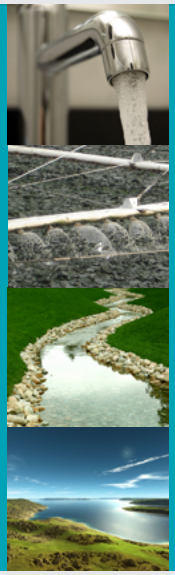


WATER MASTER PLAN & CAPITAL EFFICIENCY PLAN™

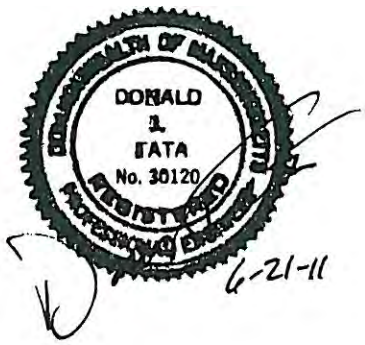
Upton, Massachusetts

June 2011

TATA & HOWARD

Water and Wastewater Consultants

Water Master Plan & Capital Efficiency Plan™
Upton, Massachusetts



Prepared by:

TATA & HOWARD

Water and Wastewater Consultants

June 2011

TATA & HOWARD

Water and Wastewater Consultants

April 25, 2011

Ms. Blythe Robinson, Town Manager
Town of Upton
One Main Street
Upton, MA 01568

Subject: Draft Upton Water Master Plan and Capital Efficiency Plan™
T&H No. 2376

Dear Ms. Robinson,

Tata & Howard is pleased to submit four copies of the Draft Water Master Plan and Capital Efficiency Plan™ for the Upton water distribution system. The analysis and improvements in this report are based on the Three Circle Approach for 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. Supply and storage needs were also evaluated.

Hydraulic recommendations were developed using recommended ISO fire flow requirements, including an estimated residential fire flow of 750 gpm. Areas in which the fire flow could not be met were considered hydraulically deficient. The system was surveyed for critical areas and tested on the hydraulic model for redundancy. Finally, each water main was evaluated based on age, material, diameter, break history, water quality, static pressure and soil conditions to determine its asset management score. 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 their estimated costs is presented in Section 7.

During the course of this project, Ms. Jenna Rzasa, P.E. served as Project Manager, Mr. James Hoyt, served as Project Engineer, Ms. Patricia Fox, served as Engineer, and the undersigned provided technical reviews. Should you have any questions, please feel free to contact our office at (508) 303-9400.

Sincerely,

TATA & HOWARD, INC.

Donald J. Tata, P.E.
President

Enclosure

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E	Critical Components Map
F	Asset Management Map
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Section 1

SECTION 1 - Introduction

1.1 General

Tata & Howard, Inc. was retained by the Town of Upton to complete a Water Master Plan and Capital Efficiency Plan™ for the Town's water distribution system. The purpose of the study is to identify areas within the water distribution system in need of rehabilitation, repair or replacement and prioritize improvements to make the most efficient use of the Town's capital budget. This study evaluates the existing water infrastructure including water transmission and distribution piping and appurtenances. In addition, current and future water supply and storage needs are evaluated and prioritized.

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 where an improvement of a deficiency in one circle will eliminate a deficiency in another circle. By integrating all three sets of criteria, the infrastructure improvement decision making process and overall capital efficiency is optimized.

Tasks in this study consisted of the following:

- Evaluated water supply needs based on existing and projected demands and existing source capacity.
- Assessed water storage needs based upon existing and projected demands and fire flow requirements.
- Conducted a workshop with the Town's staff to review operations and maintenance practices, discuss the asset management rating system, critical customers, break history, and other information pertinent to the condition of the existing system.
- Conducted fire flow tests within the distribution system and updated the existing hydraulic model using fire flow testing results.
- Evaluated improvements needed to meet the most recent Insurance Services Office (ISO) fire flow recommendations.

- Reviewed pertinent available asset management data and reports provided by the Town regarding the water distribution system and transmission mains. Data included installation date of mains, pipe size and material, soil types and other issues that can affect external corrosion, water quality, static pressures and water main break history.
- Created a customized weighted pipe rating system from the asset management data collected, using input from the Town's personnel and experience to identify the priority of mains needing rehabilitation or replacement.
- Identified critical water mains for redundancy, critical facilities and critical customers throughout the distribution system and used the hydraulic model to identify critical water mains through failure simulations.
- Developed a comprehensive prioritized list of recommendations with associated costs based on combined considerations of the system hydraulics, asset management considerations and critical component assessment.
- Created GIS maps for use of the Town personnel including, water main diameter, water main material, water main within potentially corrosive soils, hydraulic improvements, asset management rating, and recommended improvements.

Section 2

SECTION 2 - Existing Water Distribution System

2.1 Distribution System

The Town's distribution system consists of approximately 30 miles of water mains ranging in size from four inches in diameter and smaller to sixteen inches in diameter. A map of the water distribution system is provided in Appendix A. Figure No. 2-1 shows a breakdown of the water main sizes of the existing water system. As depicted, approximately four percent of the system is 16-inch diameter pipe, 30 percent is 12-inch diameter pipe, six percent is 10-inch diameter pipe, 52 percent is 8-inch diameter pipe, eight percent is 6-inch diameter pipe, and less than one percent is 4-inch diameter and smaller.

The existing water mains are constructed of various materials including cement lined ductile iron (CLDI), cement lined cast iron (CLCI), asbestos cement (AC), galvanized iron (GI) and copper. Figure No. 2-2 shows a breakdown of water main material. The system consists of 74 percent cement lined ductile iron. Six percent of the water main is cast iron. The cast iron pipe includes two types of pipe, factory lined pipe installed between 1958 and 1973 and unlined pipe installed prior to 1958. The Town's distribution system consists of approximately one percent unlined cast iron and five percent factory lined cast iron. Approximately 19 percent of the water main is asbestos cement which was installed primarily between 1953 and 1979. Further discussion of material characteristics is provided in Section 6.

2.2 Water Supply Sources

The Town's system includes two active groundwater supply sources: the Glen Avenue Wellfield and the West River Street Well. The Glen Avenue Wellfield is located in the western portion of Upton off Glen Avenue and is adjacent to the West River. The wellfield consists of two groups of 12 2 1/2-inch diameter tubular wells, which are pumped through an 8-inch diameter, cast iron main. The existing valve configuration allows both groups of wells to run at the same time or the back wellfield to be shut off while the other is pumped. Currently, both wellfields run at the same time. The well depths range from approximately 37 feet to 62 feet, while the maximum yield per well ranges from 25 to 75 gpm. The pumping capacity of the Glen Avenue Wellfield is approximately 0.316 mgd. Recently, the yield of the Glen Avenue Wellfield has declined to approximately 0.086 mgd during the summer months. The decline in yield is due to the age, configuration and condition of the existing wellfield. The Town is proceeding with the installation and permitting of replacement wells at the Glen Avenue Wellfield to regain the permitted capacity of the source. The Glen Avenue water supply includes the chemical addition of potassium hydroxide (KOH) for pH control and chlorine for disinfection. The Glen Avenue Wellfield is also equipped with a generator; however, the generator does not include an automatic transfer switch. Therefore, in the event of a power loss, the generator must be manually started.

