Massachusetts Water Resources Authority

Water System Master Plan

December 2006

BOARD OF DIRECTORS

Prepared under the direction of

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Katherine Haynes Dunphy, Chairwoman
MWRA Advisory Board
11 Beacon Street
Boston, MA 02108

Dear Chairwoman Dunphy:

This letter transmits to the Advisory Board MWRA's Master Plan for its water and wastewater systems. The Master Plan documents infrastructure investment needs over the next 40 years, identifies nearly 300 projects estimated at $3.2 billion in 2006 dollars, and prioritizes projects for consideration in the annual Capital Improvement Program (CIP). Approximately $2.3 billion of the identified projects in the Master Plan are for rehabilitation or replacement of existing MWRA infrastructure, driven by the need to both reinvest in the $5 billion in new facilities created since the agency's inception and in other facilities and infrastructure where attention is still needed.

The Master Plan has two volumes, one for wastewater and one for water, and is the product of a two and one-half year effort involving planning, operations, engineering and finance staff. Staff presented prioritized Master Plan project recommendations to the Board of Directors in the fall of 2006, and more refined project scopes and budgets were proposed and evaluated during the Proposed FY08 CIP development process.

The Advisory Board advocated for master planning to guide development of the annual CIP. The sizing of the Proposed FY08 CIP approved by the Board of Directors in December 2006 for transmittal to the Advisory Board reflects near-term rates management and capital project staffing considerations. The Master Plan is being transmitted as a companion document to the Proposed FY08 CIP to facilitate the Advisory Board's annual review process.

We appreciate your continued support and look forward to your comments.

Sincerely,

Frederick A. Laskey
Executive Director

MWRA Water Master Plan

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MWRA Master Plan - Executive Summary

OVERVIEW

The Master Plan documents the investment needs of MWRA's regional water and wastewater systems over the next 40 years, identifies 292 corresponding projects estimated at $3.2 billion in 2006 dollars, and prioritizes projects for consideration in the Capital Improvement Program (CIP) beginning in FY08. It is the product of a two and one-half year in-house effort involving Planning, Operations, Engineering and Finance staff[1]. During the process, MWRA's Board of Directors, Advisory Board and Advisory Committees were briefed and provided input at regular intervals.

The Master Plan is intended to serve as the principal framework for annual capital planning and budgeting and its spending recommendations have been incorporated in the MWRA's multi-year financial planning estimates. The Plan is a key reference document that will be updated every five-to-ten years to reflect changing needs and priorities, regulatory requirements, and other considerations as appropriate.

Approximately $2.3 billion of the identified projects are replacement of existing infrastructure at end of useful life. Staff determined early in the planning process that rehabilitation and replacement of existing assets would create the largest demand for future capital spending, driven by reinvestment in both in the $5 billion in new facilities created since the agency's inception and in other facilities and infrastructure where rehabilitation or replacement was still needed.

The CSO Program at $461 million is the next largest category of project spending; these projects have been approved by EPA and the court as part of MWRA's Long Term CSO Control Plan. The addition of two water system member communities in 2006 and the Board's discussion of the potential of using MWRA's robust water supply to serve communities in water-stressed basins on its borders gave greater urgency to filling in gaps in the water system, as did vulnerability assessments undertaken in response to the events of September 11, 2001. Current and anticipated regulatory requirements for drinking water, along with water quality, energy management and security considerations, also shaped the Master Plan. Issues being debated nationally that could impact the MWRA system, such as climate change and pharmaceuticals in wastewater, are identified in the Master Plan, but there are no project-specific recommendations at this time.

MWRA's Advisory Board advocated for master planning to guide development of the annual CIP, adjust unrealistically low out-year spending projections, and coordinate the various planning studies underway or planned throughout the agency. MWRA last produced a system-wide water plan in 1993 and wastewater plan in 1997. In 2001, the planning functions of the then-separate Waterworks and Sewerage divisions were merged as part of a new Operations Division. In 2003, an independent Planning Department

[1] The work of Lise Marx and Carl Leone to coordinate this effort and write much of the document is particularly acknowledged.

reporting to the Executive Director was established to coordinate planning toward the goal of producing an updated Master Plan for both the water and wastewater system. In December 2003, debt service assistance was eliminated by then-Governor Swift; it was restored in subsequent years but at greatly reduced levels. MWRA responded to the debt service assistance cuts by eliminating projects in the FY06 CIP. A completed master plan process was viewed as critical to CIP rebuilding.

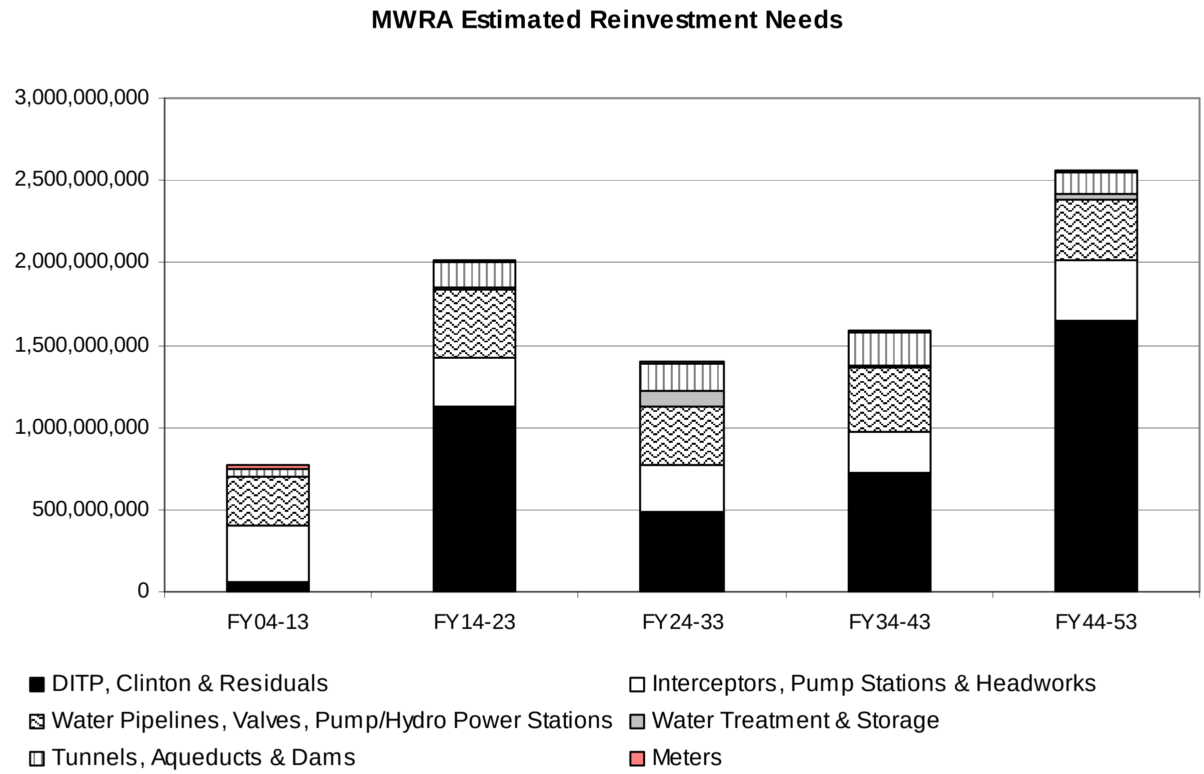
In developing Master Plan project recommendations, staff considered various studies and assessments, previous CIP projects, and asset maintenance histories. Projects were evaluated and prioritized by planning, operations and engineering managers using criteria for water and wastewater projects (see Attachment 1) developed by a broad-based staff committee. A full-day staff retreat was held in June 2006 to present preliminary findings and project recommendations.

Staff presented prioritized Master Plan project recommendations for the wastewater and water system to the Board of Directors in the fall of 2006, and more refined project scopes and budgets were proposed and evaluated during the FY08 CIP development process. The sizing of the proposed FY08 CIP approved in December 2006 for transmittal by the Board of Directors to the Advisory Board for review reflects near-term rates management and capital project staffing considerations. The Proposed FY08 CIP includes all projects receiving a Priority 1 or Priority 2 ranking and a recommended $1 billion spending cap for FY09-13. The Master Plan is intended to be a companion document to the Proposed FY08 CIP to facilitate Advisory Board review this year, as well as in the future.

The MWRA Master Plan has two volumes: a Wastewater Master Plan and a Water Master Plan. The Wastewater Master Plan includes distinct chapters for major facilities (e.g., Deer Island Treatment Plant) or groups of similar facilities (e.g., pump stations, sewers). The Water Master Plan includes major chapters on treatment, the transmission system and the metropolitan system. Chapters include project recommendations to address the issues and needs identified during the planning process. The Wastewater and Water Master Plans also describe the history of the systems and related background information, system goals and objectives, and the assumptions which provide the context for system master planning, including the regulatory framework. As such, the Master Plan is a key agency reference document.

MWRA selected a 40-year Master Plan timeframe commencing with the FY08 CIP cycle and continuing through FY48 because it was consistent with estimated reinvestment cycles for existing MWRA water and wastewater facilities and infrastructure. As shown in Figure 1, reinvestment needs are expected to peak in FY44-53 largely because substantial structural components at MWRA's largest facility, the Deer Island Treatment Plant, will require replacement at end of useful life. The Master Plan focuses on projects recommended for FY07-08 and projects that are proposed to generate capital spending during the next two 5-year CIP cap cycles FY09-13 and FY14-18. Following these two 5-year periods, additional 10-year (FY19-28) and 20-year (FY29-48) planning periods are utilized. Estimates of project costs and schedules over the shorter term are expected to be more reliable than out-year estimates.

Figure 1



The MIS Master Plan document is under development and will address MWRA's technological and system needs. The MIS Plan consists of $6,115,000 for approved projects in the current FY07 CIP (project milestones through FY10) and an additional $5,450,000 for new projects through FY18. Investment in the MIS Master Plan represents approximately 1% of MWRA CIP requirements. The major areas of focus are: replacing aging systems and the network architecture, improving disaster recovery, enhancing data integration, consolidating server/computing resources, and implementing applicable best practices as part of software vendor solutions. The goal is to continue to support efficient administrative, financial, operational, engineering and planning functions with cost-effective technology.

SUMMARY OF THE WASTEWATER MASTER PLAN

Total wastewater needs identified for the FY07-48 Master Plan timeframe are over $2 billion (in current dollars), including $461 million for the Court-approved CSO Control Plan. The needs assessment is based on the following major conditions and assumptions:

- Needs estimates extend through FY48. However, projects, timelines and cost estimates beyond FY18 will be revisited in the next iteration of the Master Plan.

- No new communities are expected to join the wastewater system, and population growth in the existing service area is expected to be modest.

- No design and construction funds are included for potential regulatory changes that may impact facility design and construction.

- The cross-harbor tunnels are assumed to be in good condition; the timeframe for tunnel rehabilitation is beyond the master planning period.

- Staff continue to track research on climate change[2] but cannot yet make any definitive statements regarding potential impacts on the MWRA water/wastewater system.

MWRA's wastewater infrastructure has an estimated replacement value of over $6 billion. The scale and scope of MWRA's operation – encompassing collections, treatment, and beneficial reuse of residuals – presents challenges in maintenance, rehabilitation and replacement. Deer Island alone has nearly 26,000 equipment components (valves, electrical, mechanical and HVAC) and over 46,000 instrumentation components; regular maintenance and replacement cycles have become standard plant operating practice but will become increasingly costly as the plant ages. Older headworks facilities now require significant reinvestment, and interceptors, while generally in fair-to-good condition, are aging and some sections now need rehabilitation or replacement. The residuals facility is expected to require large-scale equipment replacement at the end of the current operating contract with NEFCo in 2015, and MWRA will need to develop and implement a plan for long-term plant operation. Capital projects across the system will be implemented while facilities are on-line, posing operational challenges, and project staffing considerations will also need to be weighed. Finally, all system spending is against the backdrop of rates management.

Over 70%, $1.47 billion of the $2 billion needs estimate for all wastewater projects, is to replace facility equipment and structural components at the Deer Island Treatment Plant, headworks and pump stations, and to rehabilitate interceptors. The other $600 million in needs are for CSO Control Plan projects, interceptor projects that add system capacity, new equipment that supports automated facility operation (SCADA), and various studies.

[2] For example, a report issued in October 2006 by the Union of Concerned Scientists, "Climate Change in the U.S. Northeast", assesses the impact of two greenhouse gas emission scenarios, higher and lower, and concludes that by 2100 Northeast cities including Boston could be experiencing 30 or more days each summer with temperatures hitting 90 degrees Fahrenheit or more under the low emissions scenario and 60 days or more under the high emissions scenario. Also, the Climate Long-Term Impacts on Metro Boston (CLIMB) study examined infrastructure impacts and indicated that non-MWRA communities might have shortfalls in local supplies by 2050.

In its briefings to the Board of Directors and others, staff focused on the FY07-18 (12-year) timeframe because it relates directly to the current and upcoming CIP cycles, and because estimates of project costs and timeframes are more reliable than in the out-years. The Master Plan identifies $500 million in wastewater system needs in the period for which funds are not currently included in the Final FY07 CIP. The Master Plan recommends rehabilitation and replacement projects to correct system and/or structural deficiencies, replace equipment cyclically due to operability/end-of-life issues, and repair/replace interceptors in poor condition. Adding these unmet project needs to the $670 million in wastewater projects currently included in the Final FY07 CIP results in a total wastewater capital needs assessment of $1.2 billion in FY07-18.

Staff expect the Board will set a CIP spending cap for the FY09-13 period as part of the FY08 CIP process. Total wastewater needs identified for FY09-13 are approximately $485 million, including $120 million in new projects, and $365 million in projects currently programmed in the CIP (the CSO Control Plan accounts for $273 million or 75% of the cost of already-programmed projects In FY09-13).

Master Plan findings and recommendations for wastewater priority projects during the FY07-18 timeframe are summarized below under five major headings: (1) Treatment - Deer Island and Clinton plants; (2) Residuals (off-island), (3) Collection System Facilities, Sewers and Cross-Harbor Tunnels; (4) CSO Control Plan; and (5) Community Financial Assistance. All Wastewater Treatment and Sewer System projects recommended in the Master Plan are listed in Attachment 2-A.

All projects have been prioritized on a scale from 1 to 5, with 1 being projects considered critical and 5 considered desirable. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will improve system reliability and maintain effluent/residuals quality. Lower priority projects will optimize system performance, assure future capacity, and provide more efficient operation. Project ratings were assigned by MWRA senior managers in concert with Planning and Coordination Department staff. All MWRA projects (water, sewer, and business support) will be further reviewed during the FY08 CIP development process.

Treatment - Deer Island and Clinton Plants, FY07-18

The Deer Island Treatment Plant is the second largest plant in the country in terms of maximum daily capacity. Its multiple treatment processes, high level of automation, and its uniquely-constructed technical and engineering systems present challenges to operating, maintaining and replacing the plant’s equipment, structures and related support systems.

The Master Plan identifies $215 million in project needs for the FY07-18 timeframe, $204 million for Deer Island and $11 million for Clinton, including all projects currently in the FY07 CIP. Approximately half of the $215 million, $105 million, is already programmed in the FY07 CIP.

Residuals (off-island)

MWRA's sludge-to-fertilizer plant in Quincy – also known as the Residuals Processing Facility - recycles sludge (residuals) from the Deer Island Treatment Plan to produce pellets marketed for beneficial reuse. This facility is operated and maintained under a long-term contract, which expires in December 2015, with the New England Fertilizer Company (NEFCo).

Since the contractor is responsible for all operations, maintenance and capital improvements for the term of the contract, MWRA has not budgeted for any major expenditures within the existing FY07 CIP; however, staff are currently undertaking a reliability assessment of the utilities that support the facility that may lead to recommendations for infrastructure upgrade projects. The most significant short-term need identified in the Master Plan is implementation of a comprehensive Facilities Plan to assess the condition and needs of the existing equipment and facility; review new technology options, regulatory developments, and plans of other similarly-sized utilities; and recommend a long-term approach for residuals management. For the long-term, the current Residuals Processing Facility will likely need to be completely rehabilitated or replaced either in-kind or with another technology beginning in FY14.

No Residuals funds are programmed in the FY07 CIP. The Master Plan identifies a total of $77 million in recommended priority needs in the FY08-18 timeframe, which includes the post-NEFCo period.

Collection System Facilities, Sewers and Tunnels

For the wastewater collection system, $382 million in projects is identified in the FY07-18 timeframe, including $87 million in projects in the FY07 CIP and $295 million in proposed projects. Discussion on the collection system is presented in three sections: headworks, pump stations, and CSO facilities; collection system sewers; and cross-harbor tunnels.

Headworks, Pump Stations, and CSO Facilities: For the four remote headworks and twenty pump station and CSO facilities, operability of mechanical equipment and maintenance of electric/standby power systems are key elements to minimize risk of facility failure. Malfunction of mechanical equipment may impact sewer service, particularly during large storm events that stress the hydraulic capacity of the facilities, potentially requiring "choking" of the facility influent gates which can result in upstream CSOs or SSOs. Key decision making to minimize risks includes the cost/benefit of when to replace aging equipment and which/how many spare parts to pre-purchase.

The Chelsea Creek, Columbus Park, and Ward Street Headworks (all built in 1967) are almost 40 years old; equipment upgraded in 1987 is now almost 20 years old. These facilities remain operational, but are in only fair condition. The highest priority need for the Headworks is a comprehensive facility plan and subsequent upgrades.

The average age of MWRA's 20 pump stations and CSO facilities is 17 years old and, overall, these facilities are in good-to-excellent condition. Only five of these facilities are more than 20 years old. The oldest pump station, Alewife Brook in Somerville, is 55 years old. Two of MWRA's CSO treatment facilities (Cottage Farm and Somerville Marginal) are 35 years old; however, significant rehabilitation and upgrades have been performed as part of the CSO Control Plan. MWRA's newest facilities include five that have been constructed since 2002 or are soon to be completed: Quincy Pump Station (2002), Squantum Pump Station (2003), Intermediate Pump Station (2005), Union Park CSO Facility (scheduled for 2007), and Braintree-Weymouth Replacement Pump Station (scheduled for 2007).

The highest priority immediate needs for sewer pump station and CSO facilities are small scale equipment rehabilitation and replacement projects. Significant automation upgrades are being implemented under MWRA's Wastewater Central Monitoring/SCADA Implementation Project. The CSO facilities have also undergone upgrades under the CSO Control Plan and two of the stations (Commercial Point and Fox Point) are scheduled to be decommissioned in 2008 following completion of sewer separation projects.

Collection System Sewers: The primary function of the collection system is to transport wastewater received from the 43 sewer member communities (through over 1,800 community connection points) to the MWRA headworks facilities. Collection system operations are intended to optimize system performance and minimize potential CSOs and SSOs, particularly before and during storm events that stress the system's hydraulic capacity. Key decision making to minimize risks of sewer plugging or structural failure includes where/how often to perform preventive maintenance activities and the cost/benefit of when to rehabilitate aging sewer pipelines. Internal inspection information (physical, television, and sonar) is used to develop a cleaning schedule, to identify structural problems and infiltration, and to help define rehabilitation projects.

The majority of MWRA's past CIP funds spent on sewer interceptor projects were for new interceptors (a combination of sewer replacement and relief sewer construction) that were a priority to solve sewer capacity issues. The most critical need for new interceptor projects is now sewer rehabilitation construction that will eliminate known structural deficiencies as well as hydrogen sulfide-related corrosion.

Overall, the collection system is in reasonably good condition, given its average age of about 70 years. Approximately 33 percent of sewers are over 100 years old and another 25 percent are between 51 to 100 years old. Based on internal TV inspection ratings for gravity sewer pipe, approximately 18 miles (8 percent) of interceptors are severely damaged ("C-rated"), 139 miles (61 percent) are in fair to good condition with some damage ("B-rated"), and 52 miles (23 percent) are in very good condition ("A-rated")[3].

[3] An additional 18 miles (8 percent) of gravity sewer, mostly newly constructed interceptors, were unrated at the time of the analysis. The gravity sewer inspection "A"/"B"/"C" ratings have not been used for force mains, siphons, or outfalls; however, based on available data, these facilities also appear to be in reasonably good condition.

As part of the Master Plan process staff developed an interceptor renewal methodology to identify and then plan/design/construct sewer repair/rehabilitation projects targeting “C” rated (severely damaged) pipe.

Cross-Harbor Tunnels: The cross-harbor tunnels transport wastewater from the remote headworks to the Deer Island Treatment Plant. The existing condition of the cross-harbor tunnels is unknown; however, some deterioration of concrete in the tunnel shafts has been attributed to hydrogen sulfide corrosion. The older tunnels, the North Metropolitan Relief Tunnel and Boston Main Drainage Tunnel (1953), are more than 50 years old, while the Inter-Island Tunnel (1995) and Braintree-Weymouth Tunnel (2005) are relatively new. Based on the industry benchmark of 100+ years for useful life for tunnels, it is presumed that the tunnels are still in good condition. Since the condition of the cross-harbor tunnels is unknown, an inspection/condition assessment project is recommended.

CSO Control Plan

MWRA’s long-term CSO Control Plan includes $461 million in court-ordered projects (both MWRA and community managed); all are included in the FY07 CIP. Under the Master Plan, there are no future MWRA or community managed CSO Control Plan projects recommended for consideration in the CIP. Funds to replace equipment at CSO facilities are included in the funds for Collections System Facilities.

Community Financial Assistance

Since 1993, MWRA has made a commitment to assist member sewer communities finance infiltration and inflow (I/I) reduction and sewer system rehabilitation projects within their locally-owned collection systems. Funding of community projects through MWRA’s I/I Local Financial Assistance Program is provided as 45 percent grants and 55 percent interest-free loans. The loans are repaid to the Authority over five years. The program goal is to assist member communities in improving local sewer system conditions to reduce I/I and ensure ongoing repair/replacement of the collection system. This program is a critical component of MWRA’s Regional I/I Reduction Plan.

The current FY07 CIP includes a net cost of $14 million (including repayments) for approved local distribution through FY15. The Master Plan includes placeholders for two additional rounds ($40 million in grant/loans in each round) of CIP funding beginning in FY12 and FY17 at a net cost of $18 million each. For the FY07-18 timeframe, a total of $34 million is identified for community financial assistance.

SUMMARY OF THE WATER MASTER PLAN

Total water system needs identified for the FY07-48 Master Plan timeframe are approximately $1.1 billion (in current dollars), including all projects currently in the CIP. The needs assessment is based on the following major assumptions and findings:

The 300 mgd safe yield of the MWRA water system is sufficient to meet future demand for water both within the service area and additional demand outside the service area as may be approved[4].

- There is adequate treatment plant capacity, and generally adequate transmission capacity under normal operations to meet MWRA system needs under the demand planning scenario assuming current CIP projects are completed. Distribution capacity is generally adequate with the exception of a few weak spots.

- MWRA's transmission system lacks redundancy in some key areas: some issues are already being addressed, and the Master Plan recommends that other issues be addressed in the near-term. There are also areas within the distribution system without adequate redundancy which the Master Plan addresses.

- MWRA falls short of its goal of distribution system storage sufficient to meet one day of demand. The Master Plan recommends addressing the system's highest risk areas.

- No design and construction funds are included to address the impacts on the MWRA water system of potential changes in federal or state regulations[5]. Continuation of MWRA's ongoing program to systematically replace old, cast-iron water mains is recommended as this approach provides better quality

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[4] Staff used the following demand planning scenario to arrive at this conclusion: continuation of current base demand in the existing MWRA service area (230 mgd, based on five year average demand in FY2004); projected increased demand from very modest population and employment growth through 2030 in the service area (13 mgd); a total of approximately 5 mgd from new communities actively pursuing admission and/or increased withdrawals from MWRA; potential additional demand for MWRA water from partially-served communities (planning assumption is up to 18 mgd); and potential additional demand for MWRA water by as many as 22 communities not currently and actively pursuing admission to MWRA but within reasonable proximity to the MWRA water service area and that have or may face water deficits (up to 10 mgd).

[5] There are currently no anticipated changes in regulations which might require MWRA to add filtration to the Carroll Water Treatment Plant; however, any major national event similar to the Milwaukee *cryptosporidium* outbreak could cause EPA to change course. The FY07 CIP already includes funds to meet the requirement of the Long Term 2 Enhanced Surface Water Treatment Rule, adopted in January 2006, for a second treatment process at both the CWTP and Ware Water Treatment Plants by 2014; staff propose to add ultraviolet light (UV) disinfection at both plants.

water and is consistent with EPA’s anticipated direction on distribution system regulation.

- No funds are included for rehabilitation of the tunnels. Funds are included to inspect transmission tunnels in light of their average age of 53 years (excluding the new MetroWest Tunnel).

- As noted in the Wastewater discussion, staff continue to track research on climate change but cannot yet make any definitive statements regarding potential impacts on the MWRA water/wastewater system.

- Infrastructure needs estimates extend through FY48. However, projects, timelines and cost estimates beyond FY18 will be revisited in the next Master Plan iteration.

MWRA’s water system includes its source reservoirs, treatment facilities, transmission lines, and distribution system facilities and pipelines; the system (excluding the source reservoirs) has an estimated replacement value of over $6 billion. Over the last ten years, the system has benefited from the $1.7 billion Integrated Water Supply Improvement Program which included watershed protection, construction of new water treatment, transmission and storage facilities, and relining or replacing of MWRA and community water pipes. SCADA technology has been adopted throughout the system, a rehabilitation program to complete the upgrading of pump stations is now underway, and MWRA has rehabilitated 63 miles of its distribution system pipeline and constructed approximately 22 miles of new pipeline since 1993 when the last water system Master Plan was developed.

Notwithstanding MWRA’s success in carrying out this comprehensive infrastructure improvement effort, there remain system infrastructure challenges that the Master Plan recommends be addressed over the next 40 years. The major challenges not yet addressed in the CIP, and staff’s assessment of the cost and timing of addressing them, are as follows:

- Providing transmission redundancy in the eastern part of the system from Shaft 5 east to Chestnut Hill and in the western part of the system for the Cosgrove Tunnel, $203.5 million, FY11-23,

- Addressing important distribution system redundancy problems areas in the Northern Intermediate High and Southern Extra High systems, including the need for redundant piping, additional storage and, in the NIH, a back-up station for the Gillis Pump Station at Spot Pond. Other redundancy improvements include the Chestnut Hill Connecting Mains project, and the Section 75 Extension. These projects also improve operational flexibility by permitting other assets to be taken off-line for rehabilitation. $105 million, FY07-24.

- Adding storage capacity in the Low Service service area at Spot Pond to further advance toward MWRA's goal for system storage under emergency conditions, $36 million, FY09-18.

- Continuing to systematically line approximately 51 additional miles of old cast-iron MWRA pipeline to address potential water quality degradation concerns and related health risks in light of MWRA customer expectations and EPA's anticipated direction for distribution system regulation, and continuing to replace/rehabilitate 16 miles of steel pipes prone to corrosion and susceptible to leaks, $140 million, FY09-48.

- Continuing to help member communities rehabilitate their own old cast-iron mains (2,300+ miles of community pipes are unlined) and replace lead services in light of potential impact on water quality at the tap, allocating Local Financial Assistance Program loan repayments to extend community funding similar to a revolving loan fund. $125 million in new interest-free loans, FY14-23.

- Ensuring system security by continued physical hardening of facilities, replacing surveillance equipment as needed or as technological advances support, and tracking developments in real time water quality monitoring. Water supply redundancy and storage projects provide operational flexibility and enhance system security.

- Systematically addressing the long-term need to protect and eventually replace other MWRA's water system assets, including equipment, facilities, dams, and support systems, $177 million, FY08-48.

All water projects recommended in the Master Plan are listed in Attachment 2-B.

Master Plan findings and recommendations for water priority projects during the FY07-18 timeframe are summarized below. In its briefings to the Board of Directors and other parties, staff focused on the FY07-18 (12-year) timeframe because it relates directly to the current and upcoming CIP cycles, and because estimates of project costs and timeframes are more reliable than in the out-years. The Master Plan identifies $433 million in water system needs in this period for which funds are not currently included in the CIP. Adding these unmet project needs to the $438 million in water projects currently included in the Final FY07 CIP results in a total water system capital needs assessment of $871 million in FY07-FY18.

Staff anticipate that the Board will set a CIP spending cap for the FY09-13 period as part of the FY08 CIP process. Total water needs identified for FY09-13 are approximately $382 million, including $122 million in new projects and $260 million in projects currently programmed in the CIP.

All projects have been prioritized on a scale from 1 to 5, with 1 being projects considered critical and 5 considered desirable. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will fix existing reliability problems related to single points of failure, address facilities in poor condition where the ability to provide uninterrupted service or adequate flow is compromised, and meet basic hydraulic performance requirements, including adequate distribution storage. Lower priority projects will maintain infrastructure integrity and maintain efforts to manage system demands. Project ratings were assigned by MWRA senior managers in concert with Planning and Coordination Department staff. All MWRA projects (water, sewer, and business support) will be further prioritized during the FY08 CIP development process.

The Transmission System – Tunnels and Aqueducts, Facilities, and Dams

MWRA's water transmission system consists of over 100 miles of tunnels and aqueducts in daily use which transport water by gravity from the supply reservoirs to points of distribution within the service area. The basic layout of the system as designed is fundamentally sound. System improvements over time have allowed for older facilities, no longer in daily use, to remain as critical emergency standby facilities as long as maintained and linked to new facilities where necessary. The performance standards for a major transmission system are ability to transport sufficient water to meet the maximum daily demands of the service area and reliability in that there must be sufficient redundant components to ensure a continued supply of water system if any one "leg" of the system were to fail. MWRA's transmission system ably meets system demands and much of the system has redundant components that may be brought on line. However, as noted earlier, shortfalls in redundancy remain which the Master Plan recommends be addressed.

The Master Plan process has also considered the needs of over 75 facilities that are part of the transmission system. Inspections of key facilities and top-of-shaft structures were recently completed, and reports on condition assessment, recommendations and costs are being developed. Improvements to halt any ongoing deterioration and ensure safe and secure facility operation may be the short-term course of action for many of the buildings, with the study serving as the blueprint for the requirements to fully bring the asset up to its original condition, if desired, over a longer time frame.

MWRA, under its 2004 Memorandum of Agreement with the Department of Conservation and Recreation (DCR), is responsible for water supply dams, with a couple of exceptions. MWRA previously paid DCR Division of Watershed Management to perform capital improvements for these dams. Based on fall 2005 inspections, several major categories of work were identified, some of which are recommended by the Master Plan for inclusion in the CIP.

In the near-term, the Master Plan identifies approximately $276 million in transmission system project needs for the FY07-18 timeframe, including all projects currently in the FY07 CIP.

Treatment Plants

The Master Plan recommends $73 million in treatment plant projects in the FY07-18 timeframe, including $62 million in projects already in the FY07 CIP and $11 million in additional recommended spending for consideration in the FY08 CIP process.

The Metropolitan System

The Metropolitan System consists of 284 miles of distribution pipeline east of Shaft 5, eleven storage tanks, eleven pump stations, nine tunnel shafts, and approximately 4700 valves. The system is divided into 7 pressure zones.

As noted earlier, there is a need to address important distribution system pipeline redundancy problems areas in the Northern Intermediate High (NIH), Southern Extra High (SEH), and the WASM 3 service areas and, more generally, in service areas with single spine mains. The NIH and SEH also have shortfalls in shortage, as does the Southern High System. The Blue Hills Covered Storage project will address the shortfall in the Southern High service area. An additional 20 mg of storage is also proposed for the Northern Low service area (near Spot Pond). The distribution system network has approximately 100 miles of unlined cast-iron pipe, posing water quality concerns, and 47 miles of steel pipe, prone to corrosion and susceptible to leaks; both are recommended for continued focus over the long-term, as are valve replacements. Over half of MWRA member communities' water systems have more than 40 percent of their pipes unlined. The second phase of MWRA pump station replacement and modernization will be completed by FY11, but instrumentation, electrical and mechanical systems will need to be addressed for those stations in phase one. Facility automation and meter system upgrades need to addressed cyclically as well.

Land Acquisition

The FY07 CIP includes a total of $19 million to enable DCR to acquire parcels of, or interests in, real estate critical to protection of the watershed and source water quality, FY07-12.

Community Financial Assistance – Local Pipeline Assistance Program

This program makes $25 million in loans available annually to MWRA communities for pipeline relining and replacement in proportion to each community's share of total unlined pipe miles. Communities are required to pay back principal for each year's loan during a ten-year period beginning one year after project funding is approved. The Master Plan recommends allocating Local Financial Assistance Program loan repayments to extend community funding similar to a revolving fund. Currently $255.5 million has been approved by the Board of Directors to date, of which $119 million has been distributed to communities for 147 projects. Staff recommends that $125 million in loan repayments be made available to communities for additional Local Pipeline Assistance Program loans in the FY14-23 timeframe.

Attachment 1

2006 Wastewater

Priority One **Critical/Emergency** Risk moderate to high/Consequence very high

Projects which:

Resolve emergencies or critical threats to public health or worker health and safety

Prevent imminent failure of the system and significant loss of service

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Priority Two **Essential Projects** Risk variable/Consequences high

Projects which are essential to:

Critical facility assessment

Fix existing reliability or capacity problems during dry weather flow conditions

Reduce sanitary sewer overflows from the MWRA system

Address facilities in poor condition where the ability to provide uninterrupted service or adequate flow is compromised.

