new 12-inch diameter water main is recommended on Beal Street from the existing 12-inch diameter water main near Fottler Road to the existing 8-inch diameter water main at Sergeant William B. Terry Drive. This improvement would provide the inherent capacity for the ISO recommended fire flow on Beal Street in Hingham.

7. To provide the inherent capacity for the ISO recommended fire flow at the Plymouth River Elementary School between Shimmer Road and Stanford Drive in Hingham, a new 12-inch diameter water main is recommended on High Street and Friend Street from the existing 12-inch diameter water main on Main Street to the existing 8-inch diameter water main near Stanford Drive.

8. A new 12-inch diameter water main is recommended on Atlantic Avenue from Forest Avenue to near Gunrock Avenue and a new 8-inch diameter water main is recommended on Summit Avenue. A new 8-inch diameter water main is also recommended on Black Rock Road to connect the existing 8-inch diameter water main on Black Rock Road to the existing water main on Forest Avenue. This improvement will provide the inherent capacity for the ISO recommended fire flow on Forest Avenue in Cohasset as well as improve the estimated available fire flow along Atlantic Avenue in Hull and along Forest Avenue, Black Rock Avenue and Surry Drive in Cohasset.

9. To increase transmission to the northern portion of Hull and to improve the estimated available fire flow, a new 8-inch diameter water main is recommended on Central Avenue from A Street to Cadish Avenue and on Cadish Avenue from Central Avenue to Nantasket Avenue.

10. A new 12-inch diameter water main is recommended on Rockaway Avenue from Wyola Road to Rock View Road. Additionally, a new 12-inch diameter water main is recommended on Wyola Road and George Washington Boulevard from the proposed 12-inch diameter water main on Rockaway Avenue to the 10-inch diameter water main on Park View Avenue. This improvement will provide the inherent capacity for the ISO fire flow on George Washington Boulevard in Hull.

11. To provide the inherent capacity for the ISO recommended fire flow on Lincoln Street in Hingham, a new 12-inch diameter water main is recommended on Lincoln Street from the recommended 12-inch diameter water main on Thaxter Street to the existing 8-inch diameter water main near Langlee Road.

12. To provide the inherent capacity for the ISO recommended fire flow of 2,250 gpm on Jerusalem Road in Hull, a new 12-inch diameter water main is recommended on Jerusalem Road from the existing 12-inch diameter water main on Hull Street to the proposed 12-inch diameter water main on Atlantic Avenue. This ISO is likely due to the large residential homes in this area. The size of these homes results in higher recommended flows than typical residential homes.

13. A new 12–inch diameter water main is recommended on George Washington Boulevard in Hingham from the existing 12-inch diameter water main on Rockland Street to the end of the main. This improvement would provide the inherent capacity for the ISO recommended fire flow on George Washington Boulevard in Hingham.

14. A new 8-inch diameter water main is recommended on Pleasant Street in Hingham from the existing 8-inch diameter water main on Pleasant Street to the existing 20-inch diameter water main on Pleasant Street. This improvement would provide the inherent capacity for the ISO recommended fire flow on Pleasant Street in Hingham.

15. To provide the inherent capacity for the ISO recommended fire flow on East Gate Lane in Hingham, a new 12-inch diameter water main is recommended on Collins Road from the existing 20-inch diameter water main on Kilby Street to the end of Collins Road.

Priority 2 Improvements

16. A new 8-inch diameter water main is recommended on Edgewater Road from the existing 8-inch diameter water main to Nantasket Avenue to provide the recommended residential fire flow to the area.

17. A new 8-inch diameter water main is recommended on Hobart Street from the existing 20-inch diameter water main on Main Street to the existing 8-inch diameter water main near Cross Street. This improvement would improve transmission in the water distribution system, increase the available fire flow in the area of Hobart Street and Newbridge Street in Hingham, and improve a hydraulic restriction on Hobart Street.

18. To improve transmission capabilities in the water distribution system in Hingham, a new 8-inch diameter water main is recommended on Burditt Avenue and Fearing Road from the existing 6-inch diameter water main on Lincoln Street to the existing 8-inch diameter water main near Cottage Street.

19. To increase the available fire flow in the area of Howe Road and Tad Lane in Hull, a new 8-inch diameter water main is recommended from the recommended 12-inch diameter on Jerusalem Road to the end of Howe Road.

20. The existing 6-inch diameter water main on Hull Street and East Street from Chief Justice Cushing Highway to Spruce Street in Hingham should be replaced with a new 8-inch diameter water main to improve the transmission capabilities and provide the recommended residential fire flow to the area.

21. To eliminate a hydraulic restriction on Hull Street in Hingham, an 8-inch diameter water main is recommended on Hull Street from the existing 8-inch diameter water main near Clark Drive to the existing 8-inch diameter water main near Canterbury Street.

22. A new 8-inch diameter water main is recommended on Spruce Street from Hull Street to the end of Spruce Street in Hingham to provide the recommended residential fire flow to the area.

23. To provide the recommended residential fire flow on Summit Drive, a new 8-inch diameter water main is recommended on Harborview Drive from Thaxter Street to Summit Drive and on Summit Drive from Harborview Drive to the end of the main.

24. A new 8-inch diameter water main is recommended on Rockwood Road from East Street to Ledgewood Circle and on Ledgewood Circle in Hingham to provide the recommended residential fire flow to the area.

25. A new 8-inch diameter water main is recommended on Whitcomb Avenue, Howland Lane, and Grist Mill Lane from High Street to the end of Grist Mill Lane. This improvement will provide the recommended residential fire flow to the area.

26. To provide the recommended residential fire flow, a new 8-inch diameter water main is recommended on Smith Road from Hobart Street to Butler Road.

SECTION 5 – Critical Component Assessment

5.1 General

A critical component assessment was performed for the water distribution system to evaluate the impact of potential water main failures on the water distribution system. The critical component assessment includes identification of critical areas served, critical water mains, and the need for redundant mains.

5.2 Evaluation Criteria

Critical areas served are locations in the distribution system that require continual water supply for public health, welfare or financial reasons. Examples of critical service areas include hospitals, nursing homes, schools, and business districts. All water mains within 1,000 feet of a critical area are considered a critical component. Because water storage tanks and sources provide water and maintain pressure to critical service areas, tanks and primary sources are also considered critical areas. Therefore, any water main within 1,000 feet of a water storage tank or primary source is considered a critical component.

Critical water mains are those mains that are the sole transmission main from a source or tank. In addition, main transmission lines that do not have a redundant main are considered critical. The evaluation included a visual review of the water mains leading into and out of the critical areas and the transmission grid.

5.3 Critical Components

Critical areas served, critical supply mains, and redundant mains were evaluated in the water system based on the criteria described above. The following provides a listing of the areas that are considered critical components.

Critical Areas Served

A system-wide review of critical areas served such as health care facilities and schools was completed. Other critical areas were identified during the workshop with the Aquarion staff. A total of 29 critical services were identified as shown on Table No. 5-1.

Critical Water Mains

Critical water mains include primary transmission lines as well as mains connecting water storage tanks and sources to the system. Critical mains are highlighted on the Critical Components Map found in Appendix D.

In addition to transmission mains, the existing water main on Beach Avenue from L Street to X Street in Hull has historically been problematic. There have been breaks on this main and because the water main is located within the sand dunes, repairs are costly. This water main is also a concern with the Conservation Commission, because failures on this main can cause substantial damage to the sand dunes. This water main is considered critical because of the concerns associated with a failure.

Table No. 5-1
Critical Components

Name	Address	Type
Coast Guard Station at Allerton Point	93 Main Street, Hull	Large User
Town Hall – Hingham	210 Central Street, Hingham	Emergency Center
Town Hall – Hull	253 Atlantic Avenue, Hull	Emergency Center
Lillian Jacobs School	180 Harborview Road, Hull	School
Memorial Middle School	81 Central Avenue, Hull	School
Hull High School	180 Main Street, Hull	School
Hingham High School	17 Union Street, Hingham	School
Hingham Middle School	1103 Main Street, Hingham	School
Foster Elementary School	55 Downer Avenue, Hingham	School
Plymouth River Elementary School	200 High Street, Hingham	School
South Elementary School	831 Main Street, Hingham	School
Derby Academy	56 Burditt Avenue, Hingham	School
Notre Dame Academy	1073 Main Street, Hingham	School
St. Paul's School	18 Fearing Road, Hingham	School
East Elementary School	2 Collins Road, Hingham	School
South Shore Medical Center	35 Pond Park Road, Hingham	Health Care Facility
Welch Healthcare	15 Condito Road, Hingham	Health Care Facility
Hospice Residence at Turkey Hill	86 Turkey Hill Lane, Hingham	Health Care Facility
Harbor House Nursing & Rehabilitation	11 Condito Road, Hingham	Nursing Home
Queen Anne's Nursing Home	50 Recreation Park Drive, Hingham	Nursing Home
Cohasset Knoll Nursing & Rehabilitation Facility	1 Chief Justice Cushing Highway, Cohasset	Nursing Home
Deerfield Senior Services	20 Pond Park Road, Hingham	Nursing Home
Linden Ponds	203 Linden Ponds Way, Hingham	Nursing Home
Turkey Hill Tank	Turkey Hill Lane, Hingham	Water Storage
Accord Tank	Whiting Street, Hingham	Water Storage
Downing Street Well	Downing Street, Hingham	Water Storage
Russ Electric, Inc.	99 Industrial Park Road, Hingham	Business District
Central Fire – Hingham	339 Main Street, Hingham	Fire Department
Hingham/Hull District Water Treatment Facility	900 Main Street, Hingham	Pump Station

SECTION 6 – Asset Management

6.1 General

The Hingham/Hull water distribution system includes approximately 186 miles of water main varying in size and material. A number of factors including age, material, break history, soil conditions, pressure, and water quality affect the decision to replace or rehabilitate a water main. Using an asset management approach, each water main in the system was assigned a grade based on these factors. The grades were then used to establish a prioritized schedule for water main replacement or rehabilitation.