Figure No. 2-1
Water Main Diameter Distribution

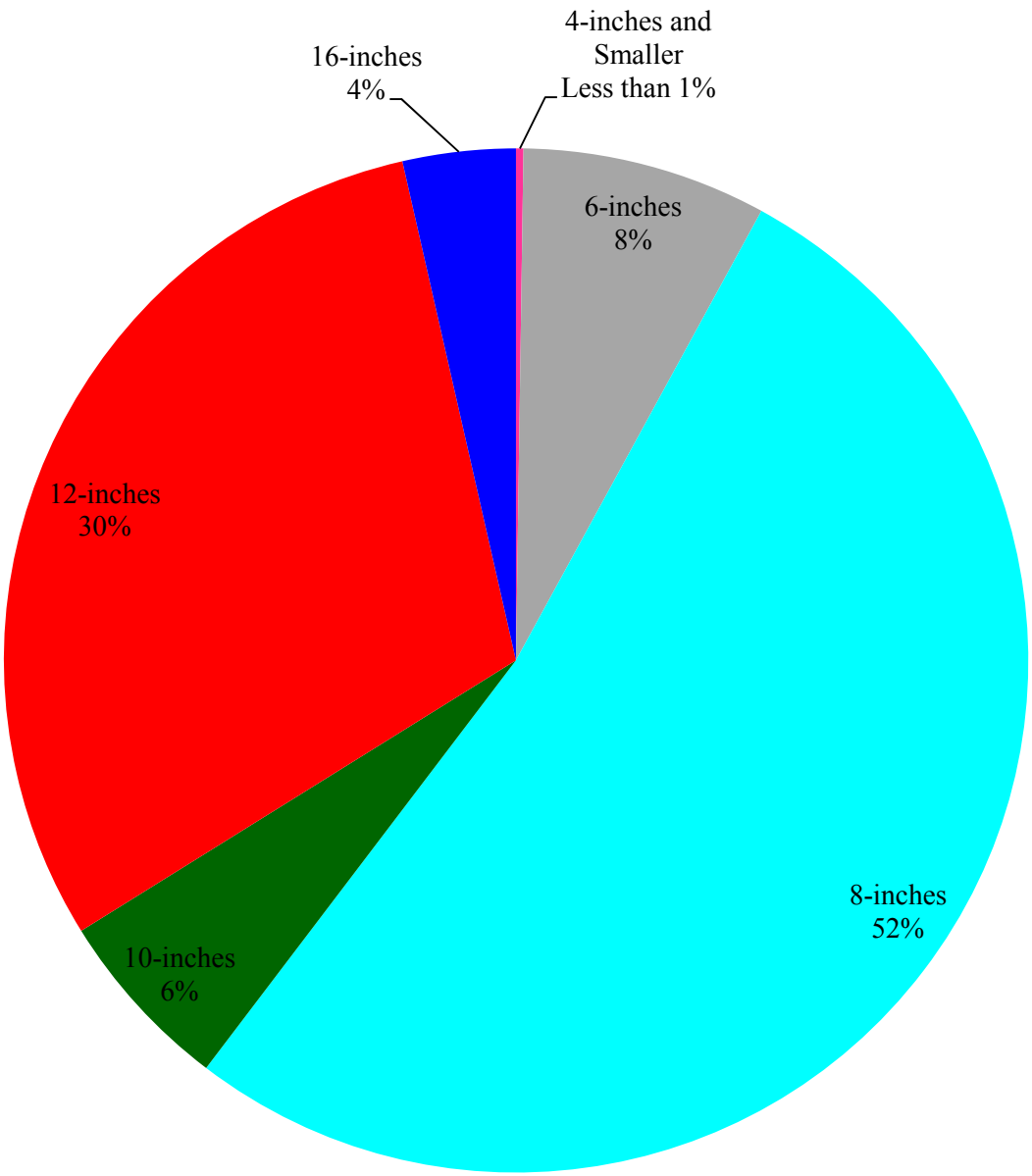
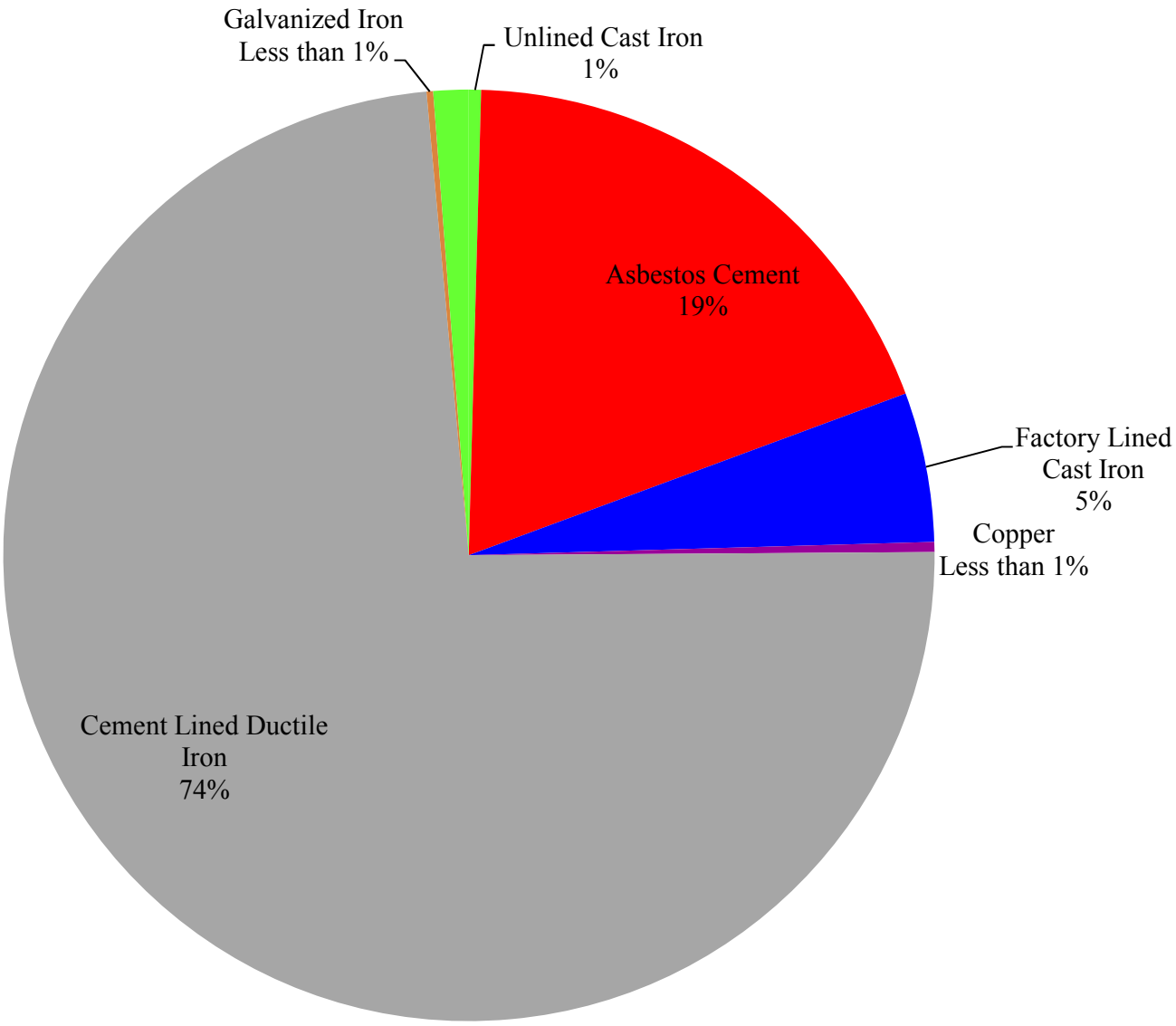


Figure No. 2-2
Water Main Material Distribution



The West River Street Well is an 18-inch diameter gravel-packed well located approximately one mile north of the confluence of the West River and Center Brook. The pumping capacity of the West River Street Well is approximately 0.432 mgd. The well is approximately 90 feet in depth and is contiguous to Center Brook. No additional withdrawal will be allowed at the West River Street Well due to the presence of endangered species. The wild brook trout present in Center Brook rely on the cold water habitat whose source is groundwater assumed to be recharging the stream. A right angle drive is present at the West River Street Well to provide emergency power.

2.3 Water Storage Facilities

The Town's water distribution system includes two water storage facilities: the Pratt Hill Water Storage Tank and the Pearl Street Water Storage Tank. The Pratt Hill Tank is located in the northwest section of the system off Warren Street. The tank is a 51 foot diameter, 46 foot tall steel tank with a capacity of 0.5 million gallons (mg) constructed in January 1954. It has an overflow elevation of 580.5 feet above mean sea level (MSL). The Pearl Street Tank is located in the eastern portion of the system off Pearl Street. The tank is a 44 foot diameter, 66 foot tall steel tank constructed in January 1976. The storage facility has a reported capacity of 1 mg with an overflow elevation of 580.5 feet above MSL. The operating water level at both tanks is currently maintained 16 feet below the overflow elevation to limit water main breaks due to high system pressures. Therefore, the available storage of the Pearl Street Tank and the Pratt Hill Tank is 0.75 mg and 0.32 mg, respectively, resulting in a combined available storage of approximately 1.07 MG under the current operating conditions.

2.4 Booster Pump Station

The Town's system includes one Booster Pump Station (BPS) located in the northwest area of the system. The North Street BPS is located off North Street and serves approximately 60 homes in the Glen Echo Estates. The BPS contains a three pump package pumping system with a maximum capacity of 180 gpm. The BPS also includes one high capacity pump. This pump is an Aurora single stage diesel drive pump with a maximum capacity of 1000 gpm. This pump is utilized during low suction pressures. The generator is a 60 kilowatt generator with an automatic transfer switch for back-up power.

2.5 Interconnections

The Town of Upton has an emergency interconnection with the Grafton Water District to provide water supply in the event of an emergency. The interconnection is located on Williams Street through an 8-inch diameter connection. The interconnection agreement between the Town of Upton and the Grafton Water District is for emergency use only of up to 200,000 gpd. The system pressure in the Grafton Water District is higher. In the event of an emergency, water can be supplied to the Upton system by opening the

isolation valves on both sides of the Town line, or by making a hydrant-to-hydrant connection.

The Town also reportedly has the infrastructure in place for an interconnection with the Whitinsville Water Company in the Town of Northbridge. The interconnection consists of a 12-inch diameter water main connecting the two systems, two jockey hydrants and associated valves. Although the interconnection has been constructed, it has not been pressure tested or chlorinated. In the event of a water emergency, the Town can pump water from the Northbridge system to the Upton system via the jockey hydrants. Since the water will be pumped from a nearby storage facility in Northbridge, the estimated emergency capacity is limited by the size of the pump and the main. The Town is in the process of developing an agreement with Whitinsville Water Company and the Town of Northbridge for emergency use of the interconnection.

Section 3

SECTION 3 – Water Supply Evaluation

3.1 General

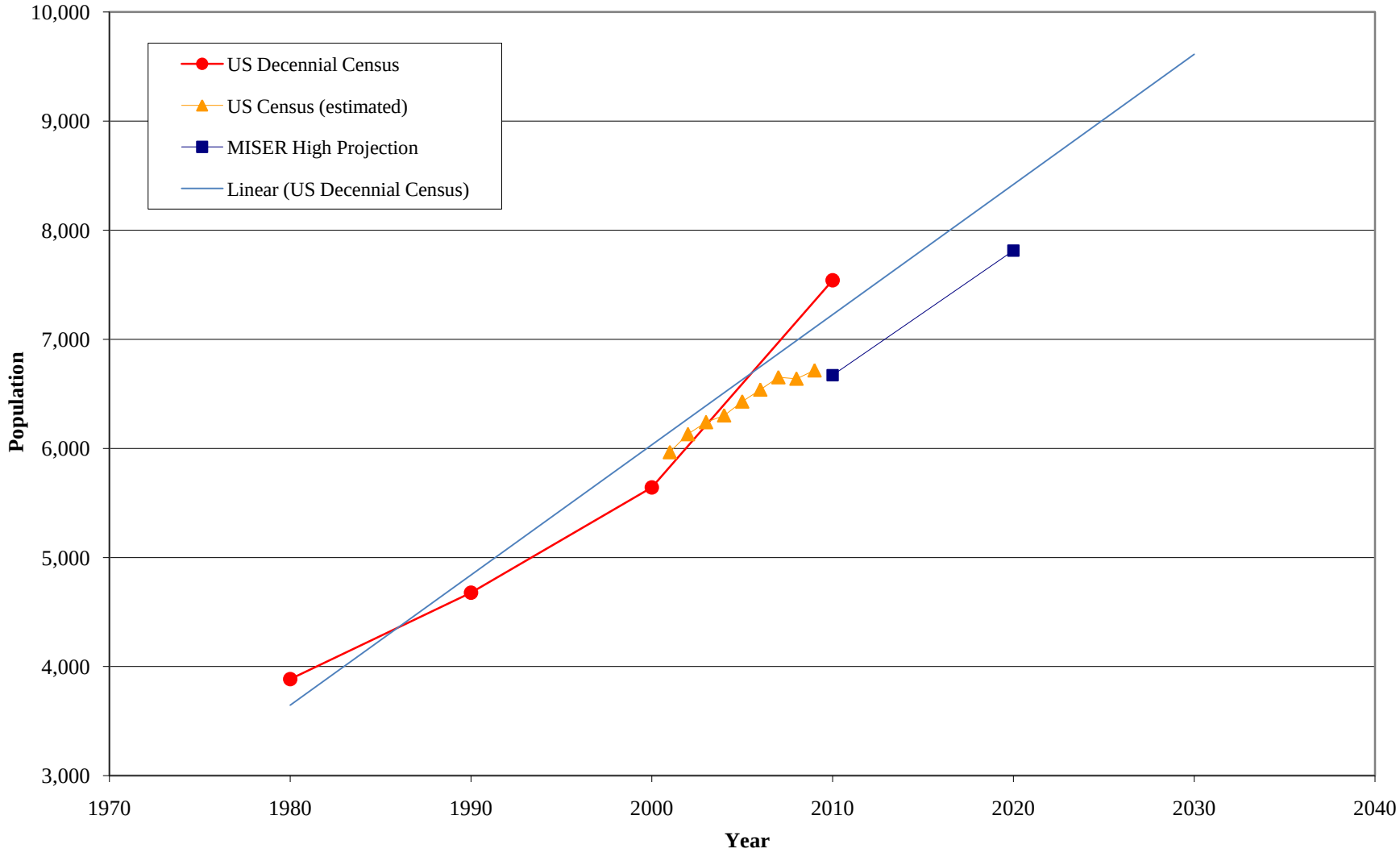
In accordance with the Massachusetts Department of Environmental Protection (MassDEP) requirements, the supply sources of a water system must be capable of meeting existing and projected maximum day demand (MDD) conditions and existing and projected summer average day demand (SADD) conditions with the 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 summarized and considered. The safe yields of the supplies and permitted withdrawals of the existing supply sources were compared to current and future demand conditions. Since population has a direct correlation to water consumption, population projections from various sources through the year 2031 were reviewed to reflect actual and planned growth within the Town of Upton.

