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Section 1
Introduction

1.1 Background

In general, the Town of Needham's water distribution system is in relatively good condition. A new water treatment plant for the local Charles River Wellfield water supply is currently under construction to meet current and future federal drinking water act regulations. The existing piping system consists of a hydraulically strong network of large diameter transmission mains serving a well-linked system of smaller diameter distribution mains. A majority of the water mains are cement-lined pipes. The two existing water system storage tanks are also in good condition and well maintained by the town.

Needham, however, was aware of several water system issues that required further evaluation including:

- water system storage capacity and operational deficiencies
- hydraulic capacity under future demands
- the age/integrity/reliability of some of Needham's water mains that were installed nearly 100 years ago
- continued tuberculation within unlined pipes in the distribution network that may reduce system pressure and available fire protection in some of the older neighborhood areas
- water quality problems originating from older, unlined mains and from distribution system operations

Accordingly, the town requested an overall assessment of the water system to develop a master plan of required improvements to serve the future needs of the town.

1.2 Purpose

This water distribution system evaluation identifies water system improvements that are required to address system deficiencies in the town of Needham. Using water demand projections for the year 2020, Camp Dresser and McKee Inc. (CDM) identified the water distribution system piping and facility improvements that are required to meet the current and future needs of the Town. Recommendations presented in this report will provide the basis for the Town's long term water system capital improvements program.

1.3 Project Objectives

The major objectives of this study are to:

- Review all available data, relevant plans, and past reports regarding the water system.

- Develop a computer simulation model of the existing water distribution system piping system, including the Charles River Wellfield, St. Mary's Street pumping station, and the Dunster Road and Birds Hill storage tanks. .

- Perform a hydrant flow test field program to evaluate the condition of the existing system.

- Calibrate the model to reflect existing hydraulic conditions in the piping network.

- Evaluate the existing distribution system, conditional capacity, identify deficiencies, and evaluate alternative system improvements, as required, to address those deficiencies.

- Evaluate the distribution system under projected future demand conditions and recommend phased capital improvements plan aimed at cost-effectively managing, upgrading and expanding the distribution system.

- Develop a long-term capital improvements program that will be implemented by the city to address all identified system deficiencies including water quality, domestic pressures and fire protection.

- Evaluate and make general recommendations regarding the city's annual water distribution system maintenance programs, such as hydrant, valve and meter inspection and replacement.

1.4 Project Approach

The initial stages of this project were devoted to the collection of existing data and generation of background information that were used throughout the evaluation. This included field inspection of water system facilities, performance of a hydrant flow testing program, and a review of past reports and water department records relative to water supply and distribution system facilities. Future water demand estimates were developed using population projections from regional and state agencies and from an analysis of trends in past water consumption.

CDM developed a computer model of the piping network to assist in the evaluation of the water system under future demand conditions. The model includes all of the transmission and distribution pipes in the water system that are 6-inches and larger in diameter. CDM calibrated the model using the data collected during the hydrant flow testing program to reflect existing field conditions.

Using the model, we evaluated the piping network to determine its capability to maintain adequate system pressures during projected future peak hour demand conditions and under simulated fire flow conditions (during maximum day demand conditions). Existing pumping and storage facilities were also evaluated to identify any current or future constraints to meet system demands. Where deficiencies exist in piping, pumping and storage facilities, CDM developed system improvements and estimated the construction cost of these improvements.

Finally, CDM prepared a prioritized program of recommended water system capital improvements to adequately meet system demands.

1.5 Previous Reports

Our evaluation for this report is based in part on previous reports prepared for the Town on population, water consumption, the adequacy and reliability of the existing water supply, storage, and distribution piping facilities, and other proposed facility upgrades.

Previous reports used in this evaluation include:

- Hydrologic Investigation for Zone II Delineation, Charles River Street Wellfield, CH2M Hill, September 1988.
- Massachusetts Water Resources Authority Study of Local Sources in MWRA Partially-Supplied Communities, Community Report, Town of Needham, Camp Dresser & McKee Inc., July 1991.
- Lead and Copper Rule Corrosion Control Study (with EPA Form 141-C), Camp Dresser & McKee Inc., May 1994.
- Automated I/I Management System: Needs Assessment and Implementation Plan, Camp Dresser & McKee Inc., May 1994.
- Charles River Wellfield Pilot Test Report, Camp Dresser & McKee Inc., November 1995.

1.6 Report Organization

The water distribution system evaluation report is divided into five basic sections:

- ***Section 2, Description of Existing System.*** Overview of Needham's water distribution system and its major components.
- ***Section 3, Population and Water Consumption.*** Discussion of future population and water consumption projections.
- ***Section 4, Distribution System Modeling.*** Overview of the hydraulic model of the distribution system, including a presentation of the results of the field-testing program and a summary of the calibration methods and results.
- ***Section 5, Evaluation of Existing Facilities.*** Discussion of the evaluation of the distribution system and identification of existing and future deficiencies.
- ***Section 6, Analysis of Alternatives.*** Development and evaluation of alternatives to address deficiencies in water system storage and service to high elevation areas.

- ***Section 7, Recommended Distribution System Improvements.*** Presentation of the system recommendations and cost estimates, and a prioritized program for distribution system capital improvements.

Section 2
Description of the Existing System

2.1 General

The Town of Needham's water distribution system is a single service pressure zone system supplied by two sources. The town's primary source of water is the Charles River Wellfield consisting of three groundwater pumping stations. A new greensand filtration water treatment plant is currently being constructed to treat the groundwater pumped from these wells. Needham's second water source is a connection to the Massachusetts Water Resource Authority's (MWRA) Hultman Aqueduct. MWRA water is pumped into the Needham system by the St. Mary's Pumping Station. The water sources are located at two opposite extremities in the distribution system: the groundwater supply is located in the southwest corner of the system and the MWRA connection is located at the far northeastern end of the system.

Needham's water system also contains two water storage tanks, the Dunster Road Standpipe and the Bird's Hill Tank.

Figure 2-1 shows the locations of these key components of the Needham water system.

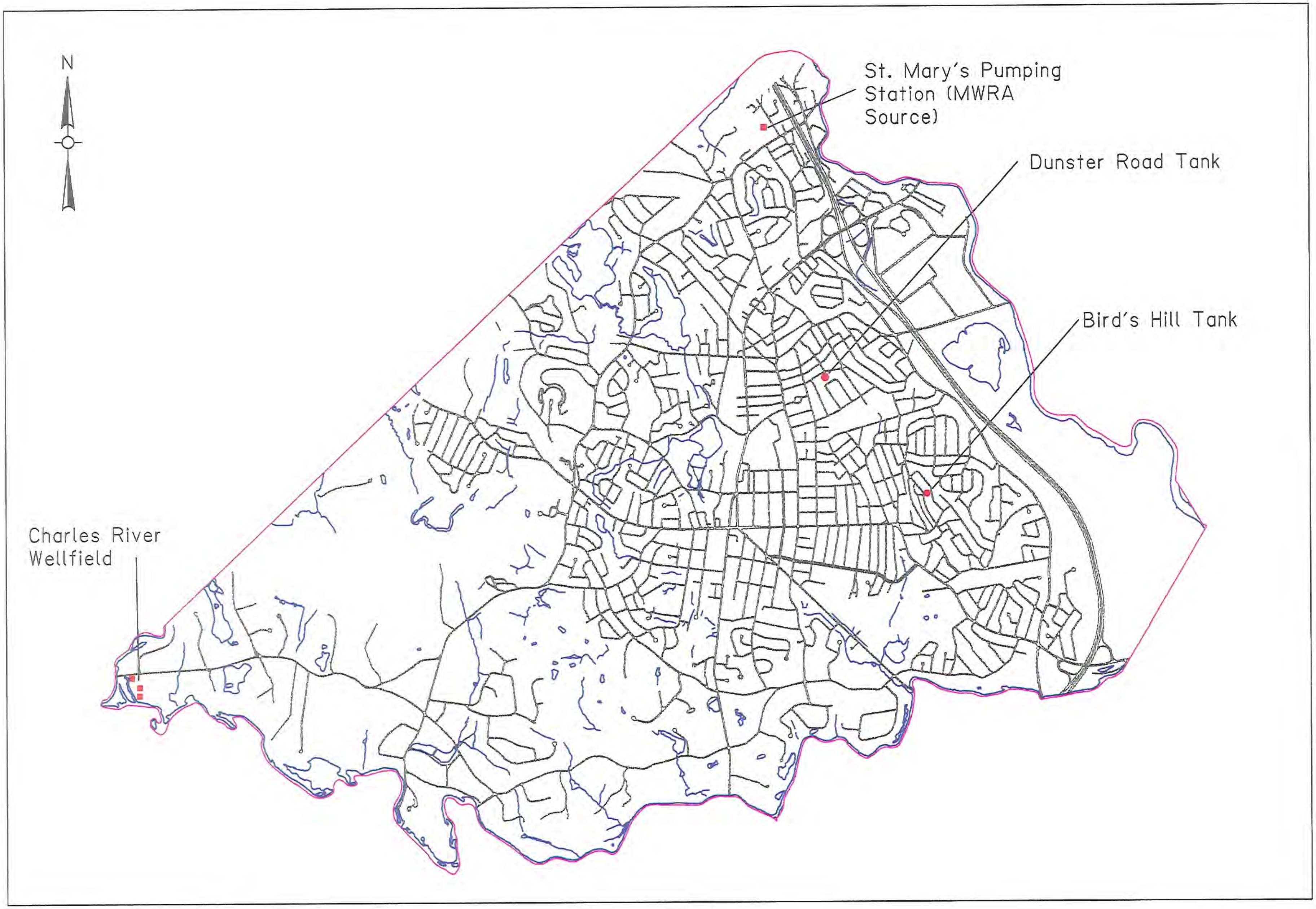
2.2 Water Supply

Needham's water supply consists of the Charles River Wellfield and the MWRA connection. During the last seven years (1991-1997), the groundwater source has supplied 74 to 92 percent of the town's potable water demand, with the MWRA supplying the remaining demand.

The Town abandoned a third groundwater supply, the Dedham Avenue Wells, located near the Needham Reservoir, because of poor yield. Previous studies of these wells indicate that the potential for reactivation of the groundwater supply is limited by its poor water quality and treatment costs. One other potential groundwater supply that may be available for the town is the Elm Bank area in Dover as identified in the MWRA Local Sources Study (CDM, 1991). This supply would be shared among several local communities as stipulated by an agreement between the towns.

No other surface or groundwater supplies have been identified for potable water in the town of Needham.

Charles River Wellfield Station No. 3



CDM Camp Dresser & McKee

Figure 2-1
Plan of Existing Facilities

2.2.1 Charles River Wellfield

The Charles River Wellfield consists of three wells (capacity in million gallons per day - mgd):

Well No.	Station No.	Date of Construction	Rated Pump Capacity (mgd)
1	2	1936	2.0
2	3	1946	1.5
3	5	1969	1.0

The rated pump capacity noted above is based on availability. Needham's wells are often referred to by the respective Well Number by various agencies, but the town commonly refers to the wells by their original Station Number.

Currently, only two of the wells are used for production. In 1983, production from Well No. 3 was discontinued, in part, because of relatively high manganese concentrations in the well water. In addition, operating costs for the well were excessive due to the high cost of fuel and maintenance requirements for the direct drive methane-powered engine. In 1990, the Department of Environmental Protection issued a letter identifying Well No. 3 as a permanent production source for the town, and required future treatment for manganese. Historically, Well No. 3 was pumped to waste annually for testing and well status purposes. Water from this well will soon be treated by the new Charles River Wellfield Water Treatment Plants, discussed later in this section.

Safe Yield and Registered Withdrawal

Historic estimates of safe yield for the wellfield ranges from 5.0-6.0 mgd, although these estimates are not well documented. DEP has approved individual pumping rates for each well with a combined total withdrawal rate of about 5.2 mgd. A hydrogeologic investigation of Well No. 3 (CH2M Hill, 1990) established its safe yield as high as 6.5 mgd, with a concurrent withdrawal of 3.5 mgd from Well Nos. 1 and 2. However, the results of this evaluation are suspect because of the uncertainty of the field investigations. In the 1991 MWRA Local Sources Study, the effective safe yield for the combined wellfield was established at 4.5-mgd based on an assessment using 1990 DEP-specified criteria.

Actual annual average withdrawal rates for any water supply in Massachusetts are ultimately established by the Water Management Act (WMA) by DEP. Under WMA, the Charles River Wellfield was originally registered (December 1988) for an average annual withdrawal rate of 2.63 mgd (based on the records from 1981 to 1985, inclusive). In November 1991, the town later obtained DEP approval of a permitted withdrawal (in addition to the registered rate of 2.63 mgd) of 1.36 mgd in 1991 that increases to 1.41 mgd in 2005. Thus, the registered and permitted annual average daily wellfield withdrawal rate for the Charles River Wellfield will be a total of 4.04 mgd by 2005. (The permit also lists a maximum daily withdrawal rate for each well that totals 4.72 mgd for all three wells).

Raw Water Quality

Raw water from the Charles River Wellfield has a relatively low pH (6.5 units), moderate alkalinity (45-mg/l as CaCO3) and moderate hardness (80-mg/l). The water has a relatively high sodium content slightly exceeding the EPA recommended level (for reporting to consumers) of 20-mg/l. All other compounds tested currently are below their respective Maximum Contaminant Levels (MCLs). As discussed above, there are relatively high concentrations of manganese in Well No. 3. Manganese concentrations in the other two wells are below generally acceptable levels (i.e., below 0.05-mg/l).

Current Treatment

Groundwater from Well No. 2 is piped to the Well No. 1 pumping station where both supplies are treated with chemicals including hydrated lime for pH adjustment, hydrofluosilicic acid for fluoridation, and sodium hypochlorite for disinfection. Average finished water concentrations are 0.43-ppm total chlorine, 1.1-ppm fluoride, and a pH of 7.4. The treated water is conveyed by a 16-inch main along Charles Street nearly 2,000 feet (east) before the main connects to the distribution system (and the first customer).

During power failures, a methane-powered standby engine supplies power to the Well No. 1 pump and chemical feed systems. There is no standby power available for Well No. 2.

Future Treatment

Future treatment of Needham's groundwater supply will be performed by the new 4.5 million gallons per day (mgd) Charles River Well Field Water Treatment Facility (WTF). This facility will replace the existing chemical facilities located at Well No. 1. Construction of this WTF began in January of 1998. It is expected that the treatment facility will be on-line in Spring 1999.

New Greensand Filtration Plant

The new treatment facility was recommended to provide water system corrosion control to comply with the Lead and Copper Rule and to remove manganese from the well water to comply with DEP requirements for the reactivation of Well No. 3. Treatment processes include oxidation with potassium permanganate and sodium hypochlorite, greensand filtration using pressure filters, pH adjustment with sodium hydroxide, and fluoridation. Each well pumping station will be upgraded with new pump and motor equipment to allow each well to pump through the treatment facility and directly into the water distribution system (i.e., no clearwell or finished water pumping). A new standby power generator will be installed to operate the plant and all three wells during power failures.

2.2.2 MWRA Supply

During periods of high water demand, the town's groundwater supply is supplemented with water from the MWRA. The town draws water from the MWRA system at Meter No. 160, which is supplied by a 48-inch and 36-inch diameter main running from Hultman Aqueduct (Shaft 5) through the neighboring Town of Wellesley. Water from the MWRA is pumped into the Needham water system through a pumping station located on St. Mary's Street (Station No. 4), which is owned and operated by the town.

St. Mary's Street Pumping Station

Water from the MWRA is treated at the Interim Corrosion Control (ICC) facility located near Shaft C (downstream of the Wachusett Reservoir) and at the Norumbega Reservoir. Chemical treatment at the ICC includes soda ash and carbon dioxide for corrosion control to raise the pH to 9.0 and raise the alkalinity to 30-mg/l as $CaCO_3$, and hydrofluosilicic acid for fluoridation. Chloramination (disinfection) is performed at the Norumbega Reservoir with sodium hypochlorite and ammonia.

Needham currently has an agreement with the MWRA that allows it to withdraw up to a daily maximum of 12.5 mgd. A description of the station and pumping capacities is described in Section 2.4.

Dunster Road Storage Tank

2.3 Distribution System Storage

Needham has two water system storage tanks located in the central and southeastern sections of town as shown in Figure 2-1. Although no major problems have been noted with either tank, the 1996 DEP Sanitary Survey recommends that the town eliminate the direct connection of each tank overflow pipe to the storm drain system and initiate regular inspections and cleanings of both tanks.

2.3.1 Dunster Road Tank

The Dunster Road tank is a standpipe that is 55 feet in diameter and approximately 86 feet high, with a total capacity of 1.5 million gallons. The standpipe is located at a high elevation area bounded by Hoover Road, Dunster Road and Dartmouth Avenue. Residential homes are located within 100 feet of this tank.

The steel tank was built by the Chicago Bridge & Iron Company in 1950. Its overflow elevation is 347.6 feet

(USGS-United States Geologic Survey, 1929 Mean Sea Level datum) and has a volume per foot of approximately 17,760 gallons. Typically, the tank fluctuates about 6-8 feet during the day.

The standpipe was last inspected by Robert L. Merithew, Inc. in 1991. Based on the inspection, it was recommended that the tank be scheduled for painting, maintenance and foundation repairs within the next two years. These recommended improvements were completed in 1993.

2.3.2 Bird's Hill Tank

The Bird's Hill Tank is a ground level reservoir located at a high elevation area bounded by Hillcrest Road and Morningside Road. Residential homes are located within 100 feet of this tank.

Bird's Hill Storage Tank

The steel tank was constructed in 1972 and has a diameter of 100 feet and a height of approximately 45 feet, with a total capacity of 2.5 million gallons. Its overflow elevation is 346.7 feet (USGS) and it has a volume per foot of approximately 58,700 gallons. Typically, this tank fluctuates about 6-8 feet during the day. Town staff report that water levels in this tank are typically 3-5 feet lower than water levels in the Dunster Road Tank.

Robert L. Merithew, Inc. inspected this reservoir in 1996 and found that the tank was in good condition and required no repairs. It was recommended that the tank be inspected again in late 1998.

2.4 Pumping Stations

Needham operates four pumping stations: the three groundwater pumping stations and the St. Mary's Pumping Station (MWRA connection). The three groundwater pumping stations and capacities are discussed in Section 2.2.

St. Mary's Pumping Station

The St. Mary's Pumping Station is a two-level building housing four pumps, and is located at the intersection of St. Mary's Street and Central Avenue.

Pump	Location	Design Capacity	Design Head	Standby Power
1	1st Floor	3500 gpm	150 feet	No
2	1st Floor	3500 gpm	150 feet	No
3	Basement	2200 gpm	85 feet	Direct Drive Diesel Engine
4	Basement	3000 gpm	115 feet	Direct Drive Diesel Engine

The town reports that Pumps No. 1 and No. 2 have never been used because the capacity of these two pumps is significantly oversized for the town's current hydraulic conditions. Pumps No. 3 and No. 4 are each directly connected to an electric motor drive and one of the diesel standby engines.

St. Mary's Street Pumping Station - Pump No. 3

The St. Mary's Pumping Station is used to supplement flow from the well supply. The pumping station operates automatically based on water levels at the Dunster Road Tank. As demands increase, and the existing wells cannot meet demand, water levels within the Dunster Road Tank drop until a preset limit elevation is that activates Pump No. 3. If water levels continue to drop in the Dunster Road Tank, Pump No. 4 is also activated.

2.5 Distribution System Piping

2.5.1 General

Needham's water system comprises a closely linked network of small diameter pipes supplied by a larger grid of transmission piping that delivers water from the Charles River Well Fields and the MWRA connection.

Needham's transmission piping system consists of a large diameter (10-inch and greater) piping network between the two water supply sources, the water storage tanks, and the major demand areas in the town. This system is hydraulically strong and well-linked. Needham's residential neighborhoods are generally supplied by a distribution piping network consisting of 6-inch and 8-inch diameter mains. The majority of the unlined smaller diameter water mains exist in the central portion of Needham along Great Plain Avenue in the older sections of town. These areas, however, are adequately (hydraulically) supported by the larger diameter transmission piping network. Generally, the extremities of Needham are served by cement-lined pipe.

Pressures in the water system generally range from about 20 psi to 110 psi. The areas with the lowest pressures are directly adjacent to the two water system storage tanks. Atop Bird's Hill, water main pressures may drop below the minimum state standard of 20 psi, depending on the diurnal fluctuation within the tank. The Town reports that some residents in this area have installed individual home pressure booster systems to provide adequate flow and pressure for household uses.

2.5.2 Breakdown of Existing Pipes

There are more than 131 miles of water mains in the Needham water distribution system ranging in size from 1.5 to 20 inches in diameter. Pipe materials consist of cement-lined ductile iron, cement-lined and unlined cast iron, steel, copper and PVC. Based on a recent review of the records, town personnel report that pipes installed after approximately 1946 are cement-lined. Needham also cleaned and cement-lined some existing unlined cast iron mains in the 1960s. Most of the original unlined cast iron water mains installed prior to 1946, however, have not been cleaned and cement lined. Approximately 68 percent of the existing water system has cement-lined pipe.

A breakdown of the distribution piping system (6 inches and greater in diameter) by cement lined versus unlined pipe and diameter is presented below:

		Miles of	
Diameter	***Lined***	***Unlined***	***Total***
6-inch	23.0	22.3	45.3
8-inch	39.6	12.8	52.4
10-inch	0.9	1.6	2.5
12-inch	20.2	3.1	23.3
14-inch	0.6	2.9	3.5
16-inch	4.3	0.4	4.7
20-inch	1.5	0.1	1.6
TOTAL	**90.1**	**43.2**	**133.3**

Approximately 68 percent of the existing water system has cement-lined pipe.

2.5.3 Reliability

As discussed above, the Needham water system is generally well-linked. However, there are three areas of concern regarding general system reliability. The first two areas are related to a limited number pipes providing service to critical areas. The last problem relates to the age of some system pipes. There are water mains in town that are more than 100 years old, with pipe diameters ranging from 6-inches to 12-inches.