6.2 Data Collection

Information regarding the water main diameters and material was obtained from existing water distribution system maps and information provided by Aquarion. Information regarding pipe age, break history, and distribution system water quality was based on the operators' field experience and best estimates.

6.3 Evaluation Criteria

To prioritize water main replacement or rehabilitation, a water main grading system has been established. The grading system uses the water main characteristics such as age, material, break history, water quality, diameter, pressure, and soil characteristics to assign point values to each pipe in the system. Each category is assigned a rating between zero and 100 with zero being the most favorable and 100 being the worst case within the category. Each category is then given a weighted percentage, which represents priorities within the system. It is at the Owner's discretion to adjust the weight based on system performance and condition. Our recommendation is to assign a maximum of 30 percent to any one category. The rating is then multiplied by the weight. The weighted rating for each performance criteria will be utilized to determine the overall rating per pipe. Those pipes with the highest grade are most in need of replacement or rehabilitation.

To establish a rating system specific to the Hingham/Hull water system, a workshop was held with the system management and operators. During the discussion, it was determined that water main diameter, corrosive soils and water main material are priorities for the Hingham/Hull system. The grading system is shown in Table No. 6-1 and discussed in detail later in this section. This grading system has been updated since the 2011 CEP due to increased knowledge of the distribution system.

Age/Material

The water industry in the United States followed certain trends over the last century. The installation date of a water main correlates with a specific pipe material that was used during that time as shown on Table No. 6-2. For example, up until about the year 1958, unlined cast iron water mains were the predominant pipe material installed in water systems. Factory cement lined cast iron mains were manufactured from the late 1940s to about the mid 1970s, when pipe manufacturers switched primarily to factory cement lined ductile iron pipe.

Table No. 6-1
Asset Management Rating

Weight	Performance Criteria	Rating	Weighted Rating
20%	Breaks		
	Five or More Breaks	100	20
	Two to Four Breaks	80	16
	One Break	60	12
	No History of Breaks	0	0
30%	Material		
	Galvanized Steel	100	30
	Asbestos Cement	80	24
	Unlined Cast Iron	70	21
	Factory Lined Cast Iron	20	6
	Prestressed Concrete	10	3
	PVC	5	1.5
	Ductile Iron	5	1.5
25%	Diameter		
	Less than 4-inch water main	100	25
	4-inch water main	90	22.5
	6-inch water main	80	20
	8-inch water main	40	10
	10-inch water main	20	5
	12-inch water main	10	2.5
	14-inch water main or larger	1	0.25
20%	Installation Date		
	Pre 1900	85	17
	1900-1909	80	16
	1910-1919	75	15
	1920-1929	70	14
	1930-1939	100	20
	1940-1949	95	19
	1950-1959	90	18
	1960-1969	30	6
	1970-1979	20	4
	1980-1989	10	2
	1990-1999	5	1
	2000-2014	3	0.6
5%	Soil		
	Salt Water	100	5
	Potentially corrosive soils	80	4
	Gravel, sand	0	0

Table No. 6-2
Pipe Material by Installation Year

Installation Year	Asbestos Cement (length, ft)	Ductile Iron (length, ft)	Galvanized Steel (length, ft)	PVC (length, ft)	Prestressed Concrete (length, ft)	Cement Lined Cast Iron (length, ft)	Unlined Cast Iron (length, ft)	Total (length, ft)
1890-1899			227				55,302	55,529
1900-1909			1,365				52,978	54,343
1910-1919			2,486				115,612	118,098
1920-1929			7,685				62,915	70,600
1930-1939			1,984				25,816	27,800
1940-1949	22,253		864				34,382	57,499
1950-1959	118,471		1,814		9,660		37,044	176,989
1960-1969	5,893	803			3,642	149,652	321	160,311
1970-1979		30,141	1,415	1,251		29,542		62,349
1980-1989		73,462				3,826		77,288
1990-1999		80,128		1,069				81,464
2000-2014		53,652		508				54,160
Total	146,617	238,186	17,840	2,828	13,302	183,020	394,637	996,430

Cast iron water mains consist of two types: pit cast and sand spun. Pit cast mains were generally manufactured up to the year 1930 while sand spun mains were generally manufactured between 1930 and 1976. Pit cast mains with diameters between 4-inch and 12-inch do not have a uniform wall thickness but are generally thicker and stronger than spun cast mains. However, pit cast mains in this range of sizes may have "air inclusions" as a result of the manufacturing process. This reduces the overall strength of the main, which makes it more prone to leaks and breaks. Although sand spun mains have a uniform wall thickness, the overall wall thickness was thinner than the pit cast mains. The uniformity provided added strength, however, the thin wall thickness made it more susceptible to corrosion and breaks. Pit cast mains 16-inch diameter and larger have very thick pipe walls and are generally stronger than the thinner walled sand spun cast mains. While the transition to factory cement lined cast iron mains had begun in the late 1940's, most cast iron water mains that were manufactured were unlined prior to the year 1958. Unlined cast iron mains increased the potential for internal corrosion. By 1958 the majority of cast iron mains manufactured had a factory cement lining. Rubber gasket joints were also introduced around 1958. Prior to this date, joint material was jute (rope type material) packed in place with lead or a lead-sulfur compound, also known as "leadite" or "hydrotite." Leadite type joint materials expand at a different rate than iron due to temperature changes. This can result in longitudinal split main breaks at the pipe bell. Sulfur in the leadite can promote bacteriological corrosion that can lead to circumferential breaks of the spigot end of the pipe. The exact date of the changeover for the Hingham/Hull system from cast iron to cement lined cast iron is not known, therefore, it was assumed that cast iron water mains installed after 1960 was factory lined.

Factory lined cast iron was manufactured and installed up until about 1973. Overlapping this period, factory cement lined ductile iron main was manufactured from the 1950s, and continues to be manufactured today. Factory cement lined cast iron and ductile iron pipe provided increased protection against internal corrosion. Aquarion has also field cement lined some of the water mains. Approximately 18 percent of the system consists of water mains that are factory or field cement lined cast iron water mains. Unlined cast iron water mains make up approximately 40 percent of the water system.

Prestressed concrete cylinder pipe (PCCP) was first produced in 1942 and most widely used in the early 1970s. There are two types of PCCP, embedded-cylinder pipe (ECP) and lined-cylinder pipe (LCP). LCP typically ranges from 16-inch to 48-inche in diameter and ECP is 48-inch and larger diameter pipe. Both types are a thin cement lined steel cylinder wrapped with prestressed wire. The ECP also has a second layer of concrete between the steel cylinder and the wire. The steel cylinder and wires are susceptible to corrosion. Approximately one percent of the system consists of PCCP water mains. These water mains are all 20-inch diameter water mains and make up a portion of the transmission grid of the system.

Between 1958 and 1970, the water industry also utilized asbestos cement (AC) pipe for their expanding water systems. An advantage of AC pipe is that it resists tuberculation build up, resulting in less system head loss. However, based on external influences such as soil type and high groundwater, the structural integrity of AC mains can deteriorate over time, thereby becoming sensitive to pressure fluctuations and/or nearby construction activities. Approximately 15 percent of the system consists of AC water mains.

Approximately 24 percent of the system is cement lined ductile iron water main. This material was introduced in the United States in 1950s, however, was not widely used until the 1970s. According to the Ductile Iron Pipe Research Association (DIPRA), ductile iron pipe retains all of cast iron's qualities such as machinability and corrosion resistance, but also provides additional strength, toughness, and ductility. It has been discovered that the ductile iron pipe manufactured in the early stages of development has had problems. The majority of the ductile iron water main installed in the Hingham/Hull system was installed after 1970.