3.2 Population Projections

According to the United States Census Bureau, the Town of Upton has experienced steady growth from 1980 through 2010. The population recorded during each decennial census has been plotted in Figure No. 3-1. The most recent available Census, performed in 2010, reports a record population of 7,542 people in the Town of Upton. According to the Upton system's 2009 Annual Statistical Report (ASR), the water distribution system serves approximately 65% of the Town's population, or approximately 4,902. Predicting that the population will over time have a steady growth rate, the estimated 2031 served population is approximately 6,325.

The US Census Bureau also estimated the annual population changes between 2000 and 2009. The Census estimated annual population has also been included in Figure No. 3-1. From 2000 through 2009 there was an overall growth in population of approximately 1.7 percent with faster growth in the early part of the decade and steadying over the last few years. This is consistent with the population projections forecasted by the organizations described below.

Population projection data collected from the Massachusetts Institute for Social and Economic Research (MISER) are also included in Figure No. 3-1. MISER projects a 1.5 percent population growth per year through 2020. This rate is slightly less than the 1.7 percent growth rate historically experienced by the Town of Upton. Due to a slower growth rate as developable land becomes less available, the MISER population projection is considered reasonable for the Town of Upton. Based on MISER projections, the estimated 2031 population is 9,069. The estimated 2031 service population, based on MISER projections, is approximately 5,895.


10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
Population
1970
1980
1990
2000
2010
2020
2030
2040
Year
US Decennial Census
US Census (estimated)
MISER High Projection
Linear (US Decennial Census)

In November 2008, the DCR developed demand projections for the Town of Upton as part of the MassDEP Water Management Act (WMA) permitting process. Based on these demand projections, DCR estimated a 2028 service population projection of 5,844. This number was projected to obtain a 2031 service population projection of 6,076. The projected service population projection developed by DCR is considered more conservative than the MISER projections, but is still less than the estimated service population based on the US Decennial Census data; however, the difference in population is marginal compared to DCR. The DCR projections are considered to be a more accurate representation of the future service demands and are used for the demand projections later in this section.

3.3 Water System Demands

The DCR follows specific guidelines when projecting the water usage for communities in conjunction with the MassDEP 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 2028 were completed for the Town by the DCR in November 2008 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.

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.

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 2005 through 2009 ASRs indicate that an average residential consumption of approximately 59 gpcd, for the Town of Upton.

Unaccounted-for Water

Unaccounted-for water consists of unmetered water used for street cleaning, water main flushing, meter inaccuracy, unauthorized water uses, fire fighting 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. Historically, unaccounted-for water percentages in the Upton system have averaged approximately 8 percent over the past five years.

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.

Based on the 2005 through 2009 ASRs, the ADD for the Town system ranged from 0.28 mgd to 0.35 mgd. Non-residential usage represents approximately 19 percent of the 2009 ADD.

DCR used the following criteria to develop the 2028 ADD:

- Residential consumption of 65 gpcd
- DCR's estimated 2028 service population of 5,844
- Maximum of 10 percent unaccounted-for water
- Non-residential demand of 70,000 gpd.

DCR estimated demand projections for five year time blocks from 2013 to 2028. The 2028 ADD is approximately 0.48 mgd. DCR also increases the volume of the last five year time block by five percent to accommodate uncertainty in growth projections. The 2028 ADD with the five percent buffer is approximately 0.50 mgd. The DCR population projections and demand projections were used to linearly project population and water demands to the design year 2031. The 2031 population projection is 6,076 and the 2031 ADD with the five percent buffer is approximately 0.56 mgd.

Summer Average Day Demand

MassDEP guidelines recommend that a system consider a projected Summer Average Day Demand (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 0.35 mgd to 0.44 mgd from 2005 to 2009. 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 2005 through 2009 monthly demand data, the average summer peaking factor is

1.25. Based on the projected ADD of 0.56 mgd, the estimated 2031 SADD is approximately 0.70 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. 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 psi. Estimates of the projected maximum day demand and an allowance for the required fire flow are used to evaluate or design pumping, transmission and storage facilities.

The projected MDD can be estimated by the MDD/ADD ratio. The MDD/ADD ratio provides a relationship between the two demands which can be used to estimate future demands. As shown on Table No. 3-1, the MDD ranged from 0.61 mgd to 0.71 mgd from 2005 to 2009. Upon comparison of the MDD to the ADD, the ratios range from 1.89 to 2.30. These peak factors are averaged to estimate the future MDD Peaking Factor. However, the 2005 value of 1.89 was omitted due to an abnormally high ADD, which is not representative of current demands. The resulting average peaking factor is 2.19. The resulting projected MDD for year 2031 is estimated to be 1.22 mgd based on the projected 2031 ADD of 0.56 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 2031 was estimated using the "Merrimac Curve". The Merrimac Curve is based on statistical analysis of sanitary sewage flows and water consumption for many towns and communities in New England, relating peak hour flows to average day flows. Based on an ADD/MDD peaking factor of 2.19, the corresponding peak hour peaking factor for the system is approximately 3.90. Using an ADD of 0.56 mgd, the projected peak hour flow for the year 2031 is estimated at 2.17 mgd.

3.4 Adequacy of Existing Water Supply Sources

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 gpd and existing sources exceeding their registered withdrawal volume by 100,000 gpd are required to obtain a withdrawal permit under the WMA. When first implemented, 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

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)	Peaking Factor (ADD/Peak Hour)
2005	0.35	0.44	1.23	0.66	1.89	N/A	N/A
2006	0.31	0.39	1.23	0.71	2.30	N/A	N/A
2007	0.32	0.40	1.23	0.70	2.20	N/A	N/A
2008	0.30	0.37	1.23	0.61	2.03	N/A	N/A
2009	0.28	0.35	1.23	0.62	2.23	N/A	N/A
2013	0.39	0.49	1.23	0.85	2.19	1.52	3.90
2018	0.42	0.53	1.23	0.92	2.19	1.64	3.90
2023	0.45	0.56	1.23	0.99	2.19	1.76	3.90
2028	0.48	0.60	1.23	1.05	2.19	1.87	3.90
2031	0.56	0.70	1.23	1.22	2.19	2.17	3.90

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 current system is comprised of two active groundwater supply sources to meet system demands. Table No. 3-2 provides the MassDEP approved withdrawal rates for each of the supply sources. The maximum daily withdrawal volume from the existing sources is approximately 0.749 mgd. Due to the age and configuration of the Glen Avenue Wellfield, the operational capacity is reduced to approximately 0.08 mgd during the summer months. The actual operational capacity of the existing supply sources is 0.51 mgd. To mitigate the reduction of available supply, the Town is proceeding with the installation and permitting of replacement wells at the Glen Avenue Wellfield to regain the permitted capacity of the source.

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. Currently, the MDD of 0.66 mgd can be met with if the wells are operating at the approved withdrawal rate of 0.749 mgd. However, the current MDD cannot be met at the current

combined operational capacity of the wells. It is recommended to rehabilitate the Glen Avenue Wellfield to mitigate the MDD supply deficit.

West River Street Well is the largest source; therefore, if the largest water supply was offline, the system supply would be 0.317 mgd which is not adequate to meet the current SADD of 0.39 mgd. The Town has permitted and plans to construct a new wellfield located on the recently purchased Richard property. The wellfield, with an approved withdrawal rate of 349 gpm or 0.5 mgd, has been approved by MassDEP. The new wellfield is scheduled to be online in 2013. Once the Richard Property Wellfield is in operation, it will become the system's largest supply source. The Glen Avenue Wellfield and West River Street Well will supply 0.749 mgd, which is adequate for the 2031 projected SADD of 0.70 mgd. With the addition of the Richard Property Wellfield, the system's combined approved withdrawal rate would be 1.249 mgd, which is adequate for the 2031 projected MDD of 1.22 mgd. The redevelopment of the Glen Avenue Wellfield and the construction of the pump station and water mains for the Richard Property Wellfield will mitigate the supply deficits.

Table No. 3-2
Approved Maximum Withdrawal Volumes

Source Name	Approved Withdrawal Rate (mgd)	Available Withdrawal Rate (mgd)
Glen Avenue Wellfield	0.317	0.08
West River Street Well	0.432	0.432
2009 Total	**0.749**	**0.510**
Richard Property Wellfield	0.500	0.500
Proposed 2031 Total	**1.249**	**1.249***

*Assumes Glen Avenue Wellfield Rehabilitation is complete.

3.5 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 fire fighting. 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 when evaluating storage requirements. These components include equalization, fire flow requirements, and emergency storage.

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 Upton system would be considered a medium size system. As a result, twenty percent of maximum day demand was used for the equalization storage calculations.

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 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. A right angle drive is present at the West River Street Well to provide emergency power. The Glen Avenue Wellfield is equipped with a generator; however, the generator does not include an automatic transfer switch. Therefore, in the event of a power loss, the generator must be manually started. Since both well sites are available in the event of power emergency, the emergency storage component can be waived.

The components of the storage evaluation were calculated under current and future demand conditions for the system. Although the system consists of two tanks, the tank overflow elevations are the same, and the system has only one service area.

1. Equalization
- Mid sized system = 20 percent of the Maximum Day Demand
- Maximum Day Demand in year 2009 = 0.62 mgd
- Estimated Maximum Day Demand in year 2031 = 1.22 mgd

- Equalization (2009) = 0.20 x 0.62 = 0.12 million gallons (mg)
- Equalization (2031) = 0.20 x 1.22 = 0.24 mg

2. Basic Fire Flow Requirement
- Representative fire flow for Upton = 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 requirement. The current (year 2009) and projected (year 2031) total required storage for the system is as follows:

- Total Required Storage (2009) = 0.12 + 0.24 = 0.36 mg
- Total Required Storage (2031) = 0.24 + 0.24 = 0.48 mg

Under existing and projected ADD, MDD and peak hour demands, a minimum pressure of 20 psi should be maintained throughout the distribution system. The Pratt Hill Tank and the Pearl Street Tank establish the hydraulic gradeline in the system.