Upgrade or maintain emergency backup facilities in poor condition

Meet minimum hydraulic performance requirements and service needs

Implement MWRA's approved CSO control plan

Maintain wastewater effluent and residuals quality

To comply with mandated legal, regulatory or statutory requirements

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Priority Three **Necessary Projects** Risk moderate to high/Consequence moderate to low

Projects which are necessary to:

Improve public health and worker safety

Restore the system's infrastructure where it is seriously deteriorated

Improve hydraulic performance

Significantly improve the effectiveness, efficiency, or reliability of system operations and service delivery including where appropriate, the ability to monitor the system

Maintain consumer confidence

To comply with other legal, regulatory or statutory requirements

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Priority Four **Important Projects** Risk moderate/Consequences low

Projects which are important to:

Maintain the integrity of the system's infrastructure

Produce significant cost savings or revenue gains for MWRA

Monitor system needs and plan appropriate longer-term responses

Provide acceptable working conditions at field sites and at maintenance support facilities

Implement the regional I/I plan

Priority Five **Desirable Projects** Risk/Consequence both low

Projects which are desirable because they would:

Yield worthwhile cost savings, revenue gains, or efficiency improvements for MWRA

Protect the long term value and usefulness of system assets

Solve future problems and conditions which are expected to arise in the latter half of the planning period

Be beneficial towards the improved operation of a local system

Attachment 2A
Wastewater Master Plan
Existing and Future Projects

Last revision 12/15/2006

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
		DEER ISLAND TREATMENT PLANT											
		Plant Optimization Program											
6.1	1	As-Needed Design Phases 4-1 & 4-2	Opti	in	2 years	1,134	now-FY07	1,134					1,134
6.2	1	As-Needed Design Phases 5-1 & 5-2	Opti	in	2 years	1,800	FY07-09	1,050	750				1,800
6.3	1	Long-Term As-Needed Design 1 & 2	Opti	in	4 years	3,200	FY09-13		3,200				3,200
6.4	1	Ancillary Modifications Design (ESDC/REI) and Construction 2-2	Opti	in	4 years	3,574	now-FY08	3,574					3,574
6.5	2	Ancillary Modifications Preliminary Design, Final Design, and Construction 4	Opti	in	5 years	4,783	FY08-12	360	4,423				4,783
		SUBTOTAL - Deer Island Plant Optimization				**14,491**		**6,118**	**8,373**				**14,491**
		Asset Protection Program - *Equipment Replacement Category:*											
6.6	1	Equipment Replacement Project	AP	in	N/A	18,653	now-FY16	300	4,900	13,453			18,653
6.7	1	Primary Clarifier Rehab Construction	AP	in	3 years	6,041	FY09-11		6,041				6,041
6.8	2	Cathodic Protection Evaluation	AP	in	2 years	250	FY09-10		250				250
6.9	3	Pump Packing Replacement	AP	in	2 years	200	FY07-08	200					200
6.10	2	LOCAT Scrubber Replacement Construction	AP	in	1 year	3,008	FY09-10		3,008				3,008
6.11	3	Grit Blower Replacement Construction	AP	in	1 year	335	FY08-09		335				335
6.12	2	Thickened Primary Sludge Pump Replacement	AP	in	3 years	5,789	FY08-11	210	5,579				5,789
6.13	1	Centrifuge Back-drive Replacements	AP	in	2 years	2,161	FY08-09	900	1,261				2,161
		CATEGORY SUBTOTAL				**36,437**		**1,610**	**21,374**	**13,453**	**0**	**0**	**36,437**
		Asset Protection Program - *Architectural Category:*											
6.14	3	Study/Concept Design- Concrete Repairs	AP	in	1 year	300	FY07-08	300					300
6.15	1	Expansion Joint Repairs 2 & 3	AP	in	6 months ea.	312	FY07-10	156	156				312
		CATEGORY SUBTOTAL				**612**		**456**	**156**	**0**	**0**	**0**	**612**

Wastewater Master Plan

Existing and Future Projects

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								2 years	5 years	5 years	10 years	20 years	
		Asset Protection Program - *Utilities Category:*											
6.16	1	Electrical Equipment Upgrades 2, 3, 4	AP	in	avg. 2 years	7,757	now–FY11	3,610	4,147				7,757
6.17	1	VFD Replacements (NMPS, WTF, Misc.)	AP	in	avg. 2.5 years	11,029	now-FY10	3,214	7,815				11,029
6.18	1	Power System Improvement Design and Construction	AP	in	4 years	7,905	now-FY10	2,401	5,504				7,905
6.19	1	DI Electrical Modifications	AP	in	1.5 years	2,000	FY07-09	1,777	223				2,000
6.20	1	Switchgear Replacements Design & Construction (Admin/Whse, All other DITP)	AP	in	avg. 1 yr each	4,447	FY08-11	1,009	3,438				4,447
6.21	1	PICS Replacement Construction	AP	in	1 year	1,582	FY10-11		1,582				1,582
6.22	2	Sodium Hypochlorite Pipe Replacement Design & Construction	AP	in	1 year	2,983	FY10-12		2,983				2,983
6.23	3	Pipeline Replacement Design and Constr 2	AP	in	2 years	1,672	FY09-11		1,672				1,672
6.24	1	Heat Loop Pipe Replacement Construction 2	AP	in	0.5 years	1,260	FY07	1,260					1,260
6.25	3	Fuel Transfer Pipe Replacement Design & Construction	AP	in	3 years	1,672	FY12-14		308	1,364			1,672
6.26	1	North Main Pump Station - Motor Control Center Design & Construction	AP	in	3 years	3,704	FY07-10	309	3,395				3,704
6.27	3	Second Deaerator Design and Construction	AP	in	3 years	353	FY08-10	12	341				353
		CATEGORY SUBTOTAL				**46,364**		**13,592**	**31,408**	**1,364**	**0**	**0**	**46,364**
		Asset Protection Program - *Support Category:*											
6.28	4	DISC Application	AP	in	2 years	125	FY07-08	125					125
6.29	3	Document Format Conversion	AP	in	5 years	353	FY07-12	116	237				353
		CATEGORY SUBTOTAL				**478**		**241**	**237**	**0**	**0**	**0**	**478**
		Asset Protection Program - *Specialties Category:*											
6.30	1	Primary Clarifier & Gravity Thickener Rehab - Design	AP	in	4 years	1,200	FY07-11	600	600				1,200
6.31	4	Gravity Thickener Improvements - Construction	AP	in	1 year	2,014	FY09		2,014				2,014
6.32	1	Sodium Hypochlorite Tank Liner Removal & Repair	AP	in	1 year	552	FY07	552					552
6.33	3	Metals Lab Fume Hood Replacement	AP	in	1 year	134	FY07-08	134					134
6.34	3	Metals Lab Modification Construction	AP	in	2 years	919	FY07-08	919					919
6.35	5	Lab Sample Area Modifications Design and Construction	AP	in	3 years	552	FY08-10	55	497				552

Wastewater Master Plan

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								2 years	5 years	5 years	10 years	20 years	
6.36	1	Clinton Soda Ash Replacement	AP	in	1 year	288	FY07-08	288					288
6.37	2	Clinton Permanent Standby Generator	AP	in	1 year	259	FY07-08	259					259
		CATEGORY SUBTOTAL				**5,918**		**2,807**	**3,111**	**0**	**0**	**0**	**5,918**
		SUBTOTAL - Deer Island Asset Protection				**89,809**		**18,706**	**56,286**	**14,817**	**0**	**0**	**89,809**
		SUBTOTAL - Existing Projects - Deer Island				**104,300**		**24,824**	**64,659**	**14,817**	**0**	**0**	**104,300**
		RECOMMENDED PROJECTS - DEER ISLAND											
6.38	1	As-Needed Technical Design $200k for FY13, $750K annually	AP	new	Annual	26,450	Annually beginning FY13		200	3,750	7,500	15,000	26,450
6.39	2	Equipment Replacement Project	AP	new	Annual $2M expense	70,000	FY11-12, then yearly FY16-48		4,000	6,000	20,000	40,000	70,000
6.40	1	Future SSPS VFD Replacements, $6M each	AP	new	3 years	24,000	FY16, 26, 36, 46			6,000	6,000	12,000	24,000
6.41	2	SSPS Pump Lube System Replacement	AP	new	2 years	1,700	FY08-09	700	1,000				1,700
6.42	3	Future SSPS shaft &/or Motor Replacements ($1.5M each)	AP	new	2 years	4,500	FY14, 29, 44			1,500		3,000	4,500
6.43	1	Future NMPS VFD Replacements, $6.5M each	AP	new	3 years	22,100	FY18, 28, 38, 48			2,600	6,500	13,000	22,100
6.44	1	North Main Pump Sta. Motor Control Ctr. Design & Constr. ($3.5M each)	AP	new	3 years	7,000	FY28, 48				3,500	3,500	7,000
6.45	3	Future NMPS shaft &/or Motor Replacements ($2.2M each)	AP	new	2 years	6,600	FY15, 30, 45			2,200		4,400	6,600
6.46	5	Enterprise Engine Removal	AP	new	1 year	600	FY14			600			600
6.47	1	Future WTF VFD Replacements, $1.4M each	AP	new	1 year	4,200	FY19, 29, 39				1,400	2,800	4,200
6.48	3	Future WTF shaft &/or Motor Replacements ($800k each)	AP	new	2 years	2,400	FY16, 31, 46			800		1,600	2,400
6.49	1	Cryogenics Plant Equipment Replacement - valves, instruments, etc. ($2M each time)	AP	new	1 year	8,000	FY14, 24, 34, 44			2,000	2,000	4,000	8,000
6.50	2	Cryogenics Plant – Cooling Towers & Related Equipment Replacement ($450k each time)	AP	new	1 year	900	FY19, 29				450	450	900
6.51	3	Secondary Clarifier Rehabs ($4M each time)	AP	new	2 years	12,000	FY14, 29, 44			4,000		8,000	12,000
6.52	1	Secondary Clarifier Drive Chain ($250k each time)	AP	new	1 year	750	FY19, 29, 39				250	500	750
6.53	1	Sodium Hypochlorite Tank Rehabs ($625k/tank). Includes tank 3 emergency repair in FY07/08	AP	new	3 years	11,875	FY07-09; 17, 27, 37, 47	625	1,250	2,500	2,500	5,000	11,875
6.54	4	Sodium Bisulfite Tank Rehabs ($500k/tank)	AP	new	3 years	3,000	FY15, 30, 45			1,000		2,000	3,000
6.55	2	Barge Berth and/or Pier Facilities Rehab ($1M each time)	AP	new	1 year	2,000	FY11, 31, 51		1,000			1,000	2,000
6.56	4	DI Outfall Modifications Construction/REI	AP	prev	2 years	1,550	FY14-15, 25, 35, 45			1,100	150	300	1,550
6.57	1	Centrifuge Replacements (cost is $1.3M per centrifuge; replace 4 every 10 years).	AP	new	1 year	20,800	FY14, 24, 34, 44			5,200	5,200	10,400	20,800
6.58	1	Digested Sludge Pump Replacements (to FRSA)	AP	new	1 year	4,000	FY10, 30		2,000			2,000	4,000
6.59	1	Dystor Tank Membrane Replacements ($750k for both tanks)	AP	new	1 year	3,000	FY15, 25, 35, 45			750	750	1,500	3,000

Wastewater Master Plan

Existing and Future Projects

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FY07 CIP Notes

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								2 years	5 years	5 years	10 years	20 years	
6.60	5	DI Cross-Harbor Cable Dredging Construction	AP	new	1 year	20,000	FY09-10		20,000				20,000
6.61	1	Heat Loop Pipe Replacement Construction phase 3 ($1.6M FY08-09, then $75 every 8 yrs)	AP	new	1 year	1,900	FY08/09; FY17, 25, 33, 41	800	800	75	75	150	1,900
6.62	1	CTG Rebuilds ($2M each time)	AP	new	2 years	6,000	FY15, 30, 45			2,000		4,000	6,000
6.63	3	Replace STG at Deer Island	Opti	new	2 years	3,500	FY11-13		3,500				3,500
6.64	5	DI Wind Power	Plan	prev	1 year	150	FY08	150					150
6.65	5	DI Wind Power Construction	NF	prev	1 year	1,200	FY10		1,200				1,200
6.66	1	Future Misc. VFD Replacements, $2M each	AP	new	3 years	6,667	FY18, 28, 38, 48			667	2,000	4,000	6,667
6.67	1	Electrical Equipment Upgrades Phase 5 and up ($2M for FY11 & 12, then $500k per yr)	AP	new	2 years	20,000	FY11-48		2,500	2,500	5,000	10,000	20,000
6.68	1	Switchgear Replacements Design & Construction (all DITP areas - $5M each)	AP	new	4 years	16,250	FY18, 28, 38, 48			1,250	5,000	10,000	16,250
6.69	3	DI Grit & Odor Ctrl Air Handler Replacements	AP	new	2 years	3,000	FY09, 24, 39		1,000		1,000	1,000	3,000
6.70	2	Pipeline Replacement/Upgrades	AP	new	1 year	500	FY26, 41				250	250	500
6.71	2	PICS Distributed Processing Units (DPU) Replacements ($4M each time)	AP	new	2 years	8,000	FY15, 35			4,000		4,000	8,000
6.72	1	PICS Replacement Construction ($1.8M each)	AP	new	1 year	5,400	FY15, 30, 45			1,800		3,600	5,400
6.73	2	HVAC Control System	AP	new	1 year	3,000	FY10, 25, 40		1,000		1,000	1,000	3,000
6.74	3	HVAC Fan Coil Replacement ($1M each)	AP	new	2 years	3,000	FY09, 24, 39		1,000		1,000	1,000	3,000
6.75	2	Fire Alarm System	AP	new	1 year	5,100	FY10, 25, 40		1,700		1,700	1,700	5,100
6.76	2	Leak Protection System Upgrade ($300k each)	AP	new	1 year	900	FY11, 26, 41		300		300	300	900
6.77	4	DI Eastern Seawall Repairs Design & Construction	AP	prev	2 years	1,700	FY11-13		1,700				1,700
6.78	3	DI Seawall Refurbishment Design/Construction	AP	new	2 years	3,500	FY11, 23, 35, 47		500		1,000	2,000	3,500
6.79	5	DI Personnel Dock Rehab Construction	AP	prev/new	1 year	4,000	FY10, 22, 34, 46		1,000		1,000	2,000	4,000
6.80	4	Cathodic Protection Testing	AP	new	FY08	120	FY08	120					120
		SUBTOTAL - Recommended - Deer Island				351,312		2,395	45,650	52,292	75,525	175,450	351,312
		SUBTOTAL - Existing and Recommended - Deer Island				455,612		27,219	110,309	67,109	75,525	175,450	455,612
		RESIDUALS											
7.1	1	Residuals Plant Electric System Reliability Design/Construct	AP	new	1 year	620	FY08	620					620
7.2	2	FRSA Pier Rehabilitation	AP	new	2 years	700	FY08-09	350	350				700
7.3	1	Residuals Condition Assessment and Facilities Plan	Plan	new	2 years	1,000	FY09-10		1,000				1,000
7.4	1	Residual Upgrades - Design & Constr Services (50% of cost for design, 50% is for ESDC/REI)	AP	new	Des FY11-12, Cons FY14-18	8,000	Des FY11-12, Cons FY14-18		4,000	4,000			8,000
7.5	1	6 Rotary Dryer Replacements	AP	new	3 years	60,000	FY14, 29, 44			20,000		40,000	60,000
7.6	2	12 Centrifuge Replacements (avg. 18 yr life)	AP	new	2 years	36,000	FY15, 33			18,000		18,000	36,000
7.7	2	Pumping Systems Upgrade	AP	new	2 years	6,000	FY15, 30, 45			2,000		4,000	6,000

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								2 years	5 years	5 years	10 years	20 years	
7.8	2	Sludge Feed Conveyor Replacements	AP	new	1 year	3,000	FY15, 30, 45			1,000		2,000	3,000
7.9	2	Sludge Storage Tank Rehabilitation	AP	new	1 year	3,000	FY16, 31, 46			1,000		2,000	3,000
7.10	1	6 Air Scrubber Replacements	AP	new	2 years	9,000	FY16, 31, 46			3,000		6,000	9,000
7.11	2	Replace 9 Pellet Storage Silos	AP	new	2 years	6,000	FY16, 31, 46			2,000		4,000	6,000
7.12	1	Plant MCC Replacements	AP	new	2 years	4,500	FY17, 32, 47			1,500		3,000	4,500
7.13	2	Rail System Rehabilitation	AP	new	2 years	3,000	FY17, 32, 47			1,000		2,000	3,000
7.14	2	Utility Upgrades	AP	new	2 years	6,000	FY17, 32, 47			2,000		4,000	6,000
7.15	3	Polymer System Upgrade	AP	new	1 year	3,000	FY17, 32, 47			1,000		2,000	3,000
7.16	3	Thermal Oxidizer Rehabilitation (avg. 18 yr life)	AP	new	3 years	24,000	FY17, 35			12,000		12,000	24,000
7.17	3	Building Envelope Rehabilitation	AP	new	2 years	5,000	FY17, 33, 48			2,000		3,000	5,000
7.18	2	Odor Control System Rehabilitation	AP	new	1 year	1,500	FY18, 33, 48			500		1,000	1,500
		SUBTOTAL - Recommended - Residuals				180,320		970	5,350	71,000	0	103,000	180,320
		REMOTE HEADWORKS AND CROSS-HARBOR TUNNELS											
8.1	1	HW Condition Assessment and Facility Plan for 3 Older Remote Headworks	AP	in S10399	2 years	2,000	FY07-08	2,000					2,000
8.2	1	HW Screen Replacement for 3 Older Remote Headworks	AP	in S10387	3 years	5,000	FY09-12		5,000				5,000
		SUBTOTAL - Existing - Headworks and Tunnels				7,000		2,000	5,000				7,000

Wastewater Master Plan

Existing and Future Projects

Last revision 12/15/2006

Prioritization

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4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

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new	new project, not previously in CIP
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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
8.3	1	HW Facility Plan Upgrades for 3 Older Remote Headworks	AP	new	20 years	35,000	FY09-28		10,000	15,000	10,000		35,000
8.4	3	Nut Island HW Fire Alarm & Wiring Conduit Replacement	AP	prev	1 year	200	FY09-13		200				200
8.5	3	Nut Island HW Mechanical Systems	AP	new	3 years	3,800	FY09-13		3,800				3,800
8.6	4	Nut Island Pier Rehabilitation Plan/Design/Construction	AP	new	2 years	500	FY14-18			500			500
8.7	3	Nut Island HW Future Equipment Replacement	AP	new	10 years	30,000	FY19-28				30,000		30,000
8.8	1	Cross-Harbor Tunnel Inspection/Assessment	Plan	prev	1 year	3,000	FY09-13		3,000				3,000
8.9	2	Cross-Harbor Tunnel Shaft Repairs Plan/Design/Construction	AP	new	3 years	5,000	FY14-18			5,000			5,000
		SUBTOTAL - Recommended - Headworks and Tunnels				77,500			17,000	20,500	40,000		77,500
		SUBTOTAL - Existing and Recommended - Headworks and Tunnels				84,500		2,000	22,000	20,500	40,000		84,500
		COLLECTION SYSTEM SEWERS											
9.1	1	Interceptor AP - existing Arlington Sections 80/83 Rehab	AP	in S145	2 years	578	now-FY08	578					578
9.2	1	Interceptor AP - existing Winchester/Medford Section 160 Rehab	AP	in S145	3 years	3,389	now-FY09	2,344	1,045				3,389
9.3	1	Cummingsville Replacement Sewer	RF/IC	in S127	2 years	2,041	now-FY08	2,041					2,041
9.4	1	Upper Neponset Valley Relief Sewer	RF/IC	in S131	3 years	36,377	now-FY09	35,825	552				36,377
9.5	3	Wastewater Process Opti/Somerville Sewer Connection Design/Construct	Opti/IC	in S141	4 years	1,136	FY09-12		1,136				1,136
9.6	2	Wastewater Process Opti/Cambridge Branch Sewer/DeLauri Siphon Plan	Plan	in S141	2 years	150	FY12-13		150				150
9.7	2	Outfall 023 Structural Improvements	AP	in S139	3 years	1,500	FY08-10	800	700				1,500
		SUBTOTAL - Existing - Sewers				45,171		41,588	3,583				45,171
9.8	2	Interceptor AP - interceptor renewal #1 Charlestown/Dorchester Sections 31/32/240/242	AP	new	3 years	2,000	FY09-13		2,000				2,000
9.9	2	Interceptor AP - interceptor renewal #2 Brighton Sections 163/164	AP	new	3 years	5,000	FY09-13		5,000				5,000
9.10	2	Interceptor AP - interceptor renewal # 3 Cambridge/Somerville Sections 26/27	AP	new	3 years	5,000	FY09-13		5,000				5,000
9.11	2	Interceptor AP - interceptor renewal #4 Everett Sections 23/24/156	AP	new	3 years	3,000	FY14-18			3,000			3,000
9.12	2	Interceptor AP - interceptor renewal #5 Milton Sections 607/609/610	AP	new	3 years	4,000	FY14-18			4,000			4,000
9.13	2	Interceptor AP - interceptor renewal #6 Chelsea Sections 12/14/15/62	AP	new	3 years	7,000	FY14-18			7,000			7,000

Wastewater Master Plan

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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
9.14	2	Interceptor AP - interceptor renewal #7 Malden/Melrose Sections 41/42/49/54/65	AP	new	4 years	10,000	FY14-18			10,000			10,000
9.15	3	Interceptor AP -interceptor renewal #8 Cambridge Section 30	AP	new	3 years	2,000	FY19-28				2,000		2,000
9.16	3	Interceptor AP - interceptor renewal #9 Winchester/Woburn/Stoneham Sections 46/47/73/74/75/153	AP	new	4 years	9,000	FY19-28				9,000		9,000
9.17	3	Interceptor AP - interceptor renewal #10 Arlington/Medford Sections 21/52/53/78/79/111/112/189	AP	new	5 years	24,000	FY19-28				24,000		24,000
9.18	3	Interceptor AP - interceptor renewal #11 Dedham/Hyde Park Sections 516/521/522/523/524	AP	new	3 years	7,000	FY19-28				7,000		7,000
9.19	3	Interceptor AP - interceptor renewal #12 Norwood Section 618	AP	new	3 years	1,000	FY19-28				1,000		1,000
9.20	3	Interceptor AP - interceptor renewal #13 Future @ $5 mil/year	AP	new	annual	100,000	FY29-48					100,000	100,000
9.21	1	B/W Rehabilitation of Section 624 Construction	AP	prev	3 years	5,000	FY09-11		5,000				5,000
9.22	3	FES/FERS Corrosion and Odor Control (biofilters) Design/Construct	AP	prev	5 years	5,000	FY09-13		5,000				5,000
9.23	3	Wellesley Extension Replacement Sewer Rehab Design/Construction/CS/RI	AP	prev	9 years	24,000	FY14-22			15,000	9,000		24,000
9.24	2	FES Tunnel Rehab Design/Construct	AP	prev	2 years	8,500	FY14-18			8,500			8,500
9.25	2	Odor Control Study (systemwide)	Plan	new	3 years	1,000	FY09-13		1,000				1,000
9.26	1	West Roxbury Tunnel Corrosion Rehab	AP	prev	8 years	80,000	FY11-18		5,000	75,000			80,000
9.27	3	Randolph Trunk Sewer Relief Study	Plan	new	2 years	750	FY08-09	250	500				750
9.28	3	Cambridge Branch Sewer/DeLauri Siphon Design/Construct	IC/Opti	prev	5 years	23,000	FY19-28				23,000		23,000
9.29	4	Neponset Valley Relief Sewer Plan/Design/Construct	RF/IC	prev	10 years	12,000	FY19-28				12,000		12,000
9.30	5	Ashland Extension Sewer Planning/Design	Plan/NF	prev	2 years	1,000	FY19-28				1,000		1,000
9.31	5	North System Hydraulic Capacity Study	Plan	new	2 years	200	FY09-13		200				200
9.32	4	Manhole Rehabilitation @ $100k/year	AP	new	annual	4,000	FY09-FY48		500	500	1,000	2,000	4,000
9.33	4	Woburn Sandcatcher Construction	AP/Opti	new	1 year	1,000	FY09-13		1,000				1,000
9.34	4	Force Main Asset Protection	AP	new	5 years	5,000	FY19-28				5,000		5,000
9.35	3	New Sonar Inspection Equipment	NF	new	1 year	130	FY09-13		130				130
9.36	4	Siphon Asset Protection	AP	new	5 years	5,000	FY19-28				5,000		5,000
9.37	4	B/W Sliplining of Section 652 Fore River Siphon Design/Construction	AP/Opti	prev	2 years	7,000	FY19-28				7,000		7,000
9.38	2	Siphon Structure Rehab Design/Construct	AP	prev	8 years	8,000	FY09-16		5,000	3,000			8,000
9.39	4	Outfall Asset Protection	AP	new	2 years	800	FY19-28				800		800
		SUBTOTAL - Recommended - Sewers				370,380		250	35,330	126,000	106,800	102,000	370,380
		SUBTOTAL - Existing and Recommended - Sewers				415,551		41,838	38,913	126,000	106,800	102,000	415,551

Wastewater Master Plan

Existing and Future Projects

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								2 years	5 years	5 years	10 years	20 years	
		WASTEWATER PUMP STATIONS AND CSO FACILITIES											
10.1	1	B/W Relief Facility Completion	NF	in S104	2 years	13,745	now-FY08	13,745					13,745
10.2	1	PS and CSO Facility AP - existing projects at 7 facilities - Alewife Brook, Caruso, Chelsea Screen House, Cottage Farm, Framingham, Hingham, and Prison Point	AP	in S145	5 years	3,705	now-FY11	976	2,729				3,705
		SUBTOTAL - Existing - Pump Stations and CSO Facilities				**17,450**		**14,721**	**2,729**				**17,450**
10.3	2	Alewife PS Improvements-Additional Costs to Existing AP Project	AP	new	2 years	2,000	FY09-13		2,000				2,000
10.4	2	Chelsea Screen House Sluice Gate Rehabilitation Design/Construct	AP	new	3 years	500	FY09-18		100	400			500
10.5	3	Framingham PS -Force Main Corrosion and Odor Improvements	NF/AP	new	3 years	1,500	FY09-13		1,500				1,500
10.6	2	Framingham PS Sluice Gate Replacement Design/Construct	AP	new	2 years	500	FY09-13		500				500
10.7	3	Framingham PS Screening Automation Study/Design/Construct	Plan/NF	new	3 years	150	FY09-18		50	100			150
10.8	2	PS and CSO Condition Assessment/Facilities Plan for 10 Older Facilities	Plan	new	3 years	3,000	FY10-12		3,000				3,000
10.9	3	PS and CSO Condition Assessment Facilities Plan Upgrades for 10 Older Facilities Design/Construct	AP	new	10 years	120,000	FY14-23			60,000	60,000		120,000
10.10	3	Long-term Wastewater Facility Asset Protection (for HW, PS & CSO Facilities) $2.0M per year for FY11-13, $3.5M per year for FY14-48	AP	new	annual	128,500	FY11-48		6,000	17,500	35,000	70,000	128,500
10.11	4	PS and CSO Future Plan/Upgrades for 8 Newer Facilities	AP	new	20 years	70,000	FY29-48					70,000	70,000
		SUBTOTAL - Recommended - Pump Stations and CSO Facilities				326,150			13,150	78,000	95,000	140,000	326,150
		SUBTOTAL - Existing and Recommended - Pump Stations and CSO Facilities				343,600		14,721	15,879	78,000	95,000	140,000	343,600

Wastewater Master Plan

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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
		CSO CONTROL PLAN (MWRA managed projects)											
11.1	1	North Dorchester Bay	NF	in S339	6 years	218,042	FY07-12	103,646	114,396				218,042
11.2	1	East Boston Branch Sewer Relief	RF/IC	in S347	5 years	63,033	FY07-11	4,104	58,929				63,033
11.3	1	BOS019 CSO Storage Conduit	NF	in S348	2 years	5,832	FY07-08	5,832					5,832
11.4	1	Union Park Detention/Treatment Facility	NF	in S350	2 years	4,695	FY07-08	4,695					4,695
11.5	1	MWRA003 Gate & Siphon	NF/IC	in S355	5 years	1,960	FY09-13		1,960				1,960
11.6	1	Charles River CSO Controls	Opti	in S357	6 years	6,000	FY07-12	850	5,150				6,000
11.7	1	CSO Support	Plan	in S324	15 years	12,709	FY07-21	6,924	5,347	195	243		12,709
		SUBTOTAL - CSO Control Plan (MWRA Managed)				**312,271**		**126,051**	**185,782**	**195**	**243**		**312,271**
		CSO CONTROL PLAN (Community managed projects)											
11.8	1	Dorchester Sewer Separation (Fox Point)	NF	in S340	4 years	1,899	FY07-10	1,568	331				1,899
11.9	1	Dorchester Sewer Separation (Commercial Point)	NF	in S341	4 years	13,457	FY07-10	9,143	4,314				13,457
11.10	1	Stony Brook Sewer Separation	NF	in S344	1 year	3,120	FY07	3,120					3,120
11.11	1	Cambridge 02-04 Sewer Separation (Alewife)	NF	in S346	8 years	33,235	FY07-14	4,021	29,202	12			33,235
11.12	1	Cambridge Floatables Control	NF	in S352	3 years	1,869	FY07-09	1,625	244				1,869
11.13	1	Fort Point Channel Sewer Separation	NF	in S356	2 years	5,534	FY07-08	5,534					5,534
11.14	1	Morrissey Boulevard Drain	NF	in S358	4 years	19,015	FY07-10	11,575	7,440				19,015
11.15	1	Reserved Channel Sewer Separation	NF	in S359	11 years	57,393	FY07-17	3,035	34,426	19,932			57,393
11.16	1	Brookline Sewer Separation	NF	in S360	9 years	9,000	FY07-15	400	8,145	455			9,000
11.17	1	Bulfinch Triangle Sewer Separation	NF	in S361	9 years	4,000	FY07-15	225	3,600	175			4,000
		SUBTOTAL - CSO Control Plan (Community Managed)				**148,522**		**40,246**	**87,702**	**20,574**			**148,522**
		SUBTOTAL - CSO Control Plan (All Projects)				**460,793**		**166,297**	**273,484**	**20,769**	**243**	**0**	**460,793**
		SCADA & WASTEWATER METERING											
12.1	1	Wastewater Central Monitoring/SCADA	AP/Opti	in S137	3 years	15,873	FY07-09	15,246	627				15,873
12.2	1	Wastewater Metering System Equipment Replacement	RF	in S142	phase 2 - 3 years	1,587	now-FY16	265	122	1,200			1,587
		SUBTOTAL - Existing - SCADA and Metering				**17,460**		**15,511**	**749**	**1,200**			**17,460**

Wastewater Master Plan

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								2 years	5 years	5 years	10 years	20 years	
12.3	2	Wastewater SCADA Related PC Upgrades, $50k every 5 years	AP	new	1 year	400	FY09-48		50	50	100	200	400
12.4	3	Wastewater SCADA Equipment (PLC) Replacement/Upgrade	AP	new	3 years	5,000	FY19-48				2,000	3,000	5,000
12.5	3	Wastewater Data Radio Replacement	AP	new	3 years	100	FY19-48				50	50	100
12.6	2	Wastewater Metering System Asset Protection Plan/Design/Construct $5M every 10 years	AP	new	3 years	20,000	FY14-48			5,000	5,000	10,000	20,000
		SUBTOTAL - Recommended - SCADA and Metering				25,500			50	5,050	7,150	13,250	25,500
		SUBTOTAL - Existing and Recommended - SCADA and Metering				42,960		15,511	799	6,250	7,150	13,250	42,960
		CLINTON WASTEWATER TREATMENT PLANT											
14.1	1	Clinton Soda Ash Replacement	AP	in S19302	1 year	0	FY08	0*					0
14.2	2	Clinton Permanent Standby Generator	AP	in S19308	0.3 years	0	FY08	0*					0
		SUBTOTAL - Existing - Clinton				**0**		**0**					**0**
14.3	3	Long-term Asset Protection @ $300k/yr for FY14-48	AP	new	annual	10,500	FY14-48			1,500	3,000	6,000	10,500
14.4	3	Landfill Cell #1 Closure Plan/Implementation	AP	new	2 years	200	FY09-13		200				200
14.5	3	Rubber Roofing Rehab	AP	new	1 year	150	FY09-13		150				150
14.6	3	2 Digesters - Internal Inspection Cleaning & Rehab	AP	new	2 years	350	FY09-13		350				350
14.7	3	Process Water Pumps (4) System Replacement/Rehabilitation	AP	new	2 years	175	FY09-13		175				175
14.8	4	Security Upgrades for Plant/Landfill	NF	new	2 years	100	FY09-13		100				100
14.9	3	Plant Processes Technology Improvements	Opti	new	5 years	3,000	FY14-18			3,000			3,000
14.10	3	Technology Upgrades to Meet Future Regulatory Requirements	NF	new	5 years	2,000	FY14-18			2,000			2,000
14.11	3	Influent (3) and Intermediate (3) Lift Pump Replacement	AP	new	5 years	750	FY14-18			750			750
14.12	4	Repair/Sealing of Plant Roadway	AP	new	1 year	100	FY14-18			100			100
14.13	3	Grit Removal Facilities Rehab/Replacement	AP	new	5 years	700	FY14-18			700			700
14.14	3	Belt Filter Press Replacement	AP	new	5 years	1,500	FY14-18			1,500			1,500
14.15	4	Landfill Expansion - Fourth Cell	NF	new	5 years	1,000	FY19-28				1,000		1,000
14.16	4	Secondary Clariflocculator - Fourth Tank	NF	new	5 years	1,000	FY19-28				1,000		1,000
14.17	4	UV Disinfection System	NF	new	5 years	3,000	FY19-28				3,000		3,000
		SUBTOTAL - Recommended - Clinton				24,525		0	975	9,550	8,000	6,000	24,525
		SUBTOTAL - Existing and Recommended - Clinton				24,525		0	975	9,550	8,000	6,000	24,525

Wastewater Master Plan

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								2 years	5 years	5 years	10 years	20 years	
		COMMUNITY-OWNED SYSTEMS/COMMUNITY SUPPORT - SEWER											
15.1	3	I/I Financial Assistance (phases 1-6)	AP	in S128	14 years	14,000	now-FY20	3,600	15,000	(1,100)	(3,500)		14,000
		SUBTOTAL - Existing - Community Support				**14,000**		**3,600**	**15,000**	**(1,100)**	**(3,500)**		**14,000**
15.2	3	I/I Financial Assistance (phase7) $18 mil grants/$22 mil loans	AP	new	13 years	18,000	FY12-24		3,000	10,000	5,000		18,000
15.3	3	I/I Financial Assistance (phase 8) $18 mil grants/$22 mil loans	AP	new	12 years	18,000	FY17-28			3,000	15,000		18,000
		SUBTOTAL - Recommended - Community Support				36,000			3,000	13,000	20,000		36,000
		SUBTOTAL - Existing and Recommended - Community Support				50,000		3,600	18,000	11,900	16,500		50,000

			Cost ($1000)	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
		TOTAL - Existing - ALL WASTEWATER	**666,174**	**268,541**	**365,204**	**35,686**	**(3,257)**	**0**	**666,174**
		TOTAL - Recommended - ALL WASTEWATER	**1,391,687**	**3,615**	**120,505**	**375,392**	**352,475**	**539,700**	**1,391,687**
		TOTAL - Existing and Recommended - ALL WASTEWATER	**2,057,861**	**272,156**	**485,709**	**411,078**	**349,218**	**539,700**	**2,057,861**

Attachment 2B

Water Master Plan

Existing and Future Projects

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								2 years	5 years	5 years	10 years	20 years	
		WATER QUALITY											
6.1	1	John J. Carroll Water Treatment Plant	NF	in, S542	8 years	56,524	FY07-14	6,972	44,140	5,412			56,524
6.2	1	Quabbin Water Treatment Plant Design/Construct	NF	in, S543	5 years	5,876	FY08-12	235	5,641				5,876
		SUBTOTAL - Existing - Water Quality				62,400		7,207	49,781	5,412			62,400
6.3	2	Carroll Water Treatment Plant Ancillary Modifications 1 & 2	AP	new	3 years	7,600	FY09-11		7,600				**7,600**
6.4	3	Carroll WTP Asset Protection	AP	new	ongoing	50,000	FY16-48			3,000	10,000	37,000	**50,000**
6.5	3	Chicopee Valley WTP Asset Protection	AP	new	3 years	4,000	FY27-29				2,000	2,000	4,000
		SUBTOTAL - Future - Water Quality				61,600		0	7,600	3,000	12,000	39,000	61,600
		SUBTOTAL - Existing and Future - Water Quality				124,000		7,207	57,381	8,412	12,000	39,000	124,000
		TRANSMISSION SYSTEM											
7.1	1	Chicopee Valley Aqued. Redundancy	NF	in, S615		5,199	FY07-08	5,199					5,199
7.2	2	Norumbega Covered Storage	NF	in, S544		1,084	FY07-10	503	581				1,084
7.3	2	MetroWest Tunnel (CP-6)	NF	in, S604		70,995	FY07-13	19,803	51,123	69			70,995
7.4	1	Wachusett Res Spill Impr/Winsor Dam Repairs	AP	in, S620		8,925	FY07-09	6,852	2,073				8,925
7.5	1	Sudbury / Weston Aqueduct Repairs	Plan/AP	in, S617		3,199	FY07-09	3,191	8				3,199
7.6	2	Quabbin Transmission System	Plan/AP	in, S616		1,029	FY07-10	885	144				1,029
7.7	3	Waterworks FAMP Cosgrove Valve Seat Replacement Design/Construct	AP	in, S766		600	FY08-09	75	525				600
7.8	3	Waterworks FAMP Cosgrove Turbine Isolation Design	Opti	in, S766		480	FY16-18			480			480
		SUBTOTAL - Existing - Transmission				**91,511**		**36,508**	**54,454**	**549**			**91,511**

Water Master Plan

Existing and Future Projects

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Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
7.9	1	Engineering Studies for Dam Risk	Plan	new	1 year	250	FY08	250					250
7.10	2	Immediate Repairs to Dams	AP	new	4 years	4,000	FY09-12		4,000				4,000
7.11	1	Redundancy Study & Tunnel Inspection Feasibility Assessment	Plan	new	2 years	1,500	FY09-10		1,500				1,500
7.12	1	Winsor Power Station (Pipeline Replacement Ph 1) Design/Construct	AP	prev	5 years	5,000	FY09-13		5,000				5,000
7.13	2	Oakdale Station Phase 1A (Electrical) Study/Preliminary Design	AP	new	3 years	3,000	FY10-12		3,000				3,000
7.14	2	Shaft 12 Quabbin Aqueduct Sluice Gate Design/Construct	Opti	new	2 years	2,000	FY10-11		2,000				2,000
7.15	2	Tunnel Inspections (Quabbin, CTE,CT)	AP	new	1 year	2,000	FY11		2,000				2,000
7.16	1	Wachusett Aqueduct Pressurization Design/Construct	Opti	new	8 years	100,000	FY11-18		10,000	90,000			100,000
7.17	3	Waterworks FAMP Roofs	AP	new	20 years	900	FY09-28		300	300	300		900
7.18	3	Quabbin Lookout Tower (electric highline replacement) Design/Construct	AP	new	2 years	500	FY09-10		500				500
7.19	3	Waterworks FAMP Transmission Facilities Construction	AP	new	10 years	9,000	FY10-19		3,000	5,000	1,000		9,000
7.20	1	Long-Term Redundancy	Opti	prev	10 years	100,000	FY14-23			50,000	50,000		100,000
7.21	3	FAMP Masonry Dam Repointing	AP	new	ongoing	3,000	FY14-48			1,000	1,000	1,000	3,000
7.22	3	FAMP Rehabilitation of Earthen Dams	AP	new	ongoing	3,000	FY14-48			1,000	1,000	1,000	3,000
7.23	4	Oakdale Station Rehab Ph 2 Design/Construct	AP	prev	5 years	8,625	FY14-18			8,625			8,625
7.24	3	Waterworks FAMP Cosgrove Turbine Isolation Construction	Opti	new	3 years	1,900	FY18-20			900	1,000		1,900
7.25	4	Winsor Dam Hydroelectric Design/Construct	AP	prev	5 years	1,534	FY09-13		1,534				1,534
		SUBTOTAL - Future - Transmission				246,209		250	32,834	156,825	54,300	2,000	246,209
		SUBTOTAL - Existing and Future - Transmission				337,720		36,758	87,288	157,374	54,300	2,000	337,720

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Existing and Future Projects

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Prioritization

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FY07 CIP Notes

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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
		METROPOLITAN SYSTEM											
8.1	1	Weston Aqueduct Supply Mains (WASMs)	AP	in, S730	10 years	55,564	FY07-16+	3,241	30,852	21,471			55,564
8.2	1	Chestnut Hill Connecting Mains-6995 Final Design CA/RI	NF	in, S719	6 years	1,404	FY07-12	140	1,264				1,404
8.3	1	NIH Redundancy & Covered Storage	Plan/NF	in, S722	7 years	7,264	FY07-13	824	6,440				7,264
8.4	2	Blue Hills Covered Storage	NF	in, S545	4 years	34,166	FY07-10	18,815	15,351				34,166
8.5	2	Valve Replacement-Ph 6&7, equipment	AP	in, S677	5 years	7,095	FY07-11	3,528	3,567				7,095
8.6	2	Walnut St. Pipeline Rehabilitation	AP	in, S732	3 years	3,303	FY07-09	2,008	1,295				3,303
8.7	2	Heath Hill Road Pipe Replacement	AP	in, S683	3 years	7,394	FY07-09	7,126	268				7,394
8.8	2	Southern Spine Distribution Mains	AP	in, S721	10 years	49,316	FY07-16+	3,462	28,191	17,663			49,316
8.9	2	Rehab of Other Pumping Stations	AP	in, S704	5 years	24,775	FY07-11	12,982	11,793				24,775
8.10	2	James L. Gillis Pump Station Rehab.Final Hazmat	AP	in, S689	2 years	741	FY07-08	741					741
8.11	2	Spot Pond Supply Mains - Rehabilitation	AP	in, S713	4 years	9,885	FY07-10	9,131	754				9,885
8.12	2	New Connecting Mains - Shaft 7 to ..	NF	in, S702	9 years	47,320	FY07-15	8,839	37,513	968			47,320
8.13	2	Lynnfield Pipeline	NF	in, S731	4 years	4,000	FY07- 10	425	3,575				4,000
8.14	2	Nor Extra High Serv - New Pipelines	AP/NF	in, S708	10 years	5,115	FY07-16+	3	33	5,079			5,115
8.15	2/3	Nor Low Service Rehab-- Secs. 8/37/38/97A	AP	in, S723	9 years	17,210	FY07-15	1,200	11,800	4,210			17,210
8.16	3	NHS - Section 27 Improvements - Construction	AP	in, S692	9 years	2,578	FY07-15	2	16	2,560			2,578
8.17	3	NHS - Revere & Malden Pipeline Improvements	AP	in, S693	10 years	8,191	FY07-16	1,674	1,057	5,460			8,191
8.18	3	Waterworks FAMP Walnut Hill Tank Design/Construct	AP	in, S766	2 years	1,300	FY09-12		1,300				1,300
8.19	4	Waterworks FAMPMeter Vault Manhole Retrofits	AP	in, S768	4 years	1,417	FY15-18			1,417			1,417
8.20	5	Cathodic Protection Of Distr.Mains-Install 2,3&4	AP	in, S712	3 years	1,268	FY19-28				1,268		1,268
		SUBTOTAL - Existing - Metropolitan System				**289,306**		**74,141**	**155,069**	**58,828**	**1,268**		**289,306**