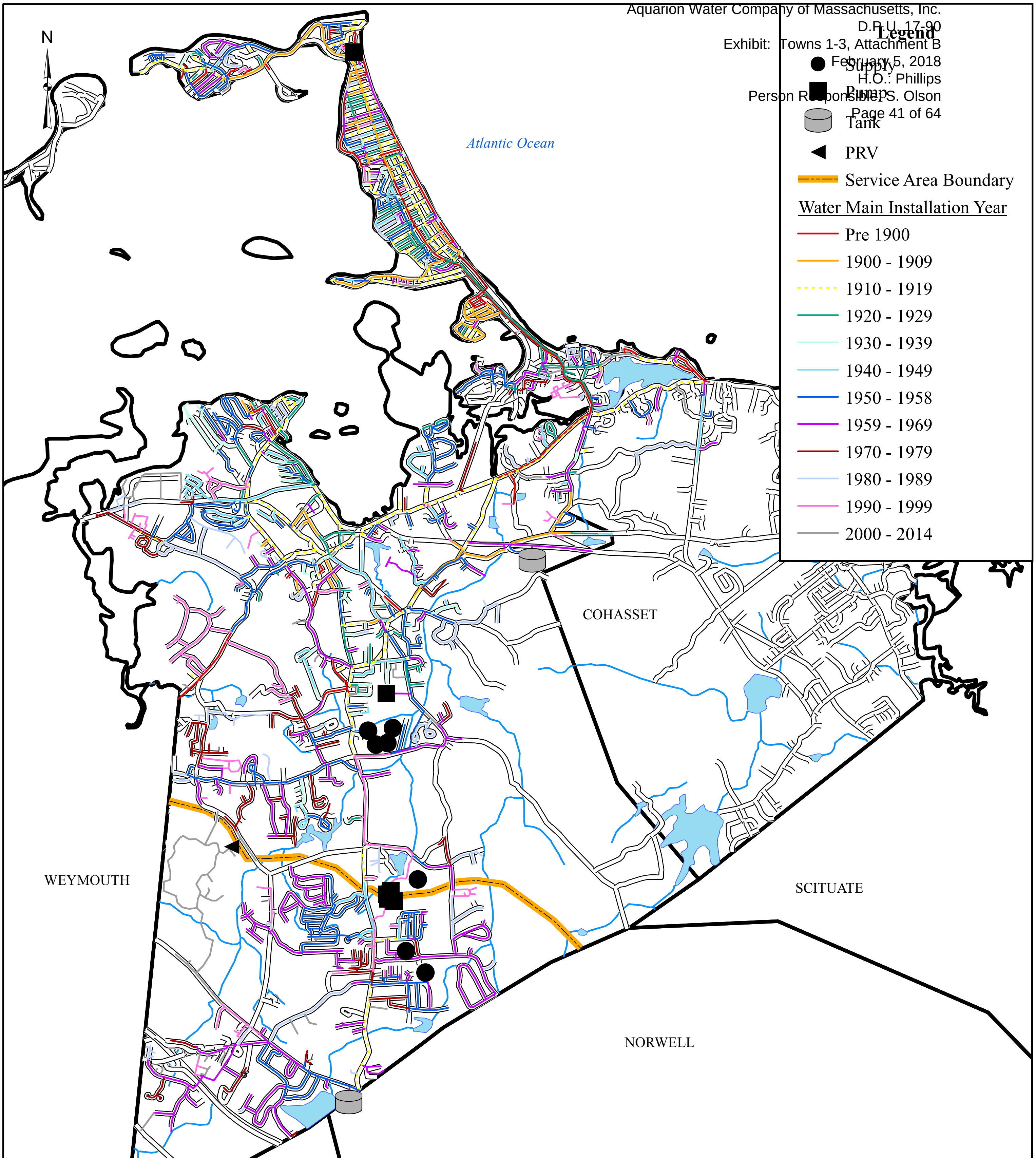
In general, the oldest water mains in the system received the highest rating. Water main installed in the 1930s to 1950s have higher ratings than mains installed prior to 1930. The 1930s to 1950s is when the sand spun cast iron water mains were utilized, which have had more known issues than the older pit cast water mains due to thinner wall thicknesses. A significant rating decrease occurs around 1958, which represents the timeframe when cement lined cast iron water mains were introduced and around 1960 when ductile iron water main was introduced into the Hingham/Hull system. Figure No. 6-1 and Figure No. 6-2 present the installation year of the water mains and the materials, respectively.

Diameter

The Hingham/Hull system consists of water mains ranging in diameter from less than 4-inch to 24-inch. Approximately 10 percent of the system is comprised of 4-inch diameter water main or smaller, approximately 30 percent is 6-inch diameter water main, 38 percent is 8-inch diameter water main, approximately one percent is 10-inch, and approximately six percent of the system is 14- inch diameter or larger water main.

In general, as the diameter of a pipe increases, the strength increases. In most cases, failure occurs in the form of ring cracks. This is primarily the result of bending forces on the pipe. Pipes that are 6-inch in diameter are more likely to deflect or bend than a larger diameter main. Pipes that are 8-inch in diameter are less likely to break from bending forces than 6-inch mains due to their increased diameter and resulting increased moment of inertia.

In addition, the pipe wall thickness typically increases as the pipe diameter increases. Pipes that are 16-inches in diameter and larger have significantly thicker walls than 12-inch diameter pipe and smaller diameter mains, such that in addition to superior bending resistance, they also are much more resistant to failure from pipe wall corrosion. The rating system for the diameter of the water mains follows the concept that 4-inch diameter water mains are not as strong as 24-inch diameter water mains. Therefore, a rating of 100 was given to 4-inch diameter and smaller water mains and a rating of five was given to the 14-inch diameter and larger water mains. Table No. 6-1 shows a significant drop in the rating score between a 6-inch diameter water main (80) and 8-inch diameter water main (40). This is due to greater bending strength. An 8-inch diameter water main has proven to have nearly twice the bending strength of a 6-inch diameter water main. Figure No. 6-3 presents the various diameter sizes throughout the distribution system.



TATA & HOWARD

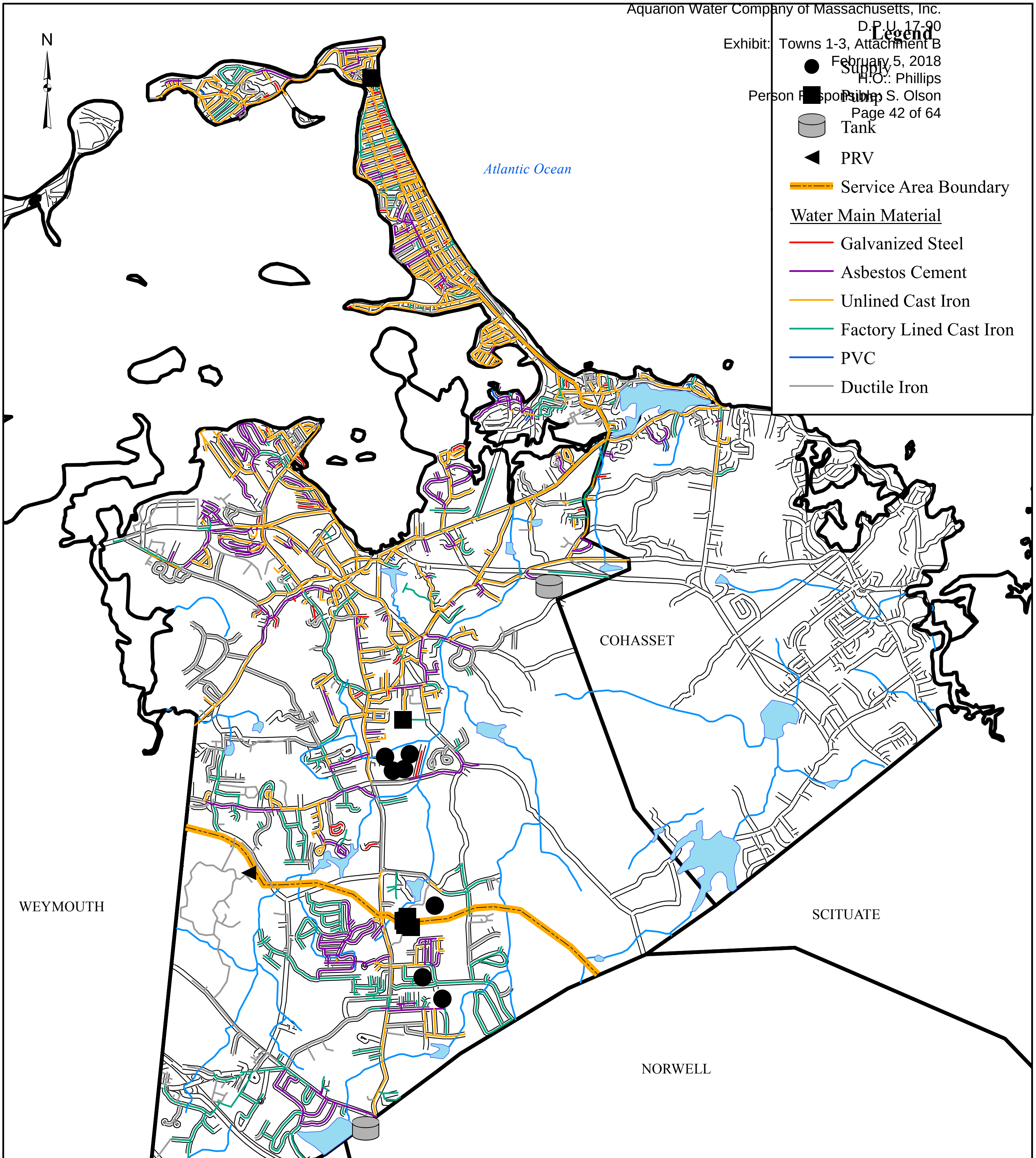
Date: November 2014
Approximate Scale: 1' = 6,000'

Water Main Installation Year

Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
Aquarion Water Company

Figure No.