Transmission Supply from the Charles River Wellfield

One concern is the two major transmission mains connecting the local groundwater supply with the central portion of town. These mains extend together along Charles River Avenue and then split, one following along South Street and the other along Central Street. If either one of these transmission mains were taken out of service for any extended period of time (due to unplanned emergencies such as leaks, breaks or other types of pipe failure, etc.), use of the local water supply would be limited due to the reduced hydraulic carrying capacity from the wellfield to the water system.

The 14-inch diameter cast iron main along Central Street is more than 60 years old and has lead joints. Coupons of the existing pipe taken by the town indicate that the pipe is in relatively good condition. In addition, no audible leaks have been noted along this pipe during the town's annual leak detection assessment. However, leakage from the lead packing type joints tends to increase with age, which could increase leaks and breaks along the pipe, causing it to be out of service more frequently. Replacement of the entire pipeline is probably not warranted nor cost-effective given its current service record. However, the town should continue to monitor the pipe, perhaps collecting additional pipe coupons, to determine the potential for any future leakage or failures along this transmission main. If the condition of the pipe deteriorates in the future, the town could consider rehabilitating the pipe with a liner or complete replacement of the existing main to ensure adequate system reliability.

The 16-inch diameter main along South Street was installed during the 1970s. This pipe was constructed in sections by the town, with new sections added each year. Along one particular section of this main (running about 4000 feet from Chestnut Street west to about 700 feet west of Burr Drive), at least six water main breaks have occurred over an 18-month period. Town staff believe that these breaks may be due to poor quality pipe that was purchased and installed by the town at the time. The town should review its leak/break records to identify the total number of times the pipe has been repaired and to determine if these sections were installed at the same time. If existing conditions warrant, the town should consider replacing this main to improve reliability and reduce the maintenance and cost requirements of repairing the main under emergency conditions.

Route 128 Crossings

Route 128 effectively splits a heavy commercial and industrial land use area (bounded by First, Second, Third and Fourth Avenues on the east side of Route 128) from the main distribution system. Two 12-inch diameter pipe crossings under Route 128 serve this industrial/ commercial area (one at Kendrick Street and one at Kearny Road). Although these mains are in relatively good condition, at least one leak/break has been reported (during the last 18 months) on the water main crossing at Kearny Road.

Maintenance of the water main crossings for leak, breaks, etc. is difficult due to the depth of the mains and the location under the interstate roadway (the current roadway surface was raised above the original ground surface that existed when the mains were constructed; thus, the reported depth of the mains under the highway is 20-25 feet).

To improve reliability to this commercial/industrial area in east Needham, the town may want to consider installing a new main under the highway in the future, at a reasonable depth and within a steel sleeve, to allow easier access for maintenance of the pipe(s). Needham could also consider constructing a third 12-inch (or larger) diameter loop to the area from St. Mary's Street along Central Street and then along Reservoir Street, running south to the 12-inch crossing at Kearny Road.

Aging Water Pipe

More than 7.5 miles of water main in Needham were installed prior to 1900; this pipe is now more than 100 years old. Typically, the reported useful life cycle (span) of cast iron pipe is about 75-100 years (although the actual lifespan is a function of the use of the pipe, its construction and bedding, external and internal corrosion, etc. that may decrease or extend the integrity of the pipe). Needham should consider systematically replacing these pipes to improve the reliability of the piping system.

2.5.4 Pipeline Leaks and Breaks

The town provided a map showing more than forty (40) locations of pipeline leaks and breaks that were repaired recently. For the most part, these locations are distributed across the town with no discernible trends in type of pipe or age. However, in several areas, there are recurring problems that should be investigated further by the town to determine the probable cause. In particular, a stretch of 12-inch diameter pipe along Central Street from West Street to Lourt Drive has had multiple (more than six) leaks and breaks during the town's reporting period. Multiple leaks/breaks have also been repaired on Chestnut Street (four), Country Way (two), Rivard Road (two), and Gatewood Drive (two). Based on the data presented by the town, the cause for these multiple breaks along these streets cannot be identified. Whenever possible, the town should identify whether breaks/leaks were a result of system operations (i.e., pressure surges due to pump/hydrant operations), inadequate bedding, localized corrosion, etc. so that these maintenance issues can be minimized.

2.6 Distribution System Quality

2.6.1 Complaints

Consumer complaints regarding water quality and pressure are recorded by town personnel at the St. Mary's Pumping Station. The Town provided CDM with a summary of the water quality complaints recorded over the last several months. Generally, customer complaints focus on red- and brown-colored water problems. Many of the water quality complaints in Needham can be attributed to water system disruptions, such as water main breaks and leaks or fires; water main flushing; algae outbreaks during lake turnover (from the MWRA system); and specific localized problem areas with unlined small diameter mains and low water main velocities.

A significant number of water quality complaints are also attributed to water system disruptions caused by the activation of the pumps at the St. Mary's Station. The activation of the pumps at St. Mary's Station is likely causing flow reversals within the pipes, which is resuspending pipeline sediment and causing dirty water complaints.

The Town performs an annual water main flushing program. The program consists of a series of flushing procedures where individual areas are partially isolated by a number of valve closures and the area is flushed using a number of hydrants from the "clean water" source. However, based on the water quality complaints received by the town, the flushing program may not be effective. A more effective program would consist of a unidirectional flushing program, where each individual pipe is isolated for a controlled flush, with a minimum flushing velocity, to ensure that pipe sediment and tuberculation are effectively flushed from the interior of the pipe.

In general, unlined water mains are more susceptible to some water quality problems. Accordingly, an annual program to rehabilitate the existing unlined mains system-wide is the ultimate solution that will eventually address the water discoloration complaints in the town.

2.6.2 Water Quality Testing

The town conducts regular scheduled testing of water quality within the distribution system to meet state regulations concerning coliform bacteria, chlorine residual, and total trihalomethanes (TTHM's). Based on these past sampling results, the town has no major distribution system water quality problems related to these drinking water standards.

However, in 1993-94, tap water testing in Needham for the EPA Lead and Copper Rule (LCR) indicated that town water delivered to consumers exceeded the action levels for lead and copper. The source of lead and copper in the tap water in Needham was primarily attributed to corrosion of interior plumbing and fixtures. In addition, there were a large number of lead service connections to homes in Needham. (The town is currently in the process of replacing these existing lead services; it is expected that all lead services will be eliminated within the next two years.).

Based on the LCR guidelines, the town was required to implement a corrosion control program to reduce the concentrations of lead and copper in the drinking water obtained at the tap. The MWRA recently began applying soda ash and carbon dioxide to its water supply to adjust the pH and alkalinity of the water before it is delivered to its member communities. This treated MWRA water should be less aggressive, thereby reducing corrosion of consumer plumbing fixtures and pipe within the water system.

In addition, the town was required to implement a corrosion control system at the Charles River Wellfield. Accordingly, Needham conducted a series of studies evaluating water treatment requirements for the wells. Based on the existing water quality and the Safe Drinking Water Act compliance standards, a greensand filtration facility was recommended for the Charles River Wellfield. The filtered water will also be treated with caustic soda to adjust the pH to 9 units to reduce the corrosivity of the groundwater supply. This will help to reduce concentrations of lead and copper in Needham's tap water to comply with the LCR. Construction of the new Water Treatment Facility should be completed in Spring 1999.

2.7 Distribution System Appurtenances

System appurtenances including hydrants, valves, and meters and their respective maintenance programs were reviewed for this report. A summary of the review is presented below.

2.7.1 Hydrants

There are approximately 1,150 public hydrants and 100 private hydrants throughout the Needham water distribution system. The town performs an annual flushing program that utilizes a number of hydrants in the water system. The town, however, has no existing formal annual hydrant maintenance or inspection program. Historically, broken or inoperable hydrants encountered during daily routines or fires or during performance of the flushing program are serviced or replaced by the town as soon as crews are available. However, staff report that there are still many hydrants in the town that may be prone to failure. These hydrants are typically avoided by town personnel, whenever possible, especially when there are no existing hydrant isolation valves. In addition, flow from several hydrants used during the hydrant flow testing program conducted for this study appeared to be severely restricted. This may indicate that the hydrant barrel and main connection pipe are tuberculated or that the mainstem valve was malfunctioning. In either case, these hydrants or valves should be repaired or replaced.

2.7.2 Valves

There are approximately 3,400 valves in the Needham water distribution system. During the flushing program, many valves are operated to isolate areas of the water system. However, the current program does not include all of the system valves and the town does not have a formal inspection program to verify the condition of the remaining valves to ensure reliable operation of all of the valves for emergencies. Any inoperable valves that are encountered during system operations are repaired or replaced by the town as soon as crews are available.

2.7.3 Meters/Services

There are approximately 9,800 water meters and 2,500 second meters in use in the distribution system. The majority of these meters (approximately 80 percent) are remote-reading type meters allowing flow measurement readings from a building's exterior. It is estimated by the town that 10-15 percent of the meters in town are under-registering. The town is considering a program to update the metering system. Meters are replaced or corrected when they need repair as a result of a customer complaint or due to a meter record inconsistency noted by town personnel.

The town also conducts an annual leak detection survey. This effort has helped to minimize unmetered water losses.

2.8 Community Interconnections

There are four interconnections between Needham and Wellesley (excluding MWRA source connections). Only one of the four is active. This is an 8-inch diameter line on Winding River Road which supplies some homes in Wellesley with Needham water. The other three are emergency interconnections, but the town does not have an existing intermunicipal agreement for emergency water use between the communities. It is unknown when the last time was that these three interconnections were used. Locations of these three interconnections are as follows:

- 8" pipe along Forest Street connecting to the Wellesley water system
- 8" pipe at 330 Grove Street connecting to the Wellesley water system
- 6" pipe at 250 Cedar Street connecting to the Wellesley water system

Section 3
Population and Water Consumption

Water consumption projections are typically determined from population projections and trends in historical water use. For this study, water consumption is projected to the year 2020.

3.1 Population

Needham's interim United States Census population for 1994 is 28,080. More recent population estimates are available from the town, but these population estimates have been about 300-1,000 persons higher than the federal census. This appears to be primarily due to differences in accounting for college students. Figure 3-1 shows historic population based on US Census data and town estimates.

Needham's population increased significantly between 1960 and 1970 (from 25,793 to 29,748), but decreased between 1970 and 1990 (to 27,557). This decline in population is attributed to a slowdown in economic growth during the late 1970s and early 1980s and a general reduction in family size for the same period. Since 1990, the US Census has shown an increase in population to 28,080 in 1994.

Several sources of population projections were reviewed for this report including:

- Metropolitan Area Planning Council (MAPC), 1996
- Massachusetts Institute for Social and Economic Research (MISER), 1994
- Long-Range Water Supply Study (LWRSS) by the MWRA, June 1987

MAPC revised its population projections in 1997 to reflect more current economic trends and a new projection methodology. The MAPC is currently projecting Needham's population to rise to 30,315 in 2020, which is approximately a 0.3 percent increase in population per year.

In 1994, MISER projected a population decline in Needham. MISER is currently revising its population projections to reflect data compiled for 1995. A final completion date for these updated projections is not available. The projections presented in the LWRSS report are based on older population trends and may likely represent Needham's long-term future population potential (approximately 32,000 persons) if all remaining available residential land is eventually developed under current zoning regulations.

Of the various population projections, MAPC's numbers are based on the most recent information available and represent an appropriate planning number given current trends in growth. Accordingly, for this study, we have adopted a projected population of 30,315 for the year 2020 for the water system analysis.

3.2 Water Consumption

CDM analyzed historical water consumption trends to project future water consumption in Needham. Data were obtained from Needham's past water supply production records, consumer metering records, and Water Supply Statistical Reports (submitted to the Department of

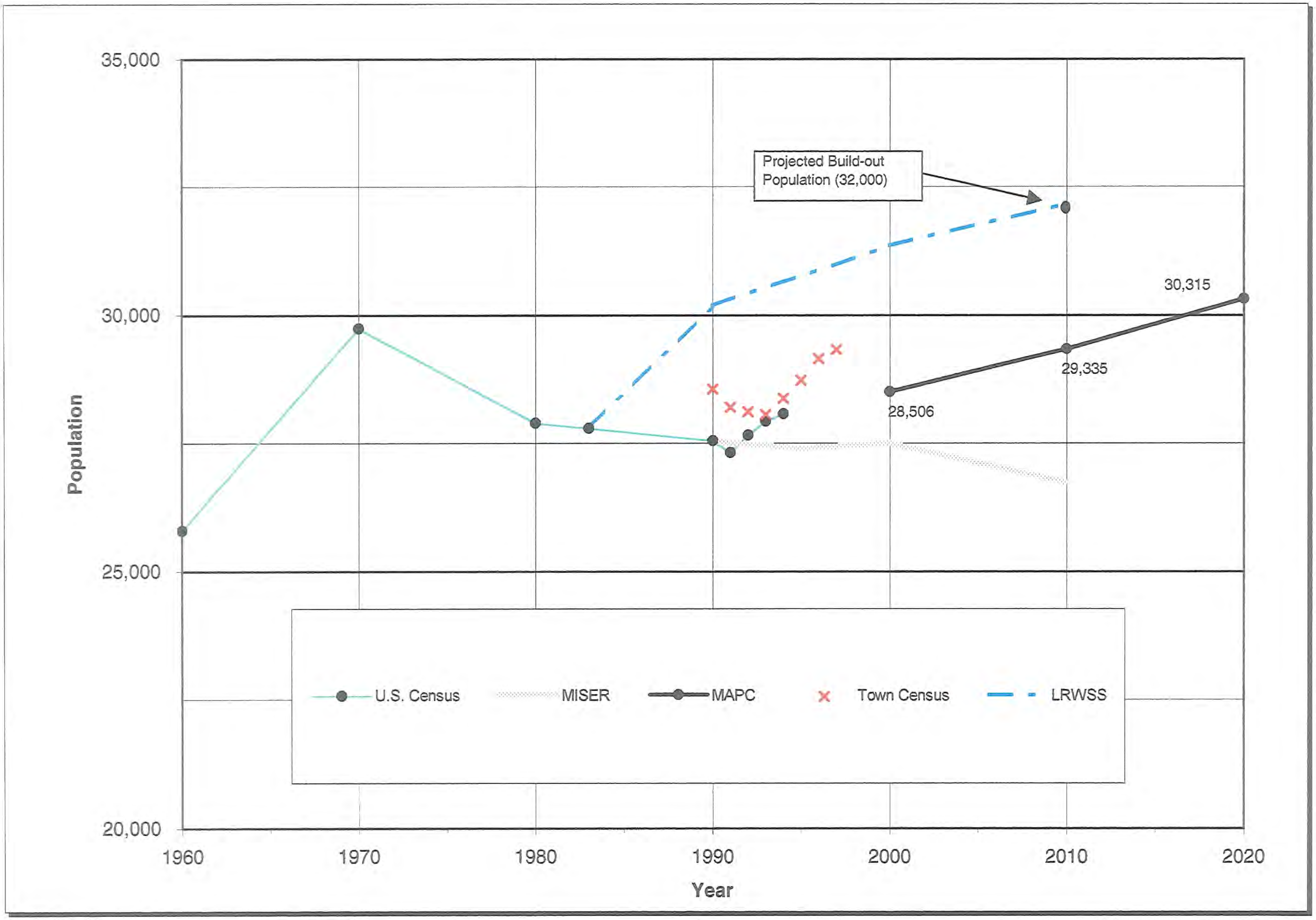


Figure 3-1
Population Projections

Environmental Protection (DEP)). Future consumption projections were determined using the population projections and the results of water consumption trends analysis.

3.2.1 Historical Water Consumption

Table 3-1 shows a comparison of annual daily water consumption, by metered category, and total water production for the years 1990-1997. Water production includes the water pumped by the Town's wells in the Charles River Well Field and the water purchased from the MWRA system, which is pumped by the St. Mary's Pumping Station. Average daily demand includes the annual volume of both metered and unmetered water uses.

Needham utilizes six categories to distinguish metered consumption for billing as follows:

- *Residential.* Includes domestic consumption from single and multi-family dwellings.
- *Industrial.* Includes use by those customers classified as industrial by the town, such as the manufacturers on the northeast side of Needham.
- *Commercial.* Includes commercial businesses such as restaurants, car washes, laundromats, offices and retail stores.
- *Institutional.* Includes water used by hospitals, private schools and other similar institutions.
- *Municipal.* Includes water supplied to municipal buildings such as public schools, town offices, department of public works, libraries, etc.
- *Agricultural.* Water used for commercial agricultural purposes such as farms and nurseries.

The breakdown of average annual daily metered demand by use category shows that:

- residential use has varied from year to year, but has generally increased
- industrial use from 1990-1997 decreased to a low in 1994 and has subsequently increased over the last three years (which is attributed to the conversion of research and development space into commercial/business office space)
- commercial use decreased until 1994 and then has remained fairly consistent
- institutional use increased to a peak in 1995, dropped in 1996 and remained consistent in 1997
- municipal use decreased until 1994 and then has remained fairly consistent
- agricultural use has declined in recent years

Table 3-1 also shows the percentage of categorical water use compared to total annual water production. The data shows that water use in each individual meter category remained in fairly consistent proportion to total metered consumption. Within the last three years (1995-1997), demand percentages for the residential, commercial, and institutional categories generally decreased while the industrial percentages increased from 1995. This may be a result of reassignments of specific water service accounts between categories.

Unmetered water use is also shown in Table 3-1. Unmetered water use represents the difference between the recorded water production (from the wells and purchased from the MWRA) and

Year	Annual Average								
	Total Water Produced (mgd)	Metered Consumption						Total Metered Consumption (mgd)	Unmetered Water (mgd)
		Residential (mgd)	Industrial (mgd)	Commercial (mgd)	Institutional (mgd)	Municipal (mgd)	Agricultural (mgd)		
1990	3.28	2.17	0.41	0.40	0.08	0.14	0.002	3.20	0.07
1991	3.33	2.21	0.44	0.38	0.10	0.08	0.004	3.21	0.12
1992	3.13	2.03	0.48	0.36	0.10	0.08	0.003	3.04	0.09
1993	3.20	2.23	0.44	0.30	0.14	0.07	0.006	3.18	0.02
1994	3.34	2.18	0.32	0.26	0.15	0.04	0.005	2.95	0.39
1995	3.49	2.34	0.33	0.27	0.16	0.04	0.005	3.14	0.35
1996	3.38	2.28	0.47	0.25	0.11	0.05	0.001	3.16	0.22
1997	3.65	2.31	0.53	0.27	0.10	0.05	0.000	3.26	0.39

Year	Total Water Produced (mgd)	Categorical Use as a Percentage of Total Metered Consumption						Total Metered Consumption by Total Production	Unmetered Water Use by Total Production
		Residential	Industrial	Commercial	Institutional	Municipal	Agricultural		
1990	3.28	67.7%	12.9%	12.4%	2.4%	4.5%	0.1%	98%	2%
1991	3.33	68.8%	13.7%	11.8%	3.1%	2.5%	0.1%	96%	4%
1992	3.13	66.6%	15.9%	11.7%	3.2%	2.5%	0.1%	97%	3%
1993	3.20	70.1%	13.7%	9.4%	4.5%	2.2%	0.2%	99%	1%
1994	3.34	74.0%	10.7%	8.8%	5.1%	1.3%	0.2%	88%	12%
1995	3.49	74.5%	10.6%	8.6%	5.0%	1.2%	0.2%	90%	10%
1996	3.38	72.0%	15.0%	7.9%	3.4%	1.6%	0.0%	94%	6%
1997	3.65	70.9%	16.2%	8.2%	3.0%	1.6%	0.0%	89%	11%

Table 3-1
Historic Water Consumption

metered consumption. This usually includes water used for street sweeping, sewer flushing, water main flushing, fires, water lost to leaks and breaks, and meter slippage. Needham performs annual water main and sewer flushing programs that likely represent a large portion of the unmetered water use. Needham also performs annual calibration of master meters and larger commercial meters, along with an annual leak detection program, that minimizes unmetered water losses.

Unmetered water use has fluctuated significantly from 1 percent in 1993 to 12 percent in 1994. Town staff report that data from 1994 to present is a better indicator of unmetered water use as record keeping has improved.

Residential per capita consumption has ranged from 77-81 gallons per capita per day over the last five years. Needham staff reports that the town is experiencing a significant growth in the use of automatic lawn sprinklers for homes and businesses. Upon request, the town installs a second meter for lawn irrigation purposes to allow customers a rebate on the sewer use charge. Currently, there are approximately 9,800 primary residential meters and 2,500 second meters. The town has a list of 1,800 customers waiting for the installation of a second meter.

The town estimates that a total of 152 million gallons of water was used for irrigation purposes in 1997 as measured by the second meters. This represents approximately 17 percent of the total residential demand. It is expected that the continued use of automatic sprinklers in Needham will eventually increase the per capita residential consumption in town.

Sprinkler systems also impact peak water consumption. Typically, sprinklers are set to activate during the morning and evening hours when system demands are already high. Accordingly, system maximum day and peak demands can be increased dramatically by the use of the sprinkler systems. As discussed later, Needham experienced one of its most significant diurnal demand peaks in 1997, which is partially attributed to the use of lawn sprinklers.

3.2.2 Future Water Consumption

The majority of Needham is already well developed and, with the exception of a few remaining areas, there is no significant vacant land available for development. However, for this study, growth is projected for residential, commercial, industrial, and institutional water uses based, in part, on trends of water use over the last three years and on two areas of projected growth in town as discussed below:

- *Residential.* Residential demands were estimated based on projected population and future per capita water use. It is expected that per capita use will increase with the increase in the installation of sprinkler systems. Accordingly, future per capita is projected to rise to 90 gallons per capita per day in 2010 and remain consistent thereafter to 2020. Residential demand is projected to be 2.64 million gallons per day (mgd) in 2010 and 2.73 mgd in 2020.