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Existing and Future Projects

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Prioritization

1 Critical
2 Essential
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Project Types

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Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
8.21	1	SEH Concept Study/EIR	Plan	new	2 years	1,000	FY07-09	750	250				1,000
8.22	1	NIH Redundant Pipeline Design/Construct	NF	new	5 years	24,000	FY09-13		24,000				24,000
8.23	2	NIH Storage Design/Construct	NF	new	7 years	10,000	FY09-16		7,000	3,000			10,000
8.24	2	SEH - Sections 77/88 Redundancy Design/Construct	NF	new	5 years	25,000	FY11-16		7,000	18,000			25,000
8.25	2	Chestnut Hill Connecting Mains (Final Pipe & Facilities Rehab. Ch 149 & 30)	NF	prev	2 years	5,600	FY10-12		5,600				5,600
8.26	2	NH - Sections 70, 71, and 79 Study and Condition Assessment	Plan	new	2 years	1,000	FY10-12		1,000				1,000
8.27	2	Valve Replacement Phase 8 & 9	AP	new	10 years	6,000	FY09-18		3,000	3,000			6,000
8.28	3	Section 80 Rehabilitation Design/Construct	AP	prev	5 years	7,119	FY10-14		6,000	1,119			7,119
8.29	3	Northern High (sections 70, 71 and 79) Design/Construct	AP	prev	10 years	35,670	FY15-24			15,670	20,000		35,670
8.30	3	Waterworks FAMP Meters- Venturi Tubes	AP	new	10 years	10,000	FY09-18		5,000	5,000			10,000
8.31	2	NIH - section 89/29 Rehabilitation Design/Construct	AP	new	4 years	5,000	FY14-17			5,000			5,000
8.32	2	NIH - Gillis Redundancy	NF	new	5 years	10,000	FY14-18			10,000			10,000
8.33	2	SEH Storage	NF	new	5 years	10,000	FY13-18		500	9,500			10,000
8.34	3	SEH - Sections 30, 40, 44 & 39 Design/Construct	AP	new	4 years	10,000	FY15-18			10,000			10,000
8.35	3	Fisher Hill Pipeline Rehabilitation Construction	AP	prev	2 years	2,711	FY16-18			2,711			2,711
8.36	3	NHS - Sections 33, 49, 49A & 50 Design/Construct	AP	prev	5 years	8,000	FY14-18			8,000			8,000
8.37	3	Spot Pond Supply Mains (Sections 66 & 57) Design/Construct	AP	prev	7 years	29,671	FY15-22			20,000	9,671		29,671
8.38	3	Southern Spine Distribution Mains (Section 19) Design/Construct backs up Heath Hill	AP	prev	5 years	8,088	FY12-16		1,500	6,588			8,088
8.39	3	Section 75 Extension Design/Construct	NF	new	4 years	4,400	FY13-16		1,000	3,400			4,400
8.40	4	Section 83 DropHole Rehabilitation Design/Construct	Opti	new	3 years	3,000	FY16-18			3,000			3,000
8.41	2	SEH Sections 77/88 Rehabilitation Design/Construct	AP	new	5 years	5,000	FY19-23				5,000		5,000
8.42	3	Northern High Service Pipeline Rehabilitation Design/Construct Sections 54, 55, 56, 69	AP	prev	5 years	16,288	FY23-28				16,288		16,288
8.43	3	Northern High Service Pipeline Rehabilitation (Sections 13-18 & 48) Design/Construct	AP	prev	5 years	18,363	FY19-23				18,363		18,363

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Existing and Future Projects

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Prioritization

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Project Types

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Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
8.44	4	Waterworks FAMP Pump Station Instrumentation/Electrical/Mechanical	AP	new	ongoing	56,000	FY16-48			2,000	4,000	50,000	56,000
8.45	4	Parallel Main to Meters 55 & 68	NF	new	4 years	5,000	FY21-24				5,000		5,000
8.46	2	Low Service Storage near Spot Pond Study/EIR	NF	prev	2 years	1,000	FY09-11		1,000				1,000
8.47	3	Low Service Storage Design/Construct	NF	prev	4 years	35,000	FY12-15		17,500	17,500			35,000
		SUBTOTAL - Future - Metropolitan System				352,910		750	80,350	143,488	78,322	50,000	352,910
		SUBTOTAL - Existing and Future - Metropolitan System				642,216		74,891	235,419	202,316	79,590	50,000	642,216
		COMMUNITY ASSISTANCE											
8.48	3	Water Local Pipeline Assistance Program	AP	in	12 years	(96,500)	now-FY18	15,500	22,000	(100,000)	(34,000)		(96,500)
		SUBTOTAL - Existing - Community Assistance				**(96,500)**		**15,500**	**22,000**	**(100,000)**	**(34,000)**	**0**	**(96,500)**
8.49	3	Water Local Pipeline Assistance Program	AP	new	10 years	0	FY14-23			50,000	(31,000)	(19,000)	0
		SUBTOTAL - Future - Community Assistance				0		0	0	50,000	(31,000)	(19,000)	0
		TOTAL - Existing and Future - Community Assistance				(96,500)		15,500	22,000	(50,000)	(65,000)	(19,000)	(96,500)
		ANCILLARY SERVICES											
9.1	3	Central Monitoring SCADA Implementation	Opti	in	2 years	450	FY07-08	250	200				450
9.2	3	Distribution System Facilities Mapping - Records Development	AP	in	2 years	1,268	FY07-13	930	338				1,268
		SUBTOTAL - Existing - Ancillary Services				**1,718**		**1,180**	**538**	**0**	**0**	**0**	**1,718**
9.3	3	Update Record Management Software	AP	new	1 year	30	FY08	30					30
9.4	3	Document Control Program	AP	prev	2 years	900	FY08	900					900
9.5	3	Evaluate Use of Wind Power at Select Facilites	Plan	new	18 months		FY08						
9.6	3	Energy Audits at Select Facilites @ $20,000 per facility (supplier pays half)	Opti	new & prev	5 years	120	FY08-12	20	100				120

Water Master Plan

Existing and Future Projects

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Prioritization		**Project Types**		**FY07 CIP Notes**	
1	Critical	NF	New Facility/System	in	included in FY07 CIP (bold)
2	Essential	RF/IC	Replacement Facility/Increase Capacity	new	new project, not previously in CIP
3	Necessary	Opti	Optimization	prev	included in prior CIP, but deleted
4	Important	AP	Asset Protection		
5	Desirable	Plan	Planning/Study		

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
9.7	3	GC-MS or LC-MS Lab Equipment	AP	new	2 years	1,000	FY09-10		1,000				1,000
9.8	3	Chromatography Data Management Sewer	AP	new	1 year	250	FY09		250				250
9.9	3	Waterworks Modem Replacement	AP	new	5 years	200	FY09-13		200				200
9.1	3	Waterworks SCADA PC Upgrade - 50k every 5 yrs.	AP	new	1 year	150	FY11-31		50	50	50		150
9.1	3	Water Data Radio Replacement	AP	new	3 years	100	FY09-13		100				100
9.12	5	Micro Hydroturbine Feasibility Study - possible installation of pilot micro hydroturbine at test location	Plan	new	2 years	70	FY09-10		70				70
9.13	3	Waterworks Meter Replacement	AP	new	1 year	5,000	FY15-16			5,000			5,000
9.14	4	Radio Feedline and Antennae Replacement	AP	new	1 year	1,000	FY14-16			1,000			1,000
9.15	3	Waterworks SCADA Equipment (PLC) Replacement/Upgrades	AP	new	1 year	2,000	FY21				2,000		2,000
		SUBTOTAL - Future - Ancillary Services				10,820		950	1,770	6,050	2,050	0	10,820
		TOTAL - Existing and Future - Ancillary Services				12,538		2,130	2,308	6,050	2,050	0	12,538
		TOTAL - Existing Projects (w/o Community Assistance) - ALL WATER				**444,935**		**119,036**	**259,842**	**64,789**	**1,268**	**0**	**444,935**
		TOTAL - Future Projects (w/o Community Assistance) - ALL WATER				**671,539**		**1,950**	**122,554**	**309,363**	**146,672**	**91,000**	**671,539**
		TOTAL - Existing and Future Projects (w/o Community Assistance) - ALL WATER				**1,116,474**		**120,986**	**382,396**	**374,152**	**147,940**	**91,000**	**1,116,474**
		TOTAL - Existing Projects (w/ Community Assistance) - ALL WATER				**348,435**		**134,536**	**281,842**	**(35,211)**	**(32,732)**	**0**	**348,435**
		TOTAL - Future Projects (w/ Community Assistance) - ALL WATER				**671,539**		**1,950**	**122,554**	**359,363**	**115,672**	**72,000**	**671,539**
		TOTAL - Existing and Future Projects (w/ Community Assistance) - ALL WATER				**1,019,974**		**136,486**	**404,396**	**324,152**	**82,940**	**72,000**	**1,019,974**

WASTEWATER AND WATER MASTER PLAN SUMMARY

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
		TOTAL - Existing - ALL WASTEWATER				**666,174**		**268,541**	**365,204**	**35,686**	**(3,257)**	**0**	**666,174**
		TOTAL - Recommended - ALL WASTEWATER				**1,391,687**		**3,615**	**120,505**	**375,392**	**352,475**	**539,700**	**1,391,687**
		TOTAL - Existing and Recommended - ALL WASTEWATER				**2,057,861**		**272,156**	**485,709**	**411,078**	**349,218**	**539,700**	**2,057,861**
		TOTAL - Existing Projects (w/ Community Assistance) - ALL WATER				**348,435**		**134,536**	**281,842**	**(35,211)**	**(32,732)**	**0**	**348,435**
		TOTAL - Recommended (w/ Community Assistance) - ALL WATER				**671,539**		**1,950**	**122,554**	**359,363**	**115,672**	**72,000**	**671,539**
		TOTAL - Existing and Recommended Projects (w/ Community Assistance) - ALL WATER				**1,019,974**		**136,486**	**404,396**	**324,152**	**82,940**	**72,000**	**1,019,974**
		TOTAL - ALL WASTEWATER AND WATER EXISTING (w/Community Assistance)				**1,014,609**		**403,077**	**647,046**	**475**	**(35,989)**	**0**	**1,014,609**
		TOTAL - ALL WASTEWATER AND WATER RECOMMENDED (w/Community Assistance)				**2,063,226**		**5,565**	**243,059**	**734,755**	**468,147**	**611,700**	**2,063,226**
		TOTAL - ALL WASTEWATER AND WATER PROJECTS (w/Community Assistance)				**3,077,835**		**408,642**	**890,105**	**735,230**	**432,158**	**611,700**	**3,077,835**

1 Introduction

1.1 Overview of MWRA

The Massachusetts Water Resources Authority (MWRA) was established by the Massachusetts Water Resources Authority Act, Chapter 372 of the Acts of 1984 of the Commonwealth of Massachusetts. In 1985, responsibility for water distribution for 46 municipalities and sewage collection and treatment for 43 municipalities was transferred from the Metropolitan District Commission (MDC) to the MWRA. MWRA's facilities span from the Quabbin Reservoir in western Massachusetts to the Deer Island Treatment Plant in Boston Harbor. Approximately 2.5 million people, about 44 percent of the total population of Massachusetts, live in the communities served in whole or in part by the MWRA.

MWRA is an independent public agency with the ability to raise its revenues from ratepayers, bond sales and grants. In addition to its operating responsibility, the MWRA was created to modernize the area's water and sewer systems and clean up Boston Harbor. MWRA's long-term business plan emphasizes improvements in service and systems and includes aggressive performance targets for operating the water and wastewater systems and maintaining new and existing facilities. Parallel to MWRA's goal of carrying out its capital projects and operating programs is its goal of limiting rate increases to its customer communities. The need to achieve and maintain a balance between these two goals is a critical issue in the development of both the Water System and Wastewater Master Plans.

1.2 Purpose of the Water System Master Plan

MWRA's Water System Master Plan presents a long-term vision of the capital development needs of the water system and the actions planned for the next forty years to meet those needs. The primary purpose of this Plan is to ensure that key staff from across the Authority engage in proactive planning to enhance system performance while minimizing long-term costs to MWRA ratepayers. The treatment and delivery of water to a major region of the state (over 2 million customers) represents an essential public service. It is the MWRA's responsibility to protect public health, promote environmental quality improvements, support a prosperous economy, maintain customer confidence, and minimize sewer charges. To fulfill this responsibility, significant expenditures for system rehabilitation and improvements will continue. This Water System Master Plan identifies system/facility conditions, operational risks and capital project needs. The Master Plan accounts for all projects included in the FY07 CIP, projects previously eliminated as line items in earlier CIP cycles, and newly-identified projects. Projects have been prioritized and a recommended implementation timetable developed that corresponds with the annual CIP development cycle.

Concurrent with the development of the Water System Master Plan, the MWRA is also developing a Wastewater Master Plan. Preparation of Water and Wastewater Master Plans was recommended by the MWRA Advisory Board to provide a more thorough context for developing, analyzing, and evaluating the annual Capital Improvement Program (CIP) and are intended to serve as the principal framework for future planning, budgeting and rate setting decisions.

1.3 Planning Approach, Assumptions and Time Frame

In its two-decade existence, MWRA has constructed billions of dollars of facilities to repair, replace, and modernize aging infrastructure. The $1.7 billion Integrated Water Supply Improvement Program greatly improved the quality and reliability of MWRA's water treatment and transmission system consistent with federal and state Safe Drinking Water Act requirements. The estimated replacement value of MWRA's water system assets is over $6 billion. MWRA is now in transition with a need to rehabilitate those portions of the system that have not been replaced and provide for maintenance and asset protection of newer facilities. Development of the Master Plan will continue the transition with respect to capital projects, shifting MWRA's primary focus from construction of new facilities to maintenance and rehabilitation/replacement.

For the Master Plan, MWRA has selected a 40-year planning period through FY48. The Master Plan focuses on projects recommended for FY07-08 and projects that are proposed to generate capital spending during the next two 5-year CIP cap cycles FY09-13 and FY14-18. Estimates of project costs and schedules over this shorter term are expected to be more reliable than looking ahead to the out-years. Following these two 5-year periods, additional 10-year (FY19-28) and 20-year (FY29-48) planning periods are utilized.

As will be explained in the specific chapters, a number of assumptions were made based on the information gathered for this plan and these assumptions explain why certain financial needs are not identified. The analyses summarized in Chapter 4 indicate that source capacity (the 300 MGD safe yield of the MWRA system) is sufficient to meet future demand for water both within the service area and additional demand outside of the existing service area as may be approved. Also, although the recommendations within the Transmission chapter stress the need to inspect the tunnels as they are approximately halfway (on average) through their expected 100 year old useful lives, it is assumed that major rehabilitation will not be required at this time. Future Master Plan updates will report on the condition as determined by the recommended inspections. Finally, at this time, no design and construction funds are included to address the impacts on MWRA's water system of potential changes in federal or state regulations. The FY 07 CIP already includes funds to meet the requirements of the Long Term 2 Enhanced Surface Water Treatment Rule for a second treatment process at both the Carroll Water Treatment Plant and the Ware Water Treatment Plant by 2014. These assumptions are further discussed in Chapters 5 through 7.

All projects have been prioritized on a scale from 1 to 5, with 1 being projects considered critical and 5 considered desirable. Priorities for the water projects reflect the water system goals and objectives found in Chapter 2 of this plan. Highest priority projects will resolve critical threats to public health and prevent imminent system failure resulting in significant service loss. High priority projects will improve system reliability including the elimination of "single points of failure". Projects that will provide critical condition assessment information were also considered high priority. Lower priority projects will monitor long-term system needs and provide more efficient operation. Project ratings were assigned by MWRA senior managers in concert with Planning and Coordination Department staff. All MWRA projects will be further prioritized during the FY08 CIP development process.

1.4 Organization of the Master Plan

The Water System Master Plan is organized into chapters for distinct topics and/or separate asset classes (such as the Transmission System, Treatment, and the Metropolitan System etc.). Each chapter that recommends capital projects includes a summary section that provides an overview of major findings, recommendations, costs, and project schedules.

1.5 Periodic Updates

The Water System Master Plan is intended to represent an ongoing process; it is not intended to be a static document. The Plan presents a broad range of recommended projects, some critical (to be completed in the short-term) and some lower priority (to be completed in the long-term). Changes in scope, details and scheduling of certain projects may be required over time to respond to emergencies, new regulations, emerging technologies, etc. Although this Plan will map out major expenditures for the water system for many years, conditions change and flexibility is important. The Plan is intended to be reviewed annually as an integral component of MWRA's Capital Improvement Program development and will be revised periodically to reflect new initiatives and/or major changes in priorities. A complete Master Plan review/update is recommended to be performed no less than every five years.

2 Planning Goals and Objectives

2.1 Planning Goals and Objectives Defining MWRA'S Water System Mission

Goals

MWRA's fundamental mission regarding water service delivery is established in the Enabling Act: to reliably and efficiently deliver an adequate quantity of high quality water to the customer communities, and to properly manage, repair, rehabilitate, and improve the waterworks system so that its service requirements can be met. For the purposes of setting priorities among needs and guiding the planning process, this basic mission is articulated in four distinct principles:

- Provide reliable water delivery.
- Provide high quality water.
- Assure an adequate supply of water.
- Operate and manage the system efficiently and effectively.

Since these principles represent basic goals and ideals for operating and caring for the water system, further definition of objectives is necessary to establish how MWRA intends to satisfy these goals.

Objectives

Guidance on the application of each principle is provided by a set of objectives. The objectives express the philosophy and emphasis for program planning and project implementation and identify where efforts should be focused and what approaches should be followed in assessing conditions and developing solutions. These objectives reflect both MWRA's current understanding of the needs and priorities of the system but also the need to be cognizant of potential future changes. These changes may be internal to MWRA or they may be driven by external events such as regulatory changes or changes in member community priorities.

Individual projects identified during the master planning process will be evaluated at a threshold level in the context of how they meet the stated objectives. However, once projects have been identified and determined to meet specific objectives, their relative prioritization for inclusion in the capital budget will be the result of a more targeted analysis.

2.2 Provide Reliable Water Delivery

Dependable and continuous water delivery at adequate pressures and flow rates is an essential public service integral to the public health, safety, and economic well-being of the region's population. It is MWRA's goal to secure, operate and maintain the water system as needed so that the potential for supply interruption within the service area is kept to an absolute minimum. Disruptions will inevitably occur but fundamental water supply principles prescribe that the consequences of such disruptions be managed and that secondary modes of delivery be available in the event that primary modes are taken off-line for servicing or due to breakdown. Distribution storage sufficient to prevent or minimize significant supply disruptions must also be developed in order to reduce risk. MWRA also recognizes its role to provide wholesale water service in a manner that supports the communities' abilities to meet local requirements for pressure and fire flows. In general, water pressures at community meters should be within an appropriate range at all times and flow rates should be capable of satisfying maximum rates of demand.

Objectives

1) Fix existing reliability problems related to "single points of failure": Use information developed through emergency planning and through vulnerability assessments to identify and prioritize points within the transmission and distribution systems where a component failure or shut-down could lead to a disruption in service. Use an analysis of the risk of failure and the consequence of failure. Consider such factors as the extent and duration of resultant supply outages or community disruption. Develop remedies that provide secondary modes of delivery at these locations or develop appropriate emergency response plans.

2) Fix facilities in poor condition: Identify and rehabilitate or replace any remaining operating or emergency facilities that are in poor condition. For maintenance projects, give priority to addressing the needs of key assets that are in poor condition, are hydraulically deficient, or that are failing to meet desired performance levels and thereby compromising the system's ability to provide uninterrupted service or adequate flow.

3) Increase distribution storage: Continue to implement the recommendations of the 1993 "Water Distribution System Storage Study", and the 1993 Water System Master Plan relative to the development of additional distribution storage.

4) Use effective planning to minimize risks: In order to reduce the risk of failure, implement systems and practices to identify, monitor, maintain and replace key equipment in an orderly way to reduce the risk of service disruptions. Continue successful programs that reduce risks such as valve exercising, valve rehabilitation and replacement, and leak detection efforts.

5) Support work force safety: Provide adequate workplace and field site conditions, and equip crews with the tools, materials and information necessary to carry out operational and maintenance duties safely. Consider staff safety when making decisions about maintenance activities and process technologies.

6) Monitor the system: Continue to implement and enhance measures that allow 24/7 monitoring of key system components.

2.3 Deliver High Quality Water

Since its inception, MWRA has invested significant funds into water quality/treatment improvements to ensure that the customer communities receive water that meets all governmental standards. Provision of high quality water involves four key elements: source water protection, effective and reliable treatment, prevention of water quality degradation in the distribution system and monitoring. In addition, because it is critical that consumers maintain confidence in the quality of their tap water, MWRA should continue to provide a water product which has a consistent and appealing character, and does not arouse doubts about its quality and healthfulness.

Objectives

1) Protect public health: Deliver water that meets, or is better than, the quality standards set by federal and state regulations. Since regulatory standards may lag scientific knowledge, monitor emerging trends in public health protection.

2) Preserve water quality within the distribution system: Maintain treatment process equipment to minimize risk of treatment disruptions. Continue to aggressively rehabilitate or replace remaining unlined pipe that tends to be in poor condition and that degrades water quality. Size, maintain and operate storage facilities to ensure protection from potential pollutants and to avoid stagnation. Continue to financially support community distribution system improvements.

3) Follow drinking water legislation and regulations: Closely follow the development of and any modifications to drinking water legislation and regulations, and actively represent the MWRA's interests in order to maximize our options and to ensure that resulting water quality requirements are reasonable and appropriate for our situation. Where appropriate, pursue flexible planning strategies that maximize opportunities for selecting treatment methods that are cost effective, meet regulatory requirements and that provide the most value and return in terms of public health benefits and water quality enhancement.

4) Continue disease surveillance efforts: Continue and enhance monitoring partnerships with public health professionals (such as MWRA's Disease Surveillance Program) in order to facilitate the ability to discern and respond to water-borne disease.

5) Implement the MOU with DCR: Implement the provisions of the MOU with the Department of Conservation and Recreation (DCR) in order to maintain excellent source water quality. Set budget and project priorities for watershed-related expenditures to ensure the prevention of contamination, and to provide strong support for DCR protection and monitoring of the watersheds. Monitoring efforts must also consider security concerns relative to water quality.

6) Ensure customer confidence: Recognize the importance of ensuring consumer confidence in the quality of water at the tap, and promote greater awareness of what can be done to prevent water quality deterioration within community and household pipes. Develop clear, understandable information and educational materials for consumers.

2.4 Assure an Adequate Supply of Water

As a regional water supply utility, the Authority maintains a fundamental goal of ensuring that enough water is available to reliably meet water needs within the areas served. Under normal circumstances, this means that water needs should not exceed the safe yield of existing supplies. MWRA's source reservoirs, the Quabbin and Wachusett, can be counted on to safely provide about 300 million gallons per day (mgd) of water. For a 20-year period from 1969 to 1988, the customers of MWRA (and its predecessor MDC) routinely drew more than the safe yield. To address this problem, MWRA launched an aggressive water conservation program in 1986. By 1989, withdrawals were below the safe yield, where they have remained ever since. Demand on the MWRA Waterworks system was 219 mgd in 2005. During infrequent episodes of drought-related shortfalls, it may be necessary to maintain supply adequacy through the institution of temporary demand reduction measures suited to the severity of the situation.

Objectives

1) Periodically review water needs: Base water needs assessments on demand forecasts that incorporate realistic assumptions about service area population, usage factors, and local source availability.

2) Maintain demand management efforts: Continue to provide educational materials to communities and to individuals. Maintain management controls to monitor community and system use in order to identify and investigate any unanticipated increases in water use. Continue to support leak detection efforts for both the MWRA system and the community systems.

3) Encourage the development and protection of local sources: Encourage additional local source capacity by user communities with access to feasible sources of water. Encourage continued local source protection efforts by local communities.

4) Provide careful review of system expansion requests: Consider requests for system expansion in the context of current and anticipated system demands and within the requirements of MWRA's Enabling Act and MWRA policies.

5) Monitor supply conditions and manage drought conditions responsibly: Remain prepared to respond effectively to changing conditions and needs by utilizing an appropriate planning approach which monitors key data, preserves and wide range of options, and allows for timely decision and actions if needed. In the event of actual or impending drought conditions, follow the actions and responses set forth in the Drought Management Plan and seek full cooperation from customer communities. Maintain a high degree of supply reliability so that drought restrictions are not imposed on the public too frequently or for long periods of time.

2.5 Manage the System Efficiently and Effectively

The Authority recognizes its responsibility as a public entity to manage the water system efficiently and effectively. This means that operations are to be conducted safely and appropriately, and that careful attention will be given to efficiency and cost-effectiveness in order to provide the greatest value to the ratepayers while meeting our standards for service.

Objectives

1) Minimize water losses and waste: Seek to continually improve water distribution efficiency by minimizing water losses, waste and in-system consumption. Monitoring of system use during start-up activities related to new water facilities will allow that use to be minimized to the extent feasible.

2) Implement measurement and monitoring technologies: Implement measurement and monitoring technologies to facilitate the accurate measurement and monitoring of flow conditions for the purposes of water accountability, determining community consumption levels, monitoring system status, and developing data for analysis and planning.

3) Fully implement SCADA: Employ appropriate technologies for improved monitoring and control of certain water system facilities that will yield benefits in terms of operational efficiency and flow control precision.

4) Support work force productivity: Support the productivity of the work force by providing adequate workplace and field site conditions, and equipping crews with all necessary tools, materials and information necessary to carry out operational, maintenance, and repair duties cost-effectively and efficiently.

5) Update and refine mapping and modeling tools as appropriate: Use up-to-date modeling and mapping tools to facilitate system analyses and decision making. Support records management activities by staff that promote the documentation of accurate, comprehensive and up to date information on the MWRA system with compilation and organization of the data and with access available to appropriate staff.

6) Optimize system operations: In designing long-term improvements, look for opportunities to optimize the operation of the system. Thoroughly review proposed engineering solutions to ensure that proposed projects will not negatively affect hydraulic performance. Consider opportunities to reduce energy costs. Look for opportunities to satisfy service area pressure requirements more efficiently by taking advantage of available hydraulic gradients within the transmission system, and by minimizing the usage of pumped water in areas where it is not necessitated by geographic conditions. Where appropriate, consider implementation of preventive measures such as corrosion protection that can extend asset life.

3 Water System History, Organization and Key Infrastructure

3.1 The Beginning - The Water System

Jamaica Pond

Boston's water supply system has had a remarkable progression dating back as far **1630** when the City was first settled and relied on water from cisterns and wells. As the City grew, so did its need to provide sufficient clean sources of water for a growing population. The pattern of looking west beyond the city for larger and cleaner water supplies repeated itself over and over again. Beginning as early as **1795,** Jamaica Pond was tapped to provide adequate water sources for metropolitan Boston, followed by Lake Cochituate in Wayland in **1846**, then, the Mystic Lakes in **1870,** and subsequently, the Sudbury River in **1872.** (See Figure 3-1, Development of the Metropolitan Water System.) At the same time, in order to ensure that there were adequate conveyance systems in place to transport the water resources, significant construction projects including the Cochituate, Mystic, and Sudbury aqueducts were completed. Boston began development of its distribution system in 1848 with the introduction of Lake Cochituate water via a system of cast iron pipes, open distribution reservoirs and, eventually, pumping stations. Other metropolitan area communities installed water works in the late 1800's such that there were already thousands of miles of smaller pipes and a variety of local sources in place by the end of the century. Poor water quality and limited yield of some of these sources, like the heavily polluted Mystic Lakes, became an issue.

Figure 3-1 Development of the Metropolitan Water System

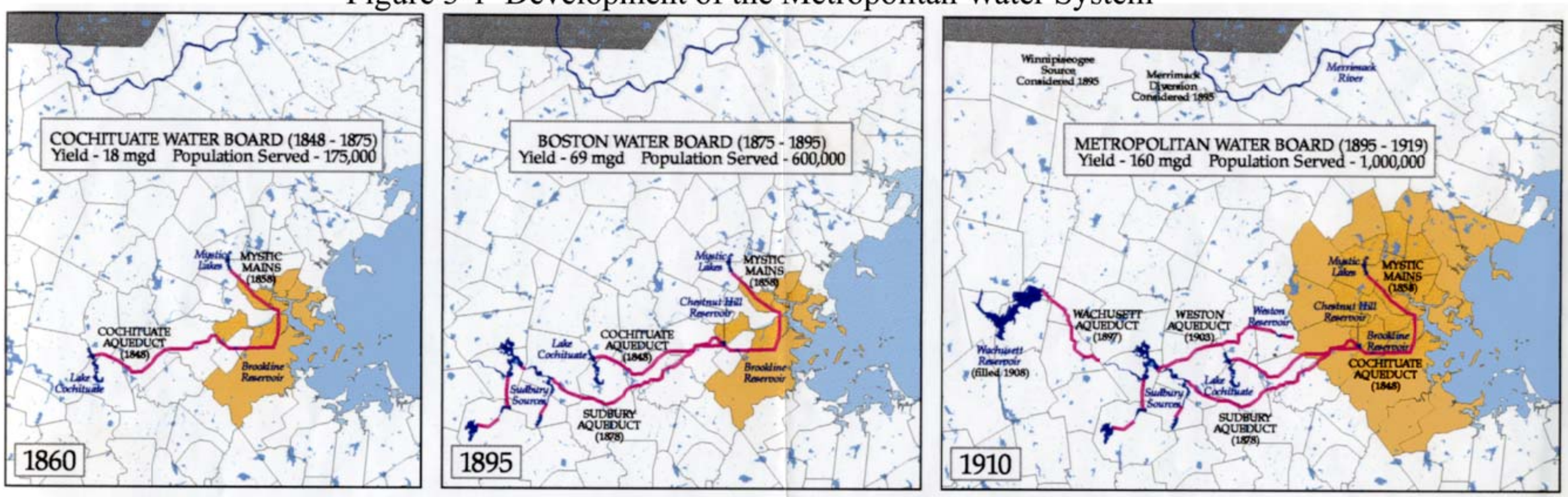
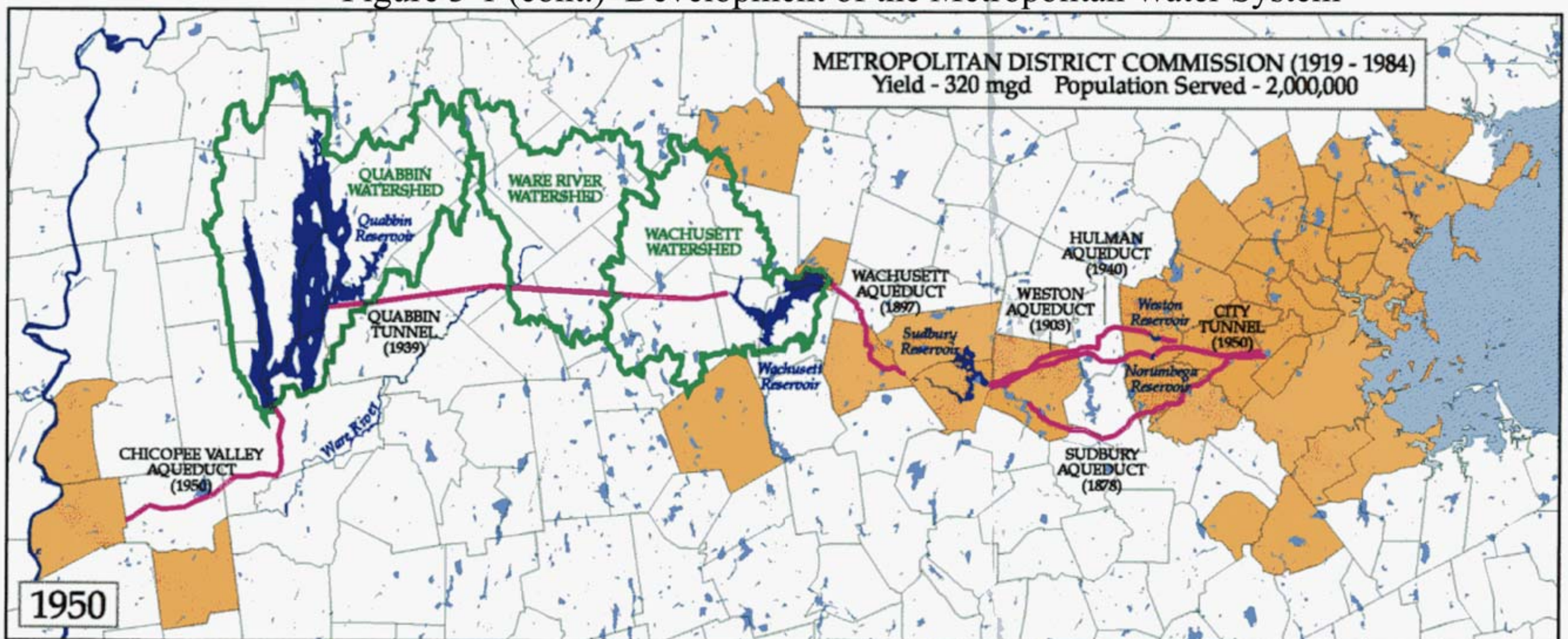


Figure 3-1 (cont.) Development of the Metropolitan Water System



By **1895**, in response to continuing growing needs spurred by population growth, the industrial revolution, and increased fire protection needs, Boston's expanding water supply system became one of the first in the nation to be integrated into a multi-municipality Metropolitan water district governed by the newly created Metropolitan Water District and Metropolitan Water Board. These two entities later became the Metropolitan Water and Sewerage Board in **1901**. Understanding the need for future planning and the need for additional water supply sources, the Board directed the construction of the Wachusett Reservoir (65 billion gallons) in **1907** which served as the principal water supply for metropolitan Boston. After World War I, it became apparent that Wachusett Reservoir would be insufficient to meet water supply needs and the State Legislature commissioned a major study in **1919** to examine other water supply sources. Later that same year, the Legislature also felt the need to create a new agency, the Metropolitan District Commission (MDC) which consolidated responsibility for metropolitan water, sewage, and parks into one agency in **1926**.

The Quabbin Tunnel, a 24 mile ling deep rock tunnel was completed in **1939** to eventually transport water from the Quabbin Reservoir to the Wachusett Reservoir. The tunnel is also used to divert water west from the Ware River into the Quabbin when such diversions are permitted. In **1944**, the MDC completed the construction of the 17.8 mile Hultman aqueduct to augment the old brick aqueduct system. The Hultman was built to deliver clean water directly from the Wachusett Reservoir to the Boston area. It was under the direction of the MDC and their visionary engineers that the last major expansion to the water supply system was finished in **1946**, with the filling of the 412 billion gallon Quabbin Reservoir (Figure 3-2). While the creation of the Reservoir brought many benefits to watershed protection and water supply for metropolitan Boston, it was not without loss. The Quabbin Reservoir was created by flooding the Swift River Valley eliminating the towns of Dana, North Dana, Greenwich, Enfield, and Prescott, Massachusetts and is one of the largest manmade reservoirs in the country accommodating over two million people in 49 cities and towns daily. This engineering feat helped lay the foundation for what continues to be today, a superb water supply source, with a gravity fed system that is the envy of many.

Historical Significance of MWRA's Metropolitan Water Supply System

Architects such as Stearns, Vinal, Olmstead and others have left their marks on many of the structures that make up the Metropolitan water supply system. As a result of the impressive architectural design and engineering features (aqueducts, bridges, reservoirs, pumping stations), it was during the mid 1980s and early 90s that the entire Metropolitan Water Supply System was listed on the National[1] and State of Massachusetts Registers of Historical Places. This initiative was undertaken by the former Metropolitan District Commission and insured that a level of historic protection not previously in place would protect the system in years to come.

[1] The National Register of Historic Places is the official list of the American cultural resources worthy of preservation. Authorized under the National Historic Preservation Act of 1966, the National Register is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archeological resources. Properties listed in the National Register include districts, sites, buildings, structures and objects that are significant in American history, architecture, archeology, engineering, and culture.

The Massachusetts Historical Commission (MHC) administers the National Register program in Massachusetts. In an effort to better coordinate projects with MHC, MWRA entered into a successful Programmatic Memorandum of Agreement (MOA) with MHC in September of 1994 to streamline review of impacts on MWRA historic properties and minimize the need for a case-by-case review of projects.