6-1



TATA & HOWARD

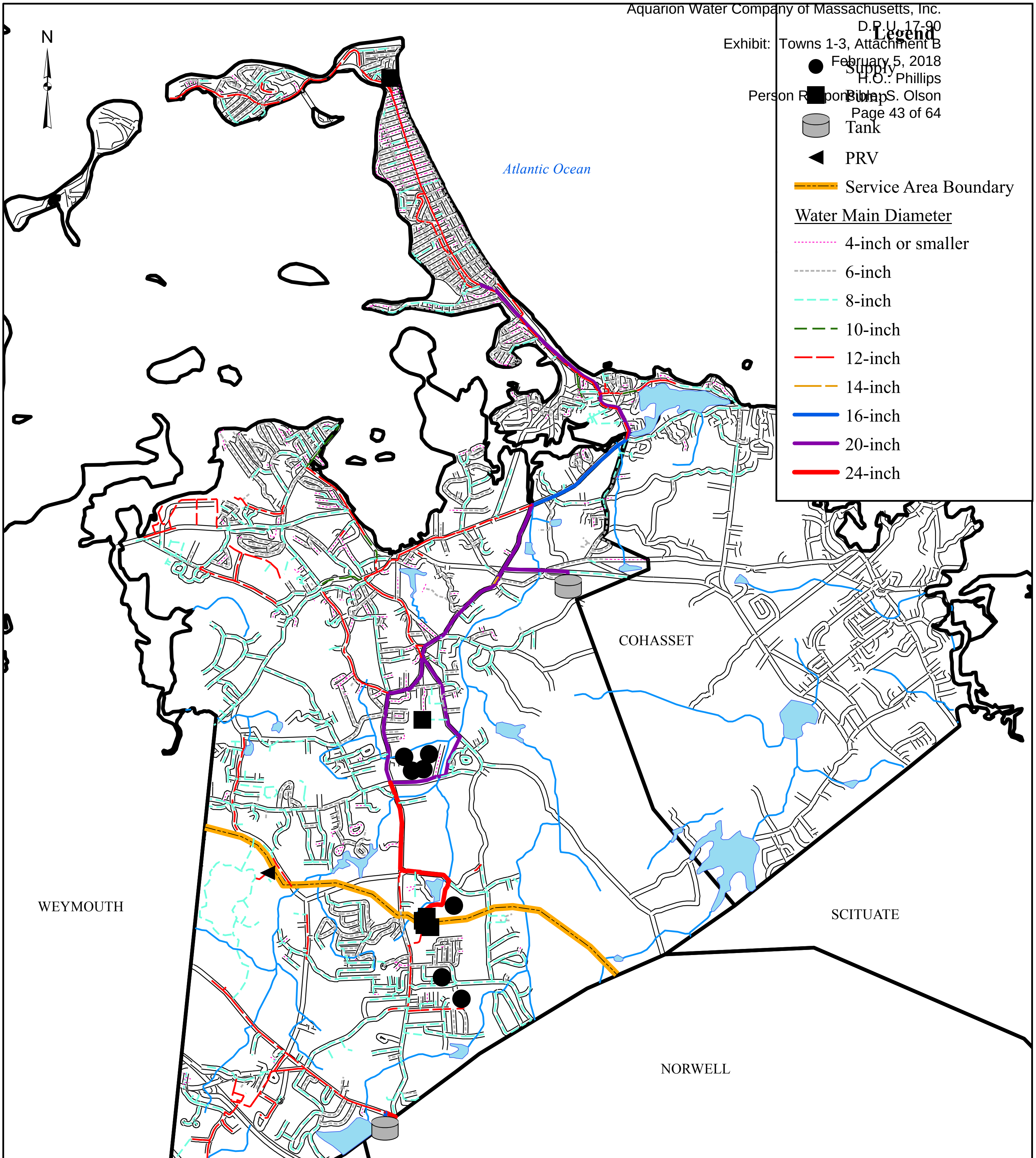
Date: November 2014
Approximate Scale: 1' = 6,000'

Water Main Material

Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
Aquarion Water Company

Figure No.

6-2



TATA & HOWARD

Date: November 2014
Approximate Scale: 1' = 6,000'

Water Main Diameter

Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
Aquarion Water Company

Figure No.

6-3

Break History

Based on conversations with company personnel, the Hingham/Hull water system experiences an average of approximately 20 breaks per year. In relation to the total miles of water main in the system, this equates to approximately 11 breaks per 100 miles per year. In comparison to the national average of 25 breaks per 100 miles per year, the Hingham/Hull water system is in good condition. However, each water main break costs the system time and labor. They also cause disruption to the public and water consumers. At some point, it becomes more efficient to replace a main than to continue repairing it. Based on Aquarion water main break records, there are several areas in the system that have experienced frequent breaks. These areas are given a rating of 100 while areas with no known breaks received a rating of zero. Figure No. 6-4 presents areas with a history of breaks. There have been main breaks on the 20-inch diameter cast iron water main on Nantasket Avenue in Hull. Due to the potential for significant disruption in services and the potential costs for damages and repair, the 20-inch was given the highest break rating.

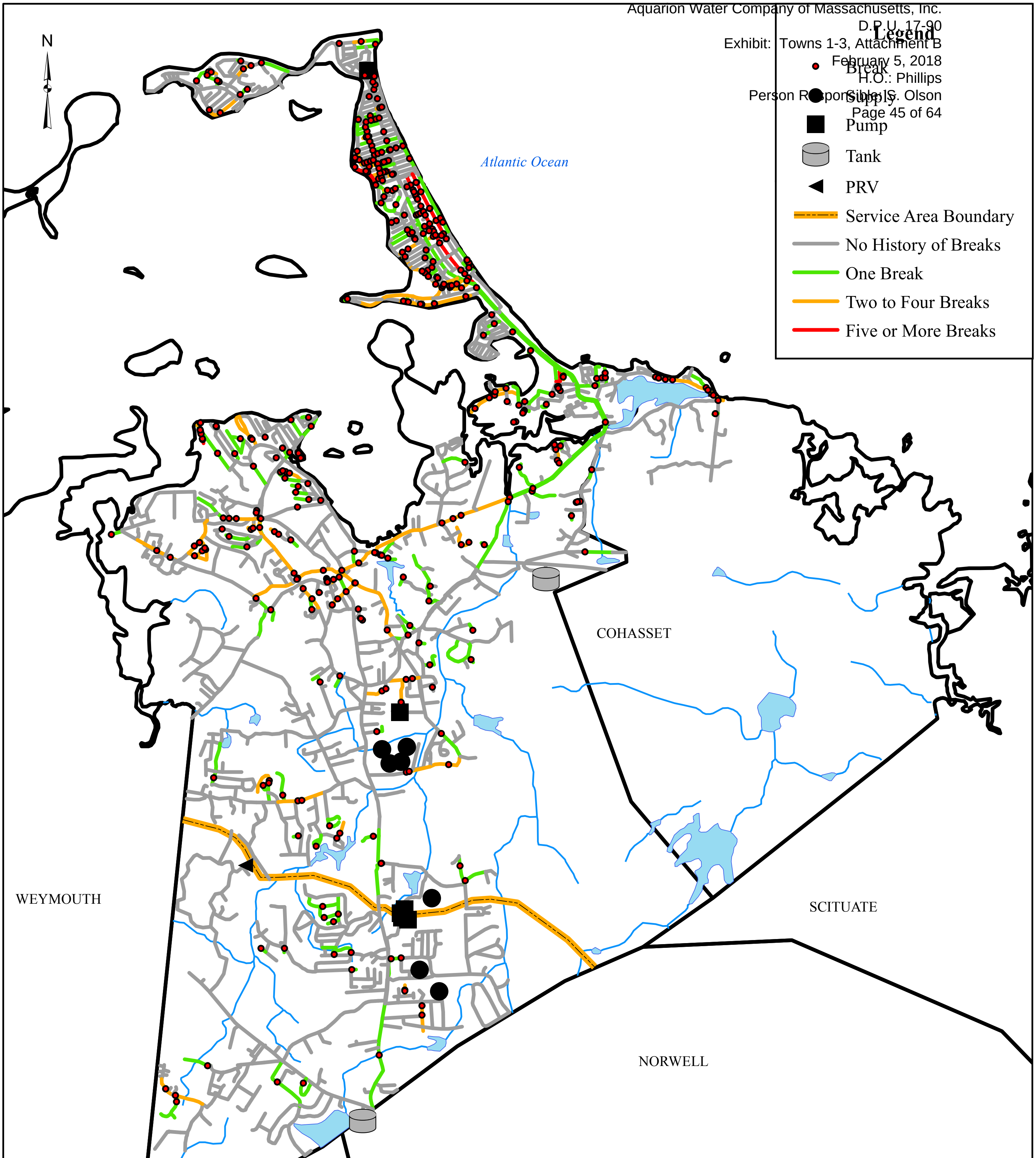
Water Quality

In general, the water quality in the Hingham/Hull water system meets or exceeds state and federal water quality standards. In the 2011 CEP, there were several areas reported as having water quality complaints. Since then, these water quality concerns have no longer been an issue. The water quality complaints from customers have decreased. Because of this, water quality is no longer an area of concern regarding the pipe condition and water quality was removed as a criteria in the asset management grading system.