- *Commercial.* Commercial water use has been fairly consistent over the last four years. Accordingly, for this report, we have assumed only modest increases in commercial water use reflecting additional population. Commercial use is projected to increase to 0.31 mgd in 2010 and 0.32 mgd in 2020.

- *Industrial*. Industrial water use has increased by about 65 percent over the last three years. Town officials attribute this growth to an ongoing conversion of existing buildings (currently used for research and development) to business/office space with a higher density of employees. The town reports that this space conversion may eventually increase the number of workers (and demand) in town by more than 1,000 people by 2010. Growth in commercial water use after 2010 is assumed to be less significant. For this report, we have assumed that industrial water use will increase from 0.53 mgd in 1997 to 0.68 mgd in 2010 and 0.73 mgd in 2020.

- *Institutional*. Growth in this water use category is expected primarily because of the construction of the F.W. Olin College of Engineering. Approximately 600-900 students and faculty will be supported by the facilities by 2010. No additional growth is expected in this category. Accordingly, institutional water use was increased by 0.15 mgd to 0.26 mgd in 2010 and 2020 respectively.

- *Municipal*. Based on historical records, municipal water use is expected to be stable in the future.

- *Agricultural*. Agricultural water use has decreased significantly over the last two years. For conservative planning purposes, the water consumption projections include an allowance of 0.005 mgd for 2010 and 2020.

Table 3-2 shows the projected total average daily metered water consumption for Needham in 2010 and 2020. Unmetered water use is estimated to be approximately 10 percent of the total average daily demand of the water system. This reflects Needham's continued efforts to identify and repair water main/service leaks and breaks, and to maintain its production and service connection meter accuracy.

Based on the projection methodology discussed above, the projected future average daily demand in Needham is estimated to be 4.38 mgd in 2010 and 4.55 mgd in 2020.

3.2.3 Daily Demand Variations

Table 3-2 also shows the expected daily demand variations - maximum day demand and peak hour demand -for the 2020. Maximum day demand is the largest volume of water that is consumed during a twenty-four hour period during a single year, and usually occurs during the summer months. Similarly, peak hour demand is the largest volume of water consumed in a one hour period, and usually occurs during the maximum day. These demands are used to assess the adequacy of the distribution system using the computer model.

Over the last seven years, the ratio of maximum day demand to average day demand has ranged from 1.8 to 2.13. In 1997, however, the town experienced one of its largest maximum day demands at 8.67 mgd on July 14th, representing a maximum day ratio of 2.38. This rise is attributed to the increasing use of automatic lawn sprinkler systems in town. Similarly, a significant peak hour (ratio of 2.78) was observed during the maximum day in 1997.

Although this maximum day demand is unique in comparison to historical records, for conservative planning purposes, the prediction of future maximum day demand was based on the 1997 ratio.

	1997	2010	2020
Population	29,340(1)	29,335(2)	30,315(2)
Consumption Projections (mgd)			
Residential	2.31	2.64	2.73
Industrial	0.53	0.68	0.73
Commercial	0.27	0.31	0.32
Institutional	0.10	0.26	0.26
Municipal	0.05	0.05	0.05
Agricultural	0.000	0.005	0.005
Total Metered Water	3.26	3.95	4.09
Unmetered Water	0.39	0.44	0.45
Total Average Day Demand	3.65	4.38	4.55
Maximum Day Demand	8.67	10.35	10.69
Peak Hour Demand	10.16	12.05	12.46

NOTE: (1) Town estimated population which is typically 300-1000 persons higher than US Census data.
(2) Projections based on MAPC/US Census data.

See text for explanation of assumptions to develop projections.

Table 3-2
Water Consumption Projections

Accordingly, similar daily demand ratios were used to project future demands, but were adjusted slightly to reflect increasing average day demand, which typically results in lower diurnal variations. The maximum day demand and peak hour demand ratios used for 2010 were 2.36 and 2.75, respectively and the ratios used for 2020 were 2.35 and 2.74.

3.3 Adequacy of the Water Supply

The future maximum day water demand in Needham is projected to be 10.69 mgd in year 2020. After new pumping station improvements are completed at the existing Charles River Wellfield, Needham's groundwater sources should have an expected safe yield of about 4.5 mgd. In addition, the town's current agreement with the MWRA allows a withdrawal of up to 12.5 mgd daily. Accordingly, the existing water supply should be adequate to meet Needham's future water consumption projections for 2020 and later.

Section 4
Distribution System Modeling

4.1 General

A computer model of Needham's water distribution system was developed by CDM to evaluate system adequacy under existing and future water demand conditions (2020). The Cybernet computer model was used as the modeling "tool." Data used to develop the model was provided by the town and was based primarily on the existing water distribution system piping maps. CDM conducted hydrant flow tests to calibrate the model to field conditions. The calibrated model was then used to identify water system deficiencies.

4.2 Computer Model

The Cybernet computer model was developed by Haested Methods. This model utilizes the University of Kentucky KYPIPE2 model along with an AutoCAD interface for modeling water distribution system piping networks. KYPIPE2 is the hydraulic program in this software that calculates the flows and pressures in the system under varying supply and demand conditions.

The KYPIPE2 computer program is pipe loop oriented and uses an iterative computational process to balance the system flows. Input data to the model includes pipe characteristics (diameter, length, C-value, and ground elevation at pipe intersections), hydraulic grade line (HGL) elevations at points of supply, storage tank water level elevations, pump operation characteristics, and total system demand apportioned throughout the system. For a specified demand condition (maximum day, peak hour, maximum day plus fire, etc.), the computer will solve for the flow in each pipe and pressure at each node (nodes are located at pipe intersections and where changes in pipe size or C-value occur). Each loop in the system is balanced to within 0.5 ft. of pressure head (0.2 psi).

4.3 Development of the System Schematic

A schematic map of Needham's distribution system piping network was prepared using Cybernet as a guide to establishing model input data and for use during the system analysis. The schematic is a representation of the piping system in which pipes are represented as numbered "links," and pipe intersections and changes in pipe size are represented as numbered "nodes." Points of supply are also represented as nodes. Generally, all mains 6-inch in diameter and larger were included in the schematic.

Information used to develop a computer model of Needham's water system included:

- pipe length and diameter
- pipe C-Value (friction factor)
- ground elevations at each node
- system demands
- connectivity
- data at the MWRA connection
- pump curves (for pumping stations)

Most data needed for the preparation of the model was available from Needham Water Department records. Existing plans show pipe diameters and location. Ground elevations were assigned to each node in the model using USGS topography data.

Selection of pipe friction factors (C-Values) and the distribution of water consumption in the model, however, required additional work as described below.

4.4 Assignment of Demands to Nodes

Water consumption demands in the distribution piping network are typically aggregated and simulated at the nearest model node. This method provides the best possible representation of the impact of water system demands. Water meter records, billing routes (if available), and general observations regarding population/use density may be used to assign demands to nodes.

Although the goal is to assign demands throughout the model as accurately as possible, water distribution models are not generally sensitive to demand distribution (as opposed to fire flows). Compared to high flow demands, such as hydrant flow tests, normal system conveyance of the low (and widely distributed) nodal demands result in only minimal pipeline flow velocities and headlosses. For this reason, simulated fire flows (high rate demands), which stress the system at discrete point locations, tend to govern system calibration more readily than average demand conditions.

Needham's 1996 average annual water consumption - the most recent data available at the time the model was created - was used as the basis for assigning demands to the model. Billing information supplied by the town from the six existing meter routes provided a further breakdown for the distribution of demands within the system model. As a first step, the ten (10) largest water users were identified (as listed below) and their average annual water usage rate was assigned to the nearest computer node.

User	Address	Average Annual Consumption
Coca Cola	9 B. Street	266 gpm
Sheraton Hotel	100 Cabot Street	28 gpm
Rosemary Ridge	100 Rosemary Way	10 gpm
Avery Manor	100 West Street	9 gpm
Glover Hospital	Chestnut St. and School St.	9 gpm
Charles Ct. East	1202 Greendale St.	9 gpm
Brook Trout Tech.	410 1st Ave.	7 gpm
Briarwood Health Care	150 Lincoln St.	6 gpm
Brookline Oriental Rugs	315 Hunneywell St.	5 gpm
McNeil Mgt.	757 Highland St.	5 gpm

Next, the 1996 average day demand, minus the demand of the largest users, was distributed evenly among the model nodes in each of the respective meter routes. Unaccounted-for water was distributed evenly to all demand nodes within the system. Generally, this method provides a good representation of actual system demands as there are more nodes (at intersection, piping interconnections, etc.) in areas with larger demands (e.g., downtown).

Accordingly, the current model demand condition reflects 1996 average day demands. To obtain daily demand variations (i.e., maximum day, peak hour, etc.) or system demands under future conditions, a global peaking factor can be applied to each nodal demand. By multiplying all demands by an appropriate peaking factor, the base model demand can be globally increased or decreased to reflect the analysis conditions.

4.5 Pipe Friction Factors

Unlined cast iron water mains that transport soft (i.e., corrosive) water usually develop a deposit of metallic salts on the interior after having been in service for a number of years. Accumulation of these deposits, or tubercles, has a twofold effect on the hydraulic flow capacity: (1) it reduces the actual inside diameter of the main and, hence the amount of water which the pipe can deliver; and, (2) it causes increased frictional headlosses because of turbulence resulting from the roughness and unevenness of deposits.

The Hazen-Williams C-value is a relative measure of the hydraulic capacity of a water main. It can be estimated in the field by measuring the flow rate and corresponding headloss through a known length of pipe, and utilizing these values in the Hazen-Williams formula. At a constant flow rate, the smaller the value of C, the greater the drop in water pressure along a given length of main. For example, a 6-inch pipe having a C-value of 100 will transport over twice as much water, with the same pressure drop, as a 6-inch pipe of the same length with a C-value of 50. It should be noted that any obstruction, such as a partially closed valve, would have a tendency to reduce the C-value in what might otherwise be a high capacity main.

For cement-lined pipes, C-values were generally assumed to be about 110 for mains of 6- to 10-inch diameter and 120 for mains 12 to 16 inches. During the initial development of the model, town staff reported that Needham began using cement-lined pipe after 1964. Installation dates for a majority of the existing pipe were available from a map provided by the town. Staff also identified areas where existing unlined cast iron pipes had been cleaned and cement-lined during past water system improvements projects.

Pipes installed prior to 1964 were assigned an initial C-Value based on age. C-Values for older, unlined pipes can be predicted using an established curve that shows the general relationship between the age of pipe and its current hydraulic capacity. Corrosion rates and the resultant C-values will be slightly different with each water system.

Many adjustments to these initial C-value assumptions, however, were made during calibration based on the hydrant flow test results.

4.6 Model Calibration

4.6.1 General

Hydrant flow tests were performed throughout the system to collect data required to calibrate the computer model. Calibration generally involves simulating each hydrant flow test on the model; comparing field test results against model results; and making adjustments or corrections to the model, as required, to closely match the computed system response with actual field data. The greatest variable in the calibration of the model is the C-value of the untested, unlined mains. The C-values of these mains are adjusted during calibration, such that the model simulates the headlosses placed on the distribution system during the hydrant flow tests.

4.6.2 Hydrant Flow Tests

Hydrant flow tests were performed at twenty-three (23) locations throughout the water system by CDM and town personnel. The tests were conducted during the nights of July 14 and 15, 1997. Five additional hydrant tests were planned but could not be completed due to problems encountered during the testing. Table 4-1 provides a summary of the hydrant flow testing results. Test locations were generally selected in areas with unlined pipes and/or problematic areas to ensure that the model reflected the field conditions for analysis. Figure 4-1 shows the hydrant flow test locations.

4.6.3 Calibration Conditions

Discharge pressures and flow rates were recorded at both the Charles River well stations and the St. Mary's Street Pumping Station during the hydrant testing program. Water levels were also recorded at the Dunster Road and Bird's Hill Tanks. This data was used to establish the system conditions in the model during the calibration flow tests.

4.6.4 Initial Calibration Results

Calibration was performed by comparing the field measured static pressure and residual pressure drop at the hydrant flow test location with the computer predicted pressures. Pressures were also compared with field pressures at the various locations monitored during the hydrant flow testing.

C-values of the pipes were adjusted to achieve calibration to the hydrant flow tests. The model was generally considered calibrated when the residual pressure drops simulated on the computer model were within 10 percent of the actual field residual pressure drops (usually within about 1-2 psi).

During model calibration, it became apparent that the water distribution piping network had more capacity available than indicated by the model using the initial C-Value assumptions. Accordingly, to calibrate many areas of the model, it was necessary to adjust most pipes in the system to a C-Value of at least 80-90 (or greater), which represents a C-Value for a pipe in relatively good and/or cement-lined condition.

However, to calibrate the model at two hydrant flow test locations (Tests #4 and #5), pipes were assumed closed or partially closed for calibration, as follows:

- Along Webster Street between Howland Street and Norfolk Street
- Along George Aggott Road between Dedham Avenue and Sutton Road
- Along Central Avenue between Oxbow Road and north of Walker Lane

It is important to note that the computer model cannot identify specific locations where valves are closed - only general areas of restrictions. Shortly after the initial calibration was completed, CDM advised the town to check these areas for closed or partially closed valves. During the field checks, the town located one closed valve on Central Avenue near Walker Lane and Oxbow Road and a

Test No.	Location	Static Pressure (psi)	Residual Pressure (psi)	Hydrant Flow (gpm)	Flow Available at 20 psi (gpm)
1	Fisher St. & Central Ave.	94	40	1,833	2,180
2	Central Ave. & Bellevue Dr.	64	59	4,140	13,355
3	Great Plain Ave. & Mason Rd.	80	53	3,842	5,875
4	Alden Rd. & Canavan Cir./Stockdale Rd.	82	47	3,130	4,277
5	Forest St. & Clarke Rd.	77	63	642	1,394
6	Central Ave. & Parish Rd.	103	93	4,849	15,239
7	Tanglewood Rd. & Hollow Ridge Rd.	98	84	2,806	7,222
8	Newell Ave. & Prospect St.	89	76	2,806	6,771
9	Sylvan Rd. & Memorial Cir.	71	43	2,975	4,132
10	Great Plain Ave. & Highland Ave./ Dedham Ave.	73	63	6,253	15,378
11	Norfolk St. & Heath St.	78	65	796	1,779
12	Dedham Ave. & DeFazio Playing Fields	94	79	1,536	3,580
13	Harris & Jr. High School	--	--	--	--
14	Great Plain Ave. & Pinewood Rd.	71	45	4,200	6,074
15	St. Mary St. & Sherman St.	76	26	1,595	1,694
16	Reservoir St. & Reservoir Ave.	91	26	639	670
17	Central Ave. & Pinegrove St.	87	80	5,045	16,460
18	Gary Rd. & Lee Rd.	99	85	1,595	3,985
19	Highland Ave. & Highland Circle	99	84	2,140	5,244
20	Gould St. & Highland Ave.	80	70	3,170	8,370
21	High & Greendale/Bennington	--	--	--	--
22	Kendrick St. & Fourth Ave.	104	80	5,834	11,576
23	Lindberg & Webster/Manning	--	--	--	--
24	Washington & Hawthorne	--	--	--	--
25	Greendale Ave. & Brookline St.	75	67	6,053	17,670
26	Helen Rd. & Audrey Ave.	52	33	4,238	5,641
27	Bird St. & Rockwood La.	63	41	2,113	3,063
28	Great Plain & South/Greendale	--	--	--	--

NOTES: Test locations represent the intersection adjacent to the flow hydrant.
Static and residual gauge pressures are adjusted for elevations to be relative to the elevation of the flow hydrant. Flow available at 20 psi is calculated based on static and residual pressures adjusted for elevations at the flow hydrant.

Hydrant flow tests were performed on the nights of July 14-15, 1997 between 11 pm and 6 am by CDM and Town personnel.
Well Nos 1 and 2 were on for the duration of the testing program and St. Mary's Station was on automatic operation as required to fill tanks.

Flow tests 13, 21, 23, 24, and 28 were not completed due to inoperative hydrant gate valves, inadequate drainage, or problems encountered during testing.

Table 4-1
Summary of Hydrant Flow Tests

partially closed valve on Walker Lane between Russell Road and Central Avenue. No closed valves were found in the areas of Webster Street or George Aggott Road.

This apparent valve problem is not unique. Numerous towns find closed or partially closed valves to be a problem, and have field crews identifying them on a continuous or annual basis.

As a conservative measure, the C-values of the pipes along these streets were kept in the calibrated position (i.e., closed/partially closed condition) during our piping analysis. This assumption did not significantly affect the magnitude of any identified deficiencies in the water system or the scope of any associated piping improvement recommendations.

4.7 Additional Data Collection

Nine additional hydrant flow tests were conducted on the night of April 30, 1998, in Needham after the model was initially calibrated. CDM performed these additional flow tests to verify the assignment of relatively high C-values for many of the reportedly unlined pipes in the model. Table 4-2 provides a summary of the additional hydrant flow testing results. Generally, this additional flow testing data supported the initial model assumptions that the existing system was in relatively good condition.

Table 4-2
Summary of Additional Flow Testing

Test No.	Location	Static Pressure (psi)	Residual Pressure (psi)	Hydrant Flow during Test (gpm)	Flow Available at 20 psi (gpm)
1	Central Ave. & Pinegrove St.	92	76	5,410	12,188
2	Alden Rd. & Stockdale Rd./Canavan Cir.	85	65	2,247	4,246
3	Central Ave. & Bellvue	71	62	3,654	9,323
4	Central Ave. & Fisher	101	71	2,288	3,912
5	Webster St. & Norfolk St.	88	77	637	1,704
6	Elmwood Rd. & Thurston Rd.	95	83	3,907	10,510
7	Brookline St. & Dell Ave.	63	53	3,448	7,579
8	Third Ave. & Kendrick St.	108	77	4,189	7,359
9	Greendale Ave., Cimino Rd. & Richdale	64	54	2,828	6,294

NOTES: Test locations represent the intersection adjacent to the flow hydrant.
Static and residual gauge pressures are adjusted for elevations to be relative to the elevation of the flow hydrant. Flow available at 20 psi is calculated based on static and residual pressures adjusted for elevations at the flow hydrant.

Bird's Hill standpipe was off-line during the hydrant flow tests
Hydrant flow tests were performed on the of April 30 - May 1, 1998 between 11 pm and 6 am by CDM and town personnel.

Soon after verification of the initial model calibration was complete, the town provided new information regarding pipe ages. Based on a later review of pipe records that was conducted by the town during the development of the geographic information system (GIS), it was determined that pipes installed after 1946 (versus 1964) were installed with cement-linings. This new pipe information provided further verification of the model calibration C-Value assumptions.

It is important to note that the overall calibration of the model, and its ability to simulate existing conditions, is not impacted by this new pipe data. The final recommendations for piping improvements as presented in Section 7 reflect the actual piping conditions now documented by the town. The town should continue to assess the existing pipe conditions to ensure the accuracy of its system maps.

Section 5
Analysis of Existing Facilities

5.1 General

CDM evaluated Needham's piping, pumping and storage facilities to determine the adequacy of the existing facilities to meet present and future water demand conditions, and to provide fire protection. As a basis for this evaluation, system analysis criteria were established to set minimum requirements for service pressures and flow capacity. CDM assessed the system's capability to meet these system analysis criteria using the results of the field testing program (described in Section 4), observations made during the field inspections of existing facilities, and the calibrated model of the distribution piping network.

5.2 System Analysis Criteria

Water system facilities (i.e., piping, pumping and storage) were evaluated to determine their ability to meet minimum system pressures under the following analysis conditions for the target year of 2020:

- peak hour on the maximum day
- fire flow requirements on the maximum day
- nighttime reservoir refill on maximum day

5.2.1 Minimum System Pressures

The water system should be capable of maintaining a minimum pressure of 35 psi during the peak hour demand period at ground elevation in all areas of the town served by the water system. During a maximum day with a coincidental fire flow, a minimum of 20 psi should be maintained throughout the system. The piping network should also be capable of refilling total peak hourly storage fluctuation volume in approximately six (6) to eight (8) hours during the minimum (nighttime) demand period on the maximum day.

The State of Massachusetts has also established a minimum water system pressure requirement of 20 psi under all operating conditions. This standard helps to avoid potential cross-connections and negative pressures (vacuum) that could occur at service connections (at high elevations) during fire flows or other significant demand events.

5.2.2 Fire Flow Requirements

General

The capacity of the distribution system to provide adequate flow during fires is typically evaluated based on fire flow requirements established for the town by the Insurance Services Office (ISO). The ISO is an association of insurance companies that compiles data used to establish rates for fire protection policies for both residential and commercial buildings. The ISO typically estimates fire flow requirements at several locations within a community. The ISO locations are selected according to their relative representation of the overall fire flow requirements of the community. Accordingly, only fire flow requirements for a small portion of the community are actually estimated by ISO.

ISO established fire flow requirements for the Needham water system in 1996. At this time, ISO adopted requirements for twenty-one locations as listed in Table 5-1.

ISO Methodology

To determine the required fire flow rate, ISO uses the Fire Suppression Rating Schedule (1980). Fire flow requirements represent the available flow at a 20 psi residual pressure. Generally, each location is rated based on the building in the area with the largest rated fire flow requirement. The fire flow requirement for each building is determined based on its use or occupancy.

Estimates for fire flow requirements for commercial buildings are based on a complex formula considering land use, building construction, occupancy characteristics, spacing between buildings, and the existence of individual building fire protection systems. Estimates of fire flow for specific commercial/industrial buildings are typically calculated individually by a representative of ISO.

Fire flow requirements for residential areas are relatively simple to estimate using simple ISO guidelines. For 1- or 2-family dwellings not exceeding two stories in height, the following required fire flows are applicable:

Distance Between Buildings	Needed Fire Flow
over 100 feet	500 GPM
31 to 100 feet	750 GPM
11 to 30 feet	1,000 GPM
10 feet or less	1,500 GPM

For larger, multi-family residential buildings, the commercial building rating schedule may apply.