Figure 3-2 QUABBIN RESERVOIR

It would be another 66 years until another agency would be created to succeed the MDC in overseeing the metropolitan Boston's water and sewer system needs when in **1985** the Massachusetts Water Resources Authority (MWRA) was created.

3.2 The MWRA Water System Today

Created by the State Legislature in **1984** as an independent public authority, the MWRA assumed responsibility for the delivery and distribution of water to 46 communities (now 49 after recent additions). What made MWRA different from its' predecessor, the MDC, was the fact that MWRA had the ability to sell bonds and raise revenues to hire essential staff, undertake major capital projects like the Boston Harbor Project and MetroWest Tunnel, as well as handle essential day-to-day routine operation and maintenance.

Today, the water system is managed as a partnership with the Department of Conservation and Recreation (DCR) (formerly MDC), which still maintains responsibility for managing the reservoirs and watersheds. The entire water system is made up water supply sources, water treatment facilities, transmission aqueducts, pumping and storage facilities and the distribution network, all illustrated in Figure 3.3. MWRA operates an elaborate system of over 400 miles of water tunnels and distribution mains, which in turn feed another 6,700 miles of locally owned water distribution pipes.

See Chapter 8 for more detailed discussion on MWRA service areas including the Northern High, Southern High, Intermediate High, Northern Intermediate High, Southern Extra High, and Northern Extra High systems.

Recent Improvements

With the creation of a new Authority, the MWRA had the ability to issue bonds and undertake long neglected large capital improvement projects not easily undertaken under the former structure of the MDC. Upon its creation, MWRA was mandated to focus on the federal court-ordered Boston Harbor Wastewater Project that was underway from the early planning in **1985 to 1996** when the project was completed. In the early 1990's, MWRA began to focus more attention to water supply issues and established a 10 year $1.7 billion Integrated Water Supply Improvement Program. Another federally mandated program, it was designed to improve the reliability and quality of MWRA water and to meet the stringent requirements of the federal safe Drinking Water Act[2]. The Program included watershed protection, construction of new water treatment facilities, a new water transmission tunnel, covered storage facilities and distribution pipelines improvements.

- Issues such as the lack of transmission system redundancy resulted in the completion of the MetroWest tunnel in **2003**, a 17.6 mile 14-foot diameter deep rock tunnel which transports water for the new Walnut Hill Treatment Plant to the City Tunnel with a 250 million gallon daily capacity. Other new pipelines have been completed and existing pipelines rehabilitated to address immediate reliability and redundancy concerns but additional work remains to be done.

- The cyclical patterns of drought also prompted MWRA to continue its service area-wide campaign working with local communities on improved water conservation techniques.

- The federal imposed deadline associated with the Safe Drinking Water Act was a catalyst for MWRA to site new covered storage facilities resulting in six new facilities in Weston, Stoneham, Ludlow, Marlborough, Norumbega, and eventually the Blue Hills in Quincy.

- The capstone project completed in 2005 was the John J. Carroll Water Treatment Plant that treats drinking water for the majority of MWRA customers, residents and businesses in Metro West and Metro Boston communities. The Plant uses ozone as a primary disinfectant and chloramines for residual disinfection, allowing MWRA to meet current and tougher future state and federal water quality standards. The plant has the capacity to treat up to 405 million gallons of water from the Wachusett Reservoir each day, though 270 million gallons per day is the average.

[2] The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells. (SDWA does not regulate private wells which serve fewer than 25 individuals.)

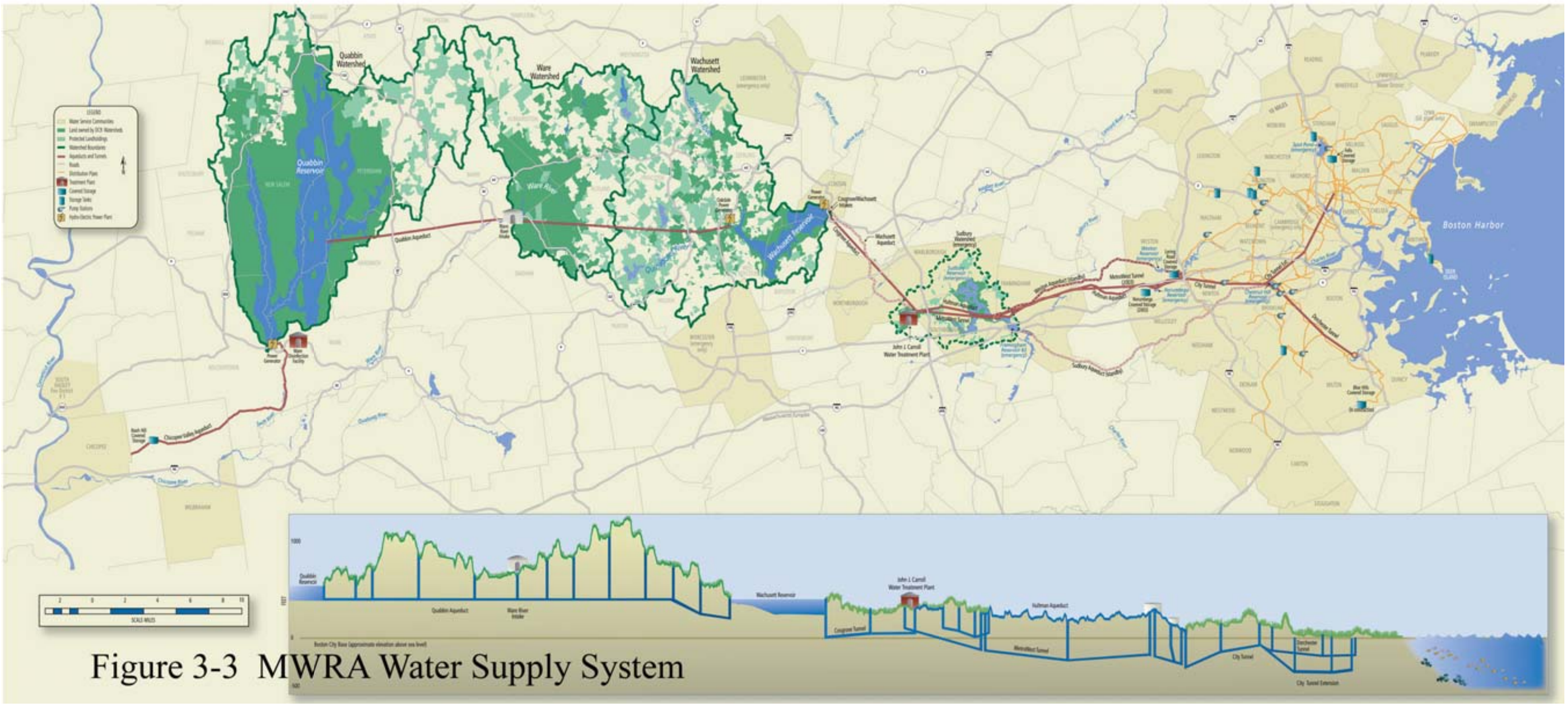


Figure 3-3 MWRA Water Supply System

- Routine pipeline inspection and rehabilitation are essential for MWRA to maintain the water distribution system and continues to be a high priority.

- Homeland Security has resulted in vulnerability assessments at key facilities and resulting facility hardening to ensure adequate safety in the daily water operations of MWRA.

Stand by Emergency Supply and Pumping Facilities

With the creation of new and improved facilities, MWRA was able to convert older facilities to standby status for emergency use only. Even though these facilities are considered standby, MWRA is still responsible for maintaining these facilities in the event an emergency situation does occur. Framingham Reservoir No. 3, Sudbury Reservoir, Chestnut Hill Reservoir, Weston Reservoir, Fells Reservoir, Norumbega Reservoir and Spot Pond all fall within this category. In addition, the Sudbury, Wachusett and Weston Aqueducts, although emergency stand by facilities, still require regular upgrades and maintenance to keep them functional in the event MWRA needs to activate any of these facilities in an emergency.

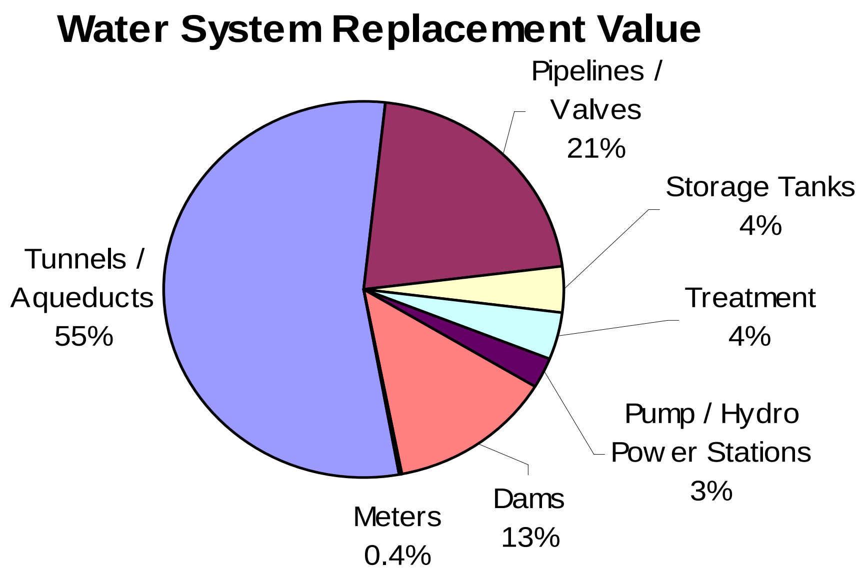
3.3 Water Infrastructure Replacement Asset Value

MWRA water infrastructure is a network of reservoirs, facilities, structures, tunnels, and pipelines. Staff spent several months developing a replacement cost valuation of MWRA's infrastructure using MWRA-specific appraisal date and actual MWRA project cost information. As shown in Table 3-1 and graphically in Figure 3-4, in 2004 staff estimated MWRA's water infrastructure had a replacement asset value of approximately $6.3 billion. These values were used where appropriate to help develop reinvestment needs.

Table 3-1
Water Infrastructure Replacement Asset Value

Asset Class	Replacement Asset Value	% of Total
Tunnels/Aqueducts	$ 3,465 million	**55%**
Dams	$ 819 million	**13%**
Treatment	$ 252 million	**4%**
Pipelines/Valves	$ 1,323 million	**21%**
Storage Tanks	$ 252 million	**4%**
Pump Stations/Hydropower	$ 189 million	**3%**
Meters	**$ 25 million**	**<1%**

Figure 3-4



3.4 The Future Years

While the early water system created in 1895 became one of the first multi municipal systems in the country, the system today in **2006**, now under the jurisdiction of the MWRA, remains one of the largest systems in the country, covering over 50 cities and towns and serving over 2.5 million people.

Parallel to MWRA's goal of carrying out its Integrated water Supply Improvement Projects and operating programs is its goal of limiting rate increases to its customer communities. The need to achieve and maintain a balance between these two goals is a critical issue facing MWRA today and into the future. MWRA remains optimistic that through smart planning, continued maintenance and upgrades of its facilities, controlling costs, and working as a partner to our service area constituencies that the Authority will successfully face and meet the challenges over the next 20 years to 2026.

4 Supply and Demand

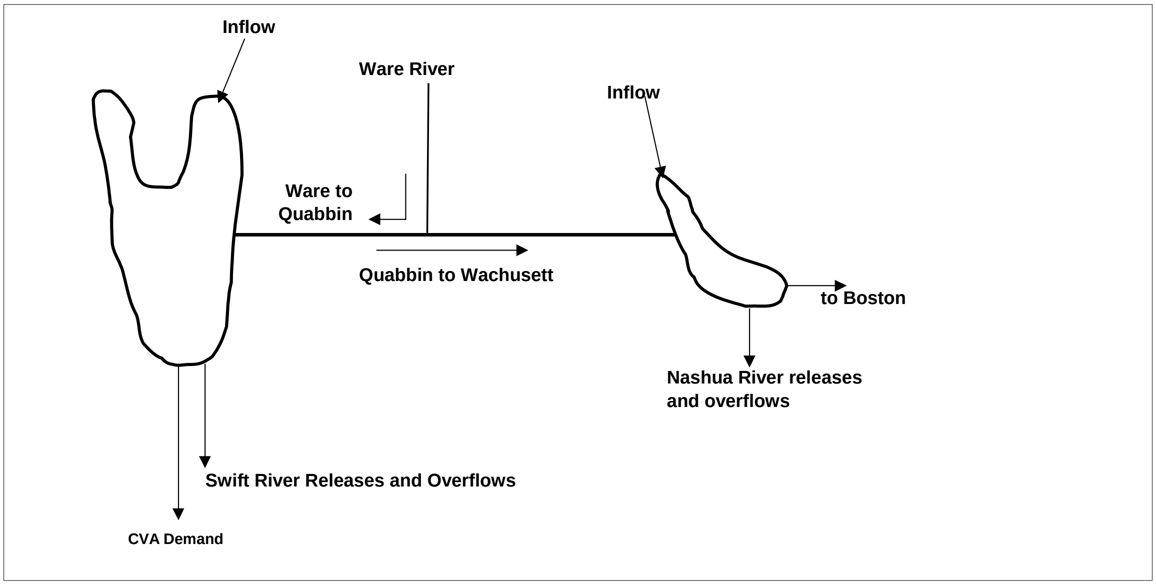
Supply and demand characteristics of the MWRA system are documented in a series of staff summaries in 2005 and 2006 and two major reports, *MWRA Water System Supply and Demand* (May 2002) and *Long Range Water Supply Planning Topics for Consideration II* (May 2006). A summary of key findings regarding supply and demand is provided below. A brief introduction to the MWRA system is provided to put the supply and capacity discussion in context.

4.1 Overview of the Water Supply System

The principal structural components of the MWRA system consist of Quabbin and Wachusett Reservoirs, the Ware River intake, the deep rock tunnels which deliver water by gravity eastwards and about 270 miles of pipe that distribute water to MWRA communities. The Quabbin Reservoir contributes about 53% of the total system yield, the Wachusett about 34%, and the Ware, 13% of total system yield. The MWRA reservoir system is operated with the primary objectives of ensuring high quality and adequate water supply and maintaining required minimum releases to both the Swift and Nashua Rivers. Another operational objective includes maintaining an adequate flood protection buffer particularly during the spring melt and hurricane seasons. Another objective is to hydropower, which is generated at two locations (Oakdale and Cosgrove Intake).

Water can flow into each reservoir from inflows or transfers (see schematic below). Flow out of the reservoirs is made up of withdrawals for water supply, required releases, and overflows when the reservoir is full. Releases are mostly controlled (i.e. result of human decision) but they can also be uncontrolled (i.e. when the reservoir fills and overflows).

Figure 4-1 Water Flow Schematic



Quabbin Reservoir

Water is discharged from the Quabbin Reservoir primarily from the Quabbin Aqueduct where it ultimately discharges into the Wachusett Reservoir, after first passing through a hydropower turbine at Oakdale Station. Quabbin flows constitute more than half of the average annual inflow to Wachusett Reservoir. Releases from Quabbin also occur through the Chicopee Valley Aqueduct to supply water to three communities west of Quabbin.

Additional outflow from Quabbin includes discharges to the Swift River at the Winsor Dam, pursuant to Chapter 321 of the 1927 Acts of Massachusetts and the 1929 War Department Requirement. The 1927 Acts of Massachusetts requires that sufficient water must be discharged from Quabbin Reservoir to provide at least 20 mgd in the Swift River at Bondsville located 5 miles downstream of Winsor Dam. No matter how low precipitation levels are, MWRA provides at least 20 mgd in the Swift. The 1929 War Department Requirement requires additional releases. From June 1 to November 30, streamflows on the Connecticut River at Montague govern the required releases from the Swift. When the daily average flows in the Connecticut River at Montague are less than the 4900 cfs and 4650 cfs, the releases from Quabbin must equal 45 mgd and 70 mgd, respectively. Between December-May, and when flows in the Connecticut River at Montague are above 4900 cfs, the minimum flow release of 20 mgd at Bondsville governs.

Wachusett Reservoir

Wachusett Reservoir is currently operated to meet three primary objectives.

The first objective is to maintain Wachusett's elevation in a narrow operating band. The range of elevations was established because it provides adequate supply to meet customer demands, minimizes shoreline erosion, provides adequate free board to minimize spillway activations (and the possibility of downstream flooding), and improves water quality by submerging gull roosting areas near the intake.

The second objective is to maintain acceptable water quality at the intake. MWRA has historically maintained water quality by mixing Wachusett water with higher quality Quabbin water, which is transferred through the Quabbin Aqueduct. Transfers from Quabbin to Wachusett are beneficial any time of the year since they lower, by dilution, the concentration of reactive organic matter considered a precursor to disinfection byproducts. Through reservoir modeling and testing MWRA has also observed the benefit of transferring water between reservoirs particularly between May and October. During this time of the year the reservoir's thermocline has developed which allows water transferred from Quabbin to move as an interflow from the aqueduct's point of discharge to the Cosgrove Intake, providing a more rapid and stronger effect. Having the higher quality water at the intake is particularly important during this period due to the relationship between warmer temperatures and disinfection processes. Testing shows that sustained flow rates of 250 to 300 mgd appear to be necessary to create this desired interflow regime. When Wachusett watershed yields are sufficient to maintain reservoir elevations within the normal operating range, and transfers of additional water for water quality purposes are made, additional releases from valves at the Wachusett Dam may and do occur.

The third objective is to meet the minimum release requirement. The MWRA currently discharges water to the Nashua River consistent with *Chapter 488 of the Acts of 1895,* which requires that not less than 12 million gallons per week must be discharged into the South Branch of the Nashua River.

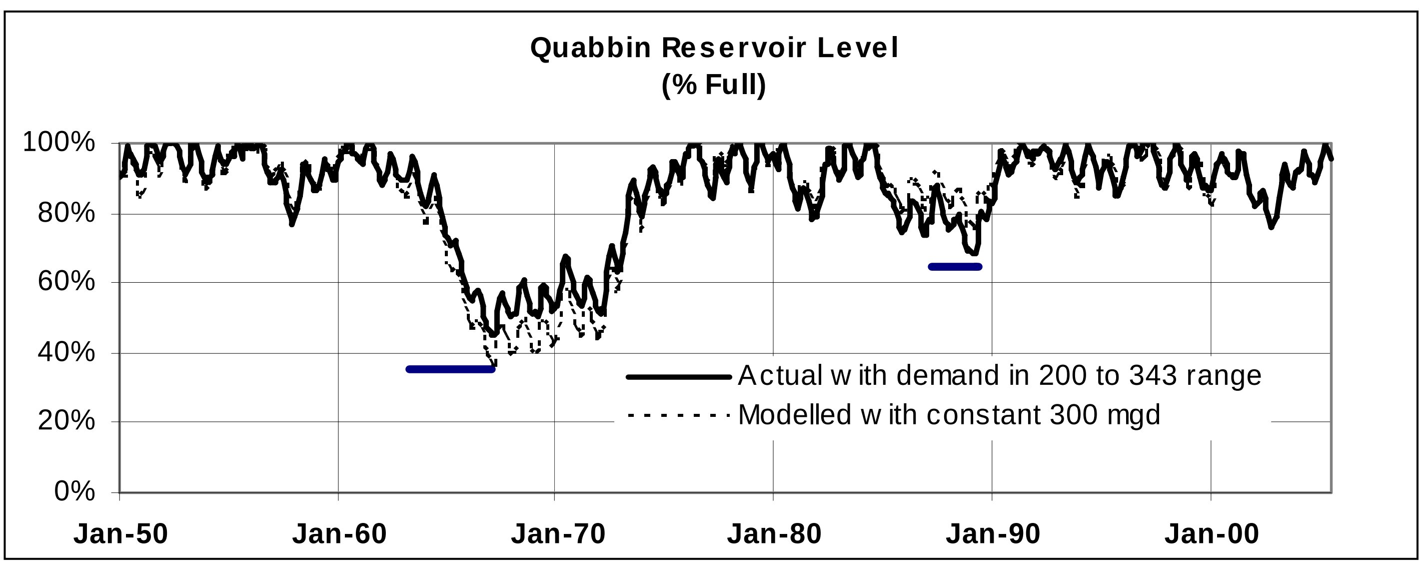
Ware River

The MWRA can increase system safe yield through transfers from the Ware River watershed to Quabbin Reservoir Ware River transfers are limited to a period when river flows exceed 85 mgd and are subject to the following conditions: no diversion of Ware River flows are allowed from June 15 to October 15. Diversions from June 1 to June 15 and from October 15 to November 30 must have prior permission from the DEP Division of Water Supply.

4.2 System Capacity

The safe yield is the quantity of water that can be reliably supplied over a period that includes a critical drought. The safe yield of the Wachusett-Ware-Quabbin system has been described as around 300 million gallons per day since the design of the Wachusett Aqueduct in 1895. Since that time, many studies have been completed – in 1922, 1950 and several during the 1980's and 1990's – which validate the number and show that 300 mgd is but a conservative estimate of safe yield. The figure below shows the modeled performance of the system during a drought as severe as the 1960s and the 1989 drought, with demands of 300 mgd as well as actual demand.

Figure 4-2



The amount of water a system can supply can be enhanced if a drought management plan is used to curtail demand. MWRA developed a Drought Management Plan in 1989 that has since been incorporated into the state plan. The objective of the plan is to conserve water through implementing demand reduction measures. Drought response actions are triggered by seasonal levels of Quabbin Reservoir. Table 4-1 presents the stages of this plan.

Table 4-1

MWRA Drought Management Stages

• **Stage**	**Trigger** Range (Quabbin % Full)	**Target Water Use Reduction**
Normal Operation	80-100	0
Below Normal	65-90	Previous year's use (Voluntary)
Drought Warning	50-75	5% (Voluntary)
Drought Emergency		(Mandatory Restrictions)
Stage 1	38-60	10%
Stage 2	25-38	15%
Stage 3	Below 25%	30%

4.3 Current System Demand

System water demand on the MDC system increased steadily during the 60's, 70's and 80's. Rather than pursue options for increasing supply, MWRA's Board of Directors opted to pursue a range of demand management strategies. Following this commitment, MWRA launched its Long-Range Water Supply Program in 1987 with 30 different recommendations and programs requiring an investment of tens of millions of dollars over the next decade. The demand management and supply protection programs were designed to reduce water use and water losses throughout the MWRA service area and prevent new demands due to local source contamination.

MWRA system demand now averages approximately 230 mgd (5-year average is 2000-2004 mgd), a decline of more than 100 mgd from the 1980 peak of 342 mgd. In 2005, exclusive of water used for the Carroll Water Treatment Plant start-up testing, total water supplied was 219 mgd. MWRA's aggressive water conservation efforts, including local leak detection and repair programs, yielded significant gains early on, with a 20 percent drop in five years. Service area demand dropped an additional 15 percent from 1992 to 2004 (the last year for which US Census data is available), at the same time that service area population increased by 2 percent (statewide, water use dropped by 5.6% while population grew 5.6%). The new plumbing code, the shift in the commercial base from water-intensive manufacturing to less intensive users, good system management, and improved metering all likely contributed to lower demand. Double-digit sewer rate increases likely also played a part in reducing water use in member communities.

MWRA serves several categories of users: fully supplied users which take all of their water from MWRA; partially supplied users which normally supply a portion of their demand with locally owned and operated surface and groundwater sources; and certain miscellaneous users. A breakdown of demand, by community, is presented in Table 4-2 and addressed further below.

Table 4-2
Population Projections and Water Demand

Service Area	Community	2000 Census	2030 Projection	2000-2030 Increase	Additional Water Demand-gpd
Intermediate High					
	Belmont	24,194	25,752		
	Watertown	32,330	33,066		
	Total	56,524	58,818	2,294	149110
Low Service					
	Boston	592,347	624,395		
	Cambridge	101,650	116,222		
	Chelsea	35,080	38,831		
	Everett	38,037	39,307		
	Malden	56,340	61,978		
	Somerville	77,493	79,867		
		900,947	960,600		
	Total w/o Cambridge	799,297	844,378	45,081	2,930,265
Northern High					
	Lynn				
	Lynnfield	11,542	12,483		
	Marblehead	20,377	21,504		
	Medford	55,765	57,628		
	Melrose	27,134	27,635		
	Nahant	3,632	3,784		
	Peabody	48,129	54,994		
	Revere	47,284	51,055		
	Saugus	26,078	28,035		
	Swampscott	14,412	15,529		
	Winthrop	18,303	19,055		
	Total	272,656	291,702	19,046	1237990
Northern	**Intemediate High**				
	Reading	23,708	26,731		
	Wakefield	24,804	27,617		
	Woburn	37,258	39,646		
	Stoneham	22,219	25,189		
	TOTAL	107,989	119,183	11,194	727610
Northern Extra High					
	Arlington	42,389	44,163		
	Bedford	12,595	13,863		
	Lexington	30,355	33,265		
	Winchester	20,810	21,822		
	Waltham	59,684	63,842		
	TOTAL	165,833	176,955	11,122	722930
Southern High off of Norumbega Supply Lines					
	Newton	83,627	83,595		
	Needham	28,911	30,752		
	Weston	11,471	13,285		
	Wellesley	26,758	28,238		
	TOTAL	150,767	155,870	5,103	331695
Southern High off of Dorchester Tunnel					
	Brookline	57,184	60,454		
	Quincy	88,025	93,740		
	TOTAL	145,209	154,194	8,985	584025
Southern Extra High					
	Canton	20,775	22,865		
	Dedham	23,464	26,317		
	Norwood	28,587	30,025		
	Milton	26,062	28,151		
	Stoughton	27,149	29,893		
	Westwood	14,117	17,769		
	TOTAL	140,154	155,020	14,866	966290
MetroWest					
	Framingham	66,910	72,008		
	Marlborough	36,255	40,308		
	Northborough	14,013	15,916		
	Southborough	9,071	10,933		
	TOTAL	126,249	139,165	12,916	839540
CVA					
	Chicopee	54,653	57,355		
	South Hadley	17,196	20,764		
	Wilbraham	13,473	14,255		
	TOTAL	85,322	92,374	7,052	458380
	Clinton	13,435	14,337	902	58630
	TOTAL	**w/o Cambridge**		137,659	8,947,835

Fully Supplied Communities

The 21 core MWRA water and sewer communities are fully supplied users that take all of their water from MWRA. Fully supplied communities also include the three Chicopee Valley Aqueduct (CVA) communities, and seven communities in the metropolitan area that are part of the MWRA water system, but not the sewer system. Average annual water demand of fully supplied communities in 2005 was 197 mgd, similar to demand in 2004 (194 mgd). In 2006, demand is tracking slightly lower.

Partially Supplied Communities

Eighteen of the communities either served or eligible to be served by MWRA (e.g., the emergency only communities – Cambridge, Worcester, and Leominster) also use water from local sources. This includes three communities/districts recently admitted to MWRA-Stoughton, Reading, and Dedham-Westwood Water District. Many of the local supplies are small and thus are subject to more significant variations in available water. Shorter-term periods of dry weather that would not have significant adverse effects on the Quabbin/Wachusett/Ware system may reduce available supply at the local level resulting in water use restrictions or the need to supplement local supplies with additional water from the MWRA.

While Leominster, Worcester and Cambridge use MWRA as an emergency back up and do not routinely purchase MWRA water, the other partial users historically, or are projected, to purchase MWRA water every year. In 2005, approximately 15 mgd of demand in the partially supplied non-emergency MWRA communities was met by MWRA (includes Stoughton, but not Reading and Dedham-Westwood which were admitted into MWRA in late 200). In these communities, on average, approximately 31 mgd was met by local sources (2000-2004 average, excluding the recently admitted communities for which five-years of data comparing MWRA to local sources is not available). MWRA's obligations to its partially supplied communities, though, are to provide the communities additional water if local sources are not sufficient. Collectively, the total demand of the emergency only communities of Cambridge, Worcester and Leominster averages 43 mgd.

Miscellaneous Uses and Obligations

Worcester's Pine Hill Reservoir is in the Quinepoxet sub-basin of the Wachusett watershed. Pursuant to Chapter 699 of the Acts of 1949, Worcester has first rights to the flows in the Quinepoxet. Therefore, Worcester's water supply indirectly exerts a demand on the MWRA/MDC reservoir system and affects system yield. Worcester's withdrawals typically account for 5-8 mgd demand on the MWRA system. Clinton is also allowed to withdraw up to 800 million gallons per year of raw water from the Wachusett Reservoir from its own intake at Wachusett Reservoir at no charge. Clinton's current demand is approximately 2 mgd.

4.4 Projected System Demand in 2030

Existing Service Area

Population projections prepared by planning agencies, primarily the Metropolitan Area Planning Council, were used as the starting point for projecting future water demand.

In January 2006, MAPC published population projections for the years 2010-2020-2030 for 46 communities of the 50 communities that are part of the MWRA service area. The Pioneer Valley Planning Commission provided projections for the three CVA communities. Projections are done routinely by the MAPC to provide an overall assessment of regional population and economic growth. Forecast methodologies included a detailed assessment of birth and death rates, age-groups, community growth trends, and net migration to develop a picture of likely growth patterns and trends. Communities collaborated and reviewed the projections, which underwent public review prior to finalization.

Population growth between 2000 and 2030 for water communities typically served by MWRA (which does not include emergency only communities of Worcester, Leominster, and Cambridge) is projected by MAPC to increase by 137,659 persons, an increase of approximately seven percent.[1] Assuming a residential consumption rate of 65 gallons per capita per day (gpcd), the total increase in residential water demand throughout the MWRA service system would be approximately 8.9 mgd. If Cambridge is included, the population increase and resulting water demand would be about 9.8 mgd. These projections assume that new population and employment growth in MWRA's partially served communities would be met by MWRA, not local sources. These projections also assume no future savings from conservation. Given the increasing focus of state water policy on reducing per capita water use and unaccounted for water and continued water use trends, decreased per capita consumption can be anticipated. Therefore, the 2030 projection of an additional 8.9 mgd in residential demand is considered conservative.

Table 4-3 presents population projections by community, and by MWRA water pressure zone/service area. Note that some communities lie in more than one service area. In these cases, the community was generally grouped into the water pressure zone where the greatest majority of its land area lay. Precisely where in the community, growth will occur is beyond the scope of this analysis, and would only lend false precision to this analysis.

MAPC also projected employment growth based on growth projections by industry sector, historic state and regional employment and sectoral trend data from the U.S. Bureau of Labor Statistics and the Massachusetts Department of Employment and Training. Most of the jobs projected by the MAPC will be professional and business services and educational and health services office and service type jobs. MAPC assigned rates of per employee water consumption

[1] An increase of 72,197 persons represents projected growth in 42 communities: it does not include Lynn, since MWRA supplies only the GE plant in Lynn, or Cambridge, since it is assumed that Cambridge would typically use local sources to meet demand.

Table 4-3

Employment Projections and Water Demand

Pressure Zone	Community	2000 Total Employed	2030 Total Employed	2030-2000 Delta	Increase Water Use (gpd/cap) Use factor 33
Intermediate High					
	Belmont	6,262	6,482		0
	Watertown	19,252	19,708		0
	Total	**25,514**	**26,190**	**676**	**22,308**
Low Service					
	Boston	558,518	596,019		0
	Cambridge	110,568	119,000		0
	Chelsea	13302	13,444		0
	Everett	10,642	10,155		0
	Malden	17,383	16,583		0
	Somerville	21,617	26,132		0
	Total	**732,030**	**781,333**	**49,303**	**1,626,999**
Northern High					
	Lynn	25,376	24,979		0
	Lynnfield	4,794	5,561		0
	Marblehead	4,650	4,759		0
	Medford	19,760	21,019		0
	Melrose	6,618	6,598		0
	Nahant	311	264		0
	Peabody	26,295	29,198		0
	Revere	8,763	9,249		0
	Saugus	11,137	11,965		0
	Swampscott	3,436	3,624		0
	Winthrop	2,548	2,521		0
	Total	**113,688**	**119,737**	**6,049**	**199,617**
Northern Intermediate High	Reading	7,211	8,050		0
	Wakefield	14,963	15,499		0
	Woburn	40,746	48,789		0
	Stoneham	7,732	8,487		0
	Total	**70,652**	**80,825**	**10,173**	**335,709**
Northern Extra High					
	Arlington	8,569	8,996		0
	Bedford	21,970	24,651		0
	Lexington	21,158	23,792		0
	Winchester	7,355	7,842		0
	Waltham	64,265	67,869		0
	Total	**123,317**	**133,150**	**9,833**	**324,489**
Southern High (off Norumbega	Newton	46,087	48,000		0
	Needham	18,363	19,892		0
	Weston	3,453	3,652		0
	Wellesley	18,650	21,138		0
	Total	**86,553**	**92,682**	**6,129**	**202,257**
Southern High (of Dorchester)	Brookline	18,691	18,340		0
	Quincy	48,270	53,316		0
	Total	**66,961**	**71,656**	**4,695**	**154,935**
Southern Extra High	Canton	19,947	23,420		0
	Dedham	14,589	15,434		0
	Norwood	24,198	26,691		0
	Milton	6,066	6,588		0
	Stoughton	12,602	15,844		0
	Westwood	10,788	12,987		0
	Total	**88,190**	**100,964**	**12,774**	**421,542**
MetroWest					
	Framingham	45,047	48,757		0
	Marlborough	27,380	32,161		0
	Northborough	6,174	7,639		0
	Southborough	5,666	6,856		0
	Total	**84,267**	**95,413**	**11,146**	**367,818**
CVA					

Note: the Pioneer Valley Region is projected to have declines in employement by 2030.

	TOTAL			110,102	3,633,366
	TOTAL	w/o Cambridge		101,670	3,355,110

that varied by employment sector. They were: 22.6 gpcd for the service (professional, business, financial activities, education, and health, other services and government) sector, 92.59 gpcd for retail and hospitality, and 15 gpcd for basic employment (everything else, including manufacturing)[2]. For the MWRA service area as a whole, the water use per employee averaged out to 33 gallons per capita per day. Using MAPC employment forecasts through 2030 and MAPC's assumption of gallons per employee per day, the MWRA water service area is projected to add 110,102 jobs with an additional water demand of 3,633,366 gallons per day with Cambridge, and 3,355,110 without Cambridge, assuming 33 gallons per employee per day. Table 4-3 above presents employment projections by community, and by MWRA water pressure zone/service area.

Projected new demand in each service area is summarized in Table 4.4 below. The greatest growth, approximately 4.6 mgd, is projected in the Low Service Area; this increased demand is but a small fraction of the delta between historical and current demand and can easily be accommodated.

Table 4.4
Existing Service Area
Projected Increase in Demand Due to Population and Employment Growth

Pressure Zone	New Residential Water Demand (mgd)	New Employment Water Demand (mgd)	Total New Demand (mgd)
Intermediate High	.149	.022	.171
Low Service	2.930	1.626	4.556
Northern High	1.237	.199	1.436
Northern Intermediate High	.727	.355	1.082
Northern Extra High	.722	.324	1.046
Southern High off of Norumbega	.331	.202	.533
Southern High off of Dorchester Tunnel	.584	.154	.738
Southern Extra High	.966	.421	1.387
Metro West	.839	.367	1.206
CVA	.458	---	.458
Clinton	.586	decrease	

In terms of total system demand, future population and employment growth is projected to be very modest – a total of 13 mgd. Adding 13 mgd to the average annual demand of the MWRA water service area for the five preceding years results in a demand estimate of 243 mgd in 2030, if it assumed that use of local sources remains roughly the same.

A factor in the overall demand on the MWRA system is the potential for changes in the use of local sources through either restrictions on use of local sources (e.g., communities in the Ipswich River Basin), decrease or loss of local sources (e.g., Reading), or potential development of new local sources (e.g. Framingham, Norwood). While it is reasonable to assume that that there will be no substantial change in local sources, as the various increases and decreases balance out, a

[2] To develop water consumption rates per employment sector, MAPC used and considered Title V estimates of water use, as well as the Institute of Transportation Engineering data, e.g., how many people are associated with each industrial/commercial/institutional use.

more conservative assumption is to provide cushion for partially supplied and emergency supplied communities to require additional water from MWRA. Assuming approximately 25% of demand now met by local sources were to be met by MWRA, this would equate to approximately 18 mgd. This would still leave a comfortable margin of approximately 40 mgd between demand from the existing service area and safe yield.

Potential Service Area Expansion

In 2006, Wilmington and the Weymouth Naval Air Station/TriTown Development are actively pursuing admission to MWRA, with demands of 1.7 mgd and 1.4 mgd, respectively. Further, Reading has discontinued normal use of its local source and is moving forward with regulatory approvals to become fully supplied by MWRA, increasing their average annual demand from .6 mgd to 2.27 mgd. Therefore, a total of approximately 5 mgd of additional demand is anticipated from these communities.

Based on a number of considerations, MWRA also identified seventeen potentially water-short communities that are not currently pursuing admission to MWRA and that are in the Ipswich River, Upper Charles River, Boston Harbor, and the SUASCO (Sudbury, Assabet and Concord) River basins. These watersheds abut, and in some cases, overlap the MWRA's water service area. MWRA's study area also included the Nashua and Chicopee River Basins where five additional communities with potential water deficits due to quantity and quality concerns were identified. 10 mgd was the potential demand from MWRA by the 22 communities not currently and actively pursuing admission to MWRA in the receiving basins that are within reasonable proximity to the MWRA water service area that have or may face water deficits. The identification of these 22 communities, though, in no way means that all these communities have expressed interest in MWRA and would be added to the system.

5 Water Quality - Regulatory Context & Requirements

5.1 Chapter Summary

MWRA decisions about water quality and treatment are made in the context of existing and expected regulations, the expectations of our customers about the taste, odor, appearance and safety of the water, and an understanding of the known and potential risks of both the water itself and the treatment processes. In addition to meeting the requirements of all the applicable EPA rules, MWRA strives to meet our customer's expectations about the quality of the water we deliver. With the advent of heavily marketed bottled waters and home filtration devices, customer expectations and misinformation about tap water have become more important drivers. MWRA staff stay abreast of current health research on drinking water topics, regularly reviewing current studies and participating in professional association expert panels both to influence the direction of future regulations and to anticipate and prepare for potential future water quality concerns.