Soils

Water main degradation can occur both internally and externally. Factors that increase the rate of external corrosion include high groundwater, soils with low calcium carbonate, or soils with high acidity or sulfate. Wetlands areas have greater potential to cause external corrosion of water mains than other soil conditions. Areas that are under the influence of ocean water also have increased corrosion potential due to the high salt content. Aquarion has experienced external corrosion in areas near the ocean as well as areas where the pipes are in clay which is a low permeable soil. As a result, groundwater will not drain away from the pipe as quickly. The additional contact with water can accelerate the rate of external corrosion of a pipe. Aquarion has identified several clay areas including Crow Point in Hingham, several hills in Hull and portions of Jerusalem Road in Cohasset.

As shown on Figure No. 6-5, much of the Hingham/Hull area is made up of potentially corrosive soils. Areas where the water system and the potentially corrosive soils coincide are considered areas of potential exterior corrosion. Water mains located in areas with salt water influence were assigned a rating of 100 and other areas of potentially corrosive soil were assigned a rating of 90, while all other pipe was assigned a rating of zero.



TATA & HOWARD

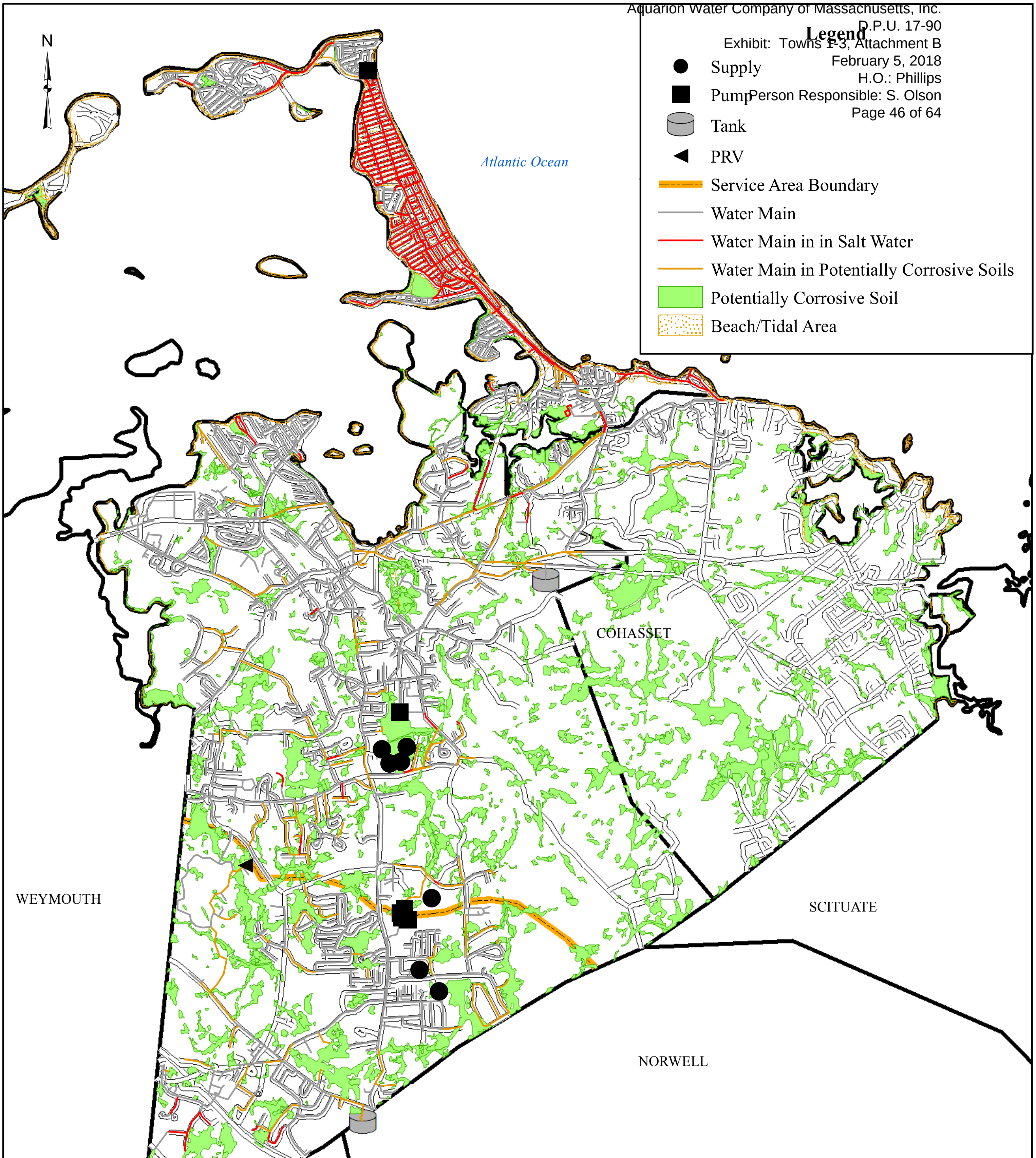
Date: November 2014
Approximate Scale: 1' = 6,000'

Areas with History of Breaks

Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
Aquarion Water Company

Figure No.

6-4



TATA & HOWARD

Date: November 2014
Approximate Scale: 1' = 6,000'

Potentially Corrosive Soils

Capital Efficiency Plan™ Update
Hingham/Hull, Massachusetts
Aquarion Water Company

Figure No.

6-5

Pressures

The static pressures of the system were evaluated under existing demands and conditions. Due to the ground elevations and the existing operating scenario, there are no areas in the system with pressures greater than 120 psi and there are very few areas of the system with static pressures greater than 100. Because high static pressures are not a concern, pressure was not considered as a criteria in the asset management grading system.

6.4 Asset Management Areas of Concern

Based on the asset management ratings, there are several areas of concern in the system. Water mains with a total rating between zero and 30 are considered to be in good to excellent condition. Areas with a total rating between 31 and 60 are considered to be in fair to good condition, and areas with a total rating greater than 60 are considered to be in poor to fair condition. Asset management ratings are presented graphically in Appendix E. Asset management input data for each pipe is included with the hydraulic input data in Appendix B.

SECTION 7 – Recommendations and Conclusions

7.1 General

The following summarizes the findings of the study and presents a prioritized plan for recommended improvements and associated costs. The prioritization of improvements allows for constructing the necessary improvements over an extended period of time as funds allow. Costs are based on the August 2014 Engineering News Record (ENR) construction cost index for Boston, MA of 12405.36 and include costs associated with water services, hydrants, and other appurtenances, permanent and temporary trench pavement, and a 25 percent allowance for engineering and contingencies. Estimates do not include costs for land acquisition, easements, or legal fees. All costs are based on completed the full length of water main indicated. If portions of the water main are completed in phases, the overall cost of the project will increase.

The capital improvement projects considered by this study will provide a direct benefit to the overall level of service to the Hingham/Hull customers, reduce operation and maintenance costs by reducing the frequency of water main failures and the damage they cause, as well as improve fire protection to the homeowners and businesses.

The Water Research Association's (formerly the American Water Works Research Foundation) study on "Cost of Infrastructure Failure," which was completed in 2002, found that in addition to direct costs paid by water utility ratepayers for water main failures, there are also societal costs, which are paid by the public. Examples of the direct costs include outside contractor costs, engineering costs, police assistance, fire department assistance, electrical, telephone, and gas utility damage costs, landscaping restoration costs, and laboratory costs. Examples of societal costs included the cost of traffic impacts, business customer outage impacts, public health impacts (including loss of life), property damage not covered by direct costs, and the cost of reduced firefighting capability during the failure event.

Replacement of one percent of a system each year (a 100 year replacement cycle) is a reasonable guideline based on industry experience and analysis. For the Hingham/Hull distribution system, this would equate to approximately 9,800 linear feet of water main replacement each year as a guideline. Regular rehabilitation of water mains reduces main failures, leakage, and water quality issues. Water main rehabilitation can also provide socio-economic benefits by reducing operational costs associated with chemical and energy usage. Rehabilitation or replacement of water mains that are inadequately sized to provide needed fire protection will improve public safety.

7.2 General Recommendations

To maintain a comprehensive database of the condition of the system, it is recommended that Aquarion establish a water main failure database. Water main failures should be recorded along with the nearest street address and the properties of the failed main such as diameter, material, joint type, type of lining, and type of failure such as ring crack, lateral split, hole in the pipe, "punky" AC pipe failure, or joint leak. If possible, Aquarion should include the apparent cause of the failure such as frost load, traffic load, direct contractor damage, settlement, water hammer, external soil corrosion, or stray current. This data can be used to create a Water Main Failure Map for identifying areas of concern in the system on an ongoing basis. The map can be used to easily identify break locations and determine if streets or areas have a higher frequency of failures and to view any patterns in the location, type, pipe manufacturer, or other patterns in occurrences of failure. The water main failure database will aid Aquarion in making water main rehabilitation and replacement decisions in the future. In addition, it is recommended that Aquarion maintain data on pipe crushing results from water mains that have failed. At the time of a main failure, a one foot section of the water main should be cut from the pipe that will remain in place (adjacent to the repair). The sample will then need to be marked with collection date, installation date, diameter, location, and any information regarding the type of main failure. It is then recommended that this coupon is analyzed further and data is recorded on results. It is also recommended that Aquarion continue to update the database of new or rehabilitated water mains. The database should include water main diameter, material, lining, joint type, soil conditions, and date of installation.