Generally, the maximum fire flow requirement that a water system must deliver to obtain the best overall town-wide insurance rating is 3,500 gpm at a 20 psi residual pressure. Large commercial, institutional, and industrial premises with fire protection needs that exceed 3,500 gpm should be supplied by individual fire protection connections and fire pumps, if necessary, to meet the flow requirement in excess of 3,500 gpm. Alternately, a sprinkler system can be used to reduce the fire flow requirements for these larger buildings.

The owner of the building is generally responsible for providing this additional flow (greater than the maximum of 3,500 gpm) to meet insurance requirements. In these cases, ISO often reports both the estimated required fire flow and the officially recognized lower required fire flow limit of 3,500 gpm.

For Needham, ISO provided two estimates of fire flow requirements at some locations - the first number ranging from 4,500 to 6,000 gpm, while the second number is actually below the 3,500 maximum fire flow standard. This is not typical of ratings provided to other communities and this discrepancy has not been fully explained by ISO. To be consistent with other communities, CDM has adopted the 3,500 gpm maximum flow requirement at the Needham locations in question.

Location	Description	Predominant Land Use	Estimated Required Fire Flow (gpm)
1	Harris Avenue & Pinewood Road	Commercial	2,250
2	Great Plain Avenue & South Street	Commercial	2,000
3	Broadmeadow Road & Bird Street	Commercial	3,500
4	Greendale Road & Highgate Street	Residential	750
5	Kendrick Street & Third Avenue	Commercial	4,500/1,750(1)
6	First Avenue & A Street	Commercial	6,000/2,250(1)
7	Last Hydrant on Cabot Street	Commercial	4,000/2,250(1)
8	Gould Street & Kerney Road	Commercial	3,000
9	Central Avenue & Reservoir Road	Commercial	4,500/2,000(1)
10	Central Avenue & Wellesley Avenue	Commercial	2,250
11	Highland Street & Cottage Avenue	Commercial	3,000
12	Webster Street & Lindberg Avenue	Commercial	5,000/2,000(1)
13	Hillside Avenue & Dale Street	Commercial	4,500/2,250(1)
14	West Street & Fenton Road	Commercial	4,000/1,750(1)
15	Central Avenue & Gay Street	Commercial	2,500
16	Great Plain Avenue & Standish Road	Residential	750
17	Stratford Road & Windsor Road	Residential	750
18	Central Avenue & Fisher Street	Commercial	2,000
19	South Street & Chestnut Street	Residential	750
20	Chestnut Street & Junction Street	Commercial	3,000
21	Dedham Avenue & Lincoln Street	Commercial	3,000
22	End of Grove Street	Residential	750
23	Gilbert Road & Frances Street	Residential	1,000
24	Central Avenue - between Pine & Charles River Road	Residential	1,000
25	South Street & Marant Drive	Residential	750
26	Middle of Laurel Drive	Residential	1,000
27	Meadowbrook Road & Meadow Lane	Residential	1,000
28	Washington Avenue & Nichols Road	Residential	1,000
29	Greendale Avenue & Parker Road	Residential	1,000
30	Forest Street & Clarke Road	Residential	750
31	Great Plain Avenue & Mary Chilton Road	Residential	1,000
32	Ardmore Road & Grasmere Road	Residential	1,000
33	End of Capt. Robert Cook Drive	Residential	1,500
34	Highland Avenue & Gould Street	Commercial	2,500
35	Dunster Road at Water Tank	Residential	1,000
36	Hillcrest Road at Water Tank	Residential	1,000

NOTES: Fire flow requirements for Locations # 1-21 obtained from 1996 ISO ratings for Needham.

For locations with no reference fire flow, a "rule of thumb" was assumed as follows:
Residential - ISO guidelines Commercial - 2,500 gpm

It is important to note that fire protection for each location is typically based on adequate flow delivery from a hydrant(s) within 300 feet of the building.

(1) According to 1980 ISO guidelines the maximum fire flow requirement is 3,500 gpm. A 3,500 gpm flow requirement was adopted for these locations.

Table 5-1
Fire Flow Requirements

Needham's Flow Requirements

For this report, fire flow requirements for analysis were adopted at a total of thirty-six (36) key locations, as shown in Figure 5-1. These fire flow analysis locations include the twenty-one (21) locations that ISO previously estimated fire flows for in 1996. Fifteen (15) additional locations were selected for analysis based on representative fire flow needs (e.g., schools, commercial uses, dense residential, etc.) and hydraulic constraints (e.g., high elevation areas and locations served by smaller diameter, unlined water mains). These locations were also used for this study to assess local area fire protection.

Fire flow requirements for these additional fifteen locations were estimated by CDM based on ISO guidelines. Flow requirements for residential land use areas at fourteen locations were assumed to range between 750-1,500 gpm (at a 20 psi residual pressure), based on house spacing and ISO ratings for similar residential areas. For the one additional commercial location, a fire flow requirement of 2,500 gpm was adopted based on similar ratings by ISO for the other commercial areas of the town.

5.2.3 Distribution System Storage Requirements

General

The major advantages of providing storage within a distribution system area are as follows:

- Storage helps to dampen hourly demand fluctuations to be met by sources of supply, thus reducing operation costs (primarily if pumping is involved).
- Storage helps to meet required fire flow, thus reducing pumping station capacity (and costs) at supply sources as well as reducing piping capacity requirements.
- Storage provides a volume of water for emergencies in case of pipeline breaks, mechanical equipment malfunctions, or power failure.
- Storage, if properly located, helps to equalize pressure throughout the distribution system, to provide pressure surge relief, and to help control pumping operations.

Storage Components and Sizing

According to acceptable water works practice, in systems having storage, water supply pumping facilities should be sized to provide maximum day demand while other system demands greater than the maximum day demand are to be met by available active system storage (peak hour storage fluctuation volume). Storage facilities are also sized to provide fire protection volume and, in some cases, emergency storage.

The basis for these storage requirements is summarized below:

- *Hourly fluctuations* - the total volume required to meet hourly consumption fluctuation on days of maximum demands. This volume is generally taken to be a percentage of the maximum daily demand unless accurate storage volume fluctuation data is available from tanks and pumping stations in the system.

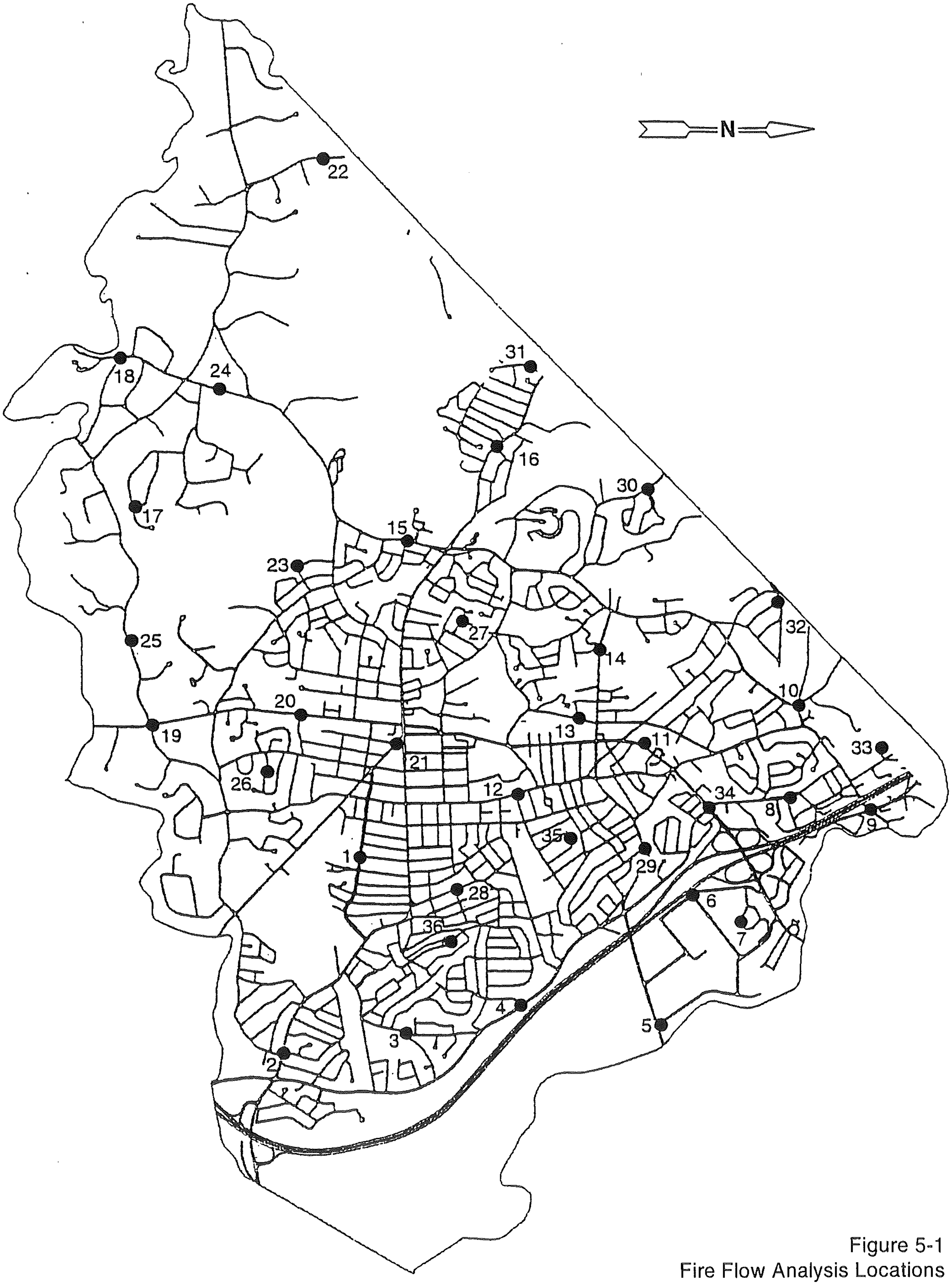


Figure 5-1
Fire Flow Analysis Locations

- *Fire Protection* - the total volume of water required to provide fire flows under maximum day demand conditions. To determine this quantity, the maximum fire flow is selected along with an appropriate duration. To meet ISO conditions, the basic fire flow is the fifth highest flow from the list of ISO fire flow requirements for the community. ISO also establishes the duration depending upon the fire flow (i.e., a 2,000 gpm flow rate at two hours, a 3,000 gpm flow rate at three hours, etc.). The maximum duration for a fire flow rate is four hours (for flows greater than 3500 gpm).

- *Emergencies* - the volume of storage allocated in case of a power failure, pipeline breaks or mechanical equipment malfunction. In most cases, if a community has an adequate emergency standby power source at its water supplies, emergency storage is considered to be a lower priority-long term requirement.

Distribution system storage facilities are considered adequate if the existing active storage volume meets the fire protection, peak hour and emergency requirements for the community (Table 5-2). Active storage is determined by existing topography and represents the volume of water in storage that provides a minimum acceptable pressure (e.g., 35 psi in Needham) at the highest service elevation in the distribution system. This analysis is initially performed using static pressures and elevations but is verified under dynamic conditions using the computer model.

In addition to having adequate storage in a water system, it is important that the water system have adequate pumping and piping capacity to refill the system storage at night. Generally, total peak hour fluctuation volume must be refilled within approximately 6-8 hours during the nighttime period following the maximum day to be considered adequate under standard waterworks practices.

5.2.4 Pumping Capacity Requirements

As mentioned above, when a distribution system includes its own storage volume to meet peak hour fluctuations, the total capacity of a pumping system should equal the maximum day demand of the service area with the largest pump out of service. If storage is not included in the system, pumping unit capacity should meet system peak hour demands (with the largest pump out of service). Accordingly, because Needham's distribution system includes water storage tanks, the Charles River Wellfield and St. Mary's Pumping Station should have the combined capacity to meet the maximum day demands of 10.69 mgd in 2020.

5.3 Distribution System Storage Analysis

5.3.1 Needham's Storage Requirements

Active storage required to meet current the town's current demands is 2.19 million gallons, while the total required storage volume for the year 2020 is 2.55 million gallons. Storage requirements are broken down as follows:

- *Hourly fluctuations* - Using available production and storage records during the highest maximum day of recent record (July 14, 1997), CDM estimated that Needham's peak hour storage fluctuation requirement was about 18 percent of the average flow rate during that maximum day or about 1.56 million gallons. For year 2020 projections, CDM used the same percentage (18 percent) to estimate the peak hourly fluctuation storage requirement of 1.92

million gallons (based on the future maximum day of 10.69 mgd). It is important to note that the 2020 requirement for peak hour storage volume is based on the conservative estimate of maximum day demand based on an expected increase in the use of sprinkler systems in town. If water use is properly managed, the projected increase in future maximum day demand may not be as significant.

- *Fire Protection* - Needham's fifth highest fire flow is 3,500 gpm; thus, the required fire flow storage volume for the town is 630,000 gallons (for a three-hour duration).

- *Emergencies* - The new Charles River Wellfield water treatment plant will have emergency standby power to operate the groundwater supplies and the treatment processes. Currently, two of the active pumps at the St. Mary's Street Pumping Station have direct drive diesel engines for power during a normal power outage. It is assumed that any future modifications to the St. Mary's Station will include provisions for adequate emergency power. Accordingly, no emergency storage for the distribution system is required.

Table 5-2 below summarizes the storage requirements for Needham.

Table 5-2

Estimated Storage Requirements (million gallons, MG)

	1997	2020
Peak Hour Fluctuation Volume	1.56 MG	1.92 MG
Fire Protection Volume	0.63 MG	0.63 MG
Emergency	-	-
Total	**2.19 MG**	**2.55 MG**

5.3.2 Available Active Storage

Needham has two tanks that can be used to help meet the storage requirements. The Dunster Road Tank has an overflow elevation of 347.6 feet (USGS) and a total capacity of 1.5 million gallons. The Bird's Hill Tank has an overflow elevation of 346.7 feet (USGS) and a total capacity of 2.5 million gallons.

In general, there are three high elevation areas in town that effect the evaluation of active storage in town. These areas, shown in Figure 5-2, include:

- the area surrounding the Dunster Road Tank, including the intersection of Paul Revere Road, Tower Avenue, and Hoover Road, with ground elevations up to 289 feet (USGS);
- the area surrounding the Bird's Hill Tank with ground elevations of up to 295 feet (USGS); and
- the North Hill area with ground elevations of about 260 feet (USGS).

There is a fourth high elevation area at High Rock hill; however, there are no existing buildings in this area and it is unlikely that this location will be developed in the future due to its steep slopes and restricted access. Customers in the high elevations areas on North Hill are reportedly served by a private water booster pumping system or individually by internal building pumping systems. Thus, these customers are generally unaffected by existing tank water levels.

Areas Above 245 Feet USGS (75 Meters)

Figure 5-2
High Elevation Areas

100 0 100 200 Meters

CDM Camp Dresser & McKee Inc.

Service customers in the neighborhoods surrounding the existing Dunster Road and Bird's Hill Tanks, however, are directly affected by storage tank water levels. Water main pressures within 150 to 200 feet of the Bird's Hill Tank are typically below the minimum state standard of 20 psi, even when the tank is almost filled. Similarly, if Dunster Road Tank water levels drop more than ten (10) feet below the tank overflow elevation (to about 336 feet USGS), system pressures at the high point of Tower Avenue could be below the 20 psi state standard.

To meet the minimum pressure criteria of 35 psi (81 feet), during peak hour, at the service connections in the Dunster Road and Bird's Hill high elevation areas, the storage reservoir levels would need to be maintained well above the existing tank overflow elevations of about 346 feet (USGS). Therefore, based on the criteria adopted for this report, no active storage is available in the main service system to meet the system storage peak hour fluctuation requirements. (It should be noted that even when minimum design pressures are obtained in the main, the customer may still experience low pressures. This may be the result of corroded or undersized service connections or plumbing, or due to the height of a particular building.)

In practice, the Dunster Road and Bird's Hill Tanks do help to meet the storage requirements of Needham's water system. The tanks normally fluctuate 6-8 feet during the day as a portion of the system demands are met by the tank volume. In addition, storage is available within the tank to help provide fire protection. However, under existing conditions, there are pressure inadequacies resulting from inadequate storage volume (based on the criteria adopted for this report).

One alternative to address this storage deficiency is to establish a reasonable ground elevation where the minimum service system pressure of 35 psi could be met at all times and a range of active storage volume could be designated in each of the two existing storage tanks. Areas with ground elevations higher than this minimum service elevation could be serviced by the creation of a high pressure zone supplied by a water booster pumping station. In Needham, the areas surrounding the tanks that would require boosted service systems is significant. Accordingly, other alternatives were considered to address this system storage deficiency. These alternatives are discussed in Section 6.

5.4 Distribution Pumping Facilities

Charles River Well Field

As mentioned above, the adequacy of pumping facilities is generally evaluated considering the largest pump is out of service. With the largest pump in the wellfield out of service (Well No. 1 rated at 2.0 mgd), the remaining two pumps at the Charles River Wellfield have a total production capacity of about 2.5 mgd. This is not adequate to meet either the current maximum day demand of 8.7 mgd or the future maximum day demand of 10.7 mgd. Accordingly, the MWRA must be used to supplement the town's maximum day demands (under the analysis conditions).

St. Mary's Pumping Station (MWRA connection)

There are four pumps located at this facility, however, the town reports that only the two pumps in the lower level of the building can be used reliably to meet water demands (the other pumps have not been operated for more than ten years). Thus, the capacity of this station, with the largest of the two pumps out of service, is about 3.2 mgd.

The total available capacity of both the Charles River Wellfield and St. Mary's Pumping Station (MWRA) is about 5.7 mgd, which is less than the current and future maximum day demands. Accordingly, immediate improvements are required to increase the capacity of this pumping station to meet current and future water demands.

In addition, this station has no standby power capability. During a power outage, there would be a significant loss of water supply without the use of the St. Mary's Pumping Station. The new improvements to the station should include a new standby power engine and electric generator.

5.5 Piping System Analysis

5.5.1 General

Using the computer model, CDM analyzed the Needham water distribution system according to the design criteria discussed above. This section describes the analysis conditions and assumptions used in the computer simulation model as well as the results of the evaluation. Analyses were conducted under both current and future demand conditions.

5.5.2 Analysis Conditions

Operating conditions are established in the model for water demands, storage tank water levels and pumping station flow rates for each of the distribution system analysis conditions.

Water Storage Levels

A first step in system analysis using the computer model is the determination of discrete active storage water levels that are established for each analysis criterion (e.g., peak hour, fire flow, etc.). As discussed previously, no theoretical active system storage is considered currently available in Needham because of existing development at the higher elevations adjacent to the two tanks.

To establish storage tank levels for the analysis of the system, it is assumed that alternative methods (i.e., new pressure zones, etc.) would be implemented to provide adequate water pressures to those services located at higher elevations that could not effectively be served by the existing tanks. Section 6 describes alternatives to establish a reasonable water level for system storage in Needham that would provide the maximum range of operation for active tank storage volume while minimizing the extent of high elevation areas that might require a new pressure zone under dynamic analysis conditions.

For the peak hour analysis using the computer simulation model, water surface elevations in the Dunster Road and Bird's Hill Tanks were established at the bottom of peak hour fluctuation volume based on the available combined volume in the tanks (76,460 gallons/foot). Accordingly, approximately 20 feet of tank volume would be required to provide for the current peak hour storage requirements of 1.56 million gallons, which represents a tank elevation of approximately 325 feet (USGS) at the bottom of the established peak hour storage volume. To meet the future storage requirement of 1.92 million gallons, the tank elevations would range over a depth of about 25 feet down to 320 feet (USGS) at the bottom of the established peak hour storage volume.

For the fire flow analysis, water surface elevations in the tanks were established at the middle of the range of fire flow volume elevations (after peak hour storage fluctuation volume has been depleted during the maximum day). Based on the combined volume per foot available in the tanks, the range of fire flow volume is about 8 feet. Accordingly, the tank elevations for the fire flow analysis were established at about 316 feet (halfway through the range of fire volume) for both current and future demand conditions. (The elevation difference of 5 feet for the range of fire flow volume in the tanks under current and future peak hour demand conditions did not affect that analysis or the improvement recommendations but was used for simplification of the analyses.)

For the analysis of storage refill adequacy, tank levels were modeled at the middle of peak hour fluctuation volume. This provides the average tank refill rate during the night of the maximum day. Typically, this analysis is performed after system improvements are selected to address the fire flow and pressure deficiencies. Thus, this analysis provides a final evaluation of system adequacy.

Demands

Average day demands in the model were multiplied by an appropriate peaking factor to simulate maximum day and peak hour demands. No intercommunity connections were considered active in our analysis.

Supply

For simplicity, both the pumps at St. Mary's and the pumps at Charles River Wellfield were simulated as point demands assuming that the largest well pump at Charles River Wellfield was out of service. Accordingly, for this analysis, the Charles River Wellfield supplied about 2.5 mgd, while the balance of the water demand (8.2 mgd) was provided by the St. Mary's Pumping Station. Existing pumping capacity at the St. Mary's Pumping Station will need to be upgraded (i.e., by the installation of new, higher capacity pump and motors) to meet these water supply requirements.

5.5.3 Analysis Results

Based on the analysis criteria and modeling conditions described above, the following distribution system piping inadequacies were identified:

Maximum Day Conditions

During both current and future maximum day conditions, water levels in the Dunster Road and Bird's Hill Tanks were not the same. Typically, water levels in the Bird's Hill Tank were about three (3) feet below the Dunster Road Tank elevations. This tank water level imbalance increases to about five (5) feet during peak hour conditions.

Balancing water tank levels helps to optimize the use of existing storage volume. This is especially important in Needham where the tank that is lagging, Bird's Hill Tank, has the greater storage volume per foot. Section 6 considers alternatives to address the storage imbalance.