The established maximum service elevation for the Town of Upton is 475 feet above MSL. No additional services will be added to the distribution system unless served by a booster pump station. It should be noted, however, that there are existing customers located at elevations above the maximum service elevation. These customers are located at the development off North Street and residences on Pearl Street and Tyler Road near the Pearl Street Tank. The development off North Street is served by the North Street Booster Pump Station. Many of the homes located near the Pearl Street Tank operate individual booster pumps or have private wells, and homes that do not, are recommended to meet a minimum system pressure of 35 psi.

In order to maintain a pressure of 20 psi for the system below the maximum service elevation, the tanks can drop to an elevation of approximately 520 feet above MSL. Based on this scenario, there is approximately 0.50 mg of usable storage in the Pratt Hill Tank and approximately 0.90 mg of usable storage in the Pearl Street Tank. The total usable storage in the system is approximately 1.40 mg. However, due to high pressures experienced in the downtown area, the tanks are operated at a level approximately 16 feet below the overflow elevation of the tanks. Therefore, the effective storage of the tanks is 0.49 mg and 0.66 mg, respectively. The total effective storage capacity of the system is approximately 1.15 mg.

As presented in the evaluation above, the effective storage currently results in a storage surplus of 0.79 mg, and a 2031 surplus of 0.67 mg for the system. Based on the amount of surplus storage, there are potential concerns with turnover rates in each of the tanks. Mixing within the tanks could improve the turnover rates and prevent water quality issues. An extended period simulation (EPS) using the hydraulic model would be required to evaluate the water age in the tanks and distribution system. Evaluating the distribution system under EPS allows the hydraulic model to account for changes in the distribution system over time. These changes include tank levels, pump controls and demand variations. The hydraulic model can be used to evaluate the water age as well as determine the ideal tank operating levels to promote turnover in the tank while maintaining adequate system pressures.

Section 4

SECTION 4 – Hydraulic Evaluation

4.1 General

In the 1998 Water Distribution System Study, Tata & Howard, Inc. developed a hydraulic model to evaluate the Upton water distribution system and as a basis for recommending water distribution system improvements. At the time of the study a hydraulic computer model of the distribution system was created using Cybernet modeling software. The model has since been upgraded to WaterGEMS software. WaterGEMS allows the user to conduct hydraulic simulations. As part of the capital improvements plan, the hydraulic model was verified under steady state conditions based on fire flow testing and information pertaining to the sources and storage facilities.

As part of this Master Plan and Capital Efficiency Plan™, the model was updated to include improvements to the system since 1998. Additional fire flow testing was competed on March 9, 2011. These test results and information pertaining to the sources and storage facilities were used for additional model verification.

After the model was verified, recommendations set forth by the Insurance Services Office (ISO) for water storage necessary for fire protection, fire flows, and peak demands were utilized in the analysis of the distribution system.

4.2 Model Verification

The computer model is represented by the node, pipe and tank information provided in Appendix B. A color-coded link map of the water distribution system can be found in Appendix B. The link map provides information on storage facilities, water supply sources, 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. C-values were assigned to water mains based on material and diameter. Larger diameter pipes were assigned incrementally higher c-values than smaller diameter pipes. Cement lined pipes were given higher c-values than unlined cast iron water mains.

Water system demands were allocated to the nearest junctions to represent actual metered demand in the system. Demand allocation was achieved using billing data and the 2010 billing data provided by the Town of Upton. The data included meter address and total usage. The meter addresses were geocoded using ArcGIS software. Some of the meters were not automatically placed geographically during the meter association process. Most of these meters were identified and manually inputted to ensure that they were properly located and accounted for in the model. Once the location of each meter was determined and demands were placed into a GIS shapefile, demands were then allocated to the junctions in the model using the "Demand Allocator" feature of the modeling software.

The Demand Allocator assigns the water usage associated with each meter to the nearest junction.

Fire flow testing was conducted by the Upton Water Department and Tata & Howard at 12 locations throughout the distribution system. Table No. 4-1 presents the results of the fire flow testing conducted on March 9, 2011. The data sheets for the fire flow tests are included in Appendix C.

Verification of the computer model was completed under steady state conditions. It should be noted that verification of the model for extended period simulations (EPS) was outside the scope of this study. The data obtained from the fire flow tests served as input data for the model verification. This data included water levels in storage tanks, pumping rates of supplies, static and residual pressure readings, and measurement of flows from hydrants. It is important that each simulation reflect actual field conditions at the time of testing. Actual field conditions include current demands on the system, varying flows from each water supply source and pump station that is online, as well as varying tank elevations.

When the results of the computer runs compared to within five percent of the hydraulic data collected from the fire flow tests, the computer model was considered verified under steady state conditions and mathematically represented the physical operating conditions of the existing water distribution system.

Once the model was verified, hypothetical conditions such as increased demands and required fire flows were simulated on the model. The simulation of these conditions provided the opportunity to identify system deficiencies and to develop necessary improvements. Projected demands through the design year 2031 were simulated.

4.3 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 pounds per square inch (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. In order to evaluate the system's ability to meet these criteria, the following hydraulic simulations were run in the model:

Minimum/Maximum Pressures

During ADD, MDD and PH conditions (no coincident fire flow), a minimum pressure of 35 psi is recommended throughout the distribution system at street level. An upper limiting pressure of 120 psi is generally recommended, as older fittings in the system are generally rated at 125 to 150 psi. Pressure above this level can result in increased water use from fixtures and also increased leakage throughout the distribution system. Also,

plumbing code states that water heaters in homes can be affected when pressures exceed 80 psi.

The majority of the Town's system meets these criteria. The areas with the lowest pressures are located near the Pearl Street Tank. The inability of the distribution system to meet a pressure of 35 psi requirements in this area is due to the elevation and not due to restrictions in the distribution system. Individual booster pumps should be recommended to any customers in these areas.

Based on the overflow elevation of the water storage tanks, any building or structure with a ground elevation less than approximately 286 feet USGS could experience pressures greater than 120 psi. There are few areas in Upton with pressures that exceed 120 psi. Most of these areas are located around the Glen Avenue Wellfield, the West River Street Well. The pressures in this area can be regulated through operational adjustments; therefore, no hydraulic recommendations are required at these locations. Additional areas that experience pressures exceeding 120 psi were located on Rockdale Hill Circle, Centerbrook Way, Meadow Avenue and the end of the main on Pleasant Street. Pressure reducing valves should be recommended to any customers with within these locations. The PRVs would be installed at the owner's expense.

Insurance Services Office (ISO) Fire Flow Guidelines

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; 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.

The Upton system was last inspected for fire insurance ratings by the ISO in 1996. The results of the ISO inspections and fire flow testing are shown in Table No. 4-2. The test results indicate the available flow and estimated recommended fire flow in various sections of the distribution system. The recommended fire flows established by ISO varied from 500 to 3,000 gpm, depending on the location and the structure. Areas with a recommended fire flow of 500 should be reevaluated if a development or large structure is to be constructed.

Additional Fire Flows Requirements

According to the AWWA, the minimum recommended fire flow in residential areas where homes are between 31 feet and 100 feet apart is 750 gpm. Based on a review of the system, the Town's system generally falls within this category. Based on the ISO recommended fire flows, there are specific areas within the system that only 500 gpm is recommended. An estimated fire flow of 750 gpm at all nodes was simulated on the computer model. Some areas of the system could not meet recommended 750 gpm fire

Table No. 4-1
Fire Flow Testing Results – March 2011

Test No.	Residual Hydrant			Flowing Hydrant				
	Location	Static Pressure (psi)	Residual Pressure (psi)	Location	Static Pressure (psi)	Pitot Reading (psi)	Estimated Flow (gpm)	Estimated Flow at 20 psi (gpm)
1	Tyler Road	59	49	Tyler Road	100	63	1320	2750
2	Pearl Street	22	22	Pearl Street	27	N/A	N/A	N/A
3	Elm Street	95	76	Elm Street	95	43	1075	2250
4	Grove Street	120	120	Grove Street	120	85	1550	N/A
5	Plain Street	117	111	Plain Street	115	60	1300	6490
6	West River Street	125	114	West River Street	125	75	1455	4910
7	Church Street	104	104	Church Street	107	60	1300	N/A
8	Plumbley Street	90	68	Plumbley Street	110	60	1300	2420
9	Mechanic Street	122	116	Mechanic Street	105	60	1300	6000
10	Williams Street	82	64	Williams Street	65	32	950	1850
11	Maple Avenue	122	114	Maple Avenue	130	85	1150	6120
12	Warren Street	97	93	Warren Street	80	45	1127	5560

Table No. 4-2
ISO Fire Flow Data - November 1996

Test No.	Location of Flowing Hydrant	Static Pressure (psi)	Residual Pressure (psi)	Available Flow at 20 psi (gpm)	Needed Flow at 20 psi (gpm)
1	Main Street & Centennial Court	110	100	8,100	2,250
2	Warren Street & Ephraim Way	55	40	3,200	500
3	School Street & Cross Street	102	100	11,200	1,500
4	Elm Street & Cedar Mill	90	45	2,600	500
5	Main Street & Church Street	115	100	7,700	2,000
6	Main Street at Memorial School	90	75	6,600	2,250
7	Pleasant Street at Regional High School	110	55	3,200	3,000
8	Grove Street & Centerbrook Way	120	80	4,400	750
9	Tyler Street & Chapin Road	55	25	1,900	500

flow, however, these areas were confirmed to be located within areas with a recommended fire flow of 500 gpm.

A review of the system was completed to identify areas where larger buildings exist that were not identified in the latest ISO evaluation. Examples include condominiums, apartment complexes, schools and other commercial or industrial buildings. Recommended flows were estimated for these areas based on location and building size.

4.4 Hydraulically Deficient Areas

The estimated recommended fire flows were simulated on the computer model. Certain assumptions were used when running the model. All scenarios were run using 2031 MDD conditions and typical tank operating levels. Areas where the available fire flows do not meet the ISO recommended fire flow or other recommended fire flows would be considered hydraulically deficient. Recommended improvements were developed to alleviate any hydraulic deficiencies. These improvements are intended to meet transmission needs, mitigate the latest ISO fire flow deficiencies, and improve areas which currently do not meet recommended fire flows. A map depicting areas with hydraulic deficiencies can be found in Appendix D. Estimates of probable construction costs are presented in Section 7.

ISO Fire Flow Improvements

Based on the results of the model, all areas of the system were able to meet the estimated ISO fire flow recommendations. As mentioned earlier in this section, areas with a recommended fire flow of 500 should be reevaluated if a development or large structure is to be constructed. Depending on the building size, location and material, a higher fire flow may be recommended.