It is recommended that prior to installation of all new ductile iron water mains, Aquarion test the soils in the area of the new main to determine corrosion potential. If the soil is found to be potentially corrosive, Aquarion should consider wrapping the main with polyethylene to protect against external corrosion. Wrapping is a relatively inexpensive practice that can extend the life of new ductile iron pipe. In addition, wrapping helps to protect the pipe from stray currents that may develop near the main.

Aquarion should continue to perform regularly scheduled maintenance programs, including hydrant flushing, inspection and maintenance at the wells and pump stations, pressure reducing valves, and meter testing/calibration. Aquarion should continue the existing replacement program during which hydrants and valves that do not function as intended are identified and replaced. These deficiencies are normally identified through routine operation and during the system-wide flushing program.

7.3 Water Distribution System Improvements

Based on the Three Circles Approach, a prioritized list of improvements was created. Improvements were separated into three phases. The Phase I and Phase II Improvements are prioritized based on hydraulic needs, location in the distribution system, and the condition of the water main. In general, the Phase I Improvements include water mains that fall into all three of the circles. Phase II Improvements generally include water mains that fall into two of the three circles. These improvements strengthen the transmission grid, eliminate potential asset management concerns, and provide redundancy.

Phase III Improvements generally fall into one circle. These improvements include the remaining hydraulic recommendations from Section 4 and areas with high asset management ratings. Phase III Improvements should be completed as funds become available. Phase III Improvements have been divided into two sections (Phase IIIa and IIIb). Phase IIIa improvements generally include recommendations that represent the remaining hydraulic improvements from Section 4. Phase IIIb Improvements include the water mains with high asset management ratings that should be replaced when funding becomes available. The hydraulically deficient areas, critical component considerations, and asset management ratings are combined on one Three Circles Integration Map included in Appendix F.

It should be noted that the list of improvements is extensive due to the nature of this report. This results in a high associated cost if all of the suggested improvements were constructed. The intent of the prioritization, therefore, is to serve as a guide for implementation from the most needed to the least needed improvements based on the prioritization and weighted criteria established jointly by Aquarion and Tata & Howard. These improvements would most logically be constructed over an extended period of time.

Table No. 7-1, at the end of this section, includes a prioritized list of Phase I Improvements and the hydraulic, critical component, and asset management status of each improvement. Table No. 7-2 includes the linear footage and estimated cost of each Phase I Improvement. Table No. 7-3 includes a prioritized list of Phase II Improvements and Table No. 7-4 includes the linear footage and estimated cost of each Phase II Improvement. Table No. 7-5 includes a list of Phase IIIa Improvements and the hydraulic, critical component, and asset management status of each improvement. Table No. 7-6 includes the linear footage, and estimated cost of each Phase IIIa Improvement. Table No. 7-7 includes the asset management rating, linear footage, and estimated cost of each Phase IIIb Improvement.

A recommended improvements map is included in Appendix G. It should be noted that for any cleaning and lining project, it is recommended that a pipe section be tested or a coupon of the water main be evaluated prior to designing the project.

Phase I Improvements

1. To increase transmission to the northern portion of Hull and to improve the estimated available fire flow, a new 12-inch diameter water main is recommended on Lewis Street from Nantasket Avenue to Beach Avenue, Beach Avenue from Lewis Street to W Street, W Street from Beach Avenue to X Street, X Street from W Street to Y Street, and Y Street from X Street to Nantasket Avenue. The existing water main on Beach Avenue is considered a critical main. The existing water main from L Street to W Street is located within the sand dunes along the beach. This impedes repair costs, inhibits substantial maintenance efforts, and causes concern with the Hull Conservation Commission. The new water main will be installed along a utility easement adjacent to Beach Avenue. Services will have to be transferred to the new water main. Most of the existing water main is considered to be in poor to fair condition. The high asset management rating of 36 to 75 is due to history of breaks, material, installation year, and soil conditions. The estimated probable construction cost for approximately 6,700 linear feet of 12-inch diameter water main is $1,885,000.

2. A new 12-inch diameter water main is recommended to replace the existing 6-inch and 8-inch diameter water mains on High Street and Friend Street from Stanford Drive to Main Street. The existing water main is considered in poor to fair condition. The high

asset management rating of 52 to 75 is due to installation year, soil conditions, and material. This improvement will provide the inherent capacity for an ISO recommended fire flow. This main is also considered critical because it serves the Plymouth River Elementary School. The estimated probable construction cost for approximately 4,800 linear feet of 12-inch diameter water main is $1,350,000.

3. A new 12-inch diameter water main is recommended to replace the existing 6-inch and 8-inch diameter water mains on North Street from Thaxter Street to West Street and on Downer Avenue from Otis Street to Broad Cove Road. This improvement will provide the ISO recommended fire flow on Downer Avenue and improve transmission capabilities in the water distribution system. The main is also critical because it is located along the transmission grid. The existing water main is considered in poor to fair condition. The high asset management rating of 52 to 70 is due to history of breaks, soil condition, size, and material. The estimated probable construction cost for approximately 11,000 linear feet of 12-inch diameter water main is $3,094,000.

4. A new 8-inch diameter water main is recommended on Pleasant Street from Hersey Street to Union Street. The existing water main is considered in poor to fair condition. The high asset management rating of 79 is due to material and installation year. This improvement would provide the inherent capacity for the ISO recommended fire flow on Pleasant Street in Hingham. This main is also considered critical because it serves a school and a hospital. The estimated probable construction cost for approximately 1,450 linear feet of 8-inch diameter water main is $318,000.

5. A new 8-inch diameter water main is recommended on Central Avenue from A Street to Q Street and on Cadish Avenue from Q Street to Nantasket Avenue in Hull. The existing water main is considered in poor to fair condition. The high asset management rating of 22 to 76 is due to installation year, history of breaks, soil condition, and material. This improvement will increase transmission to the northern portion of Hull and to improve the estimated available fire flow. This main is also considered critical because of the Hull Middle School. The estimated probable construction cost for approximately 4,450 linear feet of 8-inch diameter water main is $974,000.

6. A new 12-inch diameter water main is recommended to replace the existing 8-inch diameter water main on Main Street from Scotland Street to Whiting Street. This improvement will provide the ISO recommended fire flow to Main Street at Rosemary Lane and improve transmission capabilities in the water distribution system. This main is also considered critical because it is a main transmission line from the Accord Tank. The water main has an asset management rating of 52 to 75 and is considered in poor to fair condition. The estimated probable construction cost for approximately 5,100 linear feet of 12-inch diameter water main is $1,650,000.

7. It is recommended that the existing 6-inch diameter water main on Hull Street from the existing 8-inch diameter water main to Clark Drive be replaced with new 8-inch diameter water main. This will to improve the transmission capabilities and provide

the recommended residential fire flow to the area. The water main has an asset management rating of 73 and is considered in poor to fair condition. This water main is also critical. The estimated probable construction cost for approximately 550 linear feet of 8-inch diameter water main is $139,000.

8. A new 12-inch diameter water main is recommended to replace the existing 6-inch and 8-inch diameter water mains on Collins Road from Kilby Street to the end of Collins Road. The existing water main is considered in poor to fair condition. The high asset management rating of 45 to 67 is due to material and installation year. This improvement will provide the inherent capacity for the ISO recommended fire flow on East Gate Lane in Hingham. This main is also considered critical because it serves a school. The estimated probable construction cost for approximately 1,400 linear feet of 12-inch diameter water main is $394,000.

9. A new 12-inch diameter water main is recommended to replace the existing 8-inch diameter water main on Lincoln Street from Thaxter Street to Langlee Road. This improvement will provide the ISO recommended fire flow on Downer Avenue and improve transmission capabilities in the water distribution system. This main is also considered a critical main because of critical customers in the area including Foster Elementary School, Welch Healthcare, and Harbor House Nursing and Rehabilitation. The water main has an asset management rating of 66 and is considered in poor to fair condition. The estimated probable construction cost for approximately 1,450 linear feet of 12-inch diameter water main is $408,000.

Phase II Improvements

10. A new 8-inch diameter water main is recommended to replace the existing 4-inch diameter water main on Summit Avenue from Summit Avenue to Atlantic Avenue and a new 12-inch diameter water main is recommended to replace the existing 6-inch and 8-inch diameter water mains on Atlantic Avenue from Forest Avenue to Gunrock Avenue. This improvement will provide the inherent capacity for the ISO recommended fire flow on Atlantic Avenue. The existing water main is considered in poor to fair condition. The high asset management rating of 73 to 78 is due to material, size, installation year, and soil condition. The estimated probable construction cost for approximately 1,200 linear feet of 8-inch diameter water main and approximately 2,700 linear feet of 12-inch diameter water main is $1,023,000.

11. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Summit Drive and Harborview Drive from Thaxter Street to Summit Drive. This improvement will provide the ISO recommended fire flow on Lincoln Street. The existing water main is considered in poor to fair condition. The high asset management rating of 61 to 75 is due to history of breaks, age, and material. The estimated probable construction cost for approximately 1,850 linear feet of 8-inch diameter water main is $405,000.