Peak Hour Conditions

Ideally, a water distribution system should be able to meet peak hour demands while maintaining ground level pressures of 35 psi throughout the water system. Under peak hour demand conditions, and the modeling analysis conditions assumed above, areas in the Needham water system with elevations greater than 240-245 feet (USGS) may experience inadequate pressures (less than 35 psi) under current and future demand conditions.

There are two high elevation areas above this minimum service elevation boundary (that have water services and are not currently served by booster pumping stations) as shown in Figure 5-2 and listed below:

- An area immediately surrounding the Bird's Hill Tank including Hillcrest Road, Morningside Road, and a portion of Bird's Hill Avenue.

- An area immediately surrounding Dunster Road Tank and an adjacent area to the northeast of the Dunster Road tank including Tower Avenue and sections of Paul Revere Road and Hoover Road.

These pressure deficiencies are directly attributable to water levels in the tanks as a result of the existing high ground elevations. Thus, piping improvements alone will not meet the minimum pressure criterion. Alternatives to address the pressure deficiencies in these areas are discussed in Section 6.

The other two high elevation areas shown in Figure 5-2 - High Rock and North Hill - either do not have any buildings or house services to consider (High Rock) or are already supplied by a separate water booster pumping system to address pressure deficiencies (North Hill).

Fire Flow Analysis

Fire flow adequacy was evaluated under maximum day demand condition at the thirty-six locations selected for analysis. Fire protection was determined to be adequate if the water system could meet the fire flow requirement at a residual pressure of 20 psi. In addition, pressures in the remaining portions of the water system should be greater than 20 psi to meet the state's minimum requirements during the fire event. Fire flow deficiencies were similar during both current and future demand conditions. Flow deficiencies were noted at three locations as shown in Table 5-3.

For Fire Flow Location #3, Broad Meadow Road, local system piping improvements will increase system conveyance capacity to meet fire protection criteria (as discussed in Section 7). The area at Fire Flow Location # 7, Cabot Street, consists of commercial buildings (hotels, businesses) that already have separate booster pumping and fire protection sprinkler systems. Thus, no improvements to the town's water system are warranted. The third deficiency, Fire Flow Location #36, is located at the Bird's Hill Tank. This deficiency is directly attributable to the water levels in the tank and cannot be addressed by new piping improvements. Minimizing tank fluctuations, as discussed in Section 6, will increase the fire protection available in this area. However, because of the proximity of the tank, the use of local fire fighting equipment (with pumper trucks) should be adequate to address this deficiency.

Although not specifically modeled, available fire flow is also deficient at the high elevation point at the intersection of Tower Avenue and Paul Revere Road. Dunster Road Tank elevations must remain above 335 feet (USGS), which is ten feet below the tank overflow elevation, as a minimum condition to provide more than 20 psi pressure to this location even under normal demand conditions (i.e., without a fire flow). Accordingly, the fire flow requirement for this high elevation area will likely be met by pumping from a new high pressure booster pumping station. This condition is considered further in Section 6.

Location	Description	Estimated Required Fire Flow (gpm)	Fire Flow Available at 20 psi (gpm)	Adequate
1	Harris Avenue & Pinewood Road	2,250	3,525	Yes
2	Great Plain Avenue & South Street	2,000	4,506	Yes
3	Broadmeadow Road & Bird Street	3,500	2,767	**No**
4	Greendale Road & Highgate Street	750	1,697	Yes
5	Kendrick Street & Third Avenue	4,500/1,750(1)	6,624	Yes
6	First Avenue & A Street	6,000/2,250(1)	6,294	Yes
7	Last Hydrant on Cabot Street	4,000/2,250(1)	2,985	Yes (2)
8	Gould Street & Kerney Road	3,000	6,463	Yes
9	Central Avenue & Reservoir Road	4,500/2,000(1)	3,998	Yes
10	Central Avenue & Wellesley Avenue	2,250	5,107	Yes
11	Highland Street & Cottage Avenue	3,000	3,734	Yes
12	Webster Street & Lindberg Avenue	5,000/2,000(1)	5,877	Yes
13	Hillside Avenue & Dale Street	4,500/2,250(1)	6,277	Yes
14	West Street & Fenton Road	4,000/1,750(1)	7,726	Yes
15	Central Avenue & Gay Street	2,500	4,614	Yes
16	Great Plain Avenue & Standish Road	750	1,747	Yes
17	Stratford Road & Windsor Road	750	1,152	Yes
18	Central Avenue & Fisher Street	2,000	3,175	Yes
19	South Street & Chestnut Street	750	1,862	Yes
20	Chestnut Street & Junction Street	3,000	5,925	Yes
21	Dedham Avenue & Lincoln Street	3,000	5,111	Yes
22	End of Grove Street	750	916	Yes
23	Gilbert Road & Frances Street	1,000	1,580	Yes
24	Central Avenue - between Pine & Charles River Road	1,000	2,170	Yes
25	South Street & Marant Drive	750	1,946	Yes
26	Middle of Laurel Drive	1,000	1,205	Yes
27	Meadowbrook Road & Meadow Lane	1,000	1,967	Yes
28	Washington Avenue & Nichols Road	1,000	1,758	Yes
29	Greendale Avenue & Parker Road	1,000	2,023	Yes
30	Forest Street & Clarke Road	750	1,090	Yes
31	Great Plain Avenue & Mary Chilton Road	1,000	1,576	Yes
32	Ardmore Road & Grasmere Road	1,000	1,675	Yes
33	End of Capt. Robert Cook Drive	1,500	1,645	Yes
34	Highland Avenue & Gould Street	2,500	5,056	Yes
35	Dunster Road at Water Tank	1,000	1,280	Yes
36	Hillcrest Road at Water Tank	1,000	388	Yes(3)

NOTES: Fire flow requirements for Locations # 1-21 obtained from 1996 ISO ratings for Needham.

It is important to note that fire protection for each location is typically based on adequate flow delivery from a hydrant(s) within 300 feet of the building.

(1) According to 1980 ISO guidelines the maximum fire flow requirement is 3,500 gpm. A 3,500 gpm flow requirement was adopted for these locations.

(2) Available flow at Location #7 is considered adequate because this area (atop the hill) is served by a private booster pumping station.

(3) Available flow at Location #36 is considered adequate because of the proximity of the tank.

Table 5-3
Fire Flow Analysis Results

5.5.4 General Piping System Deficiencies

Other distribution system problem areas, not explicitly modeled, were analyzed and/or identified in this evaluation. These include a lack of adequate hydrant spacing in some areas, and several dead end mains and a substantial number of old unlined piping causing restricted flow conditions and reduced water quality. Enhancements to existing annual preventive maintenance programs were also identified. Recommendations for these system deficiencies are discussed in Section 7.

5.6 Distribution System Quality

As discussed previously, Needham records consumer water quality complaints concerning pressure problems and aesthetic water quality complaints. A majority of water system complaints in town can be directly attributed to system disruptions, primarily caused by the operation of the pumps at St. Mary's Pumping Station, but also by disruptions such as water main flushing, leaks and breaks. In these cases, sediment within the main is resuspended with the reversal of normal flow or temporarily high water main velocities. Implementation of a comprehensive unidirectional flushing program should help to reduce the occurrence of sediment within the main that can be resuspended during system disruptions and proposed modifications to the St. Mary's Pumping Station could include the use of variable frequency drives (VFD) to minimize sudden peak velocities created by the activation of the pumping station.

In addition, there are other problematic areas where services are located on small diameter pipes, old unlined water mains and/or areas with unlooped mains. Water in these areas often stagnates from significantly low water main velocities. This stagnation results in a build up of the level of iron in the water, from the corrosion of the pipe walls, resulting in water discoloration and consumer complaints. General recommendations for these areas are presented in Section 7. To the extent possible, water main improvements were prioritized in part to address the town's water quality problems in a timely manner.

5.7 Water Main Leaks and Breaks

As discussed in Section 2, Needham has experienced a number of leaks and breaks along its water distribution system piping network. A leak or a break in a water system can occur for a number of reasons including water hammer (by valves or hydrants being shut too rapidly), uneven settlement of a pipe reach, road vibration due to traffic, general wear due to age, and manufacturing defects, etc. A leak or a break along a particular reach of a pipe may be an indicator of future problems or pipe failures. The history of leaks and breaks with each water main was considered during the development of recommendations in Section 7.

5.8 Summary

Based on the analyses conducted on the pumping, piping and storage facilities, the following conclusions were made regarding the adequacy of the existing system to meet current and future water system demands.

- Existing water supply appears to be adequate to meet future demands, especially with the new water treatment plant and well pumping station upgrades currently being completed at the Charles River Wellfield. However, existing pumping equipment/facilities at the St. Mary's

Pumping Station need to be upgraded to pump MWRA water to meet current and future maximum day demands with mechanical redundancy and to provide standby power capability.

- The Bird's Hill and Dunster Road Storage Tanks can be used to meet existing distribution system storage requirements. However, pressure deficiencies occur at higher elevations of Needham's water system (adjacent to the existing tanks) when existing storage volume in the Bird's Hill and Dunster Road Tanks is fully utilized to meet current or future distribution system storage requirements. The creation of a high pressure zone around the existing tanks, a new tank or other alternative water system improvements will be required to address the pressure deficiencies. These alternatives are evaluated in Section 6.0.

- Needham's water system is hydraulically strong and provides adequate fire protection to almost all of the distribution system. Piping improvements are required to address a fire flow deficiency at only one of the thirty-six locations considered for this report. At one other location, Paul Revere Road and Tower Avenue, the fire flow requirement will probably require pumping. For the remaining analysis locations, available flow meets the assumed Fire Flow Requirement.

- Most of the water quality concerns recorded by the town are attributed to disruptions to the system (i.e., water main flushing, leaks and breaks or pump activation that resuspends existing sediment in the mains) or to areas that have well-documented problems (i.e., old, unlined, poorly looped mains, etc.). Upgrades to the St. Mary's Pumping Station could significantly reduce disruptions to the system. In the areas where the town has noted consistent water quality problems, rehabilitation or replacement of the existing pipes should eliminate water quality problems. Finally, the performance of a comprehensive unidirectional flushing program should adequately flush existing sediment from the piping system.

- A significant portion of the existing distribution system consists of older, unlined water mains that need to be cleaned and cement-lined or replaced entirely to improve conveyance capacity, increase system pressures, and reduce water quality concerns.

Recommendations for capital improvements to the distribution system are discussed in Section 7.0. These improvements are aimed at correcting the water distribution system inadequacies discussed above.

Section 6
Alternatives Analysis

6.1 General

The evaluation of Needham's water distribution system, as presented in Section 5, identified three operating issues that required further analysis to develop and evaluate alternatives to improve the water system including:

- low pressures in high elevation areas
- storage water level operating ranges
- balanced water levels between storage tanks

This section summarizes the alternatives developed to address these deficiencies.

Analysis of the water system also identified areas with inadequate fire protection (based on ISO criteria) and concerns regarding piping system reliability. These deficiencies are primarily due to localized piping restrictions. Therefore, alternatives to provide adequate fire protection in these discrete areas comprise only the selection of pipe diameters and layouts; comprehensive alternative/routing evaluations were not necessary. These required improvements are presented in Section 7.

6.2 High Elevation Areas

6.2.1 General

There are two large high elevation areas in Needham (surrounding the Dunster Road and Bird's Hill Tanks) that may experience pressures that are less than 35 psi, under both current and future peak demand conditions (shown in Figure 5-2). Thiry-five (35) psi is the minimum design pressure criteria established for this study.

In addition, within these two areas are smaller areas with elevations that result in system pressures that also fall below the minimum state standard of 20 psi. At Bird's Hill, minimal water level fluctuations within the tank can cause water system pressures at several homes within 100-150 feet of the Bird's Hill Tank to fall below 20 psi. At the intersection of Tower Avenue and Paul Revere Road, nearby the Dunster Road Tank, water system pressures may fall below the minimum state pressure standard if the Dunster Road Tank fluctuates by more than ten feet below the overflow elevation. Because of the high elevations at the top of Tower Avenue, fire flows in this area are also inadequate if the Dunster Road tanks water levels drop by ten (10) feet.

These low pressure service deficiencies cannot be adequately addressed by improvements to the existing piping network.

6.2.2 Alternatives

Three alternatives were developed and evaluated to address low pressure deficiencies in the Bird's Hill and Dunster Road Tank areas.

System-Wide Pressure Increase

One alternative is to raise pressures for the entire water system by increasing the overall hydraulic gradeline. To address storage requirements and meet at least the minimum state standard of 20 psi, system hydraulic gradelines (HGLs) would have to be increased by 20 feet or about 9 psi to provide minimum service (i.e., meeting state standard, but below the minimum pressure criteria of 35 psi established for this report) to the Bird's Hill/Dunster Road Tank areas. To meet the pressure criteria established for this report of 35 psi at all location during peak hour conditions, the HGL would have to be increased by 55 feet or about 24 psi.

To implement this plan, the two existing tanks would likely have to be replaced with new higher elevation tanks. Structural modifications to the existing tanks are impractical due to the significant increase in tank height (e.g., the existing Bird's Hill Tank is only 45 feet as compared to raising it another 20-55 feet higher). Accordingly, new, higher elevation tanks would be needed. New pumping equipment would also be required at the three Charles River Wellfield pumping stations and higher lift pumps at the St. Mary's Street Pumping Station to meet the higher system HGLs.

There are several disadvantages to this system-wide alternative. First, pressures in low elevations areas of town already exceed the state suggested maximum standard pressure of 85 psi and, in some locations, exceed 100 psi. Under the system-wide alternative to increase HGLs, higher pressures in these low elevation areas could increase the potential for water main leaks and breaks (especially in older, unlined mains), and increase the potential for service pipe leaks within homes. Second, the capital costs associated with the new facilities (e.g., two new tanks and pumping station/water treatment plant modifications at the Charles River Wellfield and at St. Mary's Street Pumping Station) is significant. Finally, because of the close proximity of homes to each of the existing tanks, it is unlikely that the town will win public approval to raise tank height due to aesthetics and other neighborhood concerns.

In summary, raising the overall system gradeline for the high elevation areas results in a significant capital cost and higher annual system operating cost to provide adequate pressures to a small portion of the system. Accordingly, this alternative was not considered further.

New High Service Pressure Zones

Adequate service to these high elevation areas could be provided by the creation of separate high pressure zones for the Duster Road/Bird's Hill Tank areas. These boosted pressure zones would each be supplied by new water booster pumping station designed to meet the pressure and flow requirements of each service area. Other communities have found that below-ground water booster pumping stations have (cost-effectively) addressed similar high elevation problem areas in their water systems.

The booster pumping station(s) would be equipped with at least two domestic pumps (one for mechanical redundancy) and a pump for fire flows (only in the Dunster Road area to serve Tower

Avenue/Paul Revere Road). The station(s) would operate automatically based on system pressures and demands. A check valve would also be installed at the station(s) to allow flow past the pumps (from the main system) during a power failure. A permanent standby power generator may be required to ensure that the minimum pressures are met at all times. This generator could be housed in a prefabricated enclosure at ground level. If these generators are not required, it is still recommended that a quick connect coupling be installed to allow a portable generator to run the pumping station during power failures. It is likely that these stations would be installed at the tank sites where the town already owns available land for the station off the roads.

The service boundaries for each new pressure zone will depend on the identification of the optimal storage fluctuation levels (Section 6.3). There is a total of approximately 100 to 220 homes (70 to 95 homes in the Bird's Hill area and 30 to 125 homes in the Dunster Road area) that could be affected by inadequate pressures depending on the water level storage range that is ultimately selected (a range of 10 to 25 feet below the overflow elevation) to provide for peak hour storage volume and fire protection.

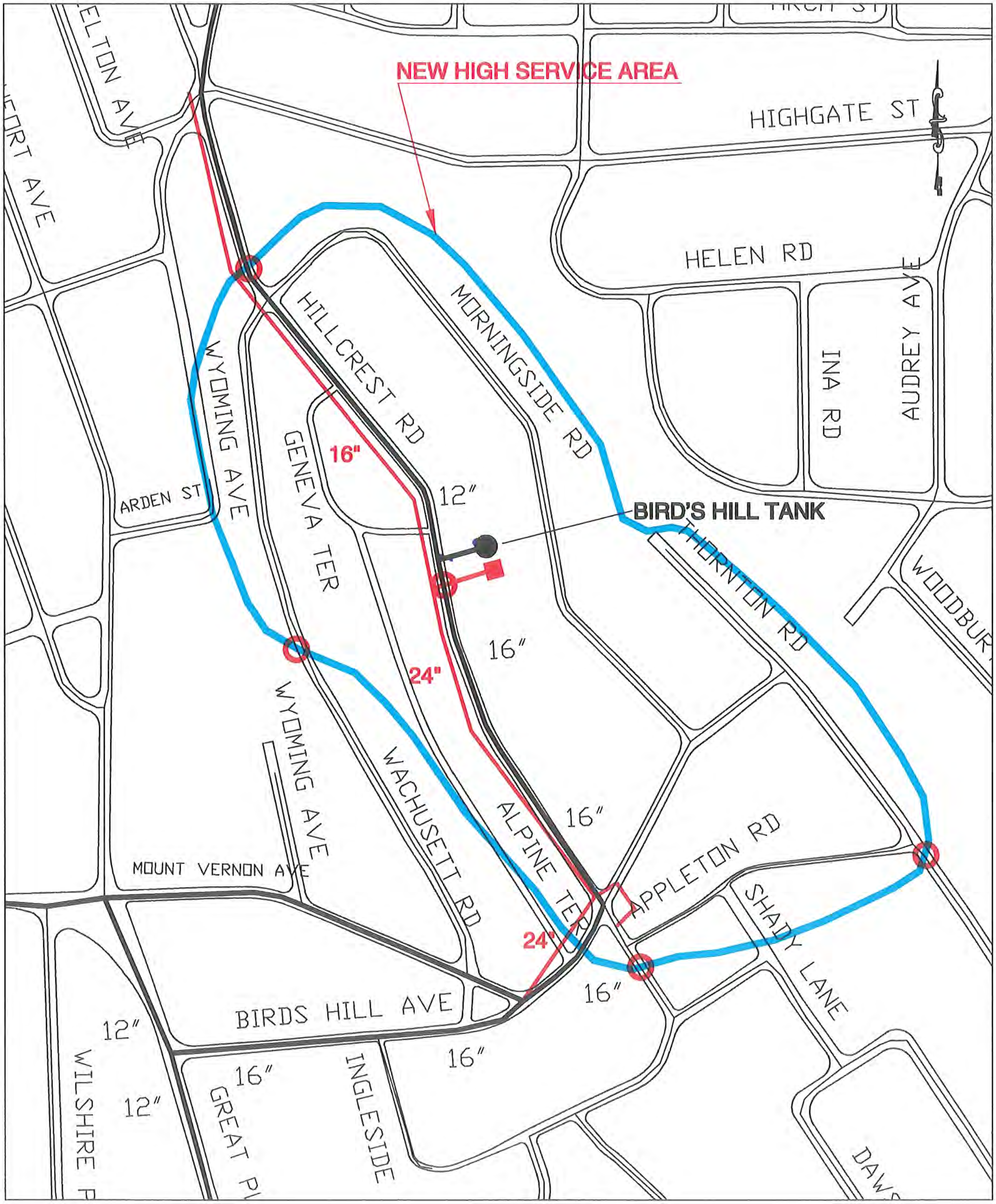
New water mains are also required to create the new pressure zone(s). All of the water mains in the tank areas provide conveyance capacity to get the water to the tanks. Accordingly, these pipes (even the small 8-inch pipes along the side streets) cannot be simply removed from the main service system to supply the high service system without increasing hydraulic losses to the tank. Thus, to create the new service systems, it is recommended that new larger diameter transmission mains be installed to connect to the existing tanks. Then, the existing transmission mains and the smaller diameter sideline connections can be converted to the high pressure service system without additional system headlosses. This method will also minimize the extent of parallel piping for both high and main service systems in the areas surrounding the tanks. Figures 6-1 and 6-2 provide proposed layouts for the new pressures zones.

Based on a preliminary estimate, the project cost for these system improvements to create <u>each</u> new pressure zone range from approximately $800,000 to $1,200,000, depending on the need for standby power and the final boundaries of the pressure zones.

Pressure problems in these two high elevation tank areas will be eliminated by the creation of these high pressure zones. This alternative also maximizes the flexibility in tank operations for current and future demands. Finally, the last advantage is that this alternative relies on a single central pumping facility to serve each area. However, station operating costs and life-cycle replacement requirements/costs represent disadvantages associated with installing new pumping facility within the water system.