Additional Hydraulic Improvements

1. In order to strengthen the transmission capability along Mendon Street, a new 12-inch diameter water main is recommended between Main Street and the existing 10-inch diameter water main on Mendon Street. This improvement also improves transmission from the West River Street Well and the proposed Richard Property Wellfield to the distribution system. This improvement will strengthen the transmission grid and reduce the influence of bottlenecking.

2. A new 8-inch diameter water main on Hartford Avenue South from Glen Avenue to Main Street is recommended. This improvement will help strengthen the available flow, improve system pressures, and reduce water quality issues.

3. A new 8-inch diameter water main on Old Grafton Road and Fowler Street connecting the existing water mains is recommended to decrease the number of dead ends in the system. Reducing the dead ends will help strengthen the available flow, improve system pressures, and reduce water quality issues.

Section 5

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 500 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, these facilities are also considered critical components. Therefore, any water main within 500 feet of a water storage tank, booster pump station 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, primary 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 Town's 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 by the Town. Twelve critical areas were identified. Table No. 5-1 presents all critical areas served including critical services and critical components of the distribution system.

Critical Water Mains

Critical water mains include primary transmission lines as well as mains connecting water storage tanks and sources to the system. In addition, primary distribution system water mains that do not have a redundant main are considered critical.

Table No. 5-1 Critical Customers		
	Critical Area	Location
1.	Nipmuc Regional High School	90 Pleasant Street
2.	Memorial School	69 Main Street
3.	Blackstone Valley Regional Vocational Technical High School	65 Pleasant Street
4.	Millhaus Apartments	134 Main Street
5.	Upton Inn	135 Main Street
6.	Family Dental Care	113 Main Street
7.	Upton Wastewater Treatment Facility	Meadow Avenue
8.	Pratt Hill Tank	Warren Road
9.	Pearl Street Tank	Pearl Street
10.	Glen Avenue Wellfield & Pump Station	Glen Avenue
11.	West River Well & Pump Station	West River Street
12.	Grafton Water District Emergency Interconnection	Williams Street

Critical water mains were identified based on a review of the distribution system model and by using the WaterGEMS criticality feature. The criticality feature runs simulations that "break" each pipe in the model. The model calculates if the system can be served with adequate flow and pressures after a pipe is taken out of service. This feature can identify areas served by multiple mains, but would no longer be able to serve customers if one of the mains were taken out of service.

The following water mains are considered critical:

- The water main on West Main Street from Mechanic Street to Williams Street,
- The water main on Mechanic Street from West Main Street to Meadow Drive,
- The water main on Williams Street,
- The water main on Main Street from Grove Street to Hartford Avenue North,
- The water main on Depot Street,
- The water main on Christian Hill Road and Pearl Street from the Pearl Street Tank to Elm Street,
- The water main on West River Street from Mendon Street to the limit of the existing of main.

The water main on West Main Street from Mechanic Street to Williams Street, if broken, causes a system demand shortfall of approximately three percent during simulated water main breaks. A main failure for the water main on Mechanic Street from West Main Street to Meadow Drive would affect approximately four percent of the distribution system served. The water main on Williams Street is considered critical because it is the primary water main that would supply water from the emergency interconnection with the Grafton Water District to the Upton distribution system. The Main Street water main is critical because it supplies water to multiple businesses, plazas and apartment complexes. Depot Street is considered critical because it crosses a railroad line causing difficulty in the construction and permitting involved in replacing or rehabilitation the

water main. The 16-inch diameter water main on Christian Hill Road is considered critical because it connects the Pearl Street Water Storage Tank to the distribution system. The water main on West River Street is considered critical because it connects the West River Street Well and the proposed Richard Wellfield to the distribution system.

Water mains that cross major highways, major rivers or active railroad tracks are also considered critical because of the difficulty in construction and permitting involved in replacing or rehabilitation the water main. Critical mains are highlighted on the Critical Components Map found in Appendix E.

Section 6

SECTION 6 – Asset Management Considerations

6.1 General

The Town's water distribution system includes approximately 30 miles of water main varying in size and material. A number of factors including age, material, break history, water quality, soil conditions, and pressure 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, material and installation year was obtained from a combination of existing water distribution system maps and information through the personnel of the Town. Information about break history, water quality and potentially corrosive soils was obtained through information provided by the Town.

6.3 Evaluation Criteria

In order to prioritize water main replacement or rehabilitation, a water main grading system was established. The grading system uses the water main characteristics such as age, material, break history, diameter, water quality, 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 is utilized to determine the overall rating per pipe. Those pipes with the highest grade are most in need of replacement or rehabilitation. The grading system is shown in Table No. 6-1 and discussed in detail later in this section.

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 early 1950's to the mid 1970's, when pipe manufacturers switched primarily to factory cement lined ductile iron pipe.

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

Table No. 6-1
Asset Management Rating System

Weight	Performance Criteria	Rating	Weighted Rating
20%	Material		
	Asbestos Cement	100	20
	Galvanized Iron	90	18
	Unlined Cast Iron	70	14
	Cement Lined Cast Iron	30	6
	Ductile Iron	10	2
	Copper	5	1
20%	Installation Date		
	Pre 1950	100	20
	1950-1957	80	16
	1958-1969	60	12
	1970-1975	40	8
	1976-1985	30	6
	1986-1995	20	4
	1996-2010	10	2
15%	Diameter		
	4-inch and smaller	100	15
	6-inch water main	80	12
	8-inch water main	50	7.5
	10-inch water main	20	3
	12-inch water main	10	1.5
	16-inch water main	5	0.75
15%	Water Quality		
	Water quality problems	100	15
	No water quality problems	0	0
15%	Break History		
	History of Breaks	100	15
	No History of Breaks	0	0
10%	Soils		
	Water main with identified corrosive soils	100	10
	Water main with potentially corrosive soils	80	8
	Gravel, sand	0	0
5%	Static Pressure		
	Greater than 125 psi	100	5
	100 to 125 psi	80	4
	80 to 99 psi	60	3
	Less than 80 psi	0	0

Table No. 6-2
Pipe Material by Installation Year

Installation Year	Length (ft)					
	Asbestos Cement	Factory Lined Cast Iron	Ductile Iron	Galvanized Iron	Copper	Unlined Cast Iron
Pre 1950				445		1,119
1950-1957	23,454					2,032
1958-1969	12,266	9,949	513			
1970-1975			550			
1976-1985			43,503			
1986-1995			41,749			
1996-2010			54,472		664	
Total	36,273	9,949	141,135	445	665	2,343

12-inch do not have a uniform wall thickness and 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. The Town's distribution system does not include cast iron mains 16 inches and larger in diameter. While the transition to factory cement lined cast iron mains had begun in the early 1950's, prior to the year 1958, most cast iron water mains that were manufactured were still unlined. Unlined cast iron water mains increased the potential for internal corrosion. By 1958, the majority of cast iron mains manufactured had a factory cement lining. The year 1958 is also when rubber gasket joints were introduced. 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 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. Therefore, the rating score is higher for water mains manufactured before 1958 as opposed to water mains manufactured after this time.

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 1950's, and continues to be manufactured today, although most New England water utilities did not begin to install ductile iron pipe until the late 1960's. Factory cement lined cast iron

and ductile iron pipe provided increased protection against internal corrosion. Cement lined cast iron water main (CLCI) make up approximately five percent of the Town's system.

Between the 1930's and 1970's, 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 the water quality, the structural integrity of AC mains can deteriorate over time, thereby becoming sensitive to pressure fluctuations and/or nearby construction activities. In addition, external influences such as soil type and high groundwater can corrode AC mains, thus reducing the strength further. According to the Town's personnel, AC main was installed between the mid 1950's and mid 1960's. Approximately nineteen percent of the system consists of AC water mains.

Approximately 74 percent of the system is cement lined ductile iron water main. 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. Ductile iron pipe is susceptible to external corrosion. Failures in ductile iron water mains due to external corrosion are occurring more frequently throughout the United States. This is a growing concern among water utilities. Soil testing is recommended prior to installation of all new ductile water mains. Wrapping the water main in polyethylene to protect against external corrosion has proved successful in areas of potentially corrosive soils.

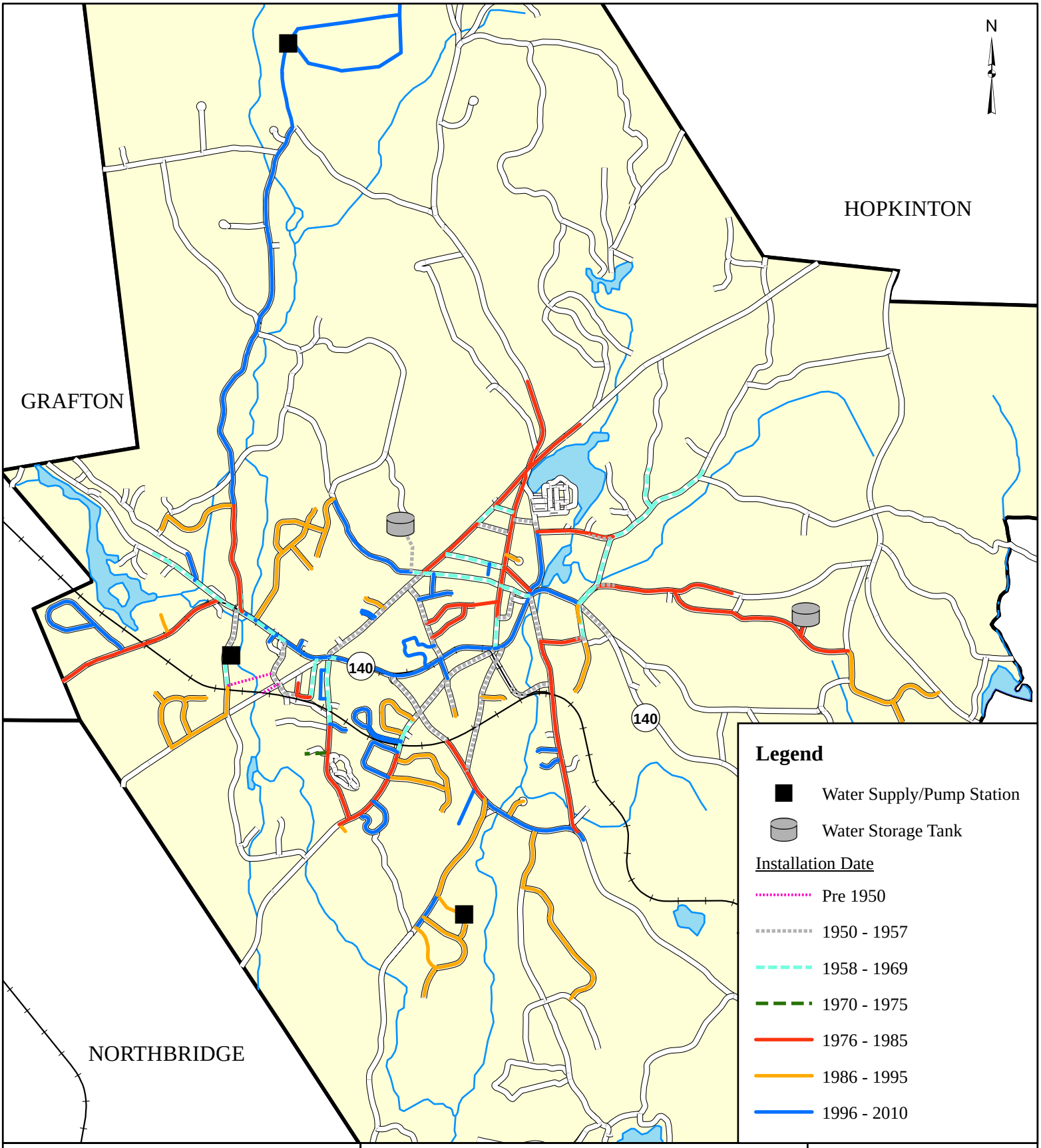
Less than one percent of the system is galvanized iron or copper main. The galvanized iron main consists of a 2-inch diameter main installed on South Hartford Avenue between Farm Road and the railroad tracks, while the copper main consist of two parallel 1-inch pipes located on Capeway Road.