12. A new 8-inch diameter water main is recommended to replace the existing 8-inch diameter water main on Nantasket Avenue from Spring Street to Harbor View Road.

The existing water main is considered in poor to fair condition. The high asset management rating of 56 to 68 is due to material, history of breaks, installation year, and soil condition. The estimated probable construction cost for approximately 1,700 linear feet of 8-inch diameter water main is $372,000.

13. A new water storage tank is recommended within the South Shore Industrial Park in Hingham to increase the amount of fire flow available in the area, provide the inherent capacity for the ISO recommended fire flow on Recreation Park Drive at Keith Way and on Industrial Park Road, and help maintain pressures in the area when building out of the South Shore Industrial park occurs. The water storage tank would have a capacity of approximately 750,000 gallons and be constructed to an overflow of 282 feet to match the existing hydraulic gradeline of the Accord Tank. Aquarion does not currently own property in the SSIP. The Town of Hingham owns property within the SSIP area; however, the ground elevations in these areas are about 125 feet. To provide a tank with an overflow elevation of 282 feet on these Town parcels would require a tank more than 150 feet tall. Thus, we have proposed a tank location at the highest elevations in the developable area, which is along Commerce Way within the 0 Commerce Road property. This property has an elevation of approximately 170 feet, which means a tank of approximately 110 foot height would be required. The estimated probable construction cost for the new water storage tank and associated water main is $2,000,000. This estimate does not include costs associated with land acquisition, easements, legal work, or significant site work. If the SSIP is not developed as anticipated, an additional evaluation should be conducted to determine a cost effective improvement to meet the existing recommended fire flows in the area.

14. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Rockwood Road and Ledgewood Circle from the end of Ledgewood Circle to East Street. This improvement will provide the recommended residential fire flow to the area. This main is considered in poor to fair condition. The asset management rating of 32 to 72 is due to history of breaks, material, and installation year. The estimated probable construction cost for approximately 2,750 linear feet of 8-inch diameter water main is $602,000.

15. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Howland Road and Whitcomb Circle from High Street to the end of Grist Mill Lane. This improvement will provide the recommended residential fire flow to the area. This main is considered in poor to fair condition. The asset management rating of 61 to 66 is due to installation year and material. The estimated probable construction cost for approximately 3,050 linear feet of 8-inch diameter water main is $668,000.

16. A new 12-inch diameter water main is recommended to replace the existing 6-inch and 8-inch diameter water mains on Wyola Road and Rockaway Avenue from Nora Way to Park Avenue and on George Washington Avenue from Rockaway Avenue to Logan Avenue. The existing water main is considered in poor to fair condition. The high asset management rating of 44 to 74 is due to material and history of breaks. This improvement will provide the inherent capacity for the ISO recommended fire flow on

George Washington Boulevard in Hull. The estimated probable construction cost for approximately 3,600 linear feet of 12-inch diameter water main is $1,014,000.

17. A new 8-inch diameter water main is recommended to replace the existing 4-inch and 6-inch diameter water mains on Smith Road from Hobart Street to Butler Road. This improvement will provide the recommended residential fire flow. The existing water main is considered in poor to fair condition. The high asset management rating of 42 to 63 is due to material and installation year. The estimated probable construction cost for approximately 300 linear feet of 8-inch diameter water main is $66,000.

18. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Howe Road from Jerusalem Road to the end of Howe Road. The existing water main is considered in poor to fair condition. The high asset management rating of 62 is due to material and installation year. This improvement will increase the available fire flow in the area of Howe Road and Tad Lane in Hull. The estimated probable construction cost for approximately 1,950 linear feet of 8-inch diameter water main is $427,000.

19. A new 8-inch diameter water main is recommended to replace the existing 4-inch diameter water mains on Burditt Avenue from Fearing Road to Lincoln Street and on Fearing Road from Burditt Avenue to Cottage Street. This improvement will improve the transmission capabilities in Hingham. The asset management rating of these water mains is 60 to 61 and the water mains are considered to be in poor to fair condition. The estimated probable construction cost for approximately 2,300 linear feet of 8-inch diameter water main is $662,000.

20. It is recommended that the existing 6-inch diameter water main on Hull Street and East Street from Spruce Street to Chief Justice Cushing Highway be replaced with new 8-inch diameter water main. This will to improve the transmission capabilities and provide the recommended residential fire flow to the area. This water main is considered critical. The asset management rating of this water main is 38 to 43 and the water main is considered to be in fair to good condition. The estimated probable construction cost for approximately 900 linear feet of 8-inch diameter water main is $298,000.

21. A new 8-inch diameter water main is recommended to replace the existing 4-inch diameter water main and 6-inch diameter water main on Edgewater Road from the existing 8-inch diameter water main to Nantasket Avenue. This improvement will provide the recommended residential fire flow to the area. The asset management rating of this water main is 59 to 72 and the water main is considered to be in poor to fair condition. The estimated probable construction cost for approximately 2,200 linear feet of 8-inch diameter water main is $633,000.

Phase IIIa Improvements

22. The existing Hull Booster Pump Station should be upgraded to include fire pumps. The fire pumps would provide additional fire flow to all services north of the pump

station and improve the estimated available fire flow to the Hull High School. The estimated probable construction cost to upgrade the booster pump station is $200,000.

23. Due to a recent break, a sample of the 20-inch diameter main on Nantasket Avenue in Hull was crushed in a testing laboratory to estimate the strength and remaining factor of safety. The remaining FOS is estimated using the original estimate of pipe strength and the tested strength. The original estimate of pipe strength is based on the pipe diameter, original wall thickness, and the modulus of rupture. The modulus of rupture is based on the pipe material.

    The sample was sand blasted to remove all dirt, debris, and non-structural metal to reveal the extent of pitting and corrosion. Minimum and maximum wall thickness was recorded and used to estimate the pipe class or equivalent pipe class. Based on the measured remaining thickness of the pipe sample wall after sandblasting, and comparison with vintage AWWA pipe thickness class information, the pipe appears to have a thickness class of C, and an original wall thickness of 0.92 inches.

    The estimated FOS for the pipe is 1.23. A FOS close to 1.0 could indicate additional potential failures. Based on an original manufacturer's FOS of 2.5, the pipe on Nantasket Avenue would not be considered a candidate for cleaning and cement lining since it does not provide any structural integrity to the pipe. Additionally, the asset management rating for this pipe is 49 to 61 which indicates the main is in fair to poor condition. This pipe should be considered for replacement or installation of a structural liner. The location of the water main is on the only access point to the Town of Hull. Therefore, it is recommended that a structural liner be installed minimizing disruption to the community. The total probable construction cost for approximately 10,500 feet of structural liner is approximately $3,300,000.

24. A new 12-inch diameter water main is recommended to replace the existing 8-inch diameter water main on Beal Street from Sargent William B. Terry Drive to Fottler Road. This improvement will provide the inherent capacity for the ISO recommended fire flow on Beal Street in Hingham. The asset management rating of this water main is 16 to 36 and is considered in fair to good condition. The estimated probable construction cost for approximately 2,100 linear feet of 12-inch diameter water main is $460,000.

25. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Hobart Street from Cross Street to Main Street. This will improve transmission in the water distribution system, increase the available fire flow in the area of Hobart Street and Newbridge Street in Hingham, and improve a hydraulic restriction on Hobart Street. The asset management rating of this water main is 32 to 39 and the water main is considered to be in fair to good condition. The estimated probable construction cost for approximately 2,650 linear feet of 8-inch diameter water main is $580,000

26. A new 12-inch diameter water main is recommended to replace the existing 8-inch diameter water main on George Washington Boulevard from the end of George Washington Boulevard to Rockland Street. This improvement will provide the inherent capacity for the ISO recommended fire flow on George Washington Boulevard in Hingham. The asset management rating of this water main is 24 and the water main is considered to be in good to excellent condition. The estimated probable construction cost for approximately 2,500 linear feet of 12-inch diameter water main is $809,000.

27. A new 12-inch diameter water main is recommended to replace the existing 8-inch diameter water main on Jerusalem Road from Atlantic Avenue to Hull Street. This improvement will provide the inherent capacity for the ISO recommended fire flow on Jerusalem Road in Hull. The asset management rating of this water main is 46 and the water main is considered to be in fair to good condition. The estimated probable construction cost for approximately 5,800 linear feet of 12-inch diameter water main is $1,269,000.

28. A new 8-inch diameter water main is recommended on Black Rock Road from the end of the existing 8-inch water main on Black Rock Road to Forest Avenue. Currently, no water main exists in this location. This improvement will eliminate a dead end in the system and provide the inherent capacity for the ISO recommended fire flow on Forest Avenue in Cohasset. Additionally, the estimated available fire flow along Atlantic Avenue in Hull and along Forest Avenue, Black Rock Avenue, and Surry Drive in Cohasset will be improved. The estimated probable construction cost for approximately 700 linear feet of 8-inch diameter water main is $197,000.

29. A new 8-inch diameter water main is recommended to replace the existing 6-inch diameter water main on Spruce Street from Hull Street to Spruce Street. This improvement will improve residential fire flows in this area. The asset management rating of these water mains is 57 and the water main is considered to be in fair to good condition. The estimated probable construction cost for approximately 3,150 linear feet of 8-inch diameter water main is $886,000.