Individual Home Booster Systems

A third alternative is the installation of individual home booster pumping systems in each home. It is estimated that there are approximately 100-220 homes that have pressures that fall below the 35 psi minimum pressure criteria established for this report. Of these homes, approximately 12-20 may experience pressures that fall below 20 psi during peak demand periods. (At homes where pressures fall below 20 psi, the town should consider, at a minimum, installing backflow preventers to ensure that cross contamination of the water supply does not occur during a significant demand



NOTES:
1) NOT TO SCALE
2) SEE TEXT FOR ADDITIONAL NOTES

LEGEND

EXISTING SYSTEM

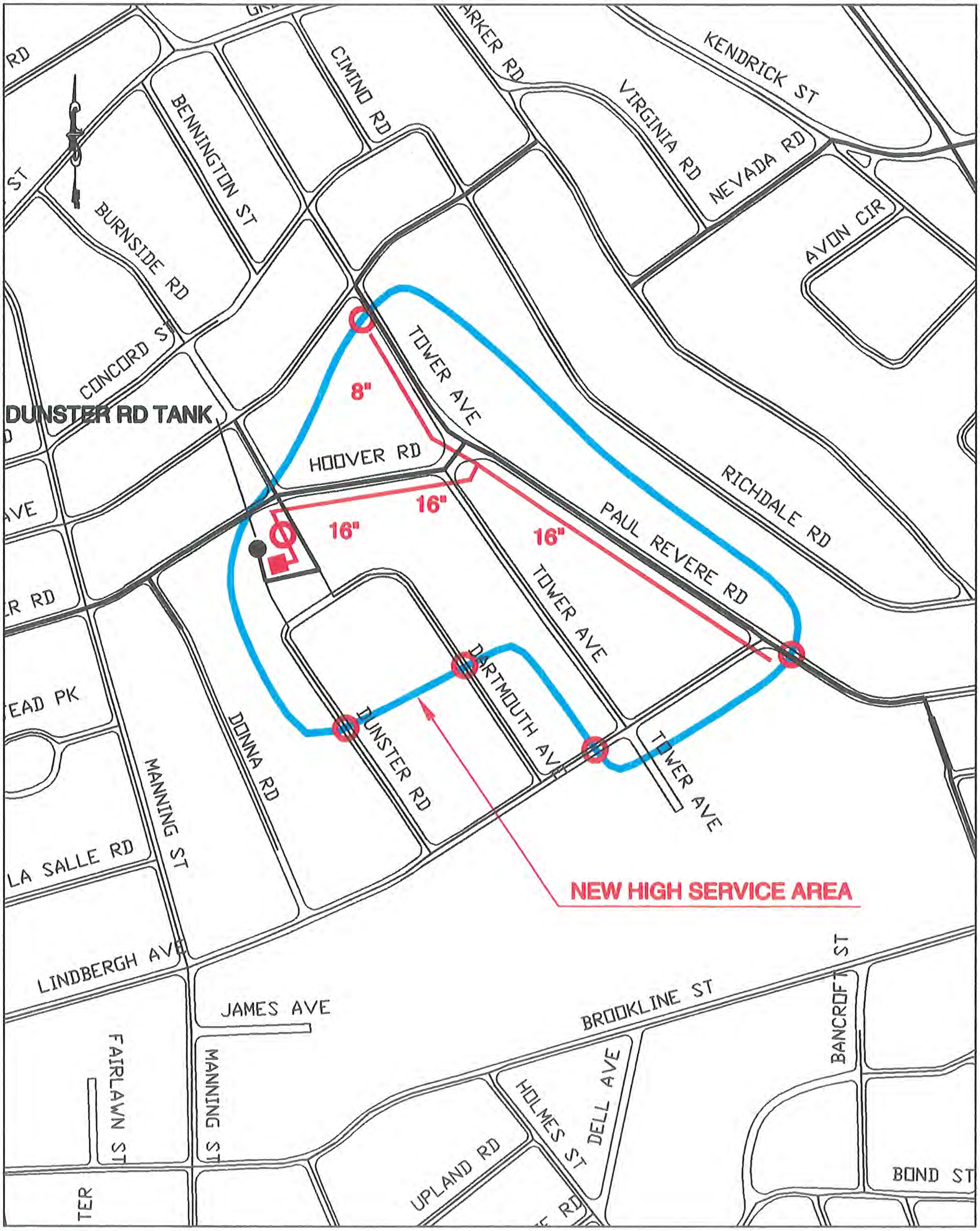
6"
8"
10'
12'
14"/16"/20" 14" / 16" / 20"

PROPOSED SYSTEM IMPROVEMENTS

Checkvalve
Booster Pump
16" Pipe Size
New Pipe

CDM Camp Dresser & McKee

FIGURE 6-1
BIRD'S HILL
HIGH SERVICE AREA



NOTE: NOT TO SCALE

LEGEND

EXISTING SYSTEM

6"
8"
10'
12'
14"/16"/20" — 14" / 16" / 20"

PROPOSED SYSTEM IMPROVEMENTS

Checkvalve
Booster Pump
16" Pipe Size
New Pipe

CDM Camp Dresser & McKee

FIGURE 6-2
DUNSTER ROAD
HIGH SERVICE AREA

event, such as a fire flow, when system hydraulics could result in a momentary negative pressure along the main).

Potential fire flow deficiencies were noted in Section 5 in the area at the top of Tower Avenue/Paul Revere Road depending on Dunster Road tank water levels. The installation of individual home booster pumps will not resolve this flow deficiency.

The estimated cost to install individual home booster pumps in the affected homes in these high elevation area ranges from about $400,000 to $880,000.

The advantage of this alternative is its lower cost in comparison to creating the high pressure service zones. In addition, this alternative could be implemented in phases or as pressure complaints occur. Since residents closest to the tanks reportedly already have home booster pumping systems and the town has not received a significant number of pressure complaints from other residents in these areas, it may not be imperative that the town immediately install the pumping systems.

The disadvantage is the significant number of these small separate pumping systems that will exist in this area of town. The long-term maintenance/replacement requirements for this alternative may not be desirable for Needham. Fire flow deficiency at Tower Avenue/Paul Revere Road will also not be corrected under this alternative. Finally, individual home booster systems do not allow for the contingency of supplying standby power on an area-wide basis in the event of a power failure.

6.2.3 Conclusion

Although the installation of home booster pumping systems is the least cost alternative, the creation of separate high pressure systems for the Dunster Road and Bird's Hill Tank areas represents a more effective solution to the widespread pressure inadequacies in these areas. There are a significant number of homes in this area that may require home booster systems; the long-term maintenance costs associated with the home booster pumps may prove to be a burden to the town. A single pumping station provides better reliability and control of the pressures in this area. In addition, the creation of a new zone and the installation of a fire pump within a new station will allow the town to address the fire flow inadequacies at the Tower Avenue/Paul Revere Road area (which could not be adequately addressed by a plan to install individual home booster pumps). Finally, the new pressure zones will allow the town to optimize use of the existing tanks, reducing current and future storage deficiencies.

6.3 Optimizaton of Storage Water Levels

6.3.1 General

As discussed in Section 5, current peak hour demands require a storage fluctuation volume range of about 20 feet below the overflow elevations of the Dunster Road and Bird's Hill Tanks. This range of operation for peak hour increases to 25 feet to meet future 2020 peak hour system demands.

If existing pressures in high elevations in town were addressed by the creation of high pressure service zones, as discussed above in Section 6.2, the existing storage volume within the two tanks could meet system storage requirements for peak hour demand fluctuations. However, the use of 25 feet of storage volume in the future may not be desirable (according to acceptable waterworks practices) as it could result in diurnal pressure fluctuations of more than 10 psi in all areas of the system. In addition, operation of the tanks over the full range for peak hour fluctuation volume could result in consumer pressure complaints regarding pressure fluctuations (i.e., possible fluctuation of 10 psi versus the current fluctuation range is about 6-8 feet, which is only about 2-3 psi).

Accordingly, two alternatives were considered to supplement existing system storage and minimize pressure fluctuations - the installation of a new tank for supplemental storage or upgrading proposed modifications to the St. Mary's Street Pumping Station to increase pumping capacity.

6.3.2 New Tank/Supplemental Storage

A new tank could be constructed to provide supplemental storage volume that would minimize fluctuations in the existing tanks and pressure variations in the water system. Replacing the existing tanks with larger diameter tanks is not practical due to the proximity of homes adjacent to the tanks. Thus, potential locations for a new tank site were considered.

Typically, areas with high ground elevations are used to site new tanks to minimize costs. In addition, proposed sites need to be in close proximity to the existing water system (to minimize new piping for connections) and in a location that works hydraulically with the water supplies and existing tanks. As discussed in Section 5, there are only a limited number of high elevation areas in Needham. In addition, most of these areas are already developed. The existing tanks occupy two of the high elevation areas. A third area, High Rock Hill, does not have enough area to support the construction of a new tank. There is no land available at the top of a fourth high elevation area, North Hill, but the town owns some land on the hill (along one of the slopes) that has been reserved for a new tank. Most other vacant areas of town have elevations that are too low to cost-effectively site a new tank.

At the North Hill site, an elevated spheroid tank could be constructed to supplement existing system storage volume. Based on an evaluation of optimal tank design (i.e., tank diameter, height, etc.) and the need to provide a reasonable range of operation in the existing tanks, a range of 15 feet (operating between 345 feet to 330 feet, USGS) was adopted for the peak hour storage fluctuation volume in the water system. Accordingly, a 2.0 million gallon spheroid tank would be constructed to meet the supplemental storage requirements in Needham. The estimated project cost (including engineering and contingencies) for this tank ranges from $4.8 million to $5.6 million, depending on the site development needs.

Construction of a new tank provides the town additional storage capacity to meet current and future demands; however, this project represents a significant cost. Although, the new tank could potentially provide additional storage for fire protection and pressure stabilization in another area of town, the water system analysis did not indicate a specific need in the North Hill area. The new tank, however, could provide the town with additional capacity when one of the other tanks is taken out of service during maintenance (i.e., tank cleanings, painting, etc.).

6.3.3 Peak Hour Pumping

As an alternative to the new tank, the St. Mary Street Pumping Station could be designed to meet a portion of the system peak hour demand by pumping. Modifications are already required at the pumping station to provide reliable capacity to meet current and future maximum day demands. It is estimated that increasing capacity at the pumping station to meet a portion of the peak hour demand (between 8.2 mgd to 10.0 mgd) represents an increase of about $150,000 to $200,000 to the cost of the station modifications already recommended for maximum day. This cost increase covers the additional cost for larger capacity pumps, motors and motor control equipment and standby power capacity.

Under this alternative, the St. Mary's Pumping Station would pump flow into the distribution system based on tank level (as it currently does now), but additional pumping capacity (with adequate mechanical redundancy) would exist to minimize tank level fluctuations, if required, to maximize system pressures. Accordingly, tank water level fluctuations could be limited to a ten to fifteen foot range. This approach also increases the flexibility (i.e., facilities, capacities, etc.) the town has available to meet future demands by modifying pumping rates and storage tank operating water levels.

6.3.4 Discussion

The provision of peak hour pumping capacity at the St. Mary's Pumping Station is the cost-effective alternative. Increasing capacity at the St. Mary's Pumping Station peak hour represents only a marginal cost because modifications to the station are already required to meet the town's maximum day demands. Pumping a portion of the peak hour demands is also similar to current operations. Accordingly, CDM recommends that the town increase the pumping capacity at the St. Mary's Station to meet a portion of the town's peak hour demands.

It is important to note, however, that the MWRA may not fully support this approach. The Authority desires that each community provide its own system storage, to the extent possible, to meet peak hour demands to reduce reliance on the MWRA system. Although the peak pumping rate at the St. Mary's Pumping Station, about 9-10 mgd to meet partial peak hour demands in the Needham system, will be well below the town's maximum withdrawal rate of 12.5 mgd, the MWRA may require the town to minimize or cease peak hour pumping in the future. In this event, the town would have to consider the need for a new tank or the full use of the existing tanks over the 20-25 foot range to meet peak hour storage requirements.

6.4 Storage Imbalance

The Bird's Hill Tank typically fluctuates about 3 feet below the water levels in the Dunster Road Tank. During peak hour demand periods, the imbalance between the water storage tanks may increase to about five (5) feet. It is important to balance water levels within these tanks, to the extent possible, to maximize available water system storage tank volumes.

Several alternatives were evaluated to correct the storage imbalance. These alternatives consisted of piping improvements to reduce the hydraulic pipe losses between the two tanks. New pipes or pipe rehabilitation was considered to improve the hydraulic connection between the Bird's Hill Tank, Dunster Road tank and the transmission piping system. Most of the piping alternatives considered did not raise the hydraulic gradeline of the Bird's Hill Tank by more than one (1) foot (at a minimum cost of about $600,000). To balance the tanks completely, a new 30-inch diameter pipe (installed along the most direct existing route between the tanks, down Hoover Road, Paul Revere Road, Falcon Street and Hillcrest Road) is required at a cost of more than $900,000.

There are many old, unlined mains surrounding the Bird's Hill Tank that contribute to the reduced operating gradeline experienced at the tank. It is expected that as the town eventually replaces or cleans and cement-lines the mains in this area that the existing hydraulic pipeline losses will decrease and future tank water levels will be more balanced. Accordingly, the installation of a new major transmission pipe between the two tanks is not warranted at this time.

The town could install an altitude valve at the Dunster Road as an alternative to maximize system operations. The altitude valve would close after the Dunster Tank was filled, allowing the town to more readily refill the Bird's Hill Tank after a peak demand period. The estimated cost of this improvement is about $150,000.

6.5 Summary

CDM recommends that the town create two new high pressure service zones (served by separate water booster pumping stations) for the high elevation areas surrounding the Bird's Hill and Dunster Road tanks. These high pressure zones will allow the town to meet the minimum state pressure standards and provide 35 psi to all areas of the water system. In addition, the service zone will allow the town to fully operate the existing tanks, if desired, to meet current and future system storage requirements.

To minimize pressure fluctuations in town, CDM recommends that Needham increase the capacity of the St. Mary Pumping station to provide a portion of the town's peak hour demand. This capacity represents only a marginal increase in pumping capacity required to meet maximum day demands.

There are no cost-effective alternatives to readily correct the storage imbalance that exists between the Dunster Road and Bird's Hill Tanks. Eventually, as the town replaces or rehabilitates existing water mains in the area, the tank water levels will become more balanced. To facilitate refill of the Bird's Hill Tank after peak demand periods, it is recommended that the town install an altitude valve at the Dunster Road Tank.

These improvements will allow the town to minimize changes to its current operations. Accordingly, if required, water levels fluctuations could be maintained at 6-10 feet in the Dunster Road Tank and all system evaluation criteria could be met.

Section 7
Capital Improvement Program

7.1 General

This section presents the water distribution system improvements that are required to correct the system deficiencies identified in Section 5. The overall objective of these improvements is to provide adequate system flow capacity and meet minimum pressure criteria, and to develop a more reliable water distribution piping system, to serve the needs of the town.

Because the Needham water distribution system is well looped and the transmission piping system is predominately consists of larger diameter cement-lined pipe, most of the recommended water system improvements consist of replacing or cleaning and cement-lining the existing unlined water mains. New pipe was generally recommended for all mains that were 70-75 years old and in discrete areas of the water system for looping.

During the development of the recommended improvements, consideration was also given to overall distribution system benefit and costs. The final program of recommended system improvements was prioritized based on the relative severity of the flow or pressure deficiency and the need to address local water quality concerns within the piping network.

7.2 Overview of Improvements Analysis

Water system improvements were recommended to address system deficiencies related to pumping capacity, system pressures at high elevation areas, storage facilities, and distribution system piping improvements.

7.2.1 Pumping Capacity

The St. Mary's Street Pumping Station pumps water from the MWRA to supplement the water supply from the Charles River Wellfield. Under standard waterworks practices, water system pumping stations should be capable of meeting water demands with the largest pump out of service. At the St. Mary's Pumping Station, only two of the four existing pumps are used to meet demands (the other two pumps have not been used for years and are not considered operable by the town). If one of these two pumps is out of service due to a mechanical failure, the town does not have the capacity to meet current or future maximum day demands. Accordingly, modifications to the pumping station are required to increase capacity and provide adequate pump redundancy for reliability.

CDM recommends that new higher capacity pumps be installed in this pumping station, along with a new electrical service and motor control centers. We also recommend that the town install a new standby power engine generator set in a new building addition to provide standby power to the station during power failures. This single standby power generator will replace the two existing direct drive diesel engines connected to the two normal duty pumps. These engines do not have the horsepower required to drive the new pumps and the installation of new direct drive engines is not cost-effective.

7.2.2 Peak Hour Demand

For this report, we established a design criterion that requires system pressures to be greater than 35 psi during peak demand periods. This is a typical analysis criterion. There are two high elevation areas in town that experience pressure deficiencies (less than 35 psi) under current and future peak hour demand conditions. These areas surround the two storage tanks at Dunster Road and Bird's Hill. Within these areas are also smaller zones where system pressures fall below the minimum state standard of 20 psi, depending on tank operations. Water levels within the tank directly impact these high elevation areas; thus, piping improvements will not resolve these pressure deficiencies.

Three alternatives were considered to address these pressure deficiencies - increasing the overall system hydraulic gradeline, which requires the construction of new storage and pumping facilities; creation of two separate high pressure service zone (supplied by new water booster pumping stations); or the installation of individual home booster pumping systems. Increasing the overall system gradeline is not cost-effective considering the significant capital costs, major modifications to existing operating guidelines and the potential for increased frequency of water main leaks and breaks (due to higher pressures). The cost of installing individual home booster pumps is the least cost alternative, however, a significant number of homes will require a home booster pumping system (100-220), which represents a potentially significant long-term maintenance burden to the town. In addition, the installation of home booster systems does not address the fire flow deficiency at the Tower Hill area.

Accordingly, CDM recommends that the town install new booster pumping stations and new piping to create separate high pressure service zones to meet the flow and pressure criteria for these high elevation areas surrounding the tanks. The new high pressure zones provide the best flexibility for the town to optimize operation of the existing tanks, allows the capability of providing flows to homes during power outages, meets fire flow deficiencies in the area, and centralizes operations and maintenance concerns.

7.2.3 Storage Volume and Operations

Storage Volume

With the creation of two new high pressure service zones, the existing tanks will have adequate volume to meet current and future peak hour storage fluctuation requirements. However, to meet these requirements, the tanks will need to fluctuate over a range of 20-25 feet (below overflow elevation), which is more than twice the current range of operation of 6-10 feet. This tank operation range is greater than what would be typically recommended for proper tank control and could result in diurnal system pressure variations of about 10 psi.

Accordingly, two alternatives were considered to reduce tank water level fluctuations - constructing a new tank to provide supplemental storage volume in the appropriate operating range or the installation of additional pumping capacity at the St. Mary's Street Pumping Station to pump a portion of the peak hour demand. Modifications to pumping capacity at the station are already required to meet maximum day demands, thus, the proposed increase in capacity represents only a marginal cost impact. The construction cost of a new, properly aligned tank is significantly more than the pumping station modifications. Accordingly, CDM recommends that the new pumping equipment to be installed in the St. Mary's Street Pumping Station be sized to provide a portion of the Needham water system peak hour demand.

Storage Imbalance/Operations

Water levels in the Bird's Hill Tank are typically lower than the Dunster Road Tank levels by about 3 feet. During peak demand periods, this storage imbalance can increase to about 5 feet. Balancing system storage water levels is important, to the extent possible, to optimize available storage volume and minimize pressure variations in the system. Several piping system improvements were evaluated to help reduce this storage level imbalance including installing new pipe and rehabilitating existing pipe. However, most of these improvements were costly and did not result in significant improvements to tank water level. In addition, it is expected that local area piping headlosses in the area adjacent to the Bird's Hill Tank will eventually be reduced by other proposed system rehabilitation improvements.

As an alternative, CDM recommends the installation of an altitude valve at the Dunster Road Tank. This control valve will close the tank when it is filled, allowing the town to pump directly to the Bird's Hill Tank for refill at night.

7.2.4 Distribution Piping Improvements

The water distribution system was evaluated under three demand conditions: peak hour demand, maximum day demand with coincident fire flow, and nighttime refill. All peak hour pressure problems in the Needham water system are associated with the high elevation areas. No other deficient pressures were noted. In addition, piping improvements are required at only one of the 36 locations analyzed for the adequacy of fire protection. A new pipe along Broadmeadow Road to replace an existing, unlined 6-inch diameter main will correct this fire protection inadequacy.

In addition to piping improvements required for the discrete fire flow analysis locations, CDM also recommends that the town eventually replace or clean and cement-line all of the remaining unlined water mains. CDM compiled a list of the unlined pipe in the system using the geographic information system (GIS) based on data provided by the town. There are many pipes in the system that are more than 70-75 years old, which is approaching the typical effective life cycle of a buried pipeline. The list of unlined pipe in the system was divided by age. We recommend that the town replace all 6-inch and 8-inch diameter pipe installed prior to 1930. Larger diameter pipe installed during this period should be independently assessed to determine its current integrity and remaining life span. If it is cost-effective, these larger diameter pipes could be clean and cement-lined versus being replaced with new pipe.

A second list of recommendations was developed for pipes installed after 1930. System piping that is 6-inches in diameter or smaller is typically replaced with properly sized cement-lined pipe (8-inch pipe is typically adequate). However, in Needham, in the local neighborhood areas tested for this study, the well-linked network of 6- and 8-inch diameter pipes provide good hydraulic capacity.

Accordingly, the town should evaluate the structural integrity of each 6-inch main to select whether cleaning and cement-lining or full replacement is warranted. For pipes with diameters 8-inches and larger, the main can be typically rehabilitated by cleaning and cement-lining. These overall system piping improvements will generally improve water quality and reduce the occurrence of stagnant water within the system due to unlined or unlooped piping. Localized fire protection will also improve with the implementation of these system improvements.

Finally, in some areas of the system, new piping is recommended to loop pipes in the distribution network that are currently dead ends. There are dead-end mains in the Needham water distribution system, like other water systems of similar size. Looping existing mains will also help to improve water quality and fire protection in the local area. Where it is possible, the town should attempt to loop dead-end pipes as development occurs and/or municipal easements exist. If looping an area is not possible due to access constraints, the town should install a hydrant at the end of the main for flushing. In all deadend areas, hydrants should be served by 6 inch diameter or larger mains. In areas where hydrants are connected by 4-inch or smaller mains, a new 8-inch pipe should be installed to ensure adequate fire protection to the area.

In summary, the recommended distribution piping improvements in Needham consist of: (1) reinforcing the local area piping network to satisfy ISO fire flow requirements; (2) installation of new pipes to create a new high pressure service zone(s); (3) replacing or cement-lining all remaining unlined and small diameter water mains in the system where specific water quality problems exist; and (4) looping piping to improve flow and water quality in dead end areas. Distribution piping improvements that fall into these three categories comprise the formal recommended piping improvement program.

Based on the computer simulations, it was determined that no specific piping improvements were necessary to address system storage refill adequacy.

7.3 Recommended Improvements Program

7.3.1 General

The recommended improvements program, shown in Table 7-1, is arranged in three system categories: Peak Hour/Fire Flow Improvements, General Piping System Rehabilitation, and Annual Planning Programs. Piping system improvements were not arranged into a formal prioritized program, but separated into improvement categories. Generally, improvements to the transmission piping system to address ISO and estimated fire protection requirements and peak hour demand needs are given first priority in a water system. However, the town's water system is already well-linked and consists of largerdiameter mains; thus, the majority of the system improvements are related to general piping system rehabilitation.