In general, the oldest water mains in the system received the highest rating of 100, while the newest received a rating of zero. Figure No. 6-1 and 6-2 present the installation year of the water mains and the materials, respectively.

Diameter

The Town's water distribution system consists of water mains ranging in diameter from four to sixteen inches. Approximately 52 percent of the system is comprised of 8-inch diameter pipes, approximately 30 percent is 12-inch diameter pipes, approximately six percent is 10-inch diameter pipe, approximately four percent is 16-inch main, approximately eight percent is 6-inch diameter pipe and less than one percent is 4-inch or smaller.

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



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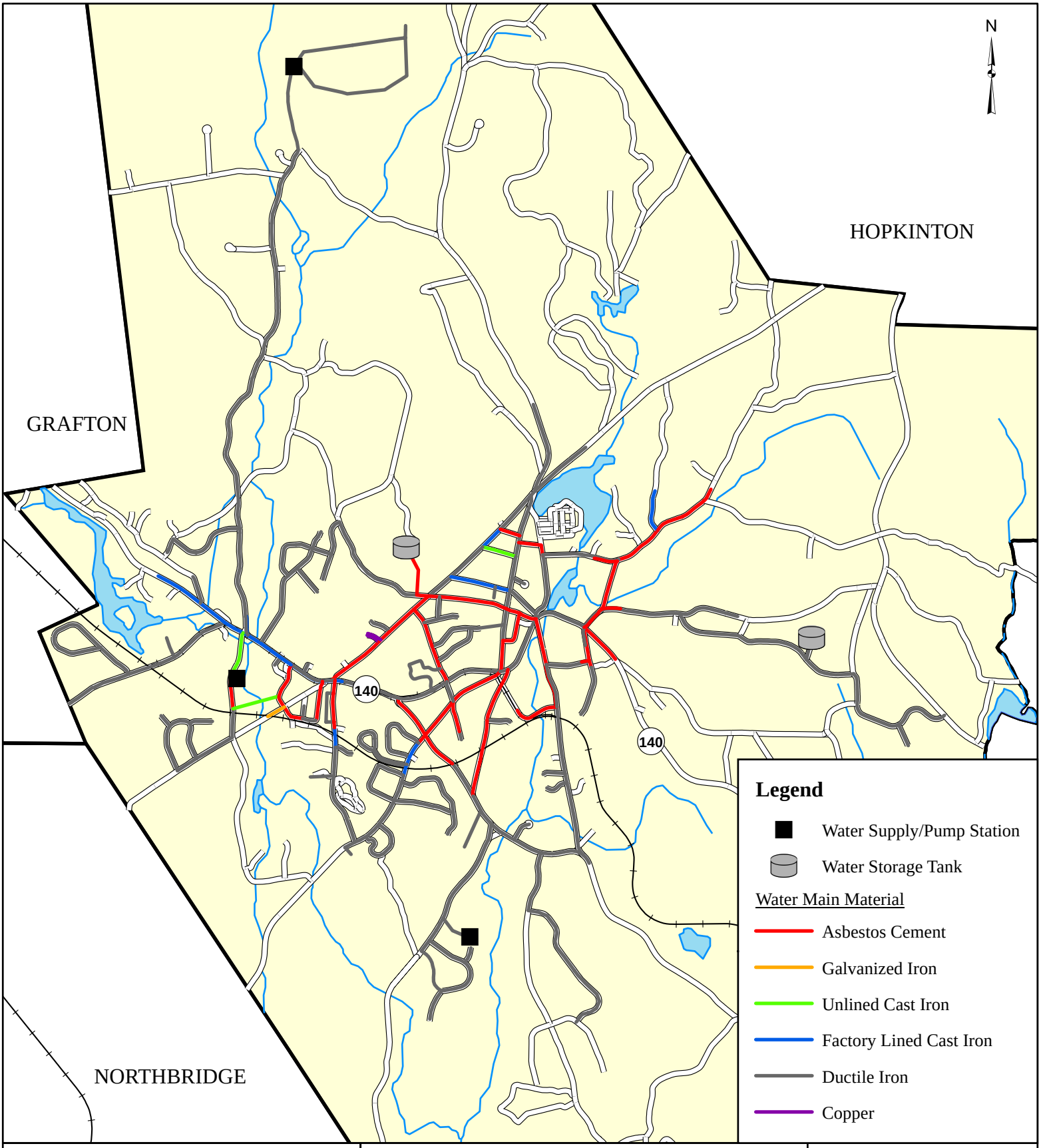
Date: June 2011 Scale: 1:36,000

Water Main Installation Year

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-1



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Water Main Material

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-2

forces than 6-inch diameter water 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 water mains such that in addition to superior bending resistance, they also are much more resistant to failure from pipe wall corrosion.

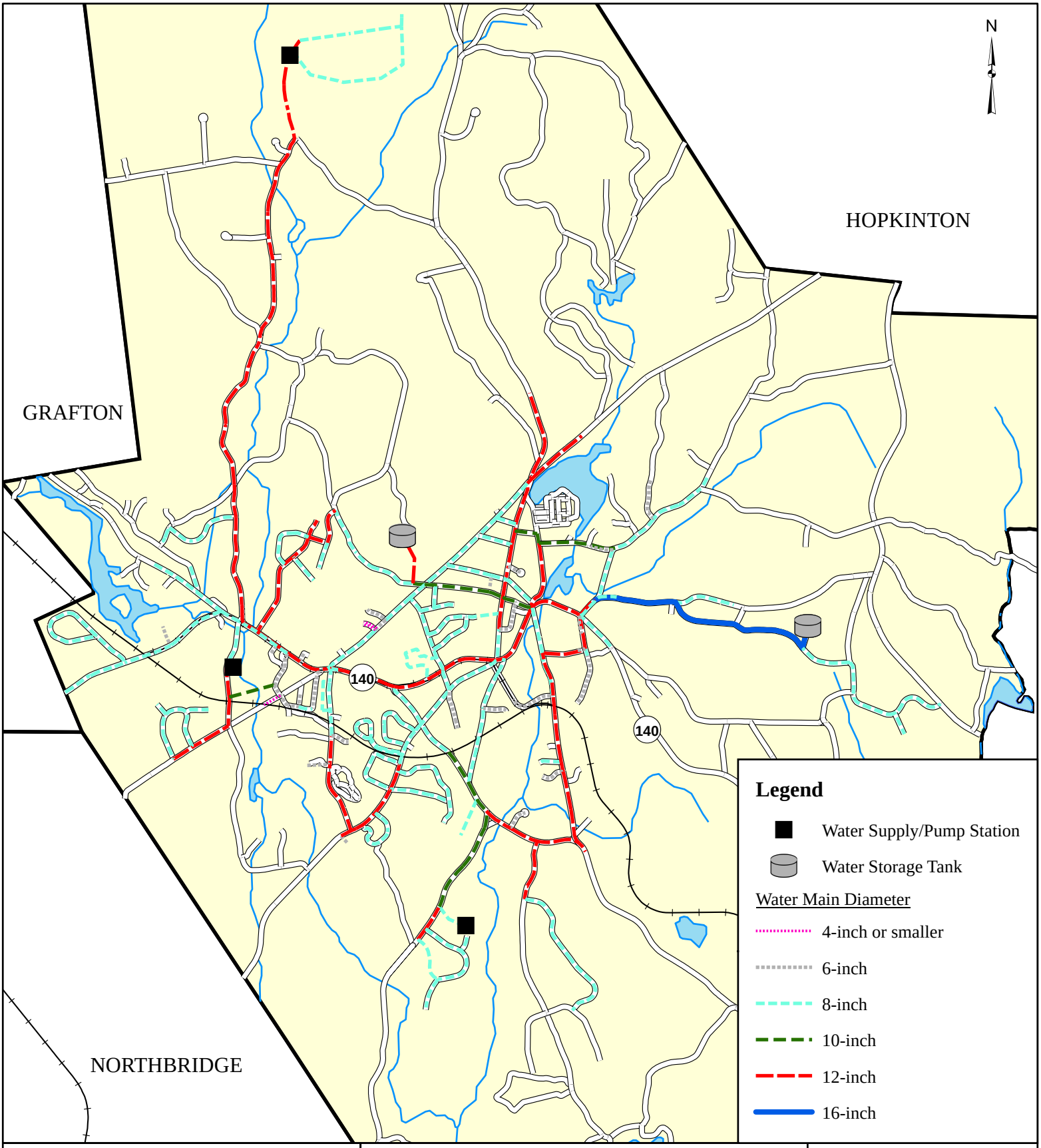
The rating system for the diameter of the water mains follows the concept that 4-inch diameter water mains are not as strong as 16-inch diameter water mains. Therefore, a rating of 100 was assigned to 4-inch diameter and smaller water mains and a rating of zero was given to the 16-inch diameter water 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 (50). 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. In general, 8-inch diameter water mains are stronger and less likely to break than 6-inch diameter pipes. Figure No. 6-3 presents the various diameter sizes throughout the distribution system.

Water Quality

Based on conversations with Town personnel, there are customer water quality complaints in selected portions of the distribution system. There are occasional complaints of chorine deficiency in a section of the distribution system near the Pearl Street Tank including Christian Hill Road, Pearl Street and Tyler Road. There are frequent red water complaints south of Main Street including Mendon Street, Plain Street, Pleasant Street, Knowlton Circle, Florence Circle and Grove Street. Figure No. 6-4 represents the areas with distribution system water quality concerns.