All the existing and new regulations and changing customer expectations also affect our partially supplied communities, and the communities on the periphery of the MWRA service area, driving short and long term local treatment investment decisions as well as long term choices about using local supplies or relying more heavily on MWRA.

This chapter provides the regulatory context and requirements which drive decision making about water quality from the sources through treatment, transmission and distribution and ultimately to customers' taps. The next chapter describes the existing treatment facilities put in place to meet those regulatory requirements and customer expectations, outlines what will be required to maintain those facilities over time, and discusses what new facilities and modifications will be needed to meet new and expected regulations.

Staff will continue to carefully track new regulations and work with our customer communities to influence the rules as they develop. MWRA will continue to provide technical assistance to communities in compliance planning.

The Master Plan recommends that:

- Recognizing the importance of local pipeline condition in preserving water quality all the way to consumers' taps, MWRA should add an additional $125 million to extend the Local Pipeline Assistance Program beyond its current 2103 end date, allocating loan repayments to extend the program similar to a revolving loan fund (see Chapter 8).

- Recognizing that a continued appropriately targeted program of watershed land acquisition is necessary to avoid longer term degradation of reservoir source water quality and to preserve the flexibility of MWRA remaining an unfiltered system, that $1 to $2 million be allocated annually after 2012 for the purchase of the most critical lands which are in danger of detrimental development. It is anticipated that these expenditures will focus on conservation restrictions and that they may not be uniform as the DCR takes advantage of opportunities as they arise to prevent degradation of water quality over the medium term (10-20 years).

5.2 Existing and New Regulatory Context & Requirements

MWRA is subject to a number of issued rules by the Environmental Protection Agency (EPA) under the federal Safe Drinking Water Act (SDWA)[1]. These rules, some in place for almost 20 years, others issued in 2006 and not yet effective, include the protection of source water, treatment processes, allowable limits on contaminants entering the distribution system, and other requirements on water all the way though the MWRA and community distribution systems to the customer's tap. The SDWA also requires that EPA review each rule every six years, resulting in a continuing series of changed requirements. The SDWA was enacted in 1974, and amended in 1986 and 1996. The 1986 and 1996 amendments introduced a number of additional requirements which the EPA is still in the process of incorporating into regulations. Table 5-1, below summarizes the applicable current and expected future rules.

Table 5-1

Promulgated Rules – Already Effective

Trihalomenthane (THM) Rule (1979)	This rule established the first limits (maximum contaminant level or MCL) for the byproducts of chlorine disinfection. The limit for the group of THM disinfection byproducts (DBPs) was set at 100 ug/l as an annual average. Two sets of new DBP rules have since modified this rule.
Surface Water Treatment Rule (1989)	This rule affects all systems using surface waters (or ground waters under the influence of surface water). It required filtration unless certain criteria on source water quality, watershed protection and disinfection effectiveness could be met. Several rounds of additional rules have added requirements to the SWTR
Total Coliform Rule (1989)	This rule requires regular and frequent monitoring of water quality within the MWRA and community distribution systems for indicator bacteria and chlorine residual. If more than 5% of the samples in a given month are positive for total coliform bacteria, a violation occurs and the public must be notified.
Lead and Copper Rule (1991)	This rule sets "action levels" for lead and copper levels in worst case samples at selected customer's taps. It requires corrosion control, and mandates education and lead service line replacement if more than 10% of tested homes are above the "action levels"
Information Collection Rule (1996) Unregulated Contaminants Monitoring	These rules are part of EPA's process for collecting the necessary information on the nation-wide occurrence of contaminants in order to determine if they ought to be regulated and what the benefits and costs

1 EPA issues rules under the SDWA. Generally, state environmental or health agencies in each state accept primacy under the SDWA, and issue their own rules to implement the EPA rules. Massachusetts Department of Environmental Protection (DEP) has primacy for almost all drinking water rules, and thus MWRA is usually regulated directly by the DEP, although EPA is an active participant in most decisions. Certain aspects of current rules require formal EPA concurrence, and generally it takes about 2 years for DEP to accept primacy for new rules.

Rules (1995 and 2005)	of that regulation will be. The ICR collected information on *Cryptosporidium* and DBPs. The UCMR establishes a new list of microbial and chemical contaminants to be tested for every several years.
Interim Enhanced Surface Water Treatment Rule (1998)	This rule added more stringent requirements on filtration processes for those large systems which filter, and a maximum contaminant level goal and watershed protection requirements for *Cryptosporidium.*
Stage 1 Disinfection/Disinfection Byproducts Rule (1998)	This rule tightened the THM limits from 100 to 80 ug/l and added limits on haloacetic acids (HAAs) at 60 ug/l and bromate at 10 ug/l. It became effective in January 2002.
Long Term 1 Enhanced Surface Water Treatment Rule (2000)	Established standards similar to those of the IESWTR for smaller systems
Inorganic Compounds Volatile Organic Compounds Synthetic Organic Compounds	Set MCLs for specific contaminants. Periodically updated with additional contaminants.
Consumer Confidence Rule (1998)	While not strictly a water quality rule, the CCR rule requires that systems publish an annual water quality report describing where the water comes from, how it is treated, and what contaminants are found in it.
Promulgated Rules – Not Yet Effective	
Long Term 2 Enhanced Surface Water Treatment Rule (1/2006)	This rule will require that systems using surface water test for *Cryptosporidium* and add additional treatment based on the levels. Unfiltered systems must achieve at least 99% inactivation, and must use two separate primary disinfection systems.
Stage 2 Disinfectants/ Disinfection Byproducts Rule (1/2006)	This rule will further tighten standards for DBPs by requiring sampling in locations expected to be high, and by changing the averaging method.
Groundwater Rule (11/2006)	This rule will require a tiered monitoring, protection and treatment protocol for groundwater to identify and remediate the systems with the highest risk to public health. May require disinfection of many currently untreated groundwater sources.
Proposed and Anticipated Rules	
Short-Term Regulatory Revisions and Clarifications to the Lead and Copper Rule (2007)	These changes and clarifications to the LCR are expected include a revamped more flexible, public education requirement, better clarity on sampling and reporting schedules, and additional requirements for the review of treatment changes to attempt to identify situations where lead levels may be increased by other actions. Draft rule was published in July 2006.
Distribution System Rule OR Revisions to the Total Coliform Rule (2008)	This rule is expected to focus intensively on management and control of the distribution system, including additional or better focused monitoring. It will include a focus on unlined cast iron pipe and older poor condition pipe. It is expected to replace the Total Coliform Rule. Alternatively, EPA may choose to update the TCR, and do a more comprehensive rule later.

5.3 Treatment and Source Water Related Rules

The series of rules related to the Surface Water Treatment Rule, most recently culminating in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR or LT2), mandates treatment of surface water (and groundwater under the influence of surface water). Generally filtration is required, but under a narrow set of criteria very well-protected sources like MWRA’s Quabbin and Wachusett Reservoirs may receive a “waiver” of the filtration requirement. Until the LT2, the SWTR was essentially a “one-size-fits-all rule, with every system being required to remove or inactivate 99.9 percent of *Giardia*[2] regardless of source water quality. Finally under the new LT2, source water quality will be considered in determining the level of treatment required, with poorer quality sources (those with higher levels of *Cryptosporidium)* requiring more treatment or other protective actions.

The filtration avoidance requirements include 11 criteria all of which must be continuously met to maintain the waiver. These criteria have not changed substantively with the recent rules.

- Low levels of source water quality fecal bacteria
- Low levels of source water quality turbidity
- Adequate watershed protection
- Adequate inactivation of *Giardia* and viruses
- Redundant disinfection equipment to ensure reliability
- Adequate and consistent disinfectant residual levels at the entry point
- Adequate disinfection residual levels within the distribution system
- Compliance with the disinfection byproducts rules
- Low levels of total coliform bacteria within the distribution system
- No evidence of waterborne disease outbreaks
- Adequate performance on annual on-site inspections

MWRA Compliance History with Surface Water Treatment Rule

When the SWTR came into effect, the Wachusett Reservoir did not initially meet the avoidance criteria, as source water fecal bacteria levels were substantially over the allowable limit. As a result, while a watershed protection plan was developed, an initial decision was made in 1991 to build a filtration plant. Subsequent implementation of the watershed plan by the MDC (now DCR[3]) Watershed Division demonstrated that the high bacteria levels were due primary to flocks of gulls roosting on the Wachusett reservoir. Employing various actions to reduce the attractiveness of the region to gulls by better management of local landfills, and harassing the gulls at dusk reduced the number of roosting gulls and bacteria levels dropped dramatically, bringing the reservoir into compliance with this source water criterion by 1993. MWRA then entered into a dual track scheduling Administrative Consent Order with DEP: the ACO required the siting and design of a filtration plant, but allowed MWRA and DCR until 1998 to demonstrate compliance with all criteria and request a waiver of filtration just prior to construction. The watershed protection plan and related activities are discussed later. This section provides a very brief overview of MWRA's compliance history as it is germane to the decision process on treatment going forward. A slightly longer version appears at the end of this chapter and provides more background on the decisions which have been made to date on treatment technologies.

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2 *Giardia* and *Cryptosporidium* are two protozoan pathogens which can cause gastro-intestinal illness. Both are excreted with the feces of certain warm-blooded animals, and exist in the environment in a protective cyst which protects them from certain kinds and levels of disinfection. Because they are had to disinfect, they are used as the target organism in various rules.

3 Hereinafter, all references to the Watershed Protection Agency, whether to the MDC or later to the DCR, will simply be made to DCR.

As the decision point in 1998 approached, staff provided a wide ranging series of briefing documents to the Board of Directors on treatment, and in October 1998 the Board decided to request from DEP a waiver of the filtration requirement. As part of this, MWRA would continue as an unfiltered water system and implement an integrated water supply improvement program from the source reservoirs to the consumers' taps. The $1.7 billion 10-year program would include improvements to watershed protection, completion of the Metro-West tunnel, building an ozone disinfection facility capable of inactivating *Cryptosporidium*, replacing all MWRA open distribution reservoirs with covered storage, implementing a $250 million zero-interest loan program for communities to replace old unlined cast iron water mains, and a commitment to monitoring water quality and health outcomes and re-evaluating the decision once the plant was on-line.

DEP approved MWRA's decision, but the Environmental Protection Agency did not agree with MWRA's approach and sued in federal court. After an extended legal process, MWRA's decision was upheld, and the ozone plant, dedicated as the Carroll Water Treatment Plant, was constructed and placed into operation in July 2005. The plant has generally performed as expected. Inactivation was greatly increased, reaching the site-specific inactivation targets of 99 percent inactivation of *Cryptosporidium*, as well as greatly increasing the inactivation of viruses and *Giardia* beyond those required by regulation. Disinfection byproduct levels were reduced even more dramatically than anticipated. While a higher chloramine dose than originally anticipated was required, once adjusted, disinfection residuals throughout the distribution system were generally as good as or better than before.

The Quabbin Reservoir had a much less significant issue with roosting gulls, and met the source water quality criteria. MWRA and DCR implemented the watershed protection plan, built interim disinfection facilities by reusing an existing chlorine injection system, and then proceeded to design and build a modern chlorine disinfection facility in Ware (2001) and replace the open distribution reservoir at Nash Hill with two covered storage tanks (1999).

New Treatment Rules

All the while MWRA was working towards the construction and operation of new facilities to comply with the SWTR, EPA was developing new rules as described in Table 5-1. While several new rules relating to surface water treatment and disinfection byproducts were promulgated during this period, none had a substantive impact on the decisions made and the processes being built. The CWTP came on line, and complied with all current regulations in July 2005.

On January 4 and 5, 2006, EPA finally issued their long anticipated new microbial and disinfection products rules[4]. These two rules will require upgrades to both the CVA and metroBoston treatment systems, and will mandate changes in monitoring programs.

4 The rules were developed using a regulatory negotiation process under the Federal Advisory Committee Act (FACA), which allows the creation of stakeholder committees (called FACAs) to agree upon and recommend approaches to complex regulatory issues. The interests of unfiltered water systems were provided a specific representative on the panel, and MWRA was an active caucus member and commented on pre-proposal and official drafts throughout the process. The FACA process began in essentially in November 1997 and culminated in September 2000 with an Agreement in Principle (AIP) which represented the compromise position of all the stakeholders. As reported to the Board at that time, notable in the agreement was the "deal" that there would remain

The pair of rules, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2, for short) and the Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 D/DBP or Stage 2), focus on the control of *Cryptosporidium* and on further reducing the amounts of chlorine disinfection byproducts to which consumers are exposed. The rules are the latest in a series of rules focusing on these issues. The LT2 Rule brings to closure EPA's efforts since the Milwaukee *Cryptosporidium* outbreak in March 1993 to tighten drinking water treatment to protect against that pathogen. It is also the first microbial treatment rule to consider source water quality in mandating treatment levels, moving away from EPA's former "one-size-fits-all" approach. The Stage 2 Rule marks a shift in EPA's focus on disinfection byproducts from only looking at long-term cancer health outcomes of DBPs to the possibility that they might also have shorter term developmental or reproductive effects (low birth weight, birth defects or miscarriages).

The two rules were developed in tandem because of the recognition that there is a strong potential for what is called a risk-risk trade-off: improvements to inactivate more pathogens may cause utilities to take actions that increase disinfection byproducts or improvements to reduce disinfection byproducts may actually reduce the effectiveness of treatment against pathogens[5].

The focus of the pathogen rules since 1993 has been on understanding and controlling the potential risk due to *Cryptosporidium*. In March 1993, over 400,000 thousand people became sick and as many as 100 died in Milwaukee due to an outbreak of Cryptosporidiosis caused by inadequate treatment of polluted source water. Research since then has shown that *Cryptosporidium* can be very infectious, with as few as one oocyst needed to infect an individual, that many source waters contain the organism, and that some infectious oocysts can and do breach even well run conventional filtration plants. It is clear that nationwide some systems are at risk. MWRA conducts very sensitive tests for *Cryptosporidium* and finds evidence of its presence occasionally at very low levels, but generally only empty oocysts regarded as unlikely to be infectious.[6] No firm conclusion about health risk can be drawn given the inadequacies of current testing methods, but MWRA levels would be considered very low even based on levels leaving conventional filtration plants, and MWRA's treatment provides some inactivation of any oocysts that are potentially infectious.

Concurrent with the attention on *Cryptosporidium*, EPA was under increasing pressure to recognize that the format of its earlier rules presented essentially a "one-size-fits-all" approach to a more complex nationwide situation. EPA's own research agenda[7] clearly pointed out the

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an unfiltered option, but that unfiltered systems would use two primary disinfectants as a "multiple barrier" and provide at least 99% *Cryptosporidium* inactivation. Over the next 5 years, EPA developed the draft and final rules based on the compromises reached in the AIP. Staff provided a series of updates to the Board on the evolving regulations.

5 It has also become increasing clear that this issue of "simultaneous compliance" affects all attempts to improve treatment and water quality. Corrosion control efforts can affect disinfection effectiveness, and changes in disinfection or filtration chemicals can affect corrosion control and cause lead levels to increase.

6 The current EPA approved testing protocol for *Cryptosporidium* calls for filtration and examination of 10 liters of water. The test has relatively low recovery efficiency (approximately 40%) and cannot actually distinguish whether the oocysts are live and potentially infectious. MWRA tests raw water weekly at the CWTP and every other week at Quabbin, and filters and examines 50 liters. MWRA is also conducting research using weekly 1000 liter samples collected at Shaft 9A in Malden.

7 Draft Report on Research to Support New Rules, EPA, November 12, 1997

fallacy of that approach, showing that some locations had too little protection, while others may have been forced into over-investing on unneeded protection. Thus the big push in the development of the LT2 rule was to develop a risk based regulation, with treatment tailored to the degree of risk.

The new LT2 calls for tiered treatment by both filtered and unfiltered water systems based on *Cryptosporidium*; testing of source water; retains an option for unfiltered systems; and mandates changes in existing uncovered distribution storage reservoirs. The retention of the unfiltered option was a significant victory, as the additional requirements for remaining unfiltered – 99% *Cryptosporidium* inactivation and use of a second primary disinfectant – are reasonably achievable and less costly than filtration.

For the MWRA system, the most important impacts of these new regulations are:

- required inactivation of *Cryptosporidium;*
- required second means of primary disinfection: and
- higher than anticipated "CT" requirements that translate into higher ozone doses.

Combined, these standards will require the addition of a second disinfection process at both the John J. Carroll and Ware Water Treatment Plants by 2014. As discussed in more detail in Chapter 6, staff propose to meet the requirements by adding ultraviolet light (UV) disinfection at both plants.

New research on disinfection byproducts continues to raise the possibility that in addition to risks for certain cancers, high levels of DBPs may affect the developing fetus, possibly resulting in lower birth weight, developmental problems or birth defects, and miscarriages. While the science is still uncertain on this issue, and research papers both supporting it and suggesting that there may not be an effect continue to be published regularly, the level of concern is such that the consensus of those working on the new regulations thought that it was prudent to call for reductions[8]. The new rule shifts the focus from a long term average exposure across the entire region, to shorter term exposures in specific locations.

Essentially the new Stage 2 D/DBP rule requires that water systems look for chlorinated DBPs where they are most likely to be high, and then adjusts the compliance calculation to focus on an annual average at each of these locations. Currently high and low locations are averaged together. This new locational running annual average (LRAA) has the effect of reducing the chance of higher exposures. There are also provisions dealing with how to respond to individual high results even when a system remains in compliance and on preventing treatment changes intended to reduce DBPs from degrading pathogen inactivation. The rule made no change in the standard of 10 ug/l for bromate, a byproduct of ozonation of water with elevated levels of bromide.

8 There have been two research papers published on MWRA water (prior to the start-up of the Carroll Water Treatment Plant) suggesting a potential effect on birth weight, but each has had methodological issues weakening the power of the conclusions. In any case, the level of disinfection byproducts has been dramatically reduced by the switch from free chlorine to ozone for primary disinfection.

For the MWRA system, there should be little impact beyond the requirement for additional sampling. Bromate levels are not expected to be a problem, and the dramatic reductions in THMs and HAAs brought about by the switch from free chlorine to ozone for primary disinfection will mean that no fully supplied community should have any risk of exceeding the new standard. Furthermore the low levels are expected to allow MWRA and the communities fully supplied by the CWTP to avoid an initial extensive sampling program, for a savings of about $500,000.

5.4 Distribution System Rules

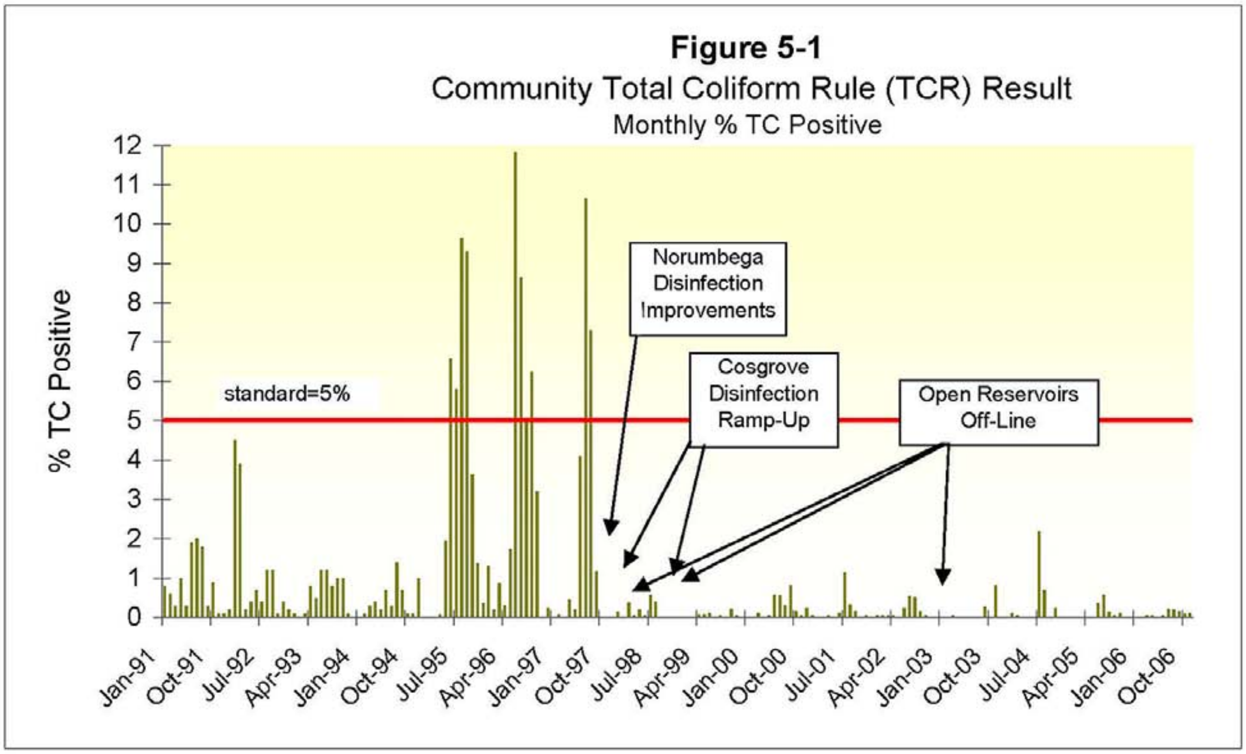
The principle current rule related to water quality within the distribution system is the Total Coliform Rule, promulgated in 1989. The rule requires an extensive monitoring program at locations within the distribution system which are representative of system wide water quality. Each community and the MWRA have their individual monitoring program. Across the MWRA/community system, over 2,400 samples are collected each month at over 460 locations. Larger communities collect samples weekly; smaller ones less frequently; and MWRA collects samples at key locations daily. Each sample includes a total coliform result, a chloramine residual measurement, temperature and heterotrophic plate count (HPC) bacteria results if the chloramine residual is very low.

The total coliform test is an *indicator* of overall water quality – not a direct test for pathogens. Total coliform bacteria can come from the intestines of warm-blooded animals, or it can be found in soil, plants, or other places. Most of the time, these bacteria are not harmful. However, their presence could signal that harmful bacteria from fecal waste may be there as well. The TCR requires that no more than 5 percent of the samples in a given month may be positive for total coliform. If a water sample tests positive for total coliform, more specific tests for E. coli are conducted. *E. coli* is a specific coliform species that is almost always present in fecal material and whose presence indicates likely bacterial contamination of fecal origin. If *E. coli* are detected in a drinking water sample, this is considered evidence of a critical public health concern. Additional testing is conducted immediately and joint corrective action by DEP, MWRA, and the community is undertaken.

If more than 5% of all samples are total coliform positive in a month (or more than one sample when less than 40 samples are collected each month), public notification is required usually via advertisement in the local paper. Public notification is also required if follow-up tests confirm the presence of *E. coli*.

The total coliform rule monitoring program is jointly conducted by MWRA and the communities. Communities conduct the actual field sampling, and MWRA's laboratories do the analysis and reporting. In addition, a portion of the MWRA's TCR monitoring program includes the results from the community sampling location nearest the MWRA connection.

The total coliform sampling results are also used in the aggregate as one of the criteria for maintenance of the filtration waiver. No more than 5 percent of all samples system-wide in any month can be positive.



With improvements to treatment and the removal of the open distribution reservoirs, the system wide total coliform positives have been reduced substantially over the past decade.

While the aggregate results are much lower, there are still occasional total coliform positives both within the MWRA system and in some community systems. Often there is a single positive sample, and none of the repeat samples are positive. These are difficult to categorize and assess. Other community positives are related to local distribution issues, especially storage tanks and low chlorine residuals. When these occur, communities can take local action to improve the residuals by flushing or tank draining, and the situation corrects itself. Less frequently, communities will have actual contamination within a tank, and the tank must be drained and cleaned.

Positive total coliform samples within the MWRA system have also been substantially reduced especially since the ozone plant went on-line, although the system still does experience some positive samples. MWRA has never violated the TCR within its own system. Occasional positive samples can occur at almost any sampled location; however, in the summers of 2005 and 2006 there are more frequent positive samples just downstream of treatment within the CWTP[9]. The cause of these positives is not well understood, and is still being investigated.

9 These positive samples occur at the “Finish Water A and B” locations (typically noted as Fin A or Fin B). They appear to be more common during warmer water temperatures, although with only just over one year of plant operation it is probably premature to make that assumption, as there are other factors which can vary across the year as well. A series of investigations, including consultation with an outside expert have occurred, and a number of system modifications and maintenance actions have or will occur.

Along with the bacteria results from the community and MWRA distribution systems, MWRA tracks the chloramine residuals. There is an upper regulatory limit on the annual average of these samples of 4.0 mg/l, but as levels at the entrance to the distribution system are typically 2 to 2.5, it is unlikely that the MWRA or community systems would exceed the limit. More important is the reduction of chlorine residuals across the distribution system, and what the lowest levels are. As with total coliform results, treatment changes over the past decade have resulted in substantial improvements.

Table 5-2 Improvements to Distribution System Chlorine

	Chlorine Residual Below 0.2 mg/l	Chlorine Residual Above 1.0 mg/l
1995	57%	2%
1996	47%	1%
1997	33%	5%
1998	8%	51%
1999	3%	74%
2000	5%	76%
2001	4%	75%
2002	5 %	70%
2003	4%	63%
2004	5%	69%
2005	5%	71%
2006	5%	75%

MWRA considers a disinfectant residual of 0.2 mg/L a minimum target level at all points in the distribution system. Many of the community systems currently have at least one location which does not meet the MWRA goal. Generally this is due to the condition of community pipes, and to prolonged detention with pipes and tanks in the community system. In addition to the *goal* of no locations below 0.2 mg/l, MWRA maintains a triggering level based on the number of samples below 0.1 mg/l. If the percentage of samples below 0.1 mg/l exceeds 5 percent, MWRA adjusts treatment and considers other actions. Generally these levels are between 2 and 3 percent each month.

5.5 New Distribution System Requirements:

EPA is overdue in conducting their statutorily required six-year review of the total coliform rule. As they began to consider what might need to be changed in the rule, and solicit input from utilities and others, it became clear that simply updating the TCR might not be sufficient. Therefore EPA has begun an effort to potentially replace the TCR with an entirely new Distribution System Rule. As EPA has only begun the process of regulatory development, an actual rule is still several years away.

Because of the wide ranging potential for required changes in operations and facilities, MWRA staff will carefully track this new rule.

The Microbial and Disinfection Byproducts (M/DBP) Federal Advisory Committee (FACA) which negotiated the LT2 and Stage 2 rules, also agreed in principle that valid health concerns from distribution systems exist, and that EPA should review available data and research on distribution system risks and work further with stakeholders. These efforts were expected to result in the review and possible revision of the TCR, as well as the potential for requirements to address finished water quality in the distribution system.

EPA, in association with distribution system experts, has begun to compile existing information regarding potential health risks that may be associated with distribution systems in "white papers" on nine distribution system issues. In addition, EPA is involved in the development of a series of ten TCR issue papers (with AWWA and others). All distribution system white papers and TCR issue papers will be used to inform EPA and stakeholders of areas of potential TCR revisions and distribution system requirements. MWRA is participating in an AwwaRF effort in support of better sampling and response protocols for total coliform and *E. coli*. Staff will also participate in AWWA and AMWA efforts as part of the stakeholder process for this new rule.

At this point EPA is only at the identification of issues stage, and has issued the following white papers for discussion:

- Intrusion
- Cross-Connection Control
- Aging Infrastructure and Corrosion
- Permeation and Leaching
- Nitrification
- Biofilms/Growth
- Covered Storage
- Decay in Water Quality over Time
- New and Repaired Mains

It is clear that as treatment has improved nationwide, that there are still potentially important risks to water quality and public health after the water leaves the treatment plant. MWRA’s approach to investment over the past decade mirrors that understanding, focusing on water quality all the way to the tap with substantial investments in MWRA distribution system storage and MWRA and community pipeline rehabilitation. Looking at the range of issues in the white papers prepared to date, it is clear the EPA will likely take a more careful look at storage tank maintenance and operation, internal condition of pipes, the possibility of contamination getting in through small holes in pipes and aging infrastructure and corrosion. The degradation of water quality which occurs as the water “ages” in pipes and tanks, and the potential of pathogen growth (or at least increased biological activity) within the pipes will also be important.

MWRA already has adopted many of the best practices for operations and maintenance being discussed, so the impact on the MWRA system operations may be limited. Some community systems may be less prepared to comply with any new requirements.

It is also clear that many of the potential distribution system health risks (or at least opportunities for degradation in water quality) are related to the age and condition of the buried infrastructure.

There is a substantial potential for increased attention and investments by communities in their own distribution systems. The recommended remedial action for many of the identified problems is essentially rehabilitation of old unlined cast iron pipelines, and replacement of pipe which is in poor condition[10]. MWRA created the Local Pipeline Assistance Program as part of the 1998 Board Decision on Treatment Technology recognizing that regardless of the level of treatment provide by MWRA, the water must pass through the pipe network before reaching customers. That program created a pool of $250 million in zero interest loans for the rehabilitation or replacement of unlined cast iron pipe[11]. At the time of the decision, 45 percent of the pipe in community systems was unlined. Since then, $148 million[12] has been loaned to communities resulting in about 278 miles of pipe rehabilitation or replacement, representing about 5 percent of the total pipe length. There is still a long way to go, and several times the $250 million will need to be invested by communities before all the old tuberculated pipe is removed. At current rates, it will take about 80 years before the last of the community unlined pipe is removed.

<u>Recommendation-Distribution system</u>

- *Prior to the completion of the Local Pipeline Assistance program in 2013, it is recommended that MWRA add an additional $125 million to extend the program, allocating loan repayments similar to a revolving loan fund. MWRA will also need to find additional ways to encourage a continued long term program of local pipeline rehabilitation.*

While MWRA cannot directly affect the rate of community efforts to deal with poor quality pipelines, and as MWRA pipeline rehabilitation will also take decades to complete, source water quality, treatment and potential distribution system impacts of treatment are within MWRA's more immediate control.

5.6 Interaction between Treatment and the Distribution System

Ozone breaks down complex naturally occurring organic carbon compounds into smaller compounds. There is concern that increased levels of these smaller compounds, referred to as biologically degradable organic carbon (BDOC) or assailable organic carbon (AOC) could lead to the proliferation of biological activity within the distribution system. Frequently, biologically active carbon filters are added after ozone to capture the BDOC by allowing bacteria to grow and feed upon the organic material in the water. During the treatment technology decision process, extensive research on this topic was undertaken to determine if filtration would be required after ozonation in the MWRA system, using both laboratory bench scale and pilot testing using actual old tuberculated cast iron water mains. Based on the results of the research, MWRA and its

10 EPA requested that the National Research Council conduct a study of what the risks associated with distribution systems were. Their report, *Public Water Supply Distribution Systems: Assessing and Reducing Risk* published in 2006 focused extensively on the issue of unlined cast iron pipe. Interestingly, they also raised the issue of the potential degradation of water within home (or "premise") plumbing.

11 Since then, the program was expanded to include newly joined communities and to allow the replacement of lead service lines as eligible projects. There was also an earlier pilot phase of the program which provided $30 million in grants and loans.

12 $30 million from the pilot program and $118 million from the current loan program.

research team drew the conclusion that proper corrosion control and the maintenance of an adequate chloramine residual throughout the system were more important than the level of BDOC in preventing issues within the distribution system. Based in part on those research conclusions, MWRA decided that treatment with ozone alone was feasible. The performance of the distribution system and levels of chloramine residual would be carefully watched after the treatment change.

During the first year of operation, there have not been indications of widespread distribution system problems. The initial dose of chloramine was raised somewhat, and with the higher initial dose, residual levels throughout the system were able to be maintained at least as high as prior to startup. There have been some indications of increased nitrification in areas with very high water age, but there does not appear to be any system-wide change at this point. Overall total coliform levels are similar or lower than pervious years, although there have been some localized issues immediately downstream of the CWTP (at least in one community served by a single 30 inch feed line, rather than the MetroWest Tunnel or Hultman Aqueduct[13]). As discussed above, MWRA is taking an aggressive and through effort to understand and resolve this issue. To date the issue has not presented itself as a systematic problem, but as of the end of 2006, no complete explanation has been developed, and staff continue to research and monitor the situation.

Initially it was felt that if there was going to be an issue with the higher levels of BDOC, that it would be in areas of the system with lower disinfection residuals, typically distant unlined cast iron mains. Thus far that does not appear to be the case and total coliform and background bacteria counts are among the lowest ever experienced, although it is possible that the effects are cumulative and another warm water season will add sufficient growth to cause a problem. There will continue to be some uncertainty about the longer term impacts of increased levels of BDOC, particularly until the current issues immediately downstream of the plant are resolved. *If it is determined that the higher levels of BDOC do present a problem which cannot be resolved by changes in how the plant and system are operated, it is possible that additional remedial actions will be required including community flushing programs, higher chloramine levels, and more aggressive targeted pipeline rehabilitation efforts. If BDOC were a problem, and it could not be resolved by those remedial efforts, filtration might ultimately need to be added to the CWTP.*

5.7 Organic and Inorganic Contaminant Rules

MWRA is required to test for and meet maximum contaminant level (MCL) standards for over 100 specific chemicals. Generally only a few are found and at levels well below the MCL. Results are required to be included in MWRA's annual water quality report each year and generate a few questions from consumers. MWRA has never failed an MCL for any of these regulated contaminants.

13 In July and August 2006, both MWRA's sampling tap at the CWTP and the first sampling location downstream in Marlborough had total coliform positives. No other locations within the metroBoston system or the rest of the Marlborough system appear to be affected. The closeness in time and location were strong evidence that the two issues were related, and research efforts are focused on both the plant and the connecting pipeline.

The SDWA requires that EPA engage in a periodic process to determine whether additional contaminants should be regulated, and Massachusetts has a parallel independent process as well. The process generally includes research into chemicals which may potentially have negative health effects, and which may be present in drinking water. Once these candidates are identified, EPA or the state will require that systems conduct "occurrence" sampling to estimate the prevalence and levels of the chemical. If the toxicological and epidemiological research indicates there is a health effect, AND the chemical is present AND EPA determines that there is a way to reduce the levels, then they will issue a standard. This lengthy process can result in an interim situation where the public receive information about the potential presence of a potentially harmful chemical long before a consensus (or perhaps even evidence) of what constitutes a safe level is available.

For well protected sources such as MWRA's, this process generally (but not always) results in our being able to simply say we didn't find the chemical. Less well protected sources will find trace levels more frequently.

<u>Lower detection levels/ more chemicals detected</u> - An area which may have profound effects on how water systems operate in the future is the continued trend toward lower detection levels for all sorts of natural and human-made environmental contaminants. Concurrent with the increased ability to find ever smaller amounts of chemicals in water is the science of evaluating their health effects. While the science of detection is always necessarily ahead of the science of understanding the health implications, researchers now regularly publish epidemiological or toxicological findings which cast doubt on the safety of chemicals which may be found in water. These may or may not eventually be determined to be of sufficient concern to be regulated, but their presence does raise concerns among consumers.

This is one area where MWRA's undeveloped watersheds are an important asset. While most water systems using surface water across the country rely on water which has passed over developed areas and includes often substantial amounts of treated wastewater, MWRA's sources are much closer to pristine. An area receiving increasing public and scientific interest is trace amounts of pharmaceutical and personal care products (often referred to as PPCP). Wastewater generally contains some amount of these chemicals, and studies by the USGS have detected them in most surface waters. At this point, relatively little is known about the effects of very low amounts of these chemicals on human health, but there are concerns that they may disrupt important hormonal processes, especially in growing fetuses and children. *No direct measurements of PPCP have yet been done in MWRA water supplies, but based on land uses, none are expected to be found.*

MWRA must regularly respond to customer concerns about chemicals or health risks reported in the media. Most frequently, we can report that we have tested for the chemical and that it is not present in the water we deliver. However, as detection limits decrease, it becomes increasingly likely that we may find some very small levels of chemicals and have to report on or otherwise disclose that information. Because it is almost always the case that the reports of possible health effects and detection in the environment or in drinking water will be years prior to a definitive assessment of safe levels, there is little that can be done to reassure consumers. Our goals for source water protection and treatment are designed to reduce the potential for harmful levels of environmental, human-caused, or treatment-related contaminants, but as knowledge evolves, we may find unexpected issues. Increasingly, attention has been focused on trace levels of regulated contaminants in the treatment chemicals used by water suppliers.

MWRA specifies strict limits on the allowable limits of any expected trace contaminants in our chemical procurements, does regular testing, and periodically reviews the specifications to avoid adding detectable amounts of reportable chemicals to the water.

A series of numbers accompanies each drinking water regulation: the MDL, the PQL, the MRL, the MCLG, the MCL and sometimes an AL.

Each regulation specifies a laboratory technique(s) to be used in detecting and quantifying the contaminant. The method detection level (MDL) is the lowest level at which the laboratory can assure the chemical is present, but it cannot be reliably quantified. The practical quantification level (PQL) specifies the lowest level at which the laboratory can say that the chemical is present and tell what the amount is. The method reporting level (MRL) is the level above which a water system must report that it has detected a chemical. It is typically set near or at the PQL. Typically if a chemical is detected below the MRL it does not need to be reported to the regulatory agency.

The MCLG or maximum contaminant level goal is a non-enforceable goal. It is set by EPA and is the level of contaminant in drinking water below which there is no known or expected risk to health. MCLGs are required to allow for a margin of safety. The Maximum Contaminant Level (MCL) is the enforceable standard, and is the highest level of a contaminant allowed in water. MCLs are required to be set as close to the MCLGs as feasible using the best available technology. Both the MCL and MCLG must be reported to the public, which occasionally can cause confusion about whether a contaminant detected above the MCLG is still “safe”. There is no good answer to the question.