Fire protection piping improvements in this report were developed to satisfy all ISO established fire flow requirements; and maintain adequate pressures along major grid mains at high points and extremities of the system during these fire flow conditions. These improvements are necessary to increase the ISO developed rating of the Town's fire protection capacity. This rating is used for

Project	Estimated Project Cost
Peak Hour/Fire Flow Improvements	
St. Mary's Pumping Station Modifications	$2,200,000
Dunster Road High Service Area	$850,000
Bird's Hill High Service Area	$1,200,000
Dunster Road Tank Altitude Valve	$150,000
Fire Protection Piping Improvements	$630,000
Subtotal	**$5,030,000**
General System Rehabilitation	
Rehabilitation of Pipes Greater Than 75 Years Old	$13,000,000
Rehabilitation of Pipes Less Than 75 Years Old	$8,300,000
Water Main Looping Improvements	$1,175,000
Replacement of Small Diameter Mains	$3,453,000
Subtotal	**$25,928,000**
Total Water System Capital Improvements Program	**$30,958,000**
Miscellaneous Maintenance Programs	
Water Main Flushing Progrm	$25,000
Annual Maintenance Programs	$75,000

Notes:

Estimated Project Costs are based on April 1999 construction costs (Boston City Base - ENR 6953) and include an allowance for engineering and contingencies. See text for additional information.

Annual Maintenance Costs represent a budgetary cost for materials.

Table 7-1
Summary of Recommendations

insurance purposes and may directly or indirectly influence insurance rates for public and private buildings and reflect major fire protection adequacy.

It is important to note that prior to the implementation of any pipeline improvement, field investigations should be conducted by the town to verify system pipeline conditions which were assumed for this study. A coupon or C-value test should be performed on each pipe recommended for cleaning and lining to verify town records indicating the unlined condition of the pipe. The existence of a lined pipe in this situation usually indicates the existence of another hydraulic restriction, such as a closed or partially closed valve along the main. For local area piping improvements, pipeline conditions should be reviewed especially where new pipes are recommended to replace supposedly unlined smaller diameter pipes. In these instances, actual field C-value or fire flow tests should probably be performed to help document the deficiencies and improvements to be provided by the new pipes.

A pipe sample should also be collected on each pipe with suspect structural integrity. For some mains, the remaining pipe material may not be adequate to fully support the pipe and the useful life of the main is exceeded. Cleaning and cement-lining will not extend the useful life of a pipe with integrity problems. In these instance, the pipe should be replaced with new water main (with 8-inch diameter being a minimum new pipe size). Where the pipes will be replaced instead of cleaned and cement-lined, the city will need to adjust the system improvement costs presented in this report.

Where new pipe is installed to replace existing, unlined pipe, the town should complete the following work: cross connections of the new pipe to any existing distribution system pipes at all intersections; adequate valve spacing; installation of properly spaced hydrants or changeover of the existing hydrants to the new main; transfer of existing service to the new pipeline; and plugging and abandonment of the older existing unlined parallel main.

A final recommendation of this study is the enhancement of existing annual system maintenance programs to maintain system reliability and improve water quality within the distribution system.

7.3.2 Project Cost Criteria

The estimated construction and project costs listed in all the tables in this section are based on current construction prices and engineering costs as of April 1999 and are referenced to an Engineering News Record (ENR) Construction Cost Index (Boston City Base) of 6953.

These costs, unless otherwise noted, include an allowance of 40 percent for engineering and contingencies. Preliminary cost estimates would have to be updated for future inflationary changes anticipated at the time of construction. Preliminary updating may be accomplished by multiplying the construction costs quoted here by the ratio of the ENR index anticipated at the mid-point of construction to the present index of 6953.

7.3.3 Peak Hour/Fire Protection Improvements

Improvements to address peak hour/fire protection improvements consist of modifications to existing facilities, the creation of new high pressure service zones and piping improvements.

Dunster Road/Birds Hill High Service Zones

The creation of two new high pressure zones for the high elevation areas surrounding the Dunster Road and Bird's Hill Tank areas is recommended to address water system pressure deficiencies in these areas. New piping will be required to create the high pressure zones. Preliminary piping layouts are shown in Figures 6-1 and 6-2. A new water booster pumping station will be constructed to supply water to each high pressure zone and will be located at the existing tanks for adequate suction pressures. The stations will be below ground, factory prefabricated pumping stations equipped with at least two pumping units to meet current and future demand and minimum pressure requirements and allow for mechanical redundancy if one of the pumps fails. If necessary, the Dunster Road pumping station would include a fire pump to meet fire protection requirements.

Provisions for standby power and alarms can also be provided at the station. Instrumentation will be provided at the station to monitor low pressures, station operations, and to contact telemetered alarms (or auto-dialer systems) to notify city personnel.

A preliminary design study should be conducted before initiating design to determine the required pumping capacities and fire flow rates. In addition, the study would consider the location for the pumping station within the tank site including any requirements for connection piping to the station. Standby power requirements, either a quick connect coupling for a portable standby power generator or a permanent on-site generator, will also be evaluated.

The estimated cost to create these new high pressure zones including the cost for the piping, check valves and new pumping station is about $850,000 for Bird's Hill and about $1,200,000 for the Dunster Road area, depending on the requirements for standby power, fire protection and site development (i.e., rock excavation, etc.). These costs include an allowance of 40 percent for engineering and contingencies. The preliminary design study is expected to be about $7,000 for each area, which is included in the costs discussed above.

St. Mary's Street Pumping Station Modifications

Modifications are recommended to increase the reliable pumping capacity at this station. Four new pumps will be installed to supply up to approximately 10 mgd, which meets the maximum day demands and a portion of the peak hour demands for the town (after consideration of the reliable capacity of the Charles River Wellfield). The new pumps will be driven by new high efficiency electrical motors and will require new motor controls and electrical connections. Two motor control centers will include variable frequency electrical drives (VFDs). VFDs will allow the town to vary the capacity of the station and help to avoid sudden flow reversals when the station is activated (helping to reduce water quality complaints). A new electrical service and lighting plan is also included in the cost. Finally, a new 25-ft. by 25-ft. building addition will be constructed to house a 400 kw electrical generator and automatic transfer switches for standby power. The generator can be powered by either diesel fuel or natural gas, if available. The generator building will be constructed with sufficient sound-proofing to limit ambient noise disruptions outside the structure.

The estimated cost of these modifications to the St. Mary's Street Pumping Station is $2,200,000, including engineering and contingencies.

System Storage Imbalance

To assist in refilling the Bird's Hill Tank, CDM recommends the installation of an altitude valve control station at the Dunster Road Tank. After the Dunster Road Tank has been refilled, the altitude valve will close, allowing the town to directly refill the Bird's Hill Tank. The control station would be located adjacent to the tank in an underground vault. The estimated cost of this improvement is $150,000 including engineering and contingencies.

7.3.4 Fire Protection

There is only fire flow deficiency identified by the analysis conducted for this report along Broadmeadow Road. CDM recommends the installation of 4,500 feet of new 12-inch diameter water main along Broadmeadow Road, from Great Plain Avenue to Greendale Avenue. This new main will meet the fire flow requirements for the area at an estimated cost of $630,000 including engineering and contingencies.

7.3.5 General Piping System Rehabilitation

As discussed previously, a portion of Needhams's water system consists of unlined and small diameter mains. Many of these unlined mains are extremely old and have experienced a reduction in carrying capacity due to tuberculation. This condition will deteriorate further as metallic salts continue to deposit on the interior walls of the pipes, further reducing the area of flow and further increasing frictional resistance of flow. An additional by-product of internal corrosion is the deterioration of water quality. As discussed in Section 5, quality problems exist in some areas of the distribution system.

The structural integrity of pipes of this age is also questionable. Exterior corrosion can weaken the strength of the pipe wall, increasing the likelihood of a break, especially in areas of the system where pressures area relatively high. Leakage through joints and service connections is also more prevalent in older pipelines due to settlement over the years, especially in heavily traveled roadways. Systems with a high amount of old, unlined piping generally have a higher percentage of unaccounted-for water.

Good waterworks practice suggests that a program to either clean and cement mortar line or to replace old, unlined piping with new, cement-lined ductile iron pipe should be implemented. CDM has divided the existing unlined mains into two system rehabilitation programs.

Pipes Greater Than 70 Years Old

The first program is for all unlined mains that are older than about 1925. These pipes have exceeded the generally accepted life span for buried pipelines. We recommended that all pipe 8-inch in diameter and smaller be replaced with a minimum 8-inch diameter pipe as shown in Table 7-2 and Figure A, attached. In several areas, we have proposed replacing existing pipe with 12-inch water main to hydraulically reinforce areas of the water system and improve circulation. In addition, for the Bird's Hill Avenue 16-inch water main, we proposed that the town clean and cement-line this pipe, if the pipe is structurally sound. The total estimated cost of this first General System Rehabilitation program is about $13,000,000 including engineering and contingencies.

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	New Pipe 12"	Clean & Cement Line	Estimated Costs
Alfreton Rd.	Existing 6" main	Mark Lee Road	4	250	X			$32,500
Alfreton Rd.	Existing 4" main	Webster Ave.	6	250	X			$32,500
Avery St.	Sunnyside Rd.	Hillside Ave.	6	800	X			$104,000
Beaufort Ave.	Bond St.	Great Plain Ave.	8	2,280	X			$296,400
Bennington St.	High St.	Richdale Ave.	6	650	X			$84,500
Birds Hill Ave.	Hillcrest Rd.	Great Plain Ave.	16	1,000			X	$100,000
Bradford St.	Glenwood Rd.	Great Plain Ave.	6	1,830	X			$237,900
Brookline St.	Webster St.	Holmes St.	6	1,350		X		$189,000
Burrill Lane	Forest St.	end of street	8	1,100	X			$143,000
Chapel St.	Great Plain Ave.	Highland Ave	6/8	980	X			$127,400
Clark Rd.	Clark Circle Rd.	Forest St.	8	1,400	X			$182,000
Coolidge Ave.	Harris Ave.	Great Plain Ave.	6	1,300	X			$169,000
Curve St.	Marked Tree Rd.	existing 6" main	4	600	X			$78,000
Dedham Ave.	existing 10" main	South St.	8	470	X			$61,100
Dedham Ave.	Great Plain Ave.	existing 8" main	10	5,460		X		$764,400
Eaton Rd.	Harris Ave.	Great Plain Ave.	6	1,290	X			$167,700
Fair Oaks Pk.	May St.	end of street	6	1,950	X			$253,500
Fairfield St.	Great Plain Ave.	Mann Ave.	6	1,275	X			$165,750
Fairview Rd.	Marked Tree Rd.	Sylvan St.	6	740	X			$96,200
Fenton Rd.	West St.	Pershing Rd.	8	600	X			$78,000
Forest St.	Brookside Rd.	end	8	3,350	X			$435,500
Gage Street	Existing 6" main	Marshall Street	4	200	X			$26,000
Garden St.	Great Plain Ave.	May St.	6	1,200	X			$156,000
Gayland Rd.	Warren St.	Gayland Rd.	6	1,320	X			$171,600
Gordon Rd.	Webster St.	Bradford St.	6	500	X			$65,000
Grant St.	Kimball St.	Dedham Ave.	6	1,100	X			$143,000
							Subtotal	**$4,359,950**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and contingencies.

Table 7-2

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	New Pipe 12"	Clean & Cement Line	Estimated Costs
Great Plain Ave.	Broad Meadow Road	Manning St.	12	5,100		X		$714,000
Greendale Ave.	Webster St.	Tower Ave.	6	1,700		X		$238,000
Greenough St.	Pine Grove St.	Avery St.	6	200	X			$26,000
Greenwood Ave.	Great Plain Ave.	Powers St.	6	1,100	X			$143,000
Grove St.	Pine Hill Dr.	end of street	8	2,230	X			$289,900
Harris Ave.	Bradford St.	Great Plain Ave.	8	3,150	X			$409,500
Hawthorn Ave.	Holmes St.	Beaufort Ave.	6	900	X			$117,000
Henderson Street	Miller Street	Overlook Ave.	6	700	X			$91,000
High St.	Webster St.	Greendale Ave.	6	1,390	X			$180,700
Highland Ave.	Hunnewell St.	Rt. 128/95	8	2,960		X		$414,400
Kimball St.	Grant St.	Pleasant St.	4	700	X			$91,000
Kimball St.	Grant St.	Lincoln St.	8	320	X			$41,600
Kingsbury St.	Oakland Ave.	Fair Oaks Pk.	6	920	X			$119,600
Laurel Dr.	Warren St.	Warren St.	6	2,300	X			$299,000
Lexington Ave.	Webster St.	Tower Ave.	6	1,500	X			$195,000
Lincoln St.	Kimball St.	Dedham Ave.	6	1,350	X			$175,500
Manning St.	Great Plain Ave.	Lindbergh Ave.	6	3,000		X		$420,000
May St.	Highland Ave.	Webster St.	8	1,700	X			$221,000
Mayo Ave.	Harris Ave.	Great Plain Ave.	6	1,060	X			$137,800
Melrose Ave.	Page Rd.	Edgewood St.	6	500	X			$65,000
Mills Road	Sachem Avenue	Davenport Avenue	4	500	X			$65,000
Morton St.	Highland Ave.	Webster St.	12	1,000		X		$140,000
Norfolk St.	Warren St.	Webster St.	6	1,300	X			$169,000
Oak Knoll Ter.	Great Plain Ave.	end of street	6	585	X			$76,050
Oakland Ave.	May St.	Highland Ave.	6	1,100	X			$143,000
Oakhurst Circle	Warren St.	end of street	6	400	X			$52,000
Otis St.	Manning St.	Woodlawn Ave.	6	600	X			$78,000
							Subtotal	**$5,112,050**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and contingencies.

Table 7-2

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	New Pipe 12"	Clean & Cement Line	Estimated Costs
Overlook Rd.	Fairview Rd.	Miller St.	6	970	X			$126,100
Parkinson St.	Manning St.	Woodlawn Ave.	6	540	X			$70,200
Pickering St.	Great Plain Ave.	end of street	6	2,000	X			$260,000
Pickering Place	Pickering St.	end of street	2	150	X			$19,500
Pine Grove St.	Pine Grove 8"	Hillside Ave.	6	600	X			$78,000
Pinewood Rd.	Harris Ave.	Great Plain Ave.	6	1,200	X			$156,000
Pleasant St.	Howland St.	Dedham Ave.	6	1,160	X			$150,800
Plymouth Rd.	Great Plain Ave.	Harris Ave.	6	1,600	X			$208,000
Powers St.	Woodlawn Ave.	Melrose Ave.	8	470	X			$61,100
Powers St.	Manning St.	Woodlawn Ave.	6	500	X			$65,000
Prince St.	Harris Ave.	Great Plain Ave.	6	1,340	X			$174,200
Prospect St.	Great Plain Ave.	Newell Ave/Lewis St.	6	950	X			$123,500
Reservoir St. (north)	Central Ave.	existing 8" main	6	585	X			$76,050
Ridgeway Ave.	Great Plain Ave.	Evans Rd.	6	300	X			$39,000
Sherman St.	St. Mary St.	end of street	4	800	X			$104,000
Stevens Rd.	Harris Ave.	Great Plain Ave.	6	1,170	X			$152,100
Thorpe Rd.	Webster St.	end of street	6	330	X			$42,900
Tower Ave.	Greendale Ave.	Lexington Ave.	6	800		X		$112,000
Utica Road	Sachem Avenue	Highland Avenue	8	600	X			$78,000
Warren St.	School St.	Junction St.	8	1,500	X			$195,000
Warren St.	Dedham Ave.	Kingsbury St.	6	2,500	X			$325,000
Washington Ave.	Great Plain Ave.	Edgewood St.	6/8	2,360	X			$306,800
Webster St.	Dedham Ave.	South St.	6	3,000		X		$420,000
Wilshire Park	Great Plain Ave.	Harris Ave.	6	1,600	X			$208,000
							Subtotal	**$3,551,250**
							TOTAL	**$13,023,250**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and contingencies.

Table 7-2

Pipes Less Than 75 Years Old

CDM generally recommends that small diameter, unlined pipes (less than 6-inches in diameter) should be replaced with a minimum 8-inch or greater diameter pipe for fire protection. However, in Needham, our analysis indicates that the 6-inch diameter mains, in well looped areas, will likely meet the fire protection requirements. Accordingly, it is possible that the town may not need to replace all of the existing 6-inch mains but may be able to clean and cement line the existing mains, as long as the pipes are structurally sound.

For the conservative planning purposes, however, CDM included the cost to replace all 6-inch mains that are less than 70 years old (or installed after 1925) with minimum new 8-inch diameter mains as shown in Table 7-3 and Figure A. As discussed above, the town should evaluate each main to determine its potential for rehabilitation or replacement. For this same program, in Table 7-3, CDM recommends that all 8-inch unlined mains (and larger) should be cleaned and cement-lined (unless structural conditions warrant replacement). Mains that have experienced a large number of breaks, or are otherwise thought to be in poor condition, should be replaced. The estimated cost of this second general piping system rehabilitation program is about $8,300,000.

Implementation

There are no formal priorities for implementation within the General System Rehabilitation program were adopted for this report. Town personnel have indicated that some piping improvements in the General Piping System Rehabilitation Program address areas with known water quality problems and generally, have a higher priority as compared to fire flow protection in other parts of the system. Accordingly, the implementation priority for these improvements will be determined by the town annually based on water quality concerns, known fire protection inadequacies, and paving and street rehabilitation projects.

This water main improvement program should be performed as an ongoing, annual effort by the town. The older 6-inch mains should be given top priority in the replacement program, especially in those areas that have high fire flow requirements due to the proximity of buildings or existing uses. Therefore, a good first step for this type of program would be to establish a database that contains sizes, ages, and material of all of the small diameter mains in the town.

This water main improvement program should be performed as an ongoing, annual effort by the city, along with the implementation of fire flow and transmission system improvements.

7.3.6 Water Main Looping Improvements/Replacement of Small Diameter Pipes

In addition to the improvements discussed above, CDM identified areas where new 8-inch diameter main should be installed to loop dead end areas or to replace existing 1-inch thru 4-inch mains. These improvements will help reduce water quality complaints originating from small diameter, unlined mains and the deadends and improve fire protection in these areas.

Table 7-4 shows the areas where new pipe should be installed to loop existing deadend water mains. The estimated cost of this program is $1,175,000. Table 7-5 shows the areas where existing small diameter mains should be replaced with new 8-inch water main. The estimated cost of this program is $3,453,000.

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	Clean & Cement Line	Estimated Costs
Allindale Rd.	Dawson Dr.	Broad Meadow Rd.	6	400	X		$52,000
Appleton Rd.	Alpine Ter.	Thornton	6	720	X		$93,600
Bird St.	Greendale Ave.	Broad Meadow Rd.	8	1,800		X	$144,000
Birds Hill Ave.	Aletha Rd.	Hillcrest Rd.	8	650		X	$52,000
Blacksmith Dr.	Meadow Lane	end of street	6	600	X		$78,000
Blake St.	Overlook Rd.	end of street	6	1,300	X		$169,000
Burnside Rd.	High St.	Concord St.	6	630	X		$81,900
Burr Dr.	South St.	end of street	4	900	X		$117,000
Central Ave.	Marked Tree Rd.	Pine St.	14	3,860		X	$366,700
Charles River St.	Winning River Road	Pine St.	14	8,000		X	$760,000
Chestnut St.	School St.	Oak St.	14	440		X	$41,800
Chestnut St.	Great Plain Ave.	School St.	8	760		X	$60,800
Chestnut St.	Junction St.	School St.	12	1,320		X	$118,800
Clark Rd.	Clark Circle Rd.	Glendale Rd.	6	480	X		$62,400
Colonial Rd.	High Rock St.	end of street	6	780	X		$101,400
Concannon Circle	Hillside Ave.	end of street	8	120		X	$9,600
Concord St.	Manning St.	end of street	6	600	X		$78,000
Cross St.	Highland Ave.	end	6	400	X		$52,000
Curtis Rd.	Great Plain Ave.	end of street	8	500		X	$40,000
Curve St.	existing 4" main	Great Plain Ave.	6	560	X		$72,800
Dale St.	Hillside Ave.	Dale St.	8	410		X	$32,800
David Rd.	Sachem Rd.	Hunting Rd.	6	780	X		$101,400
Douglas Rd.	Great Plain Ave.	Elmwood Rd.	6	1,519	X		$197,470
Edgewood St.	Melrose Ave.	Ellicott St.	8	115		X	$9,200
Ellicott St.	Great Plain Ave.	Edgewood St.	6	1,510	X		$196,300
Elmwood Rd.	Great Plain Ave.	Great Plain Ave.	8	3,020		X	$241,600
Emerson Rd.	High Rock St.	Emerson Pl.	6	750	X		$97,500
						Subtotal	**$3,428,070**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and
See text for additional notes .