Break History

Based on conversations with the Town's personnel and main failure records, the Upton water system experienced multiple problems with breaks in their AC mains. To address the frequent water main breaks, the Town has replaced the majority of the mains with DI pipe within the past eight years, decreasing the average amount of breaks to less than one break per year. In relation to the total miles of water main in the system, this equates to approximately one break per 100 miles per year. In comparison to the national average of 25 breaks per 100 miles per year, the Town's 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. Based on the Upton water main break records, there are limited areas in the system that have experienced breaks. Once a main fails, the probability of a subsequent failure along the same main with similar characteristics increases. The probability increases again when the same water main has failed a second time, and so on. Areas with history of breaks are given a rating of 100 while areas with no known breaks received a rating of zero. Figure No. 6-5 presents areas with a history of breaks.



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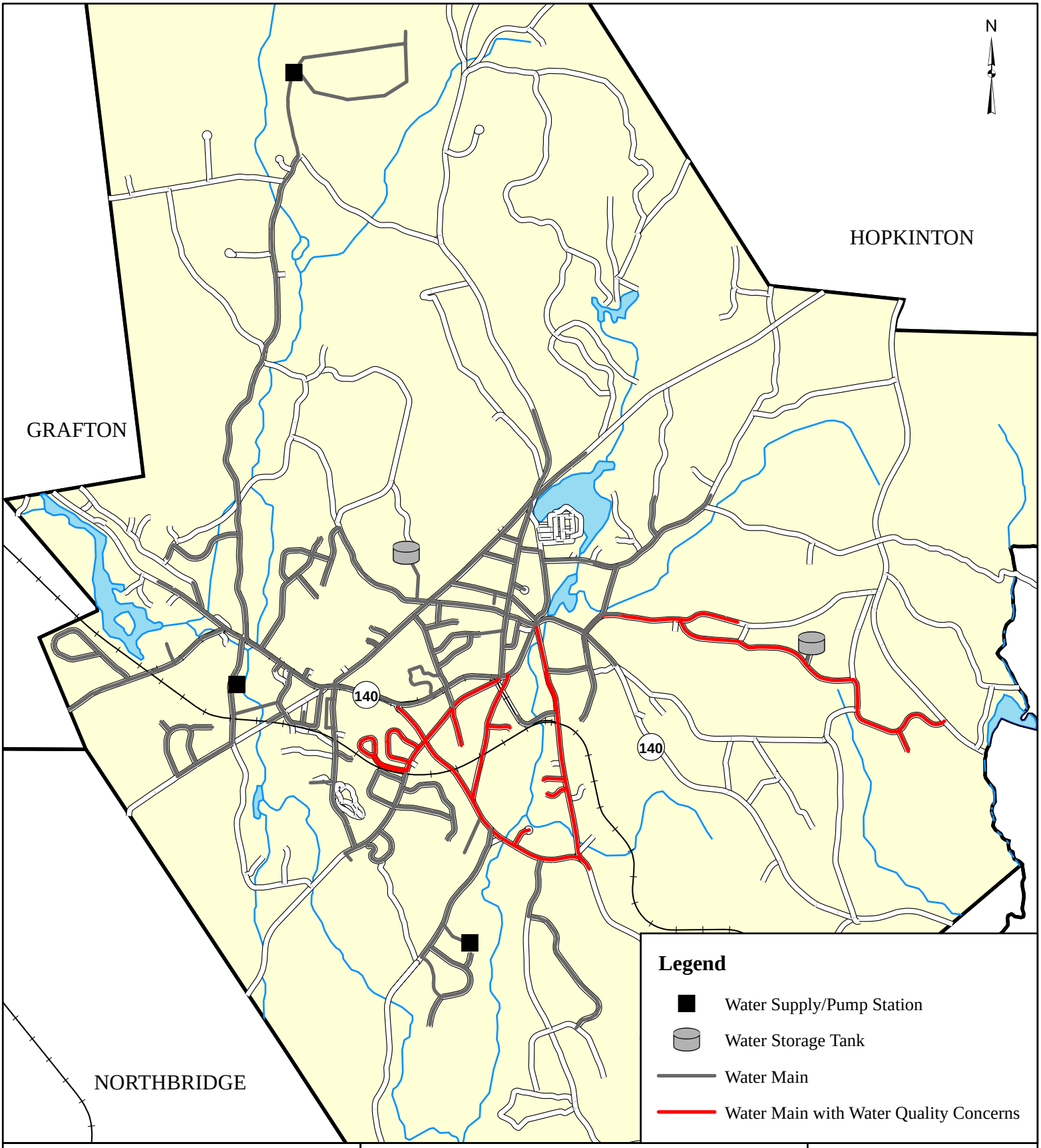
Date: June 2011 Scale: 1:36,000

Water Main Diameter

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-3



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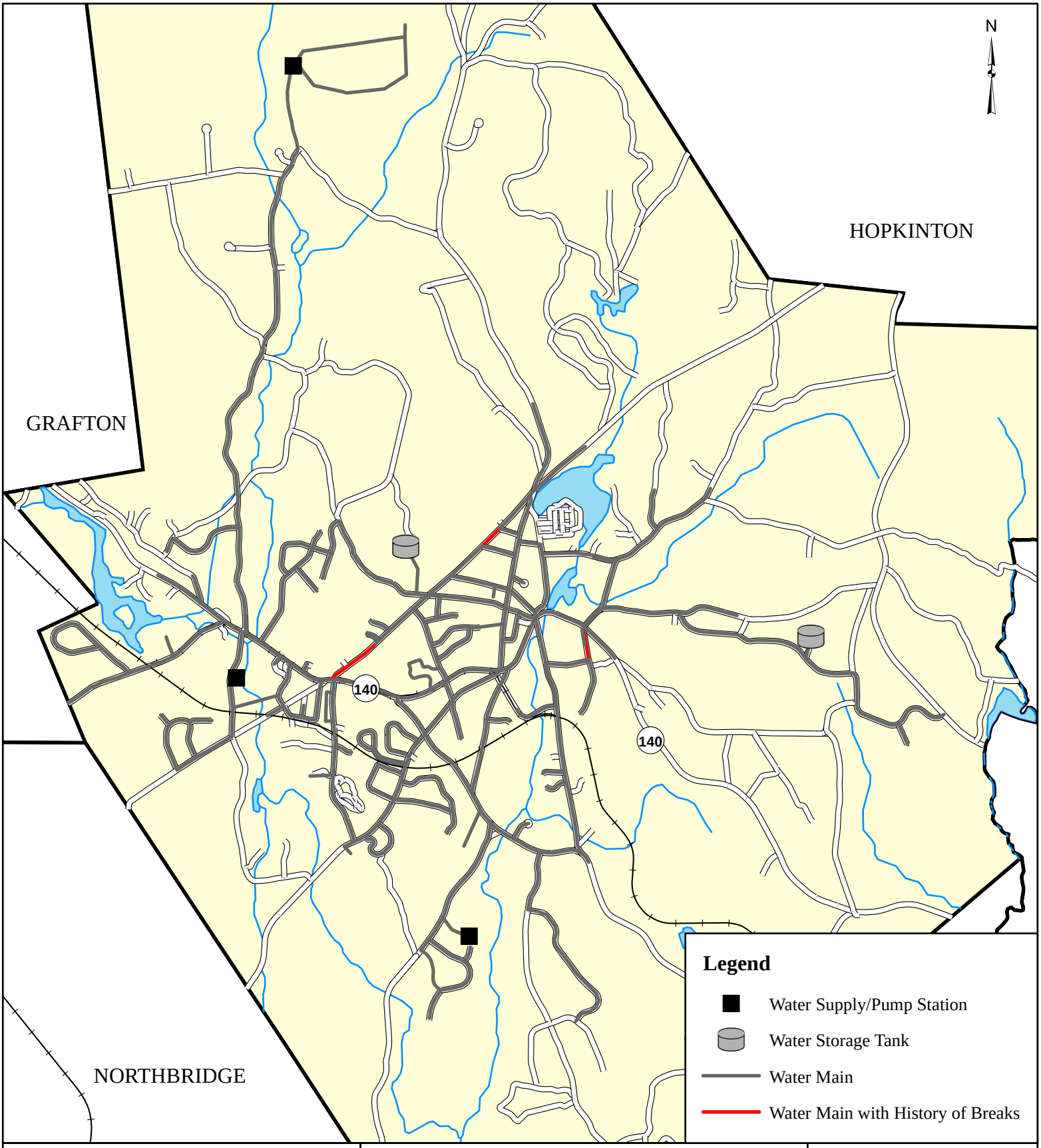
Areas with Water Quality Concerns

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-4



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Areas with History of Breaks

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Upton, MA

Figure No.