In some cases, EPA will set an action level which is essentially a trigger for certain actions, such as corrosion control or mandatory education. EPA can also set a treatment technique if a contaminant is not easily measured, but can be controlled by a specified level of treatment such as disinfection or filtration.

5.8 Potential for Regulation of Additional Ozone, Chloramine or UV DBPs

Researchers continue to identify additional compounds created when disinfectants react with natural and man-made substances in the source water. EPA continues to review the toxicological and epidemiological data associated with any potential health risk associated with these disinfection byproducts. In the past several years, their attention has moved beyond just the byproducts of chlorine to those of other disinfectants. Some of the byproducts of chloramine are already regulated, as is one ozone byproduct. To date no potential byproducts of UV have been identified.

The Unregulated Contaminants Monitoring Rule requires that water systems provide data to EPA on certain unregulated contaminants so that EPA can determine how widespread their occurrence is. There are a number of byproducts of chloramine which are being examined – it is likely that the MWRA system will have them at some level, but it remains to be seen what the level of health concern will be. Individual byproducts could be regulated as soon as several years from now, but it is more likely that new EPA rules would be later than that. Massachusetts DEP is also examining certain byproducts, and has already issued a health advisory for N-Nitrosodimethylamine (NDMA) which is both a source water contaminant from certain industrial processes and potentially a byproduct of chloramination. *MWRA and our fully and partially supplied communities could all be affected by new byproduct regulations.*

Chloramination has the advantage of producing very little of the two primary regulated DBPs – HAAs and THMs, but at least one byproduct of potential health concern – NDMA - can be produced by chloramination. NDMA is not yet regulated by EPA, but advisory or notification levels have been set by Massachusetts and California at 10 parts per trillion (nanograms per liter). EPA has listed NDMA on its Contaminant Candidate List, and national monitoring of occurrence will be conducted over the next several years.

Two rounds of limited testing of MWRA water have been conducted (as of July 2006). In both rounds, no NDMA was found in raw water, water right after treatment, or in water at an average detention time site. Detections were limited to the site selected as typical of the longest detention time. At that location, levels were approximately 5 ppt, about one half the notification limit.

As more water systems adopt chloramination to comply with the new DBP rules, it is likely that additional byproducts of concern will be identified, and possibly regulated.

Ozone is a powerful oxidant and can transform many of the naturally occurring compounds in water. To date, only one ozone DBP is regulated – bromate - at an annual average MCL of 10 ppb. Generally bromate is produced when water containing bromide is ozonated. *MWRA's source water has relatively low levels of bromide, and it appears that levels of bromate will remain well below the MCL*[14].

5.9 Uncertainty, Margin of Safety, and Perceived Risk

An area receiving increased attention on the national stage is how to set regulations and make public resource allocations decisions in the face of scientific uncertainty about the effects of various chemical or biological contaminants. The scientific community understands that how risks are understood and described can and will affect the policy debate over a particular contaminant, but there is not a consensus about how to best deal with uncertainty in risk estimates. Some believe that any risk is unacceptable, and that if the degree of the risk (or perhaps even the existence of an actual risk to health) is unknown or uncertain that a precautionary approach should be taken. In practice for water suppliers this might mean that any potential contaminant which has been described as a risk in any single animal toxicological study or preliminary epidemiological study should be regulated and removed from the water. Others believe that a weight of evidence approach is appropriate, and that action should wait until there is some reasonable certainty that an actual effect may happen at doses likely to be experienced by consumers. In practice for water suppliers this might mean that a potential risk would exist and be publicly discussed for many years before action is required. Neither approach seems particularly satisfying. MWRA's approach to date has been to stay abreast of health and contaminant research and the regulatory process, and armed with that information, examine the potential risks in the MWRA system. *If a risk seems plausible, MWRA undertakes specific investigations on whether the contaminant occurs or is likely to occur in our water. In some*

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14 Bromate is also an identified trace contaminant in the sodium hypochlorite, which MWRA uses to produce chloramines. Two monthly samples have had detectable levels of bromate since the CWTP was brought on line. It appears that the bromate was not produced by ozonation, but was most likely from the sodium hypochlorite. MWRA's purchase specifications should prevent this from happening, and there have been no additional detections since this issue was brought to the attention of the chemical vender.

cases, such as with Cryptosporidium, MWRA began taking action immediately after the issue was raised nationally by the Milwaukee outbreak, and treatment decisions were made prior to the issuance of any EPA rule.

A related question is how especially sensitive populations should be protected. The effects on any given contaminant will vary by individual and by their health circumstances. Those with weakened immune systems due to cancer therapy, transplants or disease may be at a higher risk of infection from a given level of a pathogen than the general population. Lead exposure may be of more critical importance pregnant women and small children than others. Growing evidence links the risk of certain cancers to certain genetic factors. The setting of a safe threshold in a regulation or treatment decision must account for the variability of the population risk by establishing some margin of safety or other actions may be appropriate. The recent scientific debate over an appropriate maximum contaminant level for perchlorate focused extensively on what the targeted at risk population should be. The policy conclusion by Massachusetts DEP was that the regulation should be protective of the most vulnerable. By contrast, EPA's regulations for the annual Consumer Confidence Report require the publication of specific language about the health risks of *Cryptosporidium* for those with compromised immune systems. Here the conclusion is that no water system could be expected to provide the extreme degree of protection that some might require, and that these individuals might have to take additional individual actions.

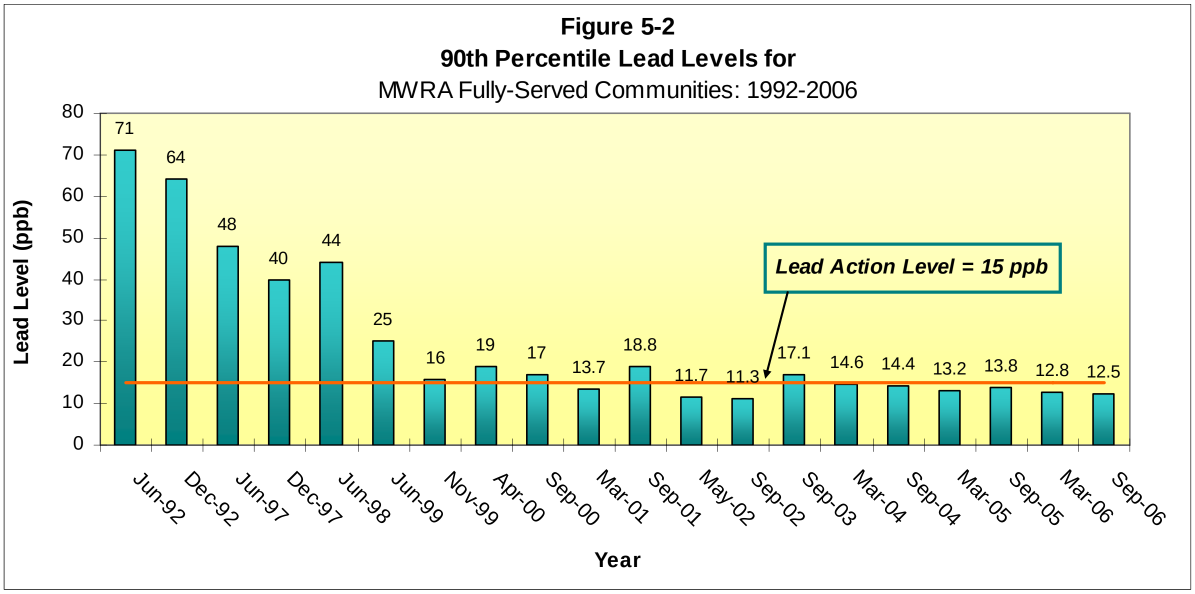
All of this relates to what our consumers expect of the water delivered to their taps. If asked, consumers will indicate that they want the water to be "safe". Unfortunately, there is no simple straightforward way of measuring "safety". As with all things in life, water cannot be delivered free of any risk to any individual. National policy decisions (as well as any local decisions) balance the degree of risk with the allocation of funds. Measured simply on the reduction of the risk from water, if disinfection is good, more disinfection is better, and more powerful disinfection and filtration is better still. Even better yet, two or three steps of filtration. Taken to the absurd, it is clear that there is some point where additional resources spent provide diminishing benefits, and that allocating those resources elsewhere make common sense. *MWRA's Integrated Water Supply Improvement Program and the treatment technology decision process balanced the investments in (and benefits derived from) treatment with additional resources allocated to community distribution systems, successfully arguing that a balanced investment profile yielded the largest benefits to consumers.*

5.10 Lead and Copper Rule

This rule is designed to reduce the risks of lead or copper being leached out of consumers' home plumbing and service lines by corrosive water. It is different than almost any other drinking water rule in that the water system does not control a large portion of the relevant physical assets. The rule requires that water systems sample for lead in certain homes, and depending on the results, provide corrosion control treatment to reduce the leaching of lead from home plumbing. In addition, if levels are above the Action Level, water systems may be required to undertake education efforts to inform their customers about lead, and to remove any lead service lines which may still exist.

The samples are not the usual samples that water systems are required to take of source water or of water as it leaves the treatment plant, but of stagnant water in individual homes. And not just any random homes or homes which are representative of average conditions within the service area, but homes which were judged by EPA to be of higher risk of having lead containing plumbing within the house, or in the service line under their front yards.

When testing began for this rule in 1992, the MWRA system had levels substantially above the action level of 15 ug/l. MWRA immediately began an aggressive education program and fast track design and construction of corrosion control. The plant went on-line in 1996 and treatment was fully ramped up by 1998. The Carroll Water Treatment Plant contains the same corrosion control processes. Lead levels have declined by about 80% as can be seen in the chart below.



System-wide lead results have been below the Action Level in each of the past six sampling rounds, and in nine of the past eleven sampling rounds. However, results continue to hover near the Action Level of 15 pbb, raising the possibility that a relatively small number of samples with slightly higher results could result in exceeding the Action Level. While the most recent round's system-wide result was similar to the previous round, there continues to be variability in the individual community results based on the small number of sampled sites and changes in individual volunteer sampling homes.

Due to the small number of homes which continue to be above the Action Level, a number of communities are required to do mandatory lead service replacement programs and mandatory lead education. *MWRA's goal is to continue to reduce the lead levels until no community has results above the action level. Reaching that goal may be difficult as MWRA's corrosion control treatment is very close to optimum according to our outside experts. This will be a continuing challenge as other treatment changes are made.*

At this point, no additional capital expenditures are recommended.

5.11 Simultaneous Compliance

An emerging issue of concern is the interaction of various rules. The interaction of disinfection to kill germs and the creation of undesirable byproducts of disinfection has been recognized for some time, but more recently it has become clear that almost all stages of treatment can potentially affect other compliance goals. The lead in drinking water debacle in Washington DC in early 2004 now seems to have been definitely related to inadequately considered changes in disinfection practice which dramatically and unexpectedly increased lead levels. Similar lead corrosion problems have been identified as potentially related to changes in coagulation chemicals in filtration plants, and one cause of the cryptosporidiosis outbreak in Milwaukee may have been a change in the type of coagulant. EPA and treatment researchers are now looking carefully at a wide range of chances for improvements in one aspect of treatment or system operation to adversely affect other important goals.

In addition, subtle seasonal or longer term changes in source water quality may have unexpected effects on treatment effectiveness. For example, in the MWRA system, levels of certain more reactive natural organic matter (as measured by UV 254 absorbance) appear to affect the amount of lead leaching from home plumbing, even if all other aspects of treatment are unchanged. These changes can occur, not because of changes in watershed activities, but due to the relative contribution of "younger" Wachusett or "older" and better Quabbin reservoir water being delivered in wetter or dryer years. It is not yet clear if there are simple changes in corrosion control which could be used to adjust for these types of source water quality shifts or if a change in the type of corrosion control may be needed.

5.12 Source Water Quality and Watershed Protection

As indicated above, source water quality and watershed protection are key factors in maintaining MWRA's unfiltered status. Both are the responsibility of MWRA's partner agency the DCR. With the exception of land acquisition, almost all DCR's water quality related activities are essentially maintenance type activities and are accounted for within DCR's annual current expense budget.

For the purposes of treatment and regulatory compliance planning, this plan assumes that DCR will be able to continue its successful watershed protection efforts, that source water quality will be maintained within the filtration waiver criteria, and that both the CVA and MetroBoston systems will remain unfiltered[15].

The key issues in remaining unfiltered are likely to continue to:

- "Control of the Watershed"
- Source water quality (bacteria and turbidity) and
- Management of organics (UV254) as related to treatment.

15 The capital cost of adding the filtration components to the CWTP is roughly estimated to be $250 million, with annual operating costs of about $4 million per year, and of course, additional asset protection costs for all the additional process equipment and facilities.

Only one aspect of watershed protection falls within the capital budget framework: land acquisition. Under the new institutional arrangements created with the Watershed Trust, MWRA directly funds any DCR land purchases through the MWRA CIP. Protection of the watershed and source water quality through the control of the land within the watershed is one of EPA's yardsticks for measuring the effectiveness of a watershed protection plan. Over the past decade, many of the unfiltered systems have added filtration to their systems. As one of a shrinking group, it can be assumed that MWRA's watershed programs will continue to be under careful EPA scrutiny.

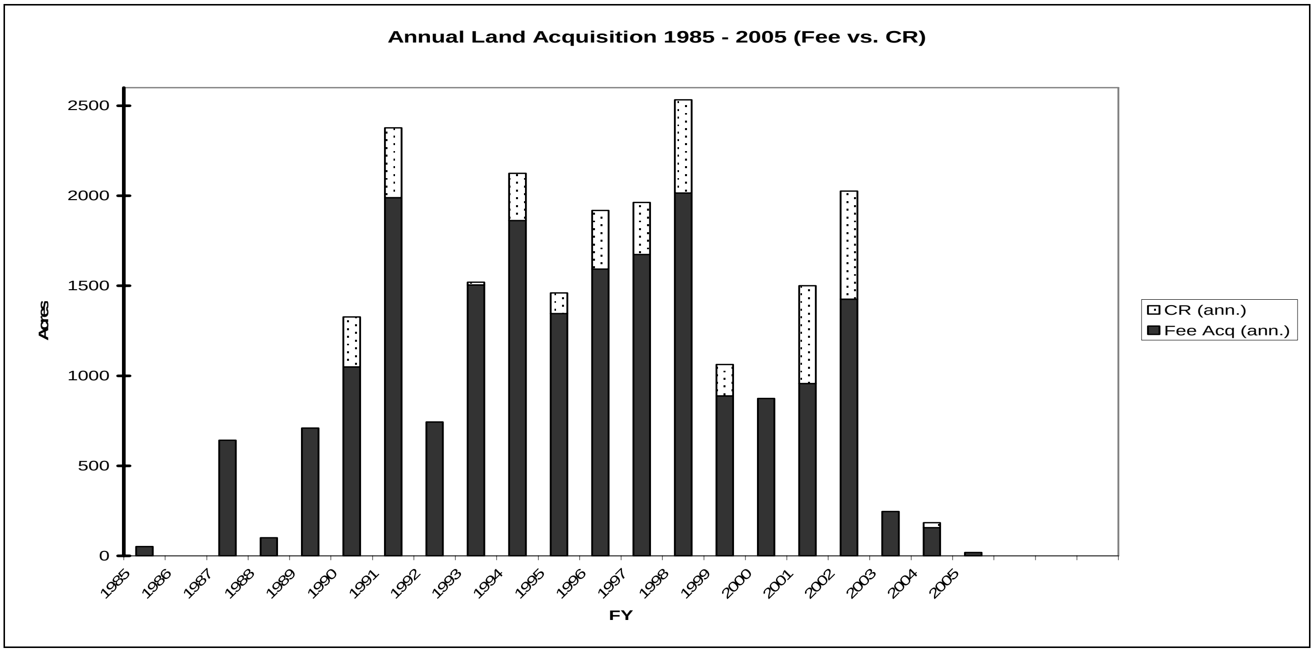
The SWTR includes the requirement that an unfiltered system "Gain ownership or control of the land within the watershed…for the purpose of controlling activities which will adversely affect the microbial quality of the water." As originally conceived by EPA in its guidance documents, a well protected watershed was one which was entirely owned and controlled by the water system.

Many of the west coast unfiltered systems achieve this standard or come close. Seattle owns essentially 100% of its watershed as does Portland Oregon. San Francisco's watershed is owned by the National Park Service, and is managed for protection of the supply. The eastern unfiltered systems generally have more fragmented ownership within their watersheds, and own less of the land. New York City still only owns less than 10 percent of their 1,970 square mile watershed: Portland Maine only owns about 2 percent. The Quabbin Ware and Wachusett watershed have a combined DCR ownership of 43 percent. If lands protected by other local, state and non-profit groups are included, approximately 64 percent is protected. (If the areas where development is regulated by the Watershed Protection Act are included, the total rises to about 75 percent.) While it began with a standard of requiring 100 percent ownership or control, EPA does recognize the value of efforts to protect undeveloped land over time and the benefits of protecting higher value lands rather than simply owning more land.

In the protection plans approved by DEP to maintain the MWRA's waiver of filtration, a continuing program of land acquisition is assumed without specifics on pace and scope. The MWRA/DCR approach has been to identify highest "value" critical lands and intercept them before adverse development occurs. The pace and scale of the program are linked to the ability to "stay ahead" of development which might adversely affect water quality. DCR is developing its next 5-year program for land acquisition. MWRA is working with DCR to develop a plan that (along with on-going regulatory activity under the Watershed Protection Act) will focus on the following:

- The need for an on-going commitment to preventing adverse development on critical lands through:
    - Support of good local community planning;
    - Use of Watershed Protection Act (Cohen Bill);
    - Purchase of conservation restrictions (CRs); and
    - The purchase of land in "fee simple" with the associated long term commitment to payments in lieu of taxes, only if necessary.

The plan is expected to focus primarily on lands and activities likely to result in microbial contamination of the source water, with more limited focus on ease of management (reduction of fragmentation and boundary issues) and protection of continuous corridors. A critical issue for MWRA over the longer term will continue to be the payment-in-lieu of taxes (PILOT) on land that the DCR owns. Purchases of development rights or conservation restrictions do not create an obligation for PILOT payments and achieve substantially the same long term protection. Therefore there is a strong MWRA preference for having future land acquisition activities largely limited to conservation restrictions.



Watershed	Total Watershed Area	Acres Owned 1985	Percent Owned 1985	Acres Owned 2005	Percent Owned 2005
Wachusett	70, 934 acres	5, 608	7.9	18,640	26.3
Ware River	61,739 acres	19,300	31.3	23,523	38.1
Quabbin	95, 411 acres	51, 792	54.3	54,311	56.9
TOTAL	**228,084 acres**	**76,700**	**33.63**	**96,474**	**42.3**

Opportunities to protect land typically come when the current owners desire to sell the land to retire or relocate. If the development rights or land are not purchased at the point in time, they will usually pass to a developer, and future protection opportunities will be more costly. Timing and the ability to respond to a particular owner's circumstances will continue to be critical to cost effective protection.

Recommendation - Land Acquisition:

- The FY07 CIP contains at total of $19 million over the next six years, with a declining pattern of $8, 3, 2, 2, 2, 2 million per year.

- *It is recommended that that $1 to $2 million be allocated annually after 2012 for the purchase of the most critical lands which are in danger of adverse development.* It is anticipated that these expenditures may not be uniform as the DCR takes advantage of opportunities as they arise to prevent degradation of water quality over the medium term (10-20 years). No recommendation is made for activities beyond that period.

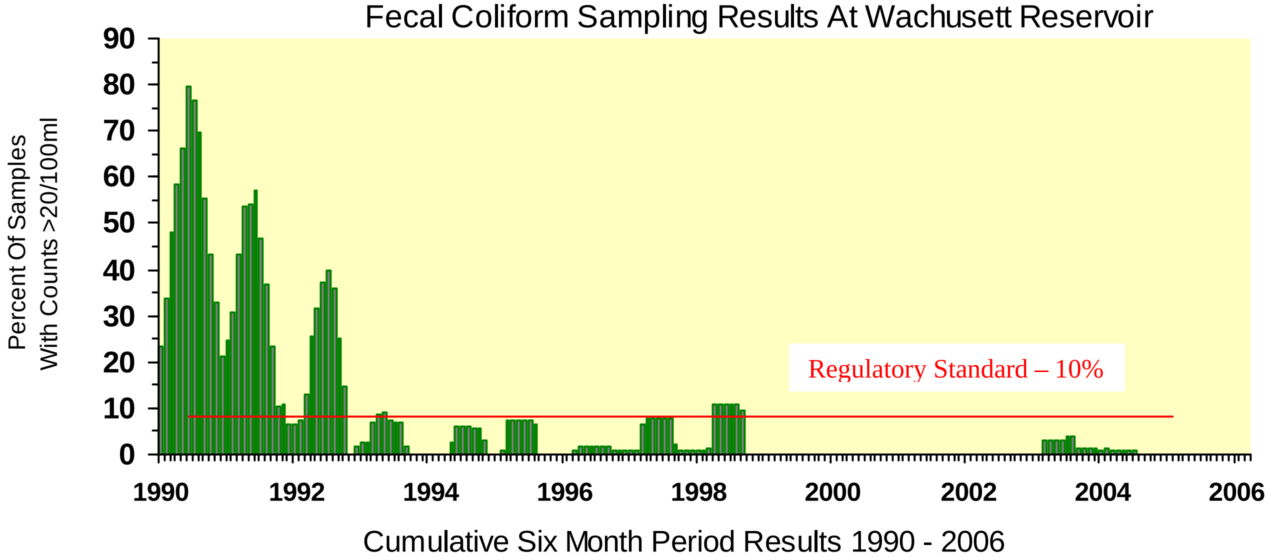
Attachment 5-1

MWRA SWTR Compliance History at Wachusett Reservoir

When the SWTR came into effect, the Wachusett Reservoir did not initially meet the avoidance criteria, as source water fecal bacteria levels were substantially over the allowable limit[16]. As a result, while a watershed protection plan was developed, an initial decision was made in 1991 to build a filtration plant. Subsequent implementation of the watershed plan by the MDC (now DCR[17]) Watershed Division demonstrated that the high bacteria levels were due primary to flocks of gulls roosting on the Wachusett reservoir. Employing various actions to reduce the attractiveness of the region to gulls by better management of local landfills, and harassing the gulls at dusk reduced the number of roosting gulls and bacteria levels dropped dramatically, bringing the reservoir into compliance with this source water criterion by 1993. MWRA then entered into a dual track scheduling Administrative Consent Order with DEP: the ACO required the siting and design of a filtration plant, but allowed MWRA and DCR until 1998 to demonstrate compliance with all criteria and request a waiver of filtration just prior to construction. The watershed protection plan and related activities are discussed later.

Figure 5-3

Fecal Coliform Sampling Results At Wachusett Reservoir



16 The Quabbin Reservoir had a much less significant issue with roosting gulls, and met the source water quality criteria. MWRA and DCR implemented the watershed protection plan, built interim disinfection facilities by reusing an existing chlorine injection system, and then proceeded to design and built a modern chlorine disinfection facility in Ware (2001) and replace the open distribution reservoir at Nash Hill with two covered storage tanks (1999).

17 Hereinafter, all references to the Watershed Protection Agency, whether to the MDC or later to the DCR, will simply be made to DCR.

After 1993, MWRA and DCR proceeded to implement the Wachusett watershed protection plan, and MWRA proceeded to locate and permit an appropriate site for whatever treatment would be built, and began parallel design of three different treatment processes:

- chlorination/chloramination;
- ozonation/chloramination; and
- dissolved air floatation/ozonation/filtration/ chloramination.

The plant was designed in a modular fashion to facilitate moving forward in design prior to a decision, but more importantly, to ensure that additional processes could be added later if necessary. Room for the filtration components and the ability to connect them were included in the other options to allow for future expansion.

During this same period of 1996 to 1998, MWRA also made a number of critical permanent and interim improvements to the system which contributed to improved water quality and movement towards compliance with the SWTR requirements.

- In 1996, completed construction of the Interim Corrosion Control Facility in Marlborough, and over the next two years optimized water chemistry. In addition to the improvements in lead levels discussed below, this also improved the effectiveness of residual disinfection within the distribution system.

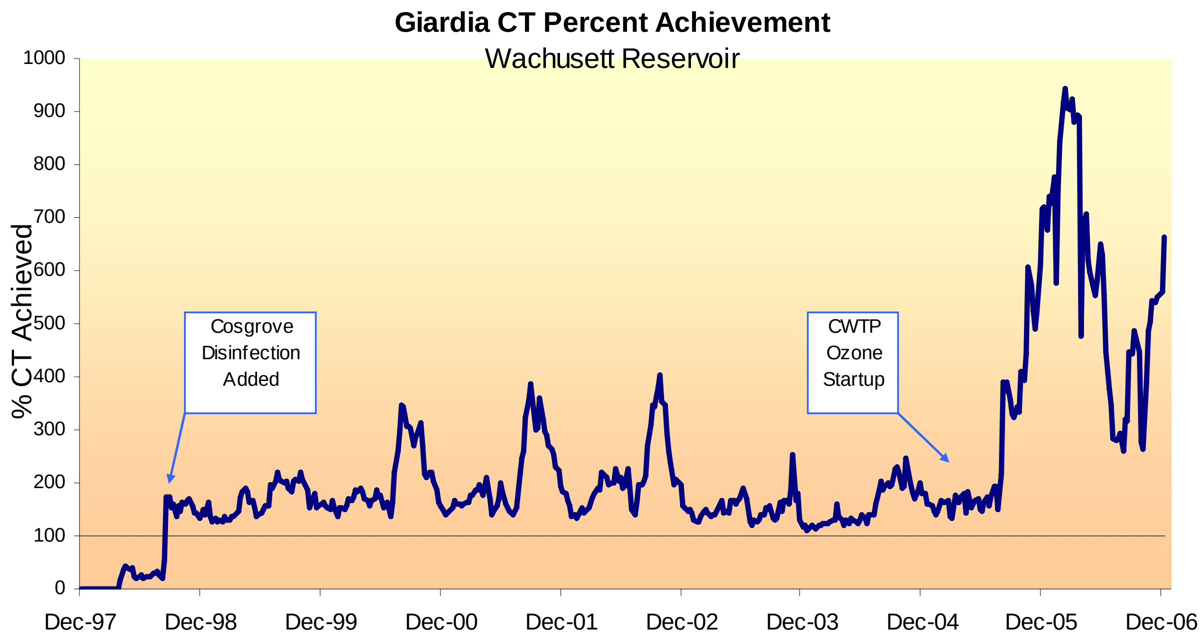
- In 1997, made improvements to the residual disinfection facilities at Norumbega Reservoir that increased the level of pathogen inactivation for water leaving Norumbega Reservoir and increased and stabilized the chloramination residual disinfectant levels within the distribution system.

- In 1997, constructed an interim disinfection facility at Cosgrove Intake which injected chlorine into the Cosgrove Tunnel at Shaft A and used the long travel time of the tunnel to allow adequate contact time to meet the necessary CT to inactivate *Giardia*[18]. By September of 1998, MWRA was providing adequate disinfection to meet the waiver disinfection criterion, and meeting all other criteria.

- Removed the Weston, Fells and Spot Pond open distribution reservoirs from service replacing them with the Loring Road, Fells Covered Storage and improved pumping operations at the renovated Gillis Pump Station at Spot Pond.

18 CT (or concentration times contact time) is used as a way of measuring inactivation. For a given level of desired inactivation of a given pathogen, at a particular temperature and pH, a CT can be determined. A higher dose, or longer contact time increases the effectiveness of the disinfection. EPA publishes CT tables for each disinfectant and each regulated pathogen which must be met.

As shown by the inactivation graph below and by the graphs in the distribution system further down, these improvements had substantial water quality implications, bringing the system into compliance with the treatment and water quality requirements of the current rules.



Also throughout 1997 and 1998, MWRA staff were completing design documents and research projects with the expectation that the MWRA Board would make a "treatment technology decision" in the fall of 1998. Several expert panels on health and water quality issues were convened, and a Board chartered panel provided oversight to the efforts. Of particular importance were a series of research projects which had been designed to resolve or reduce uncertainty about key factors in the decision:

- How effective was the existing disinfection, and were bacteria levels in the distribution related to "break through"?
- What was known about the health significance of various disinfection byproducts, and would the DBP levels produced by the alternatives be unsafe or above expected regulatory limits?
- Would the use of ozone without a subsequent filtration step create an opportunity for increased bacterial activity within the distribution system?

Complicating the decision was the fact that EPA was required by the SDWA amendments of 1996 to issue new treatment rules, but the requirements of those would not be known until after critical treatment decisions were made. While the rules were uncertain, MWRA incorporated a minimum target of 99 percent ("2-log") reduction of *Cryptosporidium* through inactivation or removal.

Staff presented a series of briefings to the Board of Directors over 1997 and 1998, reviewing the background material, presenting the results of the research and program efforts to date, assessing the likely direction of future EPA rules and discussing how to best allocate limited MWRA funds to achieve the highest level of water quality improvement at the consumers tap. The research and expert consultation indicated that the chlorination alternative would yield disinfection byproduct levels that would not meet future limits, or would cause consumer concerns. Both the ozone and the ozone plus filtration options would easily meet expected new standards, and little difference in DBP levels was expected between the two alternatives using ozone. As discussed in more detail in Chapter 5, the research findings indicated that it was unlikely that the ozonation/ chloramination alternative would cause problems within community distribution systems if combined with effective corrosion control, maintenance of adequate disinfectant residuals and community efforts to eliminate the worst of the old cast iron pipe within their systems.

The briefings, outreach, and a full day Board retreat on the treatment decision culminated in October 1998 in a integrated decision[19] to:

- Continue watershed protection efforts;
- Build the ozonation/chloramination alternative;
- Create a $250 million zero-interest loan program to encourage the rehabilitation of community owned old unlined cast iron pipe;
- Conduct public health research and surveillance to evaluate the effectiveness of the program; and
- Review the entire decision once the plant was operational.

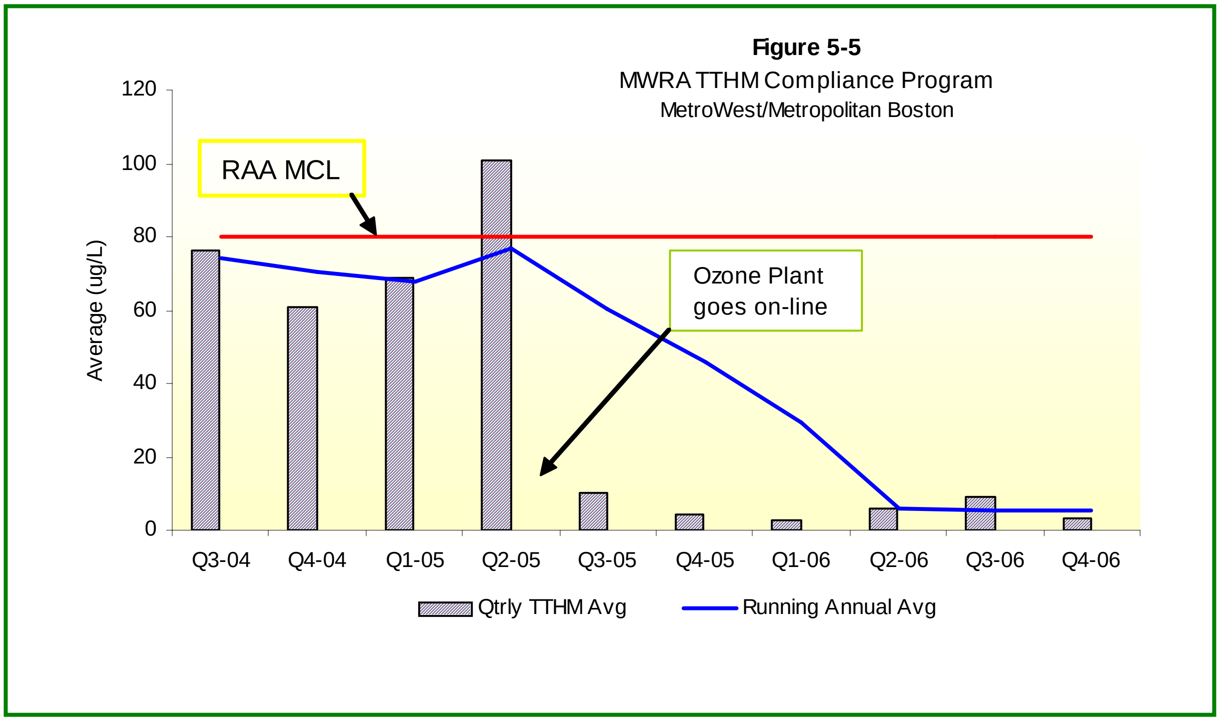
Based on the improvements to water quality and both interim and planned treatment upgrades, MWRA requested, and DEP approved a waiver of the filtration requirement of the SWTR. Unfortunately, just after the decision was made and as the dramatic improvements in treatment and water quality within the system were becoming evident, there was a relapse in fecal coliform bacteria levels in Wachusett Reservoir. In January 1999, one sample more than the allowable 10 percent of samples within a 6-month period was over the allowable limit. MWRA and DCR immediately reviewed the gull harassment program and implemented appropriate corrective action, and the DEP ruled that due to the use of an excessively sensitive non-approved sampling method, no violation had occurred. Nonetheless, this and other factors resulting in a trial in Federal court over an EPA lawsuit attempting to force MWRA to add the filtration component. A lengthy trial with substantial expert testimony on both sides related to the decision process and the potential risks resulted in a decision for MWRA, which was affirmed on appeal[20]. MWRA proceeded directly to completion of the ozonation/chloramination alternative.

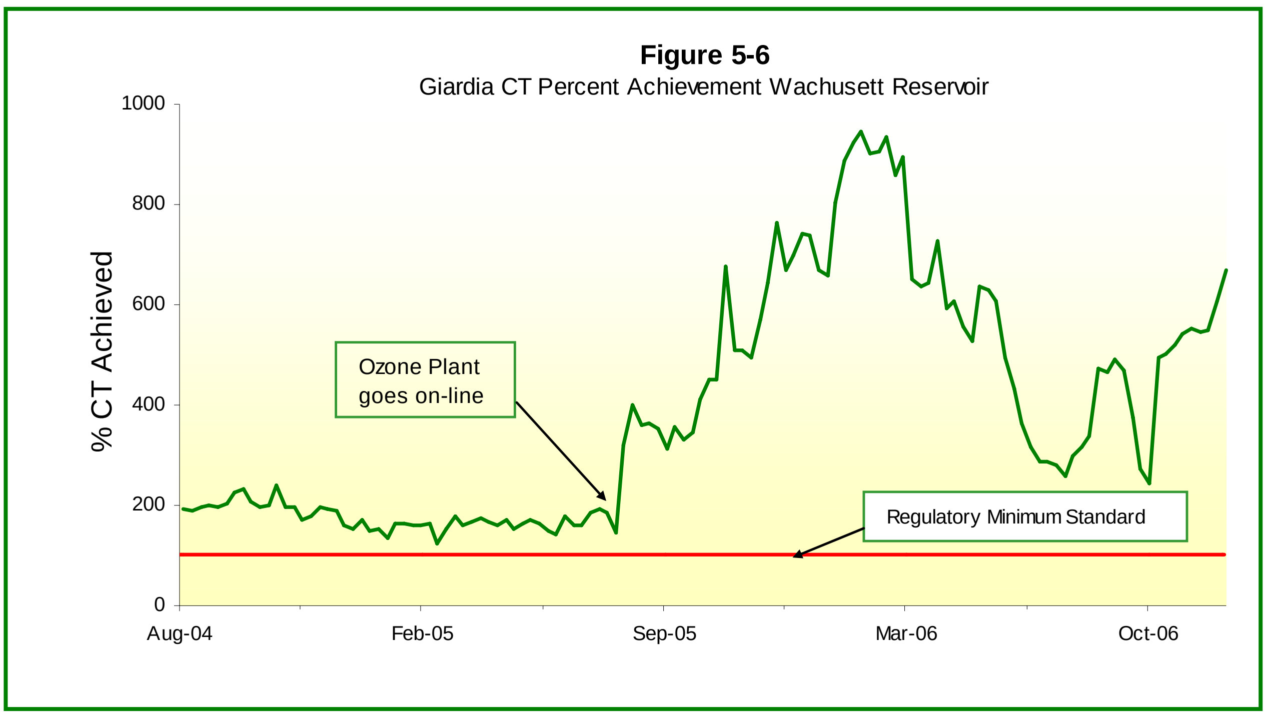
The Carroll Water Treatment Plant was brought on-line on July 2005. The plant generally performed as expected. Inactivation was greatly increased, reaching the site-specific inactivation targets of 99 percent inactivation of *Cryptosporidium*, as well are greatly increasing the inactivation of viruses and Giardia beyond those required by regulation. Disinfection byproduct levels were reduced even more dramatically than anticipated. While a higher chloramine dose

19 The context of the decision was the Integrated Water Supply Improvement Program formalized in 1995 which has called for watershed protection, the construction of the MetroWest Water Supply Tunnel, appropriate treatment for Wachusett Reservoir water, pipeline improvements and covered storage to replace the open distribution reservoirs.

20 A number of important details related to the court case, and the timing of the legal events are omitted and collapsed in this brief recounting.

than originally anticipated was required, once adjusted, disinfection residuals throughout the distribution system were generally as good as or better than before.





6 Water Treatment and Facilities

6.1 Chapter Summary

This chapter describes the existing treatment facilities put in place to meet regulatory requirements and customer expectations, outlines what will be required to maintain those facilities over time, and discusses what new facilities and modifications will be needed to meet the new and expected regulations described in the previous chapter. The chapter deals first with the Carroll Water treatment Plant serving metropolitan Boston and then with the Chicopee Valley Aqueduct system serving the three CV communities.

The Master Plan recommends that:

To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should add Ultraviolet light disinfection at the Carroll Water Treatment Plant (CWTP) by October 2013. The new facilities are expected to be constructed within the extended ozone contact chambers, will provide the ability to comply with both the requirement for 99% inactivation of Cryptosporidium and the use of two primary disinfectants, and allow for the reduction of the ozone dose. The improvements are expected to cost $43.5 million for design and construction.

To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should add Ultraviolet light disinfection at the Ware Disinfection Facility (WDF) serving the Chicopee Valley Aqueduct communities. This facility will be constructed the site of the current chlorination facility at a cost of $5.8 million.

The existing Carroll Water Treatment Plant requires certain ancillary modifications to optimize its performance and incorporate improvements from lessons learned over the first year of operation. These modifications and improvements are expected to cost approximately $ 7.6 million over the period FY2009 to 2011.

Both the CWTP and the WDF will require regular investments in asset protection to maintain them in proper working order. Based on the mix of long lived concrete facilities and shorter lived electrical and moving components, approximately $3 million is recommended in the FY16-18 period to initiate a long-term $50 million asset protection program for the CWTP and $4 million is recommended in the FY27-29 time period for asset protection at the WDF.

6.2 Current Treatment for Metropolitan Boston

The John J. Carroll Water Treatment Plant is the center piece of the Integrated Water Supply Improvement Program. When it went on-line in July 2005, it consolidated all treatment steps for the metropolitan area into one site at the junction of Marlborough, Southborough and Northborough, essentially at the western edge of the service area. The ozonation system at the plant is designed to achieve 99 percent inactivation of *Cryptosporidium*[1], at least 99.9 percent inactivation of *Giardia*, and at least 99.99 percent inactivation of viruses. The plant achieves the *Cryptosporidium* target, and regularly far surpasses required *Giardia* and virus targets.

The plant has a maximum day capacity of 405 million gallons per day. Water flows into the plant from the Cosgrove Aqueduct by gravity under all flow conditions, and passes through the plant to the MetroWest Tunnel and Hultman Aqueduct without pumping. Pumping is provided for internal plant use and for Northborough and Westborough State Hospital. The plant is designed and operated as two parallel plants allowing for half plant operations during low flow months for system maintenance and upgrades. The 45 million gallon storage tank is also able to be isolated in two parts for cleaning or maintenance.

The plant generates ozone on-site for primary disinfection using purchased liquid oxygen (LOX) and four 3,380 pounds per day ozone generators. The generators can be used in various combinations to feed ozone into four ozone contact chambers. These concrete “under and over” baffled chambers allow the water to be ozonated in several locations, and for measurements of the residual ozone to be made at several points.

The ozone generators are power intensive, and require high quality power. Interruptions, even for less than a second, can cause the ozone generators to shut down. The plant has been modified to stay in operation for very brief periods of ozone generator shut down, but if the outage extends beyond five minutes the plant shuts down and must be restarted. Plant operating procedures prevent untreated water from being sent to consumers. Ozone gas is extremely hazardous and the plant provides negative pressure in the contactors through ozone destruct units. If ozone gas is detected above safe levels in the area above the contactors, the ozone generators automatically shut down which will cause the plant to shut down. Pressure fluctuations within the Cosgrove tunnel caused by any sudden change in flow through the Cosgrove Intake and Power Station can cause vacuum changes and thus cause the ozone units to shut down. With operators trained in procedures for restarting the plant, and the onsite storage in the 45 million gallon clear well and at the 115 million gallon Norumbega Covered Storage Tank, no service disruptions have resulted due to plant interruptions and shut downs.

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1 The 99 percent or 2-log inactivation is a voluntary operating target for plant operations. It is based on site specific testing infectivity studies of ozone disinfected water. As discussed later, it was not designed to provide treatment meeting the new more stringent requirements of the recently promulgated LT2ESWTR.

The plant has full back-up power capability with four 2,000 KW diesel generators. These are used when line power is down, and may also be used to avoid a plant shutdown if a power interruption seems likely.

When the water leaves the primary contactors, it enters the extended contact chambers, which are a specially baffled area at the beginning of the storage tank prior to the addition of the rest of the treatment chemicals. This provides additional ozone contact time, allowing the plant to achieve a higher CT, and hence higher inactivation of *Cryptosporidium*. Once the water leaves the extended contact chambers, it receives corrosion control, is fluoridated, and chloraminated for residual disinfection. Corrosion control involves raising the alkalinity with sodium carbonate, and adjusting the pH with carbon dioxide. Chloramination involves first adding chlorine (sodium hypochlorite) and then after a short contact time, adding ammonia to form monochloramine.

The CWTP is the Operations Control Center (OCC) for the entire treatment and transmission system. The treatment and transmission operators on duty are responsible for operations from Shaft 5 of the City tunnel in Weston all the way to the CVA system treatment and storage facilities in Ware and Ludlow. The plant control room is connected via SCADA to all Western Operations facilities.

The CWTP OCC is also being upgraded to house duplicate equipment to serve as a back-up for the metropolitan operations control center if the Chelsea OCC is unavailable. An emergency operations center (EOC) is being constructed in the training room of the CWTP operations building to serve as a back up to the Chelsea EOC as well. Critical MIS functions will also have back up capability at the CWTP to ensure continued operations if the Chelsea MIS center is inoperable.

The plant is normally operated by a minimum of 3 operators per shift. During the day shift additional operators and management staff are present as well as maintenance staff. During off shifts, the operators also manage the CVA treatment facilities in Ware, and if available, one of the operators may perform off-site monitoring rounds.

The plant is extensively automated for both operations and regulatory compliance. Monitoring of raw water quality occurs both at the Cosgrove Intake at Wachusett Reservoir several hours upstream of the plant, and at the plant inlet. Treatment parameters are tracked throughout the process for calculating regulatory compliance and for process control feedback.

Monitoring instrumentation requires regular maintenance and calibration if it is to be relied on for process control and compliance. Instrumentation and electronic control equipment must also be supported by the manufacturer, and may become obsolete if the manufacturer no longer supports it with maintenance, updates and spare parts.

Table 6-1 Treatment Process Control Instrumentation

Parameter	Purpose	Number of Instruments
Temperature	Compliance and Process Control	2
pH	Compliance and Process Control	14
Turbidity	Compliance	4
UV 254 Absorbance	Process Control and Source Monitoring	2
Ozone residual	Compliance and Process Control	24
Ozone ambient air	Worker Safety	20
Chlorine or Chloramine	Process Control and Compliance	6
Conductivity	Process Control and Source Monitoring	1
Oxidization Reduction Potential	Process Control	2
Fluoride	Compliance and Process Control	4
Particle Count	Source Monitoring	1
Flow Metering	Process Control and Compliance	47
Totalizer	Process Control and Compliance	47

6.3 Asset Management and Ancillary Modifications to the Existing CWTP

It is typical for all major new facilities to have a several year period of plant familiarization, optimization and customization as plant staff learn the intricacies of plant operations and maintenance under a variety of conditions. The lessons learned from this period of familiarization are distilled into a series of "ancillary modifications" to the plant to optimize operations, facilitate maintenance, and achieve efficiencies in operating.

Staff are evaluating a series of possible plant improvements to be undertaken under this process.

1. During the investigation of summer 2006 detections of total coliform bacteria at Marlborough's Cedar Hill pumping station, it was determined that it would be advantageous to be able to fully flush the 30" pipeline that connects the CWTP and the Marlborough system. This currently cannot be done without shutting off service to Marlborough for an unacceptably long period. A procedure and physical provisions are needed to allow this pipe to be disinfected and flushed to remove any bio-film. A blow-off pipe on the 30" supply pipe will be installed. This will allow disinfection to be performed and will provide a path to flush the pipe at a high water velocity to remove bacterial cells after disinfection.

2. Liquid oxygen is stored in three separate storage tanks. The liquid is converted to gas in the vaporizers and then piped to the Ozone Building through two separate 4-inch diameter stainless steel pipes. The two pipes are combined into a single pipe in the Ozone Building. This single pipe carries all the oxygen to the ozone generators. Failure of this pipe would disrupt plant operation. A second oxygen pipe is currently under design. Once installed, the new pipe will provide redundancy in oxygen supply piping.

3. Vacuum relief valves were installed over the effluent channel in the Ozone Building to address high vacuum conditions that can occur during rapid flow changes. Positive pressurization has also occurred during certain flow conditions. As discussed above, both conditions can result in plant shutdowns. Positive pressurization results in ozone release inside the work space of the plant which has worker safety implications. The larger the release, the longer it takes to clear the area and allow restart of the plant. Modification of the pressure relief valves and piping is currently under design to allow positive pressure to be released outside the building, thereby limiting worker exposure to ozone, and allowing for quicker plant restart.

4. The Wachusett Aqueduct is the emergency water supply conduit to the metropolitan Boston area in the event that the Cosgrove Intake or Tunnel is damaged or taken out of service[2]. In order to meet sanitary conditions, the Wachusett Aqueduct cannot be connected "live" to the plant; some type of physical separation is required during normal operations to prevent a possible cross connection. This was achieved by the removal of a six-foot long piece of 120-inch diameter pipe and capping the pipe ends. Reactivation of the Wachusett Aqueduct would require the removal of the two 120-inch diameter flange caps and the insertion of a 6-foot long spool piece. It would take approximately two days to complete this work. Work is about to begin on the design of valves to be installed on this pipe to allow for a rapid transition to the Wachusett Aqueduct, while still achieving an acceptable sanitary air gap between raw water supply piping and the plant during normal operations.

5. The plant receives regular deliveries of commercially produced liquid oxygen. On-site generation of oxygen, while complicated, has been discussed for reasons of cost and reliability. A study will be conducted to examine the feasibility and cost-effectiveness of on-site generation of oxygen. Also to be included in this study is the alternative of providing additional liquid oxygen storage as an alternative way to achieve additional reliability.

6. Various programming and process modifications to improve the ability and speed of plant restarts after any shut-downs are being evaluated. Modifications within the generator transfer switching gear to eliminate arc-flashing and improve worker safety are also being reviewed.

7. Refinement of instrumentation and sampling to allow more effective and efficient operations and reduce required maintenance.

8. The ozone generators are currently cooled with raw water. An open-loop system was selected during design as it has a lower operating cost than a closed-loop system. Staff will monitor the condition of the ozone generators for signs of

2 It is important to note that as discussed in the Transmission Chapter the flow from the Wachusett Aqueduct is only able to meet winter time demands; and that it would require chlorine treatment at the reservoir as the flow passes below the CWTP process elevations and cannot be ozonated.

premature fouling of the generator sleeves. If fouling is found, a closed-loop cooling system could be installed that would circulate cooling water through heat exchangers. This would provide for more certain control of water quality.

9. Inspection and repairs to plant sewers to identify and remove any infiltration of clean water.

10. Concrete condition monitoring in all chambers.

11. Security to the entrance of CWTP will be improved to prevent access to the plant by unauthorized vehicles and also to document the number of people at the facility. Conceptual improvements being considered include:

    - Cameras to document activity at the entrance.
    - Covered entrance to help concentrate lighting at the entrance and provide weather protection.
    - Permanent security building.
    - Improved pipe gates.
    - Permanent security structure.
    - Roadway realignment.

It is expected that additional potential modifications will be identified over the next several years of operations and maintenance and these will be incorporated into later ancillary modifications to the plant. Approximately $7.6 million is recommended over the period FY09 to FY11.

All facilities require regular investments over the long term to maintain them in good working order. While the concrete and major piping of the CWTP should provide good service for 50-100 years, much of the operating equipment can be expected to need replacement or refurbishment after providing service on the order of 10 to 20 years. The plant as substantial electrical and mechanical systems which will likely require replacements/upgrades starting at a 10-year life.

Certain equipment is operated on a continuous basis and experiences severe duty, such as sluice gates and valves that provide continuous hydraulic control for the plant and which control application of chemicals for treatment processes. Replacement of these types of equipment is difficult as plant by-pass or complete shut downs may be required.
Other equipment, such as chemical storage tanks, ozone generators, and the plant water system, were installed and the building construction was completed around them. This sets up the potential for difficult future replacement projects toward the end of the equipment life.

It is impossible to predict which specific systems, non-equipment assets, and equipment will need replacing at any point in the future. However, it is prudent to expect that a percentage of the assets will need replacing, and that significant efforts will be required to replace some of them, after 20 years of service. Good planning for such replacements should include a regular process for project identification and prioritization along the lines of the model being developed by the MWRA's asset replacement task team.

Based on the mix of assets at the CWTP, MWRA should expect to invest approximately $3 million in FY 16-18 to initiate a long-term $50 million CWTP asset protection program.

6.4 Required Changes to Meet New Stage 2 D/DBP and LT2 ESWTR Requirements - Carroll Water Treatment Plant

As discussed in Chapter 5, the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which was promulgated in January 2006, will require that MWRA add an additional disinfectant at the John J. Carroll Water Treatment Plant (Carroll WTP) and at the Ware Disinfection Facility serving the Chicopee Valley Aqueduct (CVA) communities. Under the new rule, all unfiltered systems must have two primary disinfection systems[3], one capable of achieving 99.9 percent *Giardia* and 99 percent *Cryptosporidium* inactivation and the other capable of 99.99 percent virus inactivation. Based on the findings of pilot testing and other research, ultraviolet (UV) light disinfection appears to be MWRA's most cost-effective solution at both locations.

Compliance with LT2ESWTR is required by April 2014 for the Carroll WTP assuming that DEP grants the statutorily available two-year extension for plants requiring substantial capital modifications. (Compliance for the CVA system will be 6-months later.)

Recent developments with UV technology make it an attractive disinfectant alternative for use as a second primary disinfectant for both the Carroll WTP and the Ware Disinfection Facility. UV disinfection uses intense light energy to disrupt or alter the DNA of a microorganism rendering it incapable or reproducing and thus causing illness. UV has recently emerged as an effective disinfectant for *Cryptosporidium*. The benefits that UV disinfection offers as compared with other disinfectants are:

- No known production of disinfection by-products;
- No known increased risk of re-growth in the distribution;
- Lower capital and operational costs than ozone; and
- Higher effectiveness for inactivation of *Cryptosporidium* at cold temperatures than with ozone.

Treatment Process Evaluation - CWTP

In June 2006, staff recommended, and the Board of Directors approved, proceeding with a sequential process of ozone, UV and chloramine for the Carroll WTP in order to

3 Primary disinfection inactivates pathogens (harmful germs) in the source water. Residual disinfection is used to maintain the quality of the water as it passes through the distribution system.

comply with the new regulations. Staff anticipate that this treatment process will result in a reduced ozone dose, reducing the potential for bacterial regrowth within the distribution system and reducing energy and liquid oxygen costs. Ozone would continue to increase the clarity of the water; remove certain algae-related tastes and odors; and would also provide the required second primary disinfectant. That recommendation was based on a review of three other alternative treatment processes:

<u>Ozone, Free Chlorine and Chloramine</u> - Free chlorine could be used to provide a second primary disinfectant. However, this would require that the Carroll WTP ozone system be used for *Cryptosporidium* disinfection using the much more conservative inactivation requirements of LT2ESWTR[4]. The ozonation system design was based on a site-specific study of *Cryptosporidium* inactivation in Wachusett Reservoir water. The conservatism built into the new LT2ESWTR requires substantially higher ozone residual and contact time than the site-specific data. The higher than anticipated CT requirements would translate into higher ozone doses. While the Carroll WTP, as designed and constructed, would likely be able to physically achieve those CT values, it would be much more costly to operate and the concern about ozone creating bacterial "food" and increasing the potential for bacterial regrowth within the distribution system as discussed in Chapter 5 would be heightened. The required doses would be higher than any evaluated in the "Task 8" research efforts during the treatment technology decision process, and thus, it is not clear that those conclusions could be applied to this mode of operation. The use of free chlorine would increase chlorine disinfection byproducts. These byproducts were reduced to levels far below those in the new Stage 2 Disinfectants and Disinfection Byproducts Rule as a result of changing to ozone as the primary disinfectant with the operation of the Carroll WTP. Substantial additional testing would be required to evaluate whether this alternative would be able to meet the requirements of the new Stage 2 Disinfectant/Disinfection Byproducts Rule. Compliance is not assured.

<u>Ozone, Chlorine Dioxide and Chloramine</u> - Chlorine dioxide has been found to be effective in inactivating *Cryptosporidium* in warm, high pH waters. However, its effectiveness drops substantially in cold water to the point that chlorine dioxide would not be feasible at Carroll WTP for the inactivation of *Cryptosporidium.* Chlorine dioxide also degrades to form chlorite and chlorate. Chlorite is a regulated disinfection byproduct due to its public health implications. The generation, control and analysis of chlorine dioxide is highly complex.

<u>Ozone, Filtration and Chloramine</u> - The addition of filtration facilities to the Carroll WTP would eliminate the requirement for a second primary disinfectant and allow a lower ozone dose. However, the construction and operating costs of this alternative are far greater than for an ozone-UV facility. Based on staff's analysis of new federal regulations and the progress made to date in watershed protection, staff see no current

4 As discussed in a March 8, 2006 staff summary, while MWRA designed the CWTP prior to the issuance of the LT2 using site specific inactivation data, EPA used much more conservative national data in developing the table or required CTs in the new rule. While MWRA is inactivating 99 percent of any *Cryptosporidium* in our water, we cannot take credit for that under the new rule, without substantially increasing the ozone dose.

reason at this time to recommend any modifications to the original 1998 treatment technology decision to remain an unfiltered water system. The capital cost for this alternative would be more than $250 million. As discussed above, filtration would reduce the risk of distribution system impacts, and may be required if there were system-wide total coliform bacteria positives[5]. At this time, there is no clear evidence indicating a system-wide problem, but staff are closely monitoring the performance of the system during warmer temperatures.

Recommended Location for UV - CWTP

Based on a UV Disinfection Treatment Feasibility Study two possible locations were identified for the UV reactors. These locations were selected to:

- Not preclude later addition of filtration;
- Minimize the value of facilities that would be rendered obsolete if filtration were later added;
- Take advantage of the fact that UV disinfection is more effective after ozonation than before;
- Maximize the effectiveness of ozone treatment during construction; and
- Minimize the reduction in storage within the storage tank.

The figure below depicts the two alternative sites.

Site 1: Post Future Filters - The UV facility would be partially integrated into the west face of the future Filter Building. This site would require very deep excavation and extensive relocation of pipes and utilities. The UV Building space would be limited by existing buildings and the road. It has the advantage of having minimal impact on the operation of the existing plant because none of the extended ozone contactor volume would be taken out of service during construction.

Site 2: Storage Tank - The extended ozone contactors in the storage tank would be converted to UV treatment areas. The extended ozone contactors were added to the design of the Carroll WTP in order to increase contact time to meet the site-specific *Cryptosporidium* inactivation criteria that were established after plant design had started. This contactor volume will not be required after UV treatment is added for *Cryptosporidium* inactivation, thereby making this space available for the UV reactors. Construction of the UV process in the storage tank will require that the extended ozone contactors be taken out of service, requiring careful staging and winter construction when demand is lower.

5 It is also true that the use of UV would allow lower ozone doses, and thus form lower levels of "bacterial food". Filtration removes the precursor organic materials, while the switch to UV would reduce the conversion of larger carbon molecules to smaller more easily digested carbon molecules. The relative magnitude of the reduction in risk of bacterial regrowth for the two options is not known.

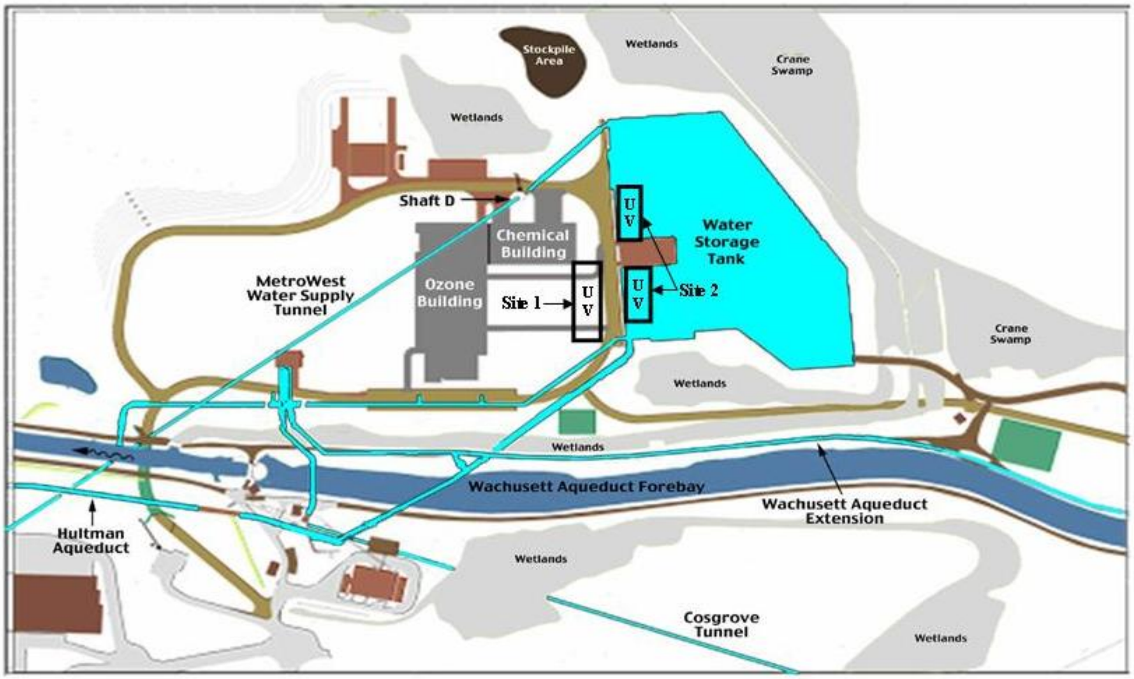


Figure 6-1 UV Alternatives at Carroll WTP

As discussed in the June briefing to the Board, the Storage Tank site is recommended for addition of the UV process.

Schedule and Cost

The design and construction schedule for the addition of UV disinfection to the Carroll WTP is:

- Design Notice to Proceed January 2008
- Construction Notice to Proceed April 2011
- Substantial Completion October 2013

Compliance is required by April 2012, or April 2014 if DEP grants the available 2 year extension for capital improvements. The estimated cost for design and UV reactor validation is $9.5 million; the estimated construction cost is $34 million. These funds are included in the Final FY07-09 CIP.

6.5 Current Treatment for the Chicopee Valley Aqueduct System

The Ware Disinfection Facility (WDF) provides primary and residual disinfection for the Chicopee Valley Aqueduct (CVA) system serving the three communities of Wilbraham, Chicopee and South Hadley Fire District No. 1. The facility, placed into service in 2000, is located adjacent to the CVA and the Swift River just north of Route 9 in Ware. The facility replaced interim disinfection facilities and allowed Wilbraham and South Hadley

Fire District #1 to discontinue their chlorination facilities. Due to its location downstream of the Nash Hill Tanks, and larger distribution system, Chicopee still needs to provide booster disinfection at their entry point to maintain an adequate chlorine residual to the ends of their system. Each community also provides their own corrosion control treatment.

The facility has a maximum day capacity of 25 million gallons per day. It consists of chemical injection equipment to inject sodium hypochlorite (chlorine) into the CVA as well as process monitoring equipment. The travel time between the addition of chlorine and a monitoring location in Ludlow ("the Ludlow Monitoring Station" or LMS) provides the necessary contact time to meet the required CT values for 99.9 percent *Giardia* inactivation and 99.99 percent virus inactivation, meeting current Surface Water Treatment Rule requirements. Process monitoring includes monitoring for pH, temperature, turbidity, UV absorbance, and chlorine residual.

The facility is highly automated and can be monitored and controlled via SCADA. The WDF is staffed a single shift each day, and monitored and controlled remotely from the CWTP during off shifts. Day shift is two operators.

6.6 Asset Management for the Existing WDF

The assumptions which lead to planning for periodic asset replacement at CWTP are similar for WDF. Most of the equipment is not subject to the kind of physical or operating constraints as equipment at CWTP and subsequently as smaller percentage of total replacement cost funding can be assumed. A recommendation is included that up to $4 million be allocated for long-term asset management at the WDF. Expenditures would be primarily in the FY27-29 time period. Project identification and prioritization procedures should be the same as for CWTP.

6.7 Required Changes to Meet New Stage 2 D/DBP and LT2 ESWTR Requirements - Ware Disinfection Facility

When the Ware Disinfection Facility was designed, it was recognized that EPA would eventually issue new rules and that those rules would probably require some level of *Cryptosporidium* inactivation. At that time, only ozone appeared to be capable of inactivating *Cryptosporidium.* As the requirements were unclear, a life cycle analysis was done on whether it was cost effective to defer construction of the ozone plant until the rules were issued. In 1995, based on the life cycle cost analysis, MWRA delayed a decision on adding ozone at a cost of $15 million until the new rules were issued.

The new LT2 ESWTR will require 99 percent inactivation of *Cryptosporidium,* and the use of two primary disinfectants. In June 2006, staff recommended and the Board of Directors approved UV as the least expensive option for the CVA system. This is the most cost-effective solution as the UV facilities could be added in essentially the same location as originally designed for the ozone expansion. Staff recommended UV, chlorine and potentially chloramine for the Ware Disinfection Facility in order to comply with the new regulations. The continued use of free chlorine as primary disinfectant at Ware Disinfection Facility is possible due to the exceptionally low amount of organic materials in the raw water, thereby resulting in lower disinfectant byproducts. Staff anticipated that the levels of disinfection byproducts should be below the levels required under the Stage 2 Disinfectants and Disinfection Byproducts Rule, but will reserve the ability to add chloramine of additional DBP monitoring indicates that it is required[6].

The recommendation was based on a review of only one other treatment alternative:

> <u>Ozone and Free Chlorine</u> - During the design of the Ware Disinfection Facility, staff anticipated the future possibility of the need for addition of a stronger disinfectant and the original design allowed for expansion with ozone. Ozone/chlorine would be substantially more expensive than UV/chlorine/chloramine.

Filtration was not considered given the higher level of protection and lower level of organic material in the Quabbin Reservoir source water, and its higher construction and operating costs.

Recommended Location for CVA UV Facility

A feasibility study was conducted to assess the advantages and disadvantages of constructing the UV system at various locations in the CVA system. The following alternative locations and treatment options were evaluated:

Site 1: Ware Disinfection Facility
- Addition of UV to existing chlorine disinfection
- Addition of UV and chloramination to existing chlorine disinfection

Site 2: Winsor Dam Power Station
- Addition of UV, chlorine remains at Ware Disinfection Facility
- Addition of UV, relocation of chlorine to Windsor Dam Power House, addition of chloramination at Ware Disinfection Facility

The final analysis indicated that the Ware Disinfection Facility was superior to the Winsor Dam Power Station location, and that the UV system should be installed upstream of chlorine injection to maximize system efficiency and to minimize lamp sleeve cleaning and maintenance requirements. It is recommended that, if necessary, ammonia injection for chloramination be located downstream from the Ware Disinfection Facility via feeder piping along the CVA to an injection port located approximately 1500

6 The highest DBPs are expected to be at the ends of the Chicopee system. If the DBP levels are higher than the new regulatory standards or too close for continued reliable compliance, the addition of chloramine for the entire CVA system will be evaluated, as will the possibility of just chloraminating the Chicopee system at their existing treatment plant at the entry point to their system. Due to the complex water chemistry, the varying corrosion control strategies and the possible need to MWRA to adjust pH and alkalinity to properly chloraminate, the Chicopee solution may be simpler from a process control basis, and significantly less expensive.

feet downstream. The site plan of the existing Ware Disinfection Facility and the conceptual design for the future UV/chlorine/chloramination facilities is shown in Figure 6-2 below.

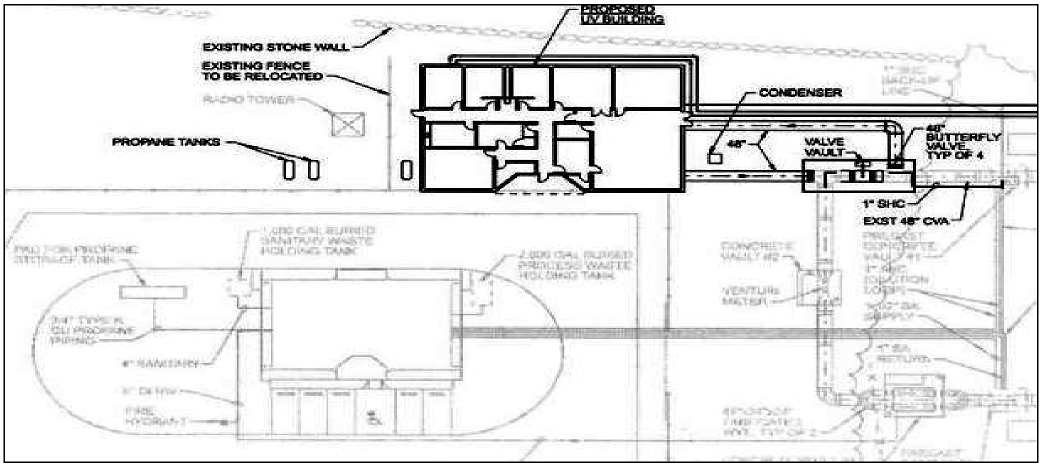


Figure 6-2 Existing Ware Disinfection Facility and Proposed UV/chlorine/Chloramination Facility

Schedule and Cost

The design and construction schedule for this project are:

Design Notice To Proceed	July 2007
Construction Notice To Proceed	February 2010
Substantial Completion	October 2011

Compliance is required by October 2012[7]. The estimated design cost is approximately $ 1 million; the estimated construction cost for the facility is approximately $4.8 million. These funds are included in the Final FY 07-09 CIP.

6.8 Recommended Actions and Future Capital Improvements

- To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should add Ultraviolet light disinfection at the Carroll Water Treatment Plant (CWTP) by October 2013. The new facilities are expected to be constructed within the extended ozone contact chambers, will provide the ability to comply with both the requirement for 99% inactivation of Cryptosporidium and the use of two primary disinfectants, and allow for the reduction of the ozone dose. The improvements are expected to cost $43.5 million for design and construction.

7 Or October 2014 if DEP grants the available 2 year extension for capital improvements

- To comply with EPA's new Long Term 2 Enhanced Surface Water Treatment Rule, MWRA should add Ultraviolet light disinfection at the Ware Disinfection Facility (WDF) serving the Chicopee Valley Aqueduct communities. This facility will be constructed the site of the current chlorination facility at a cost of $5.8 million.

- The existing Carroll Water Treatment Plant requires certain ancillary modifications to optimize its performance and incorporate improvements from lessons learned over the first year of operation. These modifications and improvements are expected to cost approximately $ 7.6 million over the period FY2009 to 2011.

- Both the CWTP and the WDF will require regular investments in asset protection to maintain them in proper working order. Based on the mix of long lived concrete facilities and shorter lived electrical and moving components, approximately $3 million is recommended in the FY16-18 period to initiate a long-term $50 million asset protection program for the CWTP and $4 million is recommended in the FY27-29 time period for the WDF.

7 The Transmission System

7.1 Chapter Summary

The transmission system consists of over 100 miles of tunnels and aqueducts in daily use which transport water by gravity from the supply reservoirs to points of distribution within the MWRA service area. The transmission system has evolved over time in response to increased population, expansion of the service area and the need to go farther from developed areas for adequate and high quality sources of water. This system was designed in such a way that the basic layout remains fundamentally sound and useable. System improvements over time have also allowed for older facilities, no longer in daily use, to remain as critical emergency standby facilities as long as maintained and linked to new facilities where necessary.

The performance standards required to be met by a major transmission system are twofold. The system must be able to transport sufficient water to meet the maximum daily demands of the service area. Secondly, the system must be reliable in that it must have sufficient redundant components to ensure a continued supply of water if any one "leg" of the system were to fail. MWRA's transmission system ably meets system demands and much of the system has redundant components that may be brought on line. However, shortfalls in full redundancy remain and are discussed in Section 7.4 of this chapter.

In addition, there remain uncertainties about the condition of certain key transmission system components and further tunnel inspections are recommended to address these concerns. Although it is expected that these tunnels are in good condition based upon their age and expected useful life, and no projects to remediate any deficiencies are identified, it is prudent to begin to assess their condition. Also, within the Transmission system, work has been ongoing to assess many of the Western Operations facilities in daily use as well as key appurtenant structures including shafts, which are associated with the tunnel and aqueduct system from Quabbin Reservoir to the eastern part of the Water system. A number of recommendations resulting from this study have been incorporated into this Master Plan effort.

The organization of this chapter is generally focused on the assessment of the transmission system in terms of both its physical condition and an assessment of how well it meets the goals for reliability, including redundancy. The components of the system that operate under normal conditions are discussed first, organized for discussion geographically, beginning at the Quabbin Reservoir and moving through facilities and structures to the eastern part of the system. Following the discussion of active facilities, the portions of the system that are not in daily use and that are maintained for emergency use, are discussed. Dams are discussed separately in Section 7.6 followed by a Summary of Recommended Improvements in Section 7.7.

Summary of Chapter Recommendations

In the near-term, the Master Plan identifies approximately $276 million in transmission system project needs for the FY07-18 timeframe, including all projects currently in the FY07 CIP.

Projects already in the FY07 CIP**:**

For the FY07-18 timeframe, the FY07 CIP includes most notably the following transmission system projects with an estimated cost of $3 million or more:

- $71 million, primarily to provide inter-connections between the MetroWest Tunnel and the Hultman Aqueduct and to rehabilitate the Hultman.
- $8.9 million to design and complete improvements to the Wachusett Reservoir spillway/North Dike and make spillway and toe drain repairs to Winsor Dam.
- $5.2 million to complete the Chicopee Valley Aqueduct Redundancy project.
- $3.2 million to complete short-term repairs to the Sudbury Aqueduct and to inspect the Weston Aqueduct, to ensure readiness of these back-up systems in an emergency. Additional funds may be required to complete the Weston Aqueduct inspection.

Projects recommended for consideration in the FY08 CIP:

Staff recommends consideration for the FY07-18 timeframe of the following projects with an estimated cost of $2 million or more:

Redundancy projects:

- $100 million for the Long-Term Redundancy project for the eastern part of the system from Shaft 5 to Chestnut Hill ($50 million in FY14-18 and $50 million in FY19-23), to provide redundancy to the transmission tunnels in the metropolitan Boston area, i.e., the City Tunnel, the City Tunnel Extension, and the Dorchester Tunnel. While these tunnels are believed to be in good condition, there is still a risk of failure, mainly due to pipe failures at the surface connections to the distribution system or major subsurface issues, including structural issues due to earthquake or fault. A rupture of piping at surface connection points on any of the metropolitan area tunnel shafts would cause an immediate loss of pressure throughout the entire High Service area and would require difficult emergency valve closures and lengthy repairs.
- $100 million to pressurize the Wachusett Aqueduct so that it can fully replace the Cosgrove Tunnel in an emergency (FY09-18, primarily in FY14-18). The flow capacity of the Wachusett Aqueduct is limited to 240-250 mgd, insufficient to meet summer demand. Also, the Aqueduct cannot supply flow into the ozone contactors at the Carroll plant, requiring the activation of temporary chlorination facilities. The

need for the project is made more urgent because the Cosgrove Tunnel requires repairs.

The timing of these two projects is still being refined.

Priority repair, rehabilitation and improvement projects:

- $11.6 million for improvements at the Oakdale Power Station, including a study and completion of preliminary design for the electrical system ($3 million), and hydraulic controls improvements and additional transfer capacity to Wachusett Reservoir ($8.6 million)

- $6.2 million for dam-related projects, including immediate repairs to earthen and masonry dams following the completion of dam risk assessments ($4.2 million); and long-term asset protection including repointing of masonry dams and rehabilitation of earthen dams ($2 million in the FY14-18 timeframe).

- $5 million for improvements to Winsor Power Station, FY09-13. The electrical system for the station is in poor condition, and the valve intended as the isolation valve for the turbine is currently being used to reduce head at the facility. A project is needed to address this valve and to complete station piping improvements which would allow water to go to the Swift River without going through the valve. Reactivation of the hydrogenation facilities at this location are estimated to cost an additional $1.5 million and this work is recommended if permitting issues can be resolved.

- $3.6 million to initiate a 10-year, $9 million program to systematically make major facility repairs as identified in the Transmission Facilities Engineering Assessment, including in the FY09-18 timeframe repairs to roofs ($600,000). Structural repairs to buildings/shafts, electrical and HVAC upgrades, safety/security improvements, and road/bridge repairs have all been identified.

- $2 million for the Quabbin Intake Structure at Shaft 12, to install a sluice gate to allow emergency stoppage of water flow to the Oakdale Power Station in the event of failure of the station's water piping.

7.2 Existing System Overview

As noted above, the system was built over time while maintaining the geographical advantage inherent to the Boston location. That is, while much of the service area is relatively low in elevation, supply sources are located at higher elevations allowing much of the system to be served by gravity. As the metropolitan areas in eastern Massachusetts grew, the service area expanded to include services areas served through the use of pump stations. However, approximately 80% of the water delivered by MWRA remains served by gravity flow. About one quarter of the MWRA communities pump some or all of the water delivered by MWRA to reach higher local service zones. Figure 7-1 shows the full system, including transmission and supply facilities currently held in reserve for emergency use. Table 7-1 provides overview information on each of the active and stand-by aqueducts and tunnels.

The principal structural components of the MWRA system consist of Quabbin and Wachusett Reservoirs, the Ware River intake and the deep rock tunnels and surface aqueducts that deliver water by gravity eastwards to the approximately 280 miles of pipe that distribute water to 44 metropolitan area communities. In addition, Clinton, Leominster and Worcester take directly from Wachusett Reservoir or the Quabbin Aqueduct and the Chicopee Valley Aqueduct (CVA) system delivers water to three communities to the southwest of Quabbin Reservoir, (i.e. Chicopee, Wilbraham and South Hadley Fire District No. 1).