Phase IIIb Improvements

30. Based on the asset management ratings, the water mains with asset management ratings greater than 60 are considered poor to fair. This represents approximately 25 percent of the water distribution system. Some of these water mains are included in Phase I and Phase II improvements. There are approximately 42 miles of main with high asset management ratings that should be replaced as part of this recommendation. There are approximately 25 miles of main in Hingham and approximately 17 miles of water main in Hull. In general, the water mains with the highest asset management rating should be replaced first. These mains should be completed as funds become available. Also, these mains should be considered when reviewing proposed Town projects.

These water mains are identified on the Recommended Improvements Map found in Appendix G. The total amount of recommended water main by diameter is summarized in Table No. 7-7. The estimated probable construction cost to replace these water mains is also included in Table No. 7-7. These water mains were not considered to be hydraulically deficient, however, while estimating costs, it was assumed that all water mains with diameter 8-inch or less would be replaced with an 8-inch diameter main. The location of the water main being replaced should be evaluated to determine if a smaller diameter main would be appropriate.

Table No. 7-1
Prioritization of Improvements - Phase I

Item No.	Location	From	To	Hydraulic	Critical	Asset Management Rating
1	Beach Avenue, Y Street, X Street, W Street, and Lewis Street	Nantasket Avenue at Y Street	Nantasket Avenue at Lewis Street	Yes	Yes	36-75
2	High Street and Friend Street	Stanford Drive	Main Street	Yes	Yes	52-75
3	Downer Avenue	Otis Street	Broad Cove Road	Yes	Yes	52-62
	North Street	Thaxter Street	West Street			65-70
4	Pleasant Street	Hersey Street	Union Street	Yes	Yes	79
5	Central Avenue	A Street	Q Street	Yes	Yes	36-76
	Cadish Avenue	Q Street	Nantasket Avenue			22-57
6	Main Street	Scotland Street	Whiting Street	Yes	Yes	52-75
7	Hull Street	Existing 8-inch on Hull Street	Clark Drive	Yes	Yes	73
8	Collins Road	Kilby Street	End of Collins Road	Yes	Yes	45-67
9	Lincoln Street	Thaxter Street	Langlee Road	Yes	Yes	66

Table No. 7-2
Estimated Improvement Cost - Phase I

Item No.	Location	From	To	Water Main Diameter (in)	Length (LF)	Estimated Cost
1	Beach Avenue, Y Street, X Street, W Street, and Lewis Street	Nantasket Avenue at Y Street	Nantasket Avenue at Lewis Street	12	6,700	$ 1,885,000
2	High Street and Friend Street	Stanford Drive	Main Street	12	4,800	$ 1,350,000
3	Downer Avenue	Otis Street	Broad Cove Road	12	8,700	$ 2,447,000
	North Street	Thaxter Street	West Street		2,300	$ 647,000
4	Pleasant Street	Hersey Street	Union Street	8	1,450	$ 318,000
5	Central Avenue	A Street	Q Street	8	3,350	$ 733,000
	Cadish Avenue	Q Street	Nantasket Avenue		1,100	$ 241,000
6	Main Street	Scotland Street	Whiting Street	12	5,100	$ 1,650,000
7	Hull Street	Existing 8-inch on Hull Street	Clark Drive	8	550	$ 139,000
8	Collins Road	Kilby Street	End of Collins Road	12	1,400	$ 394,000
9	Lincoln Street	Thaxter Street	Langlee Road	12	1,450	$ 408,000
					Total Estimated Phase I Cost:	**$10,212,000**

Table No. 7-3
Prioritization of Improvements - Phase II

Item No.	Location	From	To	Hydraulic	Critical	Asset Management Rating
10	Atlantic Avenue	Forest Avenue	Gunrock Avenue	Yes	No	76-78
	Summit Avenue	Summit Avenue	Atlantic Avenue			73
11	Summit Drive and Harborview Drive	Thaxter Street	Summit Drive	Yes	No	61-75
12	Nantasket Avenue	Spring Street	Harbor View Road	No	No	56-68
13	New Water Storage Tank	South Shore Industrial Park		Yes	Yes	N/A
14	Rockwood Road & Ledgewood Circle	End of Ledgewood Circle	East Street	Yes	No	32-72
15	Howland Road and Whitcomb Circle	High Street	End of Grist Mill Lane	Yes	No	61-66
16	Wyola Road	Rockaway Avenue	Park Ave	Yes	No	44
	Rockaway Avenue	Wyola Road	Nora Way	Yes	No	44
	George Washington Avenue	Rockaway Avenue	Logan Avenue	Yes	No	74
17	Smith Road	Hobart Street	Butler Road	Yes	No	42-63
18	Howe Road	Jerusalem Road	End of Howe Road	Yes	No	62
19	Burditt Avenue	Fearing Road	Lincoln Street	Yes	No	60
	Fearing Road	Burditt Avenue	Cottage Street			61
20	Hull Street and East Street	Spruce Street	Chief Justice Cushing Highway	Yes	Yes	38-43
21	Edgewater Road	Existing 8-inch	Nantasket Avenue	Yes	No	59-72

Table No. 7-4
Estimated Improvement Costs - Phase II

Item No.	Location	From	To	Water Main Diameter (in)	Length (LF)	Estimated Cost
10	Atlantic Avenue	Forest Avenue	Gunrock Avenue	12	2,700	$ 760,000
	Summit Avenue	Summit Avenue	Atlantic Avenue	8	1,200	$ 263,000
11	Summit Drive and Harborview Drive	Thaxter Street	Summit Drive	8	1,850	$ 405,000
12	Nantasket Avenue	Spring Street	Harbor View Road	8	1,700	$ 372,000
13	New Water Storage Tank	South Shore Industrial Park		N/A	N/A	$2,000,000
14	Rockwood Road & Ledgewood Circle	End of Ledgewood Circle	East Street	8	2,750	$ 602,000
15	Howland Road and Whitcomb Circle	High Street	End of Grist Mill Lane	8	3,050	$ 668,000
16	Wyola Road	Rockaway Avenue	Park Ave	12	2,450	$ 690,000
	Rockaway Avenue	Wyola Road	Nora Way	12	550	$ 155,000
	George Washington Avenue	Rockaway Avenue	Logan Avenue	12	600	$ 169,000
17	Smith Road	Hobart Street	Butler Road	8	300	$ 66,000
18	Howe Road	Jerusalem Road	End of Howe Road	8	1,950	$ 427,000
19	Burditt Avenue	Fearing Road	Lincoln Street	8	1,300	$ 374,000
	Fearing Road	Burditt Avenue	Cottage Street		1,000	$ 288,000
20	Hull Street and East Street	Spruce Street	Chief Justice Cushing Highway	8	900	$ 298,000
21	Edgewater Road	Existing 8-inch	Nantasket Avenue	8	2,200	$ 633,000
					Total Estimated Phase II Cost:	**$8,170,000**

Capital Efficiency Plan™ – Hingham/Hull Water System

Table No. 7-5
Prioritization of Improvements - Phase IIIa

Item No.	Location	From	To	Hydraulic	Critical	Asset Management Rating
22	Hull Booster Pump Station Upgrades			Yes	No	N/A
23	Nantasket Avenue	Rockland Street	Westminster Road	No	No	49-61
24	Beal Street	Sargent William B. Terry Drive	Fottler Road	Yes	No	16-36
25	Hobart Street	Cross Street	Main Street	Yes	No	32-39
26	George Washington Boulevard	End of George Washington Boulevard	Rockland Street	Yes	No	24
27	Jerusalem Road	Atlantic Avenue	Hull Street	Yes	No	46
28	Black Rock Road	Black Rock Road	Forest Avenue	Yes	No	N/A
29	Spruce Street	Hull Street	Spruce Street	Yes	No	57

Table No. 7-6
Estimated Improvement Costs - Phase IIIa

Item No.	Location	From	To	Water Main Diameter (in)	Length (LF)	Estimated Cost
22	Hull Booster Pump Station Upgrades			N/A	N/A	$ 200,000
23	Nantasket Avenue	Rockland Street	Westminster Road	Structural Liner	10,500	$3,300,000
24	Beal Street	Sargent William B. Terry Drive	Fottler Road	12	2,100	$ 460,000
25	Hobart Street	Cross Street	Main Street	8	2,650	$ 580,000
26	George Washington Boulevard	End of George Washington Boulevard	Rockland Street	12	2,500	$ 809,000
27	Jerusalem Road	Atlantic Avenue	Hull Street	12	5,800	$1,269,000
28	Black Rock Road	Black Rock Road	Forest Ave.	8	700	$ 197,000
29	Spruce Street	Hull Street	Spruce Street	8	3,150	$ 886,000
					Total Estimated Phase IIIa Cost:	**$7,701,000**

Table No. 7-7
Summary of Improvement and Estimated Costs – Phase IIIb Asset Management

Item No.	Existing Diameter (in)	Length (LF)	Estimated Replacement Cost
30	4-inch or smaller	60,200	$13,169,000
	6-inch	139,600	$30,538,000
	8-inch	21,300	$4,660,000
Total Estimated Phase IIIb Asset Management Cost:			**$48,367,000**