6-5

Soils

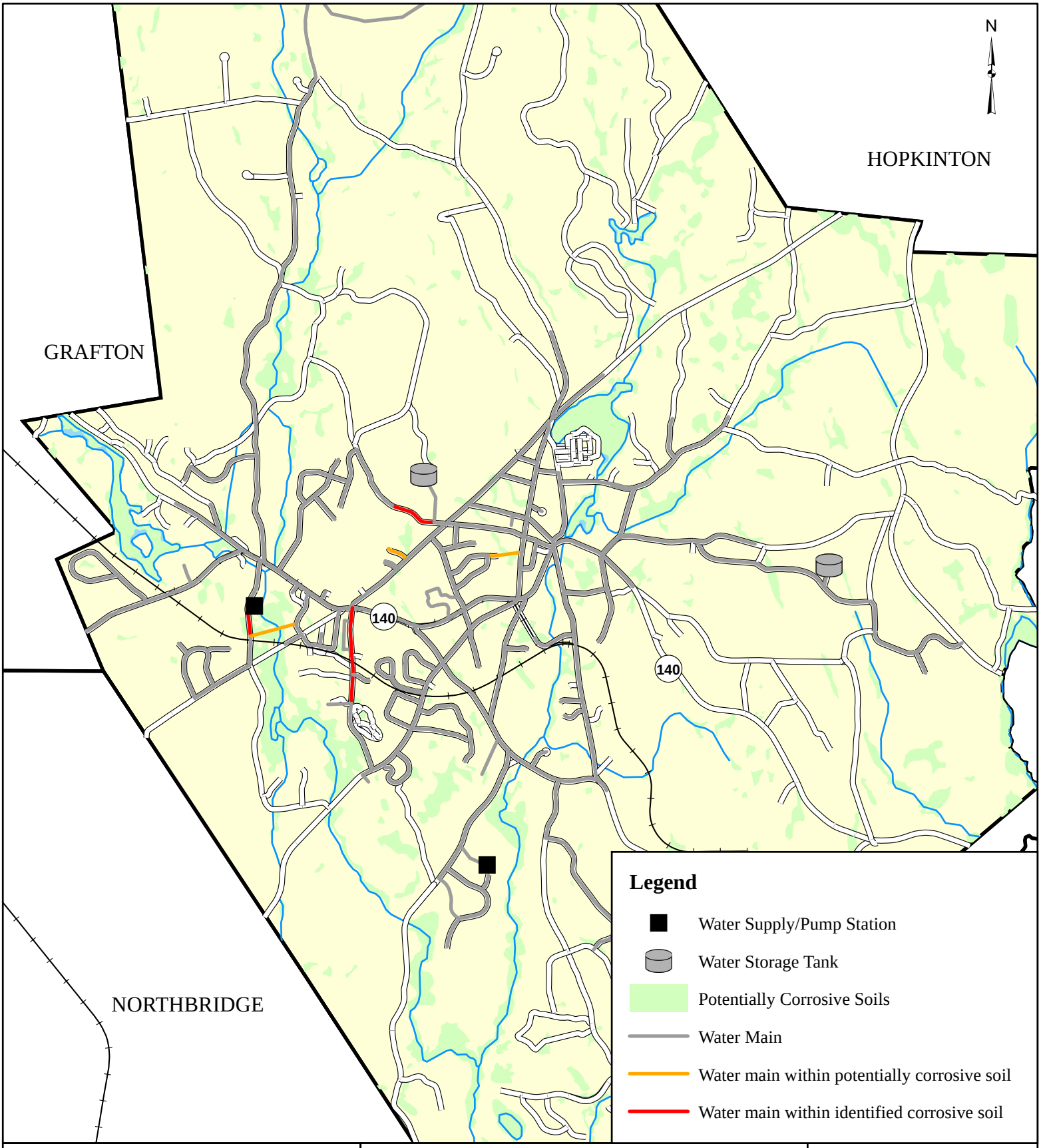
Water main degradation can occur both internally and externally. Factors that increase the rate of external corrosion include soils within a floodplain, poorly drained soils, high groundwater and groundwater with low calcium carbonate or high acidity or sulfate. The chemical and biological composition of soils and areas that vary in soil types can cause external pipe corrosion. Soil moisture provides the electrolyte for the galvanic battery that causes external pipe pitting. Wetlands areas, which are typically high in natural soil organics, have greater potential to cause external corrosion of water mains than other soil conditions. Clay soils and clay/sand or clay/silt interfaces can also cause external pipe corrosion. In addition, clay is a low permeability soil and as a result, groundwater will not drain away from the pipe quickly. The additional contact with soil moisture can accelerate the rate of external pipe corrosion.

Figure No. 6-6 represents the areas of potentially corrosive soils scattered throughout the Town's system. Areas where personnel from the Town have observed external corrosion on the main are considered areas of identified exterior corrosion. These areas were given the highest rating (100). Areas within wetlands are considered areas of potential corrosion and are given the next highest rating (80). All other pipes were assigned a rating of zero.

Pressures

Approximately 87 percent of the Town's water system has a pressure above 80 psi. Approximately 75 percent of the distribution system experiences pressures above 100 psi as noted below. Plumbing code states that water heaters can be affected when pressures exceed 80 psi. Pressures above 100 psi can result in increased water use from fixtures and also increased leakage throughout the distribution system. MassDEP Guidelines and Policies for Public Water System states that normal working pressures should be approximately 60 psi and not less than 35 psi. Areas with pressures exceeding 125 psi are required to have pressure reducing valves on the water mains. These areas are more susceptible to water main breaks. In addition, main failures in areas of higher pressures typically cause more disruption, and result in more costly repairs for damages. All areas with pressures above 125 psi were given a rating of 100, while pipes with pressures under 80 psi were assigned a pressure rating of 0. Figure No. 6-7 presents static pressures in the system. As a result of the high pressure in the system, the tanks operating levels are typically maintained at sixteen feet below the tank overflow.

Pressure Range	Percentage in System
Less than 80 psi	13
80 – 99 psi	15
100 – 125 psi	63
Greater than 125 psi	9



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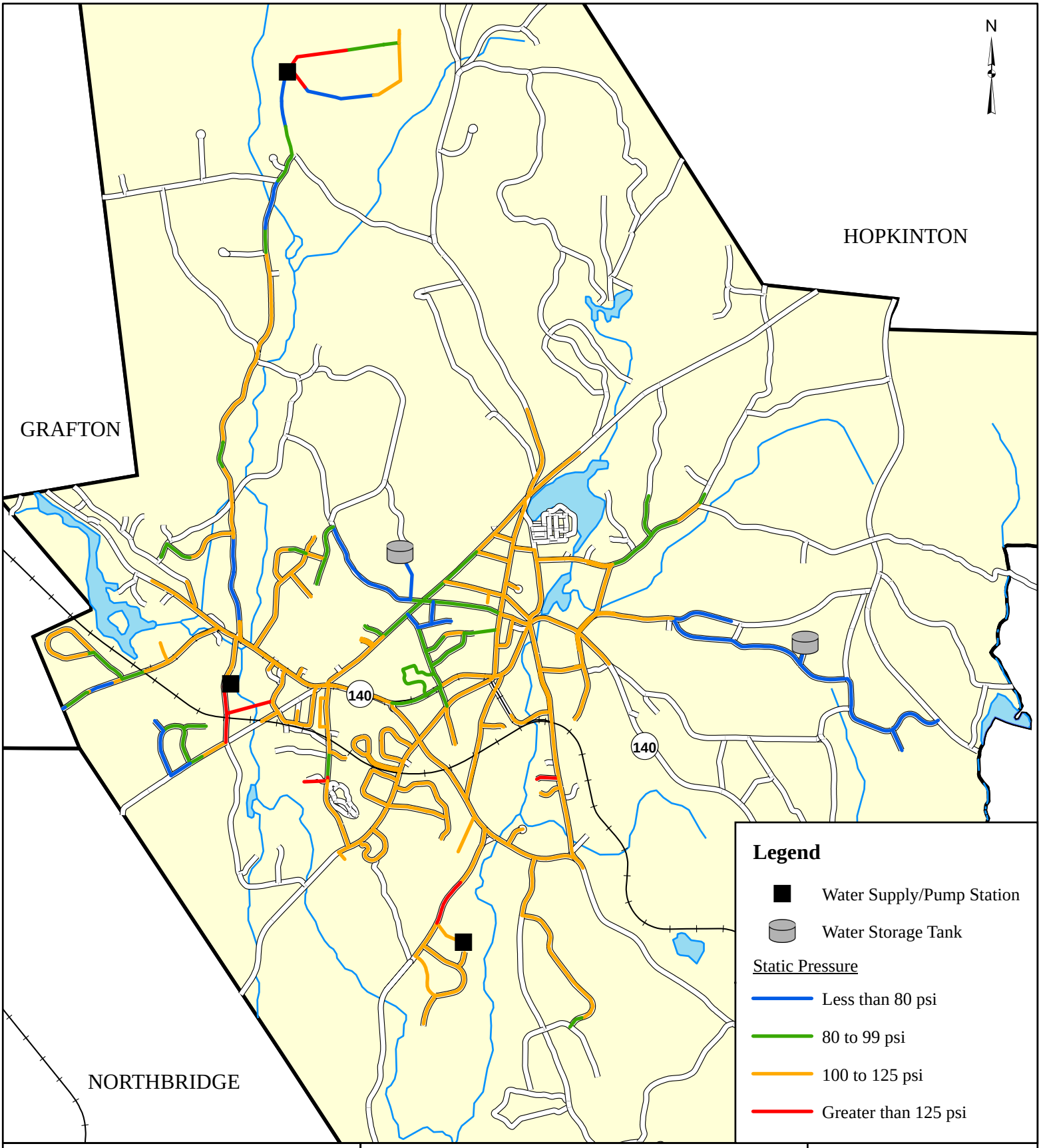
Potentially Corrosive Soils

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-6



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Static Pressure in Water Main

Water Master Plan and
Capital Efficiency Plan™
Upton, MA

Figure No.

6-7

6.4 Asset Management Areas of Concern

Based on the Asset Management ratings, approximately 73 percent of the system is in good to excellent condition. Water mains with a total rating between zero and 25 are considered to be in good to excellent condition. Areas with a total rating between 26 and 42 are considered to be in fair to good condition, and areas with a total rating of 43 or more are considered to be in poor to fair condition. Water mains considered poor to fair are included in Table No. 6-3. Asset Management ratings are presented graphically in Appendix F.

Table No. 6-3 Asset Management Areas of Concern		
	Street	Rating
1	Hartford Avenue North from Main Street to Warren Street	46-62
2	Hartford Avenue South from Farm Street to End of Main	57
3	Maple Avenue from Main Street to Cast Iron Pipe	54
4	Farm Street from Main Street to Railroad Avenue	52
5	Piccadilly Street from Brooks Street to End of Main	52
6	Station Street from Grove Street to End of Main	52
7	Brooks Street from Milford Street to Piccadilly Street	52/48
8	Nelson Street	52
9	River Street from Elm Street to End of Main	52
10	Warren Road from Pleasant Street to Ductile Iron Main	52
11	Cross Country Main Between Glen Avenue and Farm Street	50
12	Glen Avenue from the Glen Avenue Pump Station to Cross Country Main	48
13	Plain Street from Main Street to Mendon Street	48
14	Depot Street from Main Street to DI Main	48
15	Christian Hill Road from Elm Street to End of Main	48
16	Grove Street from Main Street to Station Street	48
17	Milford Street from Brooks Street to End of Main	48
18	Mendon Street from Main Street to 10-inch Main	48
19	Pleasant Street from Main Street to Florence Circle	48
20	Fiske Avenue from Hartford Avenue North to Main Street	46/44
21	High Street from Stoddard Street to Cross Street	44
22	Elm Street from Milford Street to River Street	44
23	School Street from Main Street to Nelson Street	44
24	Cross Street	44
25	Maple Street & N. Main Street from School Street to River Street	43

Section 7

SECTION 7 –Conclusions and Recommendations

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 February 2011 Engineering News Record (ENR) construction cost index for Boston, MA of 11433.13, and include a 25 percent allowance for engineering and contingencies and costs associated with water services, hydrants and permanent and temporary trench pavement. Estimates do not include costs for land acquisition, easements or legal fees.

The capital improvement projects considered by this study will provide a direct benefit to the overall level of service to the Upton customers, reduce operation and maintenance cost by reducing the frequency of water main failures and the damage they cause, as well as provide redundancy and improve the transmission grid.

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 include 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 fire fighting 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 Upton distribution system, this would equate to approximately 1,600 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. Also, rehabilitation or replacement of water mains that are inadequately sized to provide needed fire protection will improve public safety.

7.2 General Recommendations

Based on the water storage calculations, Upton has approximately 0.67 mg of surplus through the design year 2031. Based on the amount of surplus storage, there are potential