Quabbin Reservoir has a maximum storage capacity of 412 billion gallons, equivalent to about five years worth of supply at current demands. It is fed by a well-protected watershed of 186 square miles. Quabbin Reservoir can also receive water from the Ware River watershed through the Shaft 8 intake structure, which diverts water to the Quabbin. Wachusett Reservoir has a maximum capacity of 65 billion gallons and is fed by a slightly more developed watershed that is 107 square miles.

Figure 7-2 shows system inflows and outflows. Water flows directly into each reservoir from its watershed so Quabbin normally receives approximately 2/3 of the runoff in proportion to its larger watershed area. Wachusett's runoff is often enough to support all metropolitan area demands in the spring but it needs supplemental supply from Quabbin in the drier months to maintain water elevation. Ware River water is normally diverted to Quabbin in high runoff months to take advantage of Quabbin's long detention times to improve water quality. Flow out of the reservoirs is made up of withdrawals for water supply, required releases, and overflows when the reservoirs are full.

Water is discharged from the Quabbin Reservoir primarily from the Quabbin Tunnel, which has a flow capacity of 610 MGD. However, flow is restricted by the Oakdale Turbine and bypass valve capacity to approximately 300 MGD. The water enters the aqueduct at Quabbin Tunnel Intake, Shaft 12, and travels over 24 miles to Wachusett Reservoir. Releases from Quabbin also occur through the Chicopee Valley Aqueduct, which supplies an average of 9 MGD to three communities west of the Quabbin.

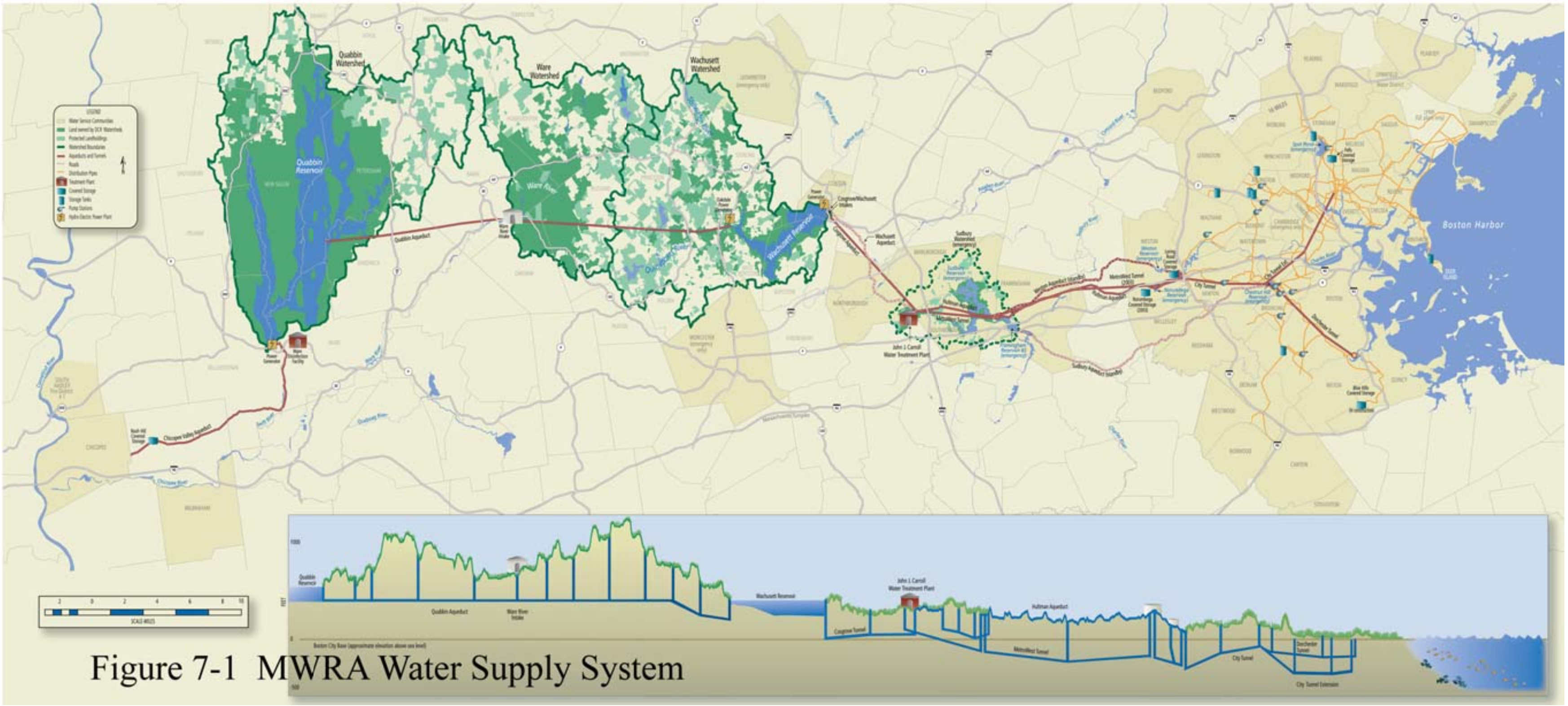


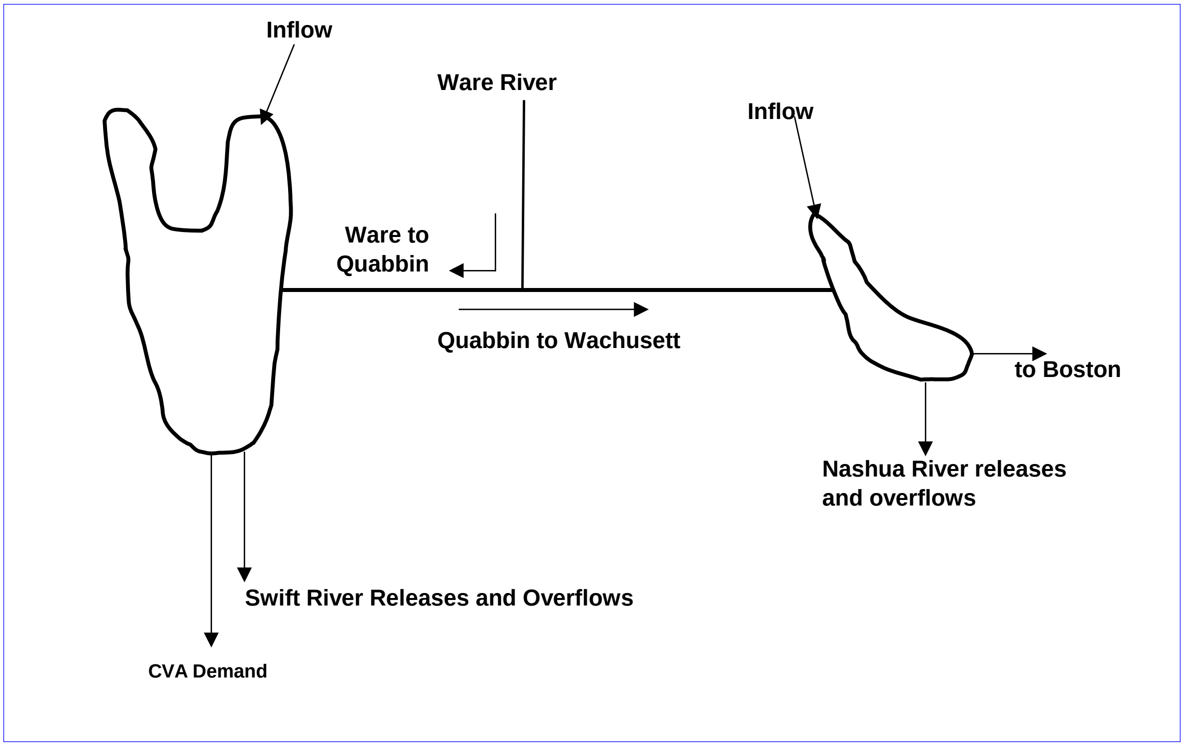
Figure 7-1 MWRA Water Supply System

Table 7-1
Overview Information on Aqueducts and Tunnels

Aqueduct/Tunnel	Year Built	Capacity (mgd)	Diameter (ft)	Length (miles)	Types of Construction	Status
Chicopee Valley Aqueduct	1949 [1]	24	3-4	14.8	steel reinf. Concrete	Active
Quabbin Tunnel	1939	610	13	24.6	concrete lined rock	Active
Cosgrove Tunnel	1967	600	14	8	concrete lined rock	Active
Wachusett Aqueduct	1897 [2]	320	10-12	12	brick, concrete, open channel, gravity	Stand-by
MWWST	2003	450	14	17.6	concrete lined rock	Active
Southborough Tunnel [3]	1940	600	14	3	concrete lined rock	Active
Hultman Aqueduct	1940	325	11-12	15	concrete; steel	Active
Weston Aqueduct	1903	250	10-12	13.5	brick, concrete gravity	Stand-by
City Tunnel	1950	300	12	5.4	concrete lined rock	Active
City Tunnel Extension	1963	200	10	7	concrete lined rock	Active
Dorchester Tunnel	1976	200	10	6.4	concrete lined rock	Active
Sudbury Aqueduct	1878	90	7-9	17.4	brick, gravity	Stand-by

1. Redundant section scheduled for completion in 2007
2. Rehab completed in 2002
3. part of Hultman system

Figure 7-2 System Inflows and Outflows



When Ware River flow is diverted westward to Quabbin Reservoir, shutter flaps at the Shaft 12 intake force the water to discharge into the Quabbin Reservoir at Shaft 11A so as to keep the lower quality Ware River flow from accumulating around the Shaft 12 intake. Baffle dams direct the Ware diversion water northward into the reservoir and force the water to flow many miles to reach the Quabbin Tunnel intake structure at Shaft 12. As referenced in Chapter 4, Ware River transfers are limited to the portion of river flows above 85 mgd and are subject to the following conditions: no diversion of Ware River flows allowed from June 15 to October 15. Diversion from June 1 to June 15 and from October 15 to November 30 must have prior permission from the DEP Division of Water Supply.

Under normal operating conditions, the Cosgrove Intake and Tunnel carry 100 percent of the flow from the Wachusett Reservoir to the newly constructed John G. Carroll Water Treatment Plant ("CWTP"). This tunnel is backed up by the old Wachusett Dam Intake and the rehabilitated Wachusett Aqueduct, both of which were used in the winter of 2004/2005 while new connections to the CWTP were constructed.

From the plant, flow can continue east from through the new Metrowest Water Supply Tunnel ("MWWST") or through the Hultman Aqueduct. The MWWST was constructed to remedy the significant lack of transmission system redundancy when the decision was made to not build the second barrel of the Hultman Aqueduct following WWII. Construction of the tunnel has eliminated a major weakness in the transmission system and has allowed MWRA to not only proceed on the necessary repairs to the 60 year old pipe but also has reduced reliance on antiquated facilities, such as the 103 year old Weston Aqueduct (which was also taken off line due to its connection to the open Weston Reservoir). The MWWST tunnel also provided some hydraulic benefits and, given the depth of the tunnel (200-600 feet below the surface), provides additional security for the water transmission system.

The Hultman Aqueduct is a 1940's vintage reinforced concrete pipeline for most of its length, the upper section being 12.5' diameter and the lower section being 11.5' diameter. A portion of the Hultman Aqueduct consists of the three-mile long tunnel section, known as the "Southborough Tunnel", which travels beneath the Sudbury Reservoir. The Hultman Aqueduct historically was connected to the Norumbega open storage reservoir, but is now connected to the CWTP and is being connected to the MWWST and to the new Norumbega Covered Storage Facility. When work on Hultman repairs is complete, either the MWWST or Hultman Aqueduct will be able to be isolated for emergencies with no loss of service to metropolitan Boston or the Metrowest communities.

East of the new Norumbega facility, the MWWST or Hultman Aqueduct flow can be directed to the 20 MG storage tank at Loring Road to supply the Boston Low service area. The facility can also be configured to supply the Northern Low Service area and the City Tunnel which feeds both the City Tunnel Extension to the north and the Dorchester Tunnel to the south. The City Tunnel, constructed in 1950, is a 12' diameter deep rock tunnel that extends five miles to Shafts 7 and 7B in Brighton. The City Tunnel Extension was constructed in 1963 and is a 10' diameter deep rock tunnel that goes from Shaft 7 north to Shaft 9A in Malden. The Dorchester Tunnel is a 10 ' diameter tunnel that extends southward from Shaft 7B to Shaft 7D in Dorchester. The Dorchester Tunnel was constructed in 1976. Shafts along each of these tunnel sections bring water up riser pipes that feed the distribution system.

7.3 Hydraulic Capacity Issues

As noted earlier, one of the prime functions of the transmission system is to ensure the capacity to supply maximum day demands for the foreseeable future. It should be noted that during the peak water use years in the 1980's, water demands had reached as high as 340 mgd with maximum days of well over 400 mgd. During these earlier periods, maximum day flow required the use of the older aqueducts, e.g. Weston Aqueduct supply to Boston Low and Sudbury Aqueduct use with Chestnut Hill pumping. It also required the use of the large open distribution reservoirs like Spot Pond, Fells, Blue Hills, Chestnut Hill and Weston. These large reservoirs allowed the old Cosgrove/Hultman backbone to function, albeit with some bottlenecks and weaker max day hydraulic gradients to the distribution system. Addition of the MWWST has significantly improved hydraulic capacity but the replacement of older open distribution storage with smaller tanks has placed more of a peak hour burden on the tunnel backbone. The trend towards removal from service of local community tanks has also increased peak flows.

The net effect of these changes is that the current system with CWTP and the MWWST/Hultman backbone is adequate to meet projected maximum day demands but it should be noted that the goal of maintaining one day of distribution storage continues to be an important one to maintain transmission system adequacy.

7.4 Reliability and Condition Assessments-Normal Operations

The following section focuses on those parts of the Transmission system that are in active use under normal operating conditions for the system. Summary information is provided on redundancy shortfalls in the MWRA system and an overview of condition assessment information for the Transmission system is provided. Following that, each facility is discussed in greater detail and for each asset or facility notes what is known of the condition and what level of redundancy exists for that facility. Any current work in progress or identified for funding in the current CIP is identified and any future recommended projects are also discussed.

Reliability and Redundancy

To evaluate the ability of the Transmission system to meet the performance standard for reliability, one must consider both the risk of failure for any part of that system but also the consequence of a failure. To do this, information on the condition of the asset is critical to determining risk. The consequence of any particular failure can vary from insignificant to catastrophic. Redundancy in a water transmission system serves to reduce the consequence of failure because emergency back-up or stand-by facilities can be brought on-line. This means that the condition of these back-up facilities must also be ascertained and evaluated.

Redundancy Shortfalls

Table 7-2 provides an overview of the risk and consequence of failure for those tunnels and aqueducts (including surface pipe and other appurtenant facilities) that are used during normal operations. It must be noted that a number of the tunnels have not been able to be inspected since they can not be removed from service. The Southborough Tunnel component of the Hultman Aqueduct has not yet been inspected but will be as part of an upcoming contract. Results of that inspection will help clarify any risks associated with that facility. The upcoming Cosgrove-Wachusett Redundancy Study is expected to include a feasibility analysis for an inspection of the Quabbin Tunnel but at this time no funds have been allocated for the actual inspection of the Quabbin Tunnel City Tunnel or City Tunnel Extension.

Since the 1993 Master Plan, completion of the MWWST has made the system significantly more robust and has alleviated much concern over a single-spine surface conduit as the major supply line to the metropolitan area. That said, there remain areas of concern where additional transmission improvements could increase operational flexibility both in the event of an emergency and would also allow regular inspection and rehabilitation of the system. Ideally, in the event of an emergency, the best resolution is to have a transition to a backup system that is unnoticeable by the end consumer. MWRA's system is not at that point and depending upon the location of a failure, service could be significantly disrupted.

Although the rehabilitation of the Wachusett Aqueduct allowed its use during a short winter duration period so that the Cosgrove Tunnel could be connected to the CWTP, it cannot fully replace the Cosgrove. Since the Cosgrove Tunnel's inspection has indicated the need for repairs, this is problematic. The Wachusett Aqueduct is limited in its flow capacity of 240-250 MGD which does not allow it to meet summer demands. Also, since the aqueduct delivers water at a low elevation, it cannot supply flow into the ozone contactors at the CWTP and would require that temporary chlorination facilities be activated for treatment. It would also take at least a day to activate the Wachusett Aqueduct to deliver flow into the MWWST for use in the metropolitan Boston area in the same manner that was done for the CWTP start-up. Since the CWTP plant flow system would not be supplied, the current supply to Northboro, Marlborough, Southborough and the Westboro State Hospital would require special temporary pumping as was done temporarily during CWTP start-up but which was disassembled afterward. The most likely alternative to address redundancy for the Cosgrove is to pressurize the Wachusett Aqueduct which would allow it to meet system demands to the full CWTP capacity to create a transparent changeover during an emergency.

The transmission system between CWTP and Shaft 5, the beginning of the City Tunnel, will be fully redundant after completion of the interconnections that are part of the Hultman Aqueduct repairs. This section will then be capable of seamless transfer of flow delivery, i.e. no significant service impacts, if either MWWST or Hultman requires an emergency shutdown.

The tunnels in the Metropolitan Boston area, (i.e. the City Tunnel, City Tunnel Extension and Dorchester Tunnel) remain a weak link. While the integrity of the underground tunnel sections is believed to be good based on very low unaccounted for water levels in the MWRA Transmission system, there is still risk of failure, mainly due to pipe failures at the surface connections to the distribution system or major subsurface issues such as structural issues due to earthquake or faults. A rupture of piping at surface connection points on any of the metropolitan area tunnel shafts would cause an immediate loss of pressure throughout the entire High Service area and would require difficult emergency valve closures and lengthy repairs. Although the assumption is that tunnels have a useful life of 100 years, due to the need to keep these lines in service, these subsurface emergency shutdown.

The tunnels in the Metropolitan Boston area, (i.e. the City Tunnel, City Tunnel Extension and Dorchester Tunnel) remain a weak link. While the integrity of the underground tunnel sections is believed to be good based on very low unaccounted for water levels in the MWRA Transmission system, there is still risk of failure, mainly due to pipe failures at the surface connections to the distribution system or major subsurface issues such as structural issues due to earthquake or faults. A rupture of piping at surface connection points on any of the metropolitan area tunnel shafts would cause an immediate loss of pressure throughout the entire High Service area and would require difficult emergency valve closures and lengthy repairs. Although the assumption is that tunnels have a useful life of 100 years, due to the need to keep these lines in service, these subsurface structures have not been inspected and their actual condition is unknown. Facilities at the tops of tunnel shafts have been examined and a number of hardening measures are needed for risk reduction at these sites. Completion of planned distribution system storage projects like the Blue Hills Tanks also provide mitigation of the effects of a piping rupture at these points.

In the event of a failure of the City Tunnel, a limited amount of water could be transferred through the WASM 3 line (scheduled for major rehabilitation) and WASM 4 and the Sudbury Aqueduct would need to be brought on line. Extensive use of the Sudbury Aqueduct/Chestnut Hill Emergency Pump Station and open distribution storage at Spot Pond and Chestnut Hill would be required. Supply would be limited and a boil order would be put in place.

Failure of the City Tunnel Extension would be similar with reliance on WASM 3 and open storage at Spot Pond.

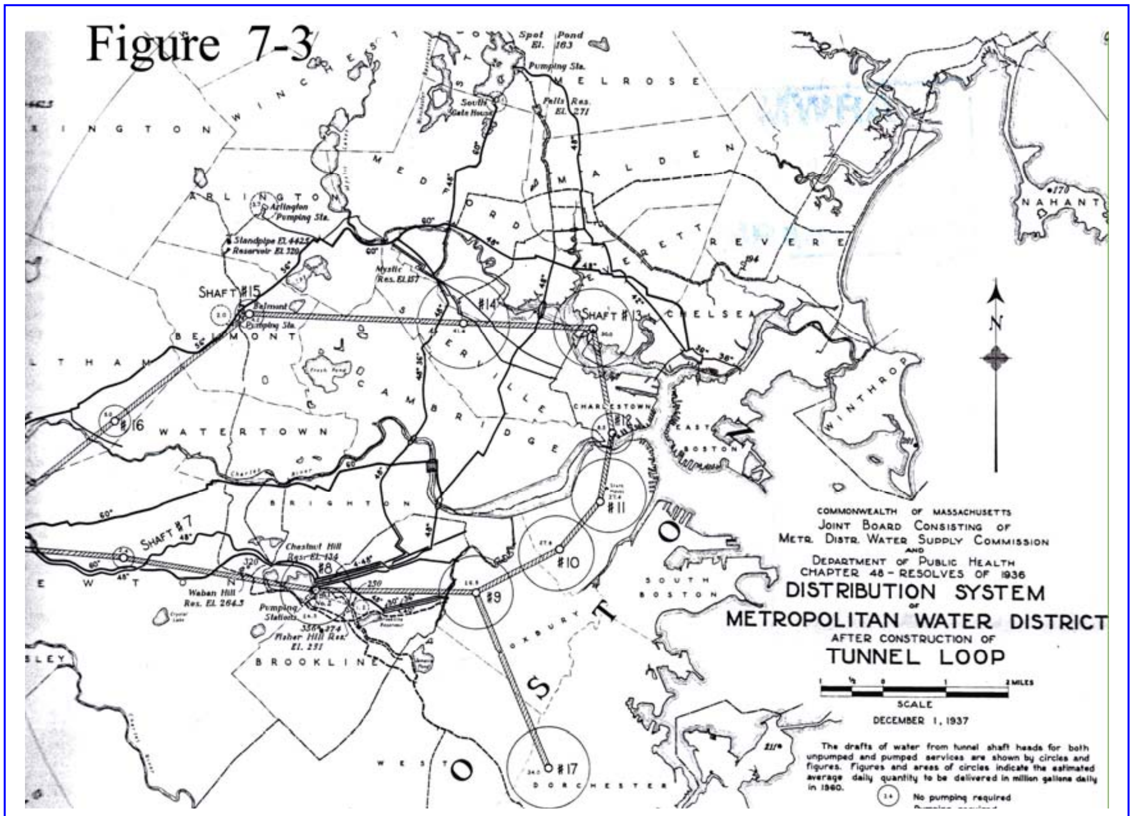
Table 7-2
Risk and Consequence of Tunnel/Aqueduct Failure

Aqueduct/Tunnel	Age (yrs)	Risk of Failure	Consequence of Failure
Quabbin Tunnel	67	Low	Low
Chicopee Valley Aqueduct	57	Moderate	Moderate
Cosgrove Tunnel	39	Tunnel - Low Surface Pipe – Mod	High
Metrowest Tunnel	3	Low	Low
Southborough Tunnel	66	Low	Low
Hultman Aqueduct	66	Moderate	Low
City Tunnel	56	Tunnel - Low Surface Pipe - Mod	High
City Tunnel Extension	43	Tunnel - Low Surface Pipe - Mod	High
Dorchester Tunnel	30	Tunnel - Low Surface Pipe - Mod	High

If the Dorchester Tunnel were to experience a problem, flow could be routed to the south through surface mains. However, this relies on the completion of the Chestnut Hill Connecting Mains project which was previously removed from the CIP (see Chapter 8).

The original solution proposed to address redundancy in the metropolitan area was the 1936 plan for a tunnel loop as shown in Figure 7-3. Although the City Tunnel, City Tunnel Extension and Dorchester Tunnel were built, the section to the north, completing the loop, was never constructed. The closed loop system increases reliability by allowing flow to reach any point from two directions. If constructed today, a northern loop would go further north and west of the plan developed in 1936 because the City Tunnel Extension itself extends further north. A new tunnel could begin at Norumbega and continue to Fells Reservoir and end at the City Tunnel Extension.

Depending upon system needs, a southern tunnel loop could also be constructed. Such a loop might go from Norumbega Covered Storage to the Blue Hills Covered Storage facility and proceed to the end of the Dorchester Tunnel.



<u>Recommended Redundancy Projects:</u>

To address these shortfalls in system redundancy, the following work is recommended:

- Procure Final Design services for the short-term repairs to the Sudbury Aqueduct to allow it to be used in the event of an emergency. A list of critical repairs includes cleaning of the Rosemary Brook siphon and structural repairs at targeted locations identified during the Aqueduct inspection. The estimated cost is $500,000 for design with a start date in FY08.

- Fund the construction of the short-term repairs to the Sudbury Aqueduct using remaining funds available in the CIP. The estimated cost is $2.8 million and work should be initiated immediately following design of the repairs.

- Separately, procure services to conduct an inspection and report on the condition of the Weston Aqueduct. This will provide baseline information on condition and the ability to reactivate the aqueduct in an emergency. Between 4250,000 and $500,000 is anticipated to be required and this should be initiated in FY08.

- Move forward with the construction of the Chestnut Hill Connecting Mains Project at a cost of $5.6 million. Final design work is in the current CIP but construction has not yet been funded.

- Initiate a new study of long term redundancy alternatives. This study would address the eastern part of the system from Shaft 5 east. It would consider long term use of the Sudbury Aqueduct (pressurization), the tunnel loop alternatives and other possible solutions. This study would also determine the feasibility and develop plans for the inspection of the Quabbin Tunnel, City Tunnel, Dorchester Tunnel and City Tunnel Extension. The estimated cost for this work is $1.5 million and it should be started in the FY09-13 time frame in order to maximize MWRA's ability to coordinate ongoing system improvements with a planned long term solution. Following this study, it is expected that design and construction of recommended redundancy improvements for the eastern part of the system would cost approximately $100 million.

- Following the above study, move forward with inspections of the Quabbin Tunnel, the City Tunnel, Dorchester Tunnel and the City Tunnel Extension. Although the feasibility studies will further define the costs, $2 million should be added to the CIP for this purpose.

- Add funding to the CIP for the pressurization of the Wachusett Aqueduct with design to start in the FY09-13 time period. The preliminary estimated cost of this work is $100 million.

<u>Condition Assessment</u>

An initial step in this master planning effort was to conduct a quick assessment of gaps in MWRA's knowledge about key infrastructure. Because so many of the water transmission facilities were in daily use and could not be taken off line for inspections, it was determined that better information on tunnels, aqueducts and other transmission facilities would need to be obtained. As seen below, much has now been learned about facilities but additional work to inspect tunnels and aqueducts are still recommended.

A significant work effort was undertaken in the mid-1990's to use contract staff to inspect all western operations facilities and to identify deficiencies. These reports then became the basis for repairs and/or decisions to block access to certain facilities or locations due to safety hazards. More limited staff resources and the attention to the start-up of Integrated Water Supply Improvement Program projects has resulted in a slow-down of these activities. Where possible, critical projects have been identified as capital projects and been proposed for inclusion in the CIP.

As a next step, Water Engineering has initiated a consultant study, called the *Transmission Facilities Engineering Assessment*. Staff has recently completed the inspections of key transmission facilities and top of shaft structures. Reports on condition assessment, recommendations and costs are expected in late 2006. The recommendations will be tiered and will consider both the minimum level of work necessary to operate or stabilize the asset and a higher level that will enhance the operation of the facility or bring the facility fully up to its original condition. Given the historic status and architectural style of many of the facilities, the latter level of rehabilitation may not be financially feasible at this time. Thus, improvements to halt any ongoing deterioration and ensure safe and secure facility operation may be the short-term course of action with the study serving as the blueprint for the requirements to fully bring the asset up to its original condition, if desired, over a longer time frame. Once the recommendations have been accepted by MWRA, the Consultant will be expected to complete facility plans and conceptual designs for the recommended improvements.

Table 7-3 shows the list of facilities addressed by this study and a preliminary review of the types of deficiencies noted in the facility. Although specific costs and projects have not yet been fully identified, it is important to note that a large number of these facilities
appear to need rehabilitation. This suggests that an ongoing asset protection program for these Western Operations facilities is necessary to facilitate repairs. The preliminary ranking of facility needs on this table ranks the level and projected costs of improvements for each of the facilities relative to each other on a 1-3 scale with a "3" indicating that more rehabilitation is expected to be necessary. That said, there are many commonalities in the initial inspection reports. Most of the facilities require some level of structural repairs, varying from mortar repairs to far more significant deterioration of structural elements. Roof and gutter repairs are also needed for many of these facilities. Ultimate implementation of the study recommendations will involve the identification of opportunities for facilitating work and saving money through the economies of scale that may be present.

In the discussion of individual facilities below, the inspection information obtained to date is not referenced in detail but only identified when specific projects are already recommended or when the level of deficiency noted warrants further discussion.

<u>Recommended Projects</u>:

- Increase asset management funds in the CIP to facilitate ongoing repairs of the transmission system facilities. A initial project to address roofs at a proposed cost of $900,000 is proposed for the FY09-13 time period.

- An additional $9 million in asset protection funds to make major repairs to facilities as identified in the Transmission Facilities Engineering Assessment Study. Although cost information has not yet been identified, it is clear from the information below, that some facilities have critical needs. These funds should be available beginning in the FY09-13 time frame but would be used over a twenty year period.

The following section focuses on those parts of the Transmission system that are in active use under normal operating conditions for the system. Each facility is discussed in greater detail and for each asset or facility notes what is known of the condition and what level of redundancy exists for that facility. Any current work in progress or identified for funding in the current CIP is identified and any future recommended projects are also noted.

Table 7-3 (page 1)

TRANSMISSION FACILITIES ENGINEERING ASSESSMENT
PRELIMINARY FACILITY NEEDS

FACILITY / STRUCTURE	STRUCTURAL	ELECTRICAL	MECHANICAL	HVAC	PLUMBING	I&C	SECURITY	COMMENTS	PRELIMINARY NEEDS RANKING
Chicopee Valley Aqueduct Facilities									
CVA Intake	X	X						Minor rehabilitation	1
Winsor Power Station	X	X	X					Poor condition; significant work required	3
Wachusett Reservoir Facilities									
Cosgrove Intake building	X								2
WR Lower Gatehouse and Power Station	X							Separate Lancaster Mills piping	2
WR Upper Gatehouse	X						X	Investigate crane safety	1
City Tunnel Top of Shafts									
Shaft 5		X		X				Condensation problem; seal building	2
Shaft 6							X		1
Shaft 7B									1
Shaft 7C							X		1
Shaft 7D							X		1
Shaft 8							X		1
Shaft 9	X	X	X	X			X	Poor condition; significant work required	3
Shaft 9A									1

Table 7-3 (page2)

TRANSMISSION FACILITIES ENGINEERING ASSESSMENT

PRELIMINARY FACILITY NEEDS

FACILITY / STRUCTURE	STRUCTURAL	ELECTRICAL	MECHANICAL	HVAC	PLUMBING	I&C	SECURITY	COMMENTS	PRELIMINARY NEEDS RANKING
Quabbin Aqueduct Top-of-Shafts									
Shaft 2 (Overflow Structure)	X						X	Concrete repairs may be necessary	2
Shaft 3							X	Coordination with Worcester required	–
Shaft 4	X								1
Shaft 5							X		1
Shaft 6							X		1
Shaft 7							X		1
Shaft 8							X		1
Shaft 9	X							Minor building rehabilitation required	1
Shaft 10							X		1
Shaft 11							X		1
Quabbin Aqueduct Misc. Facilities									
Shaft 1- Oakdale Power Station	X	X					X	60+ year old electrical system	2
Shaft 3- City of Worcester Interconnection Bldg								Worcester facility	–
Shaft 8- Lonergan Intake Bldg	X	X	X					Potential Upgrades to be considered	2
Shaft 8- Lower Garage	X				X			Minor building rehabilitation required	1
Shaft 8- Service Building									–
Shaft 11A- Ware River Diversion Discharge							X		1
Shaft 12- QA Intake Building	X		X					Sluice gate project recommended	3
Shaft 12- QA Service Building	X	X							1
Southborough Tunnel Top-of-Shafts									
Shaft 1							X		1
Shaft 2	X							May require signicant reconstruction	2
Shaft 3	X						X		1

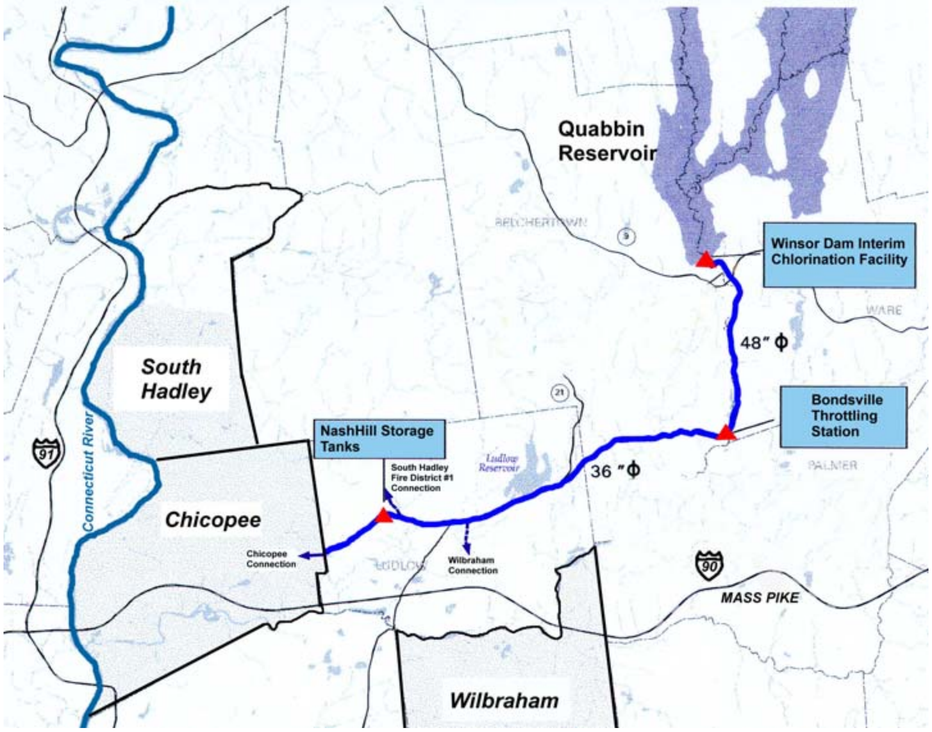
<u>Chicopee Valley System</u> *(shown in Figure 7-4 below)*

<u>Chicopee Valley Aqueduct</u>

The Chicopee Valley Aqueduct was initially constructed in 1949 to serve the communities of Chicopee Wilbraham and South Hadley Fire District #1. The Aqueduct

Figure 7-4

Chicopee Valley Aqueduct System



extends approximately 15 miles in length and is reinforced concrete pipe with an embedded steel cylinder. The pipe varies from 36”-48” in diameter. The pipe has a capacity of 23 MGD which is sufficient to meet peak summer demands. There is no alternate means of providing water to these communities. If supply were shut off upstream of Nash Hill Covered Storage, Chicopee would be without water after two days and South Hadley and Wilbraham would lose service sooner than that. If the CVA were to be shut off shut off downstream of Nash Hill Covered Storage, Chicopee would be without water supply immediately.

<u>Current Work</u>: The recent effort to provide redundancy to a key segment of this pipeline consists of construction of a 8,100 foot long second barrel of the CVA from Nash Hill Covered Storage to the City of Chicopee of 30-inch diameter pipe; 3,100 feet of 16-inch redundant pipeline between Nash Hill Covered Storage and the take-off point for South Hadley; and 2,400 feet of 20-inch redundant pipeline between the Route 21 valve chamber and the Wilbraham takeoff. With these new pipelines in place, the communities will be connected to Quabbin Reservoir, Nash Hill Covered Storage or both in the event of a failure along the Aqueduct. The contract will also

rehabilitate the Bondsville throttling station and the Route 21 valve chamber. This project will also provide additional mainline valves that will allow the isolation of manageable sections of the CVA. The cost of this project is approximately $11.4 million.

Associated CVA Structures and Facilities

CVA Intake Facility

The CVA Intake structure controls water flow from the Quabbin Reservoir into the Chicopee Valley Aqueduct. It also conveys water to be released to the Swift River. It is located on the Winsor Dam and is partially located in the Reservoir itself. It houses two bays with rotating screens to prevent debris from entering the aqueduct.

Winsor Power Station

The Winsor Power Station was constructed below the Winsor Dam to house the valving and hydrogeneration equipment associated with supplying the CVA and releasing water to the Swift River. The facility had actively generated power on the flow being released to the Swift River until an electrical system fire in 1991. In addition to damage from the fire, the overall facility is now over 60 years old and the pipes and valving need replacement based on recent condition assessments and leakage problems. Restoration of the generation capabilities is recommended but will require relicensing the facility with FERC which may impose changed water release requirements which could impact the amount available for water supply. Whether there is sufficient benefit to reactivating this facility will not be clear until both technical requirements and permitting issues have been fully identified.

Recommended Projects:

- Improvements at the Winsor Power Station far exceed the routine improvements that could be implemented under the general FAMP funds. The electrical system for the station is in poor condition and would need improvement whether or not the station is reactivated for hydropower generation. More importantly, the valve intended as the isolation valve for the turbine is currently being used to reduce head at the facility. A project is needed to address a safer way of dissipating head and to consider station piping improvements which would allow water to go to the Swift River without going through the valve. Consultant recommendations have not yet been fully developed but it is anticipated that this site will require extensive work. A design and construction cost estimate of $5 million should be inserted into the CIP with design work to commence as soon as possible. In addition, staff recommends that since this contract will be addressing significant rehabilitation at the station, it should also provide some additional information on the feasibility of reactivating this facility for hydropower but at a lower flow (a 20 MGD turbine) than previously used. This can be accomplished within the $5 million recommended above.

- Reactivate the Winsor Hydroelectric facility at an estimated cost of $1.5 million in the FY09-13 time period.

Ware Disinfection Facility

The Ware Disinfection Facility has two main purposes, the first being to provide primary disinfection using sodium hypochlorite, and the second being flow regulation via SCADA controlled throttling valves to supply CVA demands in response to Nash Hill Tank variations. The facility was constructed in 1999. In order to comply with the future Cryptosporidium