Table 7-3
Pipes < 75 Year Old

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	Clean & Cement Line	Estimated Costs
Evans Rd.	Broad Meadow Road	existing 8" main	6	140	X		$18,200
Evans Rd.	Ridgeway Ave.	existing 6" main	8	280		X	$22,400
Falcon St.	Brookline St.	Highgate St.	6	1,220	X		$158,600
Fourth Ave.	Second Ave.	Kendrick St.	12	2,200		X	$198,000
Freemont St.	Wexford St.	Charles St.	8	230		X	$18,400
Fuller Rd.	Elmwood Rd.	Great Plain Ave.	8	860		X	$68,800
Gibson St.	Page Rd.	Manning St.	6	560	X		$72,800
Glendale Rd.	Forest St.	Clarke Rd.	6	820	X		$106,600
Glendoon Rd.	Great Plain Ave.	Nehoiden St.	6	675	X		$87,750
Grant St.	Junction St.	Kimball St.	6	1,000	X		$130,000
Great Plain Ave.	Manning St.	Pickering St.	12	2,200		X	$198,000
Hancock Rd.	Paine Rd.	end of street	6	220	X		$28,600
Harris Ave.	Webster St.	Eaton St.	12	900		X	$81,000
High Rock St.	Frances St.	Linden St.	8	1,020		X	$81,600
Highgate St.	Falcon St.	Audrey Ave.	8	1,710		X	$136,800
Highgate St.	Audrey Ave.	Greendale Ave.	8	1,120		X	$89,600
Highland Ave.	Highland Terrace	end	12	320		X	$28,800
Hillcrest Rd.	Birds Hill Ave.	Great Plain Ave.	8	1,500		X	$120,000
Hillcrest Rd.	Bird's Hill Tank	Birds Hill Ave.	16	800		X	$80,000
						Subtotal	**$1,725,950**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and
See text for additional notes .

Table 7-3
Pipes < 75 Year Old

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	Clean & Cement Line	Estimated Costs
Hillcrest Rd.	Bird's Hill Tank	Highgate St.	12	1,280		X	$115,200
Hills Rd.	Sachem Rd.	Davenport Rd.	4	360	X		$46,800
Holland St.	Webster St.	Manning St.	6	500	X		$65,000
Holmes Rd..	Beaufort Ave.	Washington Ave.	6	900	X		$117,000
Hoover Rd.	Webster St.	Dartmouth Ave.	12	1,160		X	$104,400
Howland St.	6	Pleasant St.	4	460	X		$59,800
Hunnewell St.	6"	Taylor St.	8	1,140		X	$91,200
Ingleside Rd.	Birds Hill Ave.	end	6	350	X		$45,500
Intervale Rd.	Greendale Ave.	Peacedale Rd.	8	735		X	$58,800
Lancaster Rd.	Fuller Rd.	Elmwood Rd.	6	530	X		$68,900
Lewis St.	Newell Ave.	Nehoiden St.	6	900	X		$117,000
Lindbergh Ave.	Dunster St.	Paul Revere Rd.	8	1,140		X	$91,200
Manning St.	High St.	Lindbergh Ave.	8	2,140		X	$171,200
Manson St.	Guild Rd.	end	4	120	X		$15,600
Marked Tree Rd.	Oak St.	Central Ave.	14	2,950		X	$280,250
Mayflower Rd.	Alden Rd.	Great Plain Ave.	6	1,300	X		$169,000
McCulloch St.	Glen Gary Rd.	West St.	8	560		X	$44,800
Meadowbrook Rd.	Meadow Lane	Nehoiden St.	6	900		X	$67,500
Meadowbrook Rd.	Newell Ave.	Meadow Lane	8	1,400		X	$112,000
Melrose Ave.	Edgewood St.	Powers St.	8	250		X	$20,000
Melrose Ave.	Great Plain Ave.	Powers St.	6	1,160	X		$150,800
Mercer Rd.	Webster St.	Park Ave.	6	515	X		$66,950
Miller St.	Overlook Rd.	end of street	6	250	X		$32,500
Morley St.	Page Rd.	Edgewood St.	6	520	X		$67,600
Morningside Rd.	Morningside Rd. - 8"	Birds Hill Ave.	6	1,295	X		$168,350
Needhamdale Rd.	South St.	Green St.	6	770	X		$100,100
Newell Ave.	Great Plain Ave.	Nehoiden St.	6	1,710	X		$222,300
						Subtotal	$2,669,750

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and
See text for additional notes .

Table 7-3
Pipes < 75 Year Old

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	Clean & Cement Line	Estimated Costs
Norwich Rd.	Peacedale Rd.	Valley Rd.	6	1,200	X		$156,000
Oak St.	Chestnut St.	Marked Tree Rd.	14	2,350		X	$223,250
Page Rd.	Melrose Ave.	Holmes St.	6	785	X		$102,050
Parish Rd.	Pershing Rd.	Tanglewood Rd.	8	1,050		X	$84,000
Parker Rd.	Nevada Rd.	Richdale Rd.	8	420		X	$33,600
Parker Rd.	Greendale Ave.	Virginia Rd.	6	460	X		$59,800
Parkland Rd.	Central Ave.	end of street	6	500	X		$65,000
Parkvale Rd.	South St.	end of street	6	415	X		$53,950
Paul Revere Rd.	Greendale Ave.	Falcon St.	8	100		X	$8,000
Paul Revere Rd.	Tower Ave.	Falcon St.	10	1,530		X	$130,050
Peacedale Rd.	Great Plain Ave.	Valley Rd.	6	1,395	X		$181,350
Pilgrim Rd.	Winslow Rd.	Great Plain Ave.	6	480	X		$62,400
Pine St.	Central Ave.	Charles River St.	14	1,980		X	$188,100
Pinewood Rd.	Harris Ave.	end of street	8	420		X	$33,600
Redington Rd.	Warren St.	Warren St.	6	1,070	X		$139,100
Reservoir St. (north)	existing 6" main	end of street	8	650		X	$52,000
Reservoir St. (south)	Central Ave.	existing 8" main	6	1,250	X		$162,500
Reservoir St. (south)	existing 8" main	MBTA tracks	8	500		X	$40,000
Richdale Rd.	Lexington Ave.	Paul Revere Rd.	8	800		X	$64,000
Richdale Rd.	Cimino Rd.	Tower Ave.	6	220	X		$28,600
River Park St.	Central Ave.	Hampton Ave.	6	400	X		$52,000
Riverside St.	Highland Ave.	Highview St.	6	1,060	X		$137,800
Robinwood Ave.	High Rock St.	end of street	6	1,240	X		$161,200
School St.	Chestnut St.	Warren St.	12	1,080		X	$97,200
Stevens Rd.	Harris Ave.	Stevens 6"	4	200	X		$26,000
						Subtotal	**$2,341,550**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and
See text for additional

Table 7-3
Pipes < 75 Year Old

Street	From	To	Pipe (in.)	Length (ft.)	New Pipe 8"	Clean & Cement Line	Estimated Costs
Stockdale Rd.	Stockdale Rd.-8"	Great Plain Ave.	6	440	X		$57,200
Stockdale Rd.	Stockdale Rd.-6"	end of street	4	260	X		$33,800
Sutton Rd.	Webster St.	Norfolk St.	6	1,240	X		$161,200
Thornton Rd.	Broad Meadow Rd.	existing 6" main	8	1,130		X	$90,400
Thornton Rd.	existing 8" main	end of street	6	1,000	X		$130,000
TV Place	Gould St.	end of street	8	260		X	$20,800
Upland Rd.	Holmes St.	Manning St.	6	1,150	X		$149,500
Valley Rd.	Norwich Rd.	Peacedale Rd.	6	505	X		$65,650
Valley Rd.	Great Plain Ave.	Peacedale Rd.	8	1,680		X	$134,400
Wachusett Rd.	Hillcrest Rd.	Great Plain Ave.	6	1,600	X		$208,000
Warren St.	School St.	Dedham Ave.	12	200		X	$18,000
Warren St.	Norforlk St.	High Rock St.	8	2,000		X	$160,000
West St.	Eliot Rd.	Central Ave.	12	800		X	$72,000
Whittier Rd.	Elmwood Rd.	Fuller Rd.	8	845		X	$67,600
Wildale Circle	Cynthia Rd.	end of street	4	220	X		$28,600
Woodlawn Ave.	Great Plain Ave.	Powers St.	6	1,090	X		$141,700
						Subtotal	**$1,538,850**
						TOTAL	**$8,276,100**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and
See text for additional notes .

Table 7-3
Pipes < 75 Year Old

Street	From	To	Length (ft.)	Estimated Costs
Alfretton Road	Mark Lee Road	Existing	240	$31,200
Arch Street	Rae Ave.	Woodledge Rd.	280	$36,400
Avalon Road	Bonwood Rd.	Marked Tree Rd.	480	$62,400
Bancroft Street	Washington Ave.	Brookline St.	240	$31,200
Bond Street	Falcon St.	Hillcrest Rd.	240	$31,200
Bower Street	Evelyn Rd.	Gary Rd.	320	$41,600
Brackett Street	Tolman St.	Existing	160	$20,800
Chestnut Place	Clyde St.	Dead End	160	$20,800
Colby Street	Woodledge Rd.	Existing	280	$36,400
Concord Street	Bennington St.	Existing	160	$20,800
Cook Street	Plymouth Road	Prince Street	320	$41,600
Dawson Drive	Dunbarton Rd.	Broad Meadow Rd.	280	$36,400
Donna Road	Lindbergh Ave.	Existing	240	$31,200
Edgewood Street	Morley St.	Washington Ave.	200	$26,000
Ellis Street	Gould St.	Hampton Ave.	480	$62,400
Frank Street	Horace St.	Webster St.	320	$41,600
Glendale Road	Existing	Existing	240	$31,200
Hampton Avenue	Ellis St.	Existing	320	$41,600
Harding Road	Sylvan Rd	Existing	80	$10,400
Helen Road	Ina Rd.	Audrey Ave.	320	$41,600
Helmlock Street	Melrose Ave.	Existing	240	$31,200
Ingleside Avenue	Hillcrest Rd.	Existing	240	$31,200
Mann Avenue	Fairfield St.	Greendale Ave.	280	$36,400
May Street	Garden St.	Chapel St.	440	$57,200
Melrose Avenue	Page Rd.	Upland Rd.	280	$36,400
Norman Road	Parkvalve Rd.	Green St.	240	$31,200
Pond Street	Central Ave.	Smith St.	240	$31,200
Rivard Road	Curve Rd.	Existing	240	$31,200
Second Avenue	Existing	Existing	320	$41,600
Shady Lane	Wendlington Rd.	Appleton Rd.	160	$20,800
Standish Road	Alden Rd.	Existing	480	$62,400
Sunnyside Road	Wayne Rd.	Avery St.	280	$36,400
Washington Avenue	Hawthorn St.	Holmes St.	240	$31,200
		Total		**$1,175,200**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering and contingencies.
See text for additional notes .

Table 7-4
Water Main Looping Improvements

Street	From	To	Pipe (in.)	Length (ft.)	Estimated Costs
Allen Street	Harris Ave.	Dead End	1-2"	280	$36,400
Amelia Road	Noanett Rd.	Dead End	1-2"	240	$31,200
Arnold Street	Gould St.	Hampton Ave.	!-2"	480	$62,400
Avery Street	Hillside Ave.	Dead End	1-2"	200	$26,000
Beech Street	Gould St.	Hampton Ave.	1-2"	480	$62,400
Blackman Terrace	Existing	Dead End	1-2"	120	$15,600
Blake Street	Linden Street	Existing	1-2"	240	$31,200
Bonwood Road	Bellevue Dr.	Dead End	1-2"	280	$36,400
Carey Place	Highland Ave.	MBTA Tracks	1-2"	240	$31,200
Central Terrace	Central Ave.	Dead End	1-2"	240	$31,200
Cleveland Road	Webster St.	Bradford St.	1-2"	480	$62,400
Coulton Park	Existing	Dead End	1-2"	160	$20,800
Crane Street	Central Ave.	Dead End	1-2"	160	$20,800
Dana Place	Highland Ave.	Dead End	1-2"	280	$36,400
Dana Place	Highland Ave.	MBTA Tracks	1-2"	280	$36,400
Dawson Drive	Existing	Dead End	1-2"	40	$5,200
Defrancesco Circle	Bird St.	Dead End	1-2"	320	$41,600
Dell Avenue	Holmes St.	Brookline St.	1-2"	560	$72,800
Elizabeth Circle	Meadow Ln.	Dead End	1-2"	160	$20,800
Emerson Place	Existing	Dead End	1-2"	40	$5,200
Fairlawn Street	Brookline St.	Dead End	1-2"	240	$31,200
Fletcher Street	Existing	Dead End	1-2"	40	$5,200
Freemen Place	Chestnut St.	MBTA Tracks	1-2"	320	$41,600
Garden Street	Existing	Dead End	1-2"	240	$31,200
Glover Street	Cynthia Rd.	Dead End	1-2"	240	$31,200
Great Plain Ave.	Powder House Cir.	Town Line	4"	600	$78,000
Great Plain Terrace	Great Plain Ave.	Dead End	1-2"	240	$31,200
Hamilton Place	Central Ave.	Dead End	1-2"	400	$52,000
Highland Place	Highland Ave.	Dead End	1-2"	160	$20,800
Hill Street	Booth St.	Hunnewell St.	1-2"	560	$72,800
Holland Terrace	Holland St.	Dead End	1-2"	240	$31,200
Homestead Park	Webster St.	Existing	1-2"	640	$83,200
Howland Street	Pleasant St.	Existing	4"	400	$52,000
Hunnewell Street	Hillside Ave.	MBTA Tracks	1-2"	240	$31,200
Hunnewell Terrace	Hunnewell St.	Dead End	1-2"	240	$31,200
Ivy Road	Great Plain Ave.	Dead End	1-2"	200	$26,000
James Avenue	Manning St.	Dead End	1-2"	320	$41,600
Kent Road	Prospect Street	Dead End	1-2"	240	$31,200
Kerrydale Road	Prince Street	Dead End	1-2"	240	$31,200
Lawrence Road	Washington Ave.	Dead End	1-2"	120	$15,600
Ludwig Road	Parish Rd.	Dead End	1-2"	240	$31,200
Manson Road	Highland Ave.	Dead End	4"	280	$36,400
		Subtotal			**$1,523,600**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering
See text for additional notes .

Table 7-5
Small Diameter Main Replacement Program

Street	From	To	Pipe (in.)	Length (ft.)	Estimated Costs
Maple Place	Maple St.	Dead End	1-2"	200	$26,000
Melvern Road	Sutton Road	Webster St.	1-2"	320	$41,600
Memorial Circle	Sylvan Rd	Dead End	1-2"	240	$31,200
Newbury Park	Hillcrest Rd.	Birds Hill Ave.	1-2"	240	$31,200
Newbury Park	Ridgeway Ave.	Existing	1-2"	280	$36,400
Oak Knoll Terrace	Existing	Dead End	1-2"	240	$31,200
Oakcrest Road	Marked Tree Rd.	Henderson St.	1-2"	400	$52,000
Oakcrest Road	Blake St.	Dead End	1-2"	160	$20,800
Oakhurst Circle	Existing	Dead End	1-2"	80	$10,400
Otis Street	Webster St.	Manning St.	1-2"	520	$67,600
Parkinson Street	Webster St.	Manning St.	1-2"	520	$67,600
Parkvalve Road	Norman Rd.	Dead End	1-2"	160	$20,800
Peacedale Circle	Peacedale Rd.	Dead End	1-2"	240	$31,200
Pershing Road	Fenton Rd.	Dead End	1-2"	320	$41,600
Pheasant Road	Mallard Rd	Winfield St.	1-2"	400	$52,000
Pickering Place	Pickering St.	Dead End	1-2"	160	$20,800
Pleasant Terrace	Pleasant St.	Dead End	1-2"	280	$36,400
Power Street	Melrose Ave.	Dead End	1-2"	320	$41,600
Putnam Street	Cross St.	Dead End	1-2"	240	$31,200
Pythias Circle	Damon Rd.	Dead End	4"	200	$26,000
Reservoir Park	Reservoir Pk.	Dead End	1-2"	240	$31,200
Ridgeway Avenue	Evans Rd.	Newbury Pk.	1-2"	480	$62,400
Ridgeway Ter./Adams Hillway	Hillcrest Rd.	Ridgeway Ave.	1-2"	720	$93,600
Rockwood Lane	Richards Rd.	Dead End	1-2"	160	$20,800
Roscoe Street	Horace Street.	Webster St.	1-2"	560	$72,800
Rosegate Road	Central Ave.	Dead End	1-2"	560	$72,800
Sargent Street	Melrose Ave.	Beaufort Ave.	1-2"	1200	$156,000
Sherman Street	St. Mary St.	Dead End	1-2"	320	$41,600
Tamarack Lane	Garden St.	Dead End	1-2"	80	$10,400
Taylor Street	Central Ave.	Hunnewell St.	1-2"	520	$67,600
Tower Avenue	Lindbergh Ave.	Dead End	1-2"	280	$36,400
unknown	Broad Meadow Rd.	Dead End	4"	400	$52,000
unknown	Dwight Rd.	Dead End	4"	320	$41,600
unknown	Lincoln St.	Warren St.	4"	160	$20,800
unknown (near Burr)	South St.	Dead End	4"	880	$114,400
unknown (near Hamlin)	Greendale Ave.	Dead End	4"	360	$46,800
unknown (near Harris/Mayo)	Existing	Existing	4"	120	$15,600
unknown (near Stockdale)	Great Plain Ave.	Dead End	4"	240	$31,200
Vara Lane	Reservoir St.	Dead End	1-2"	400	$52,000
Washington Avenue	Bancroft St.	Bond St.	1-2"	600	$78,000
Wildale Circle	Cynthia Rd.	Dead End	4"	240	$31,200
Wyoming Avenue	Nichols Rd.	Arden St.	1-2"	480	$62,400
		Subtotal			**$1,929,200**
		TOTAL			**$3,452,800**

Note: Estimated piping costs based on April 1999 construction costs (Boston City Base ENR of 6953) and includes an allowance for engineering
See text for additional notes .

Table 7-5
Small Diameter Main Replacement Program

7.3.7 Annual Planning Programs

In addition to the formal improvements programs discussed in the preceding sections, there are additional programs and policies that are recommended to generally improve and maintain the distribution system piping and facilities. This will help to ensure efficient and reliable long-term system operation.

Abandonment of Small Diameter (Parallel) Mains

Additional benefit in the water system can be achieved by abandoning existing, unlined water mains that are parallel to larger diameter mains in the same street. Transferring services and hydrants to the larger main (and abandoning the smaller main) will improve water quality in the system, decrease the likelihood of water main breaks, and increase fire fighting capabilities. In these cases, total hydraulic capacity should not be significantly impacted. An initial list of the small mains, which, because they parallel larger mains, should be considered for abandonment. Costs were not estimated for this work since the number of cross-connections and service connections are not known at this time. This work may also be more effectively performed by town personnel when manpower/time permits.

Street	From	To	Diameter	Length
Kimball Street	Lincoln Street	Warren Street	4-inch	700 feet
Greendale Avenue	Great Plain Avenue	south to town line	6-inch	1000 feet
Greendale Avenue	Hunting Road	Brookline Street	6/8-inch	2000 feet
Greendale Avenue	north of Highgate Rd.	south of Bird St.	6/8-inch	2800 feet
Greendale Avenue	Broad Meadow Rd.	Grovsner Rd.	6/8-inch	1800 feet

The assumed unlined condition of these mains should be field verified before the pipes are taken out of service.

Water Main Flushing

Historically, the town has performed a hydrant flushing program. Recently, the CDM prepared and the town initiated a comprehensive flushing program that systematically operates valves to isolate water mains and direct flushing water. This procedure results in a one-way movement of deposits within the pipelines which facilitates cleaning. Broken valves and hydrants in the distribution system resulted in the temporary conclusion of this comprehensive program.

CDM recommends that the town continue to perform water main flushing on a regular basis. Major field operations such as the current flushing program help the town to continually assess the status of the hydrants and valves in the system. This assessment can then be coordinated with a hydrant and valve replacment/improvement program as discussed below.

It is recommended that the town continue to perform the water main flushing and as soon as possible, restart the comprehensive flushing program. Field operations such as this help the town to continually assess the status of its hydrants and valves in the system. This assessment can then be coordinated with the hydrant and valve improvement programs as discussed below.

Hydrant Replacement and Spacing

As stated earlier in this report, individual fire flow requirements are considered to be met if a 20 psi residual pressure is available, under design fire flow conditions, at a specific location from contributing hydrants. However, even if adequate water main capacity is provided to convey the flow, if the hydrants are not in good condition, the system may not be capable of delivering the required fire flow. Accordingly, hydrant exercising and maintenance is an important function in the water system to maintain the reliability of the system to provide fire protection.

If the hydrant is old, clogged with sediment, or corroded, it should be removed and replaced with a new hydrant. Because there is no current record of which hydrants are in a state of disrepair, the total number requiring replacement is not known. The town should complete a comprehensive assessment of fire hydrant conditions and to assess hydrant replacement and maintenance needs.

However, during the hydrant flow testing program, several hydrants were noted to have apparent flow constrictions. In addition, city personnel have indicated a number of hydrants that are not operated because of high potential that the hydrant cannot be closed after it is opened. The city should complete a comprehensive assessment of fire hydrant conditions and to assess hydrant replacement and maintenance needs.

In addition, the town should evaluate hydrant spacing adequacy in all areas throughout the Town. General waterworks practice suggests that hydrants be spaced not more than 500 feet apart. Closer spacing, up to about 300 feet apart, is recommended in areas requiring fire flows larger than 2,000 gpm or commercial/industrial areas. Additionally, the town should review areas where existing hydrants are connected to old, unlined mains that are parallel to larger diameter mains nearby. In these instances, the older pipe, will, most likely, eventually be abandoned and hydrants reconnected to the better pipes, under the main replacement program, discussed above. However, in some areas, the town should consider installing new hydrants or transferring hydrants to the larger mains on a more timely schedule. This effort will significantly increase fire protection in most areas. We recommend that the Town budget about $50,000 a year for replacement of defective hydrants until the entire system has been appraised and upgraded. This would allow replacement of about 20 hydrants annually.

Valve Exercising and Spacing

Good waterworks practice suggests that all town valves be operated annually. This procedure will allow water department personnel to note malfunctioning valves and initiate maintenance work or possible replacement. Valves to be operated should be located using tie plans to review the accuracy of the recorded measurements and update them as needed.

One significant problem impacting the town's current ability to operate the distribution system is the lack of a complete assessment of valve locations. The town should adopt a record keeping system that ensures that the location of each valve is duly recorded. Numbering of each valve on a comprehensive set of maps is recommended to facilitate maintenance and status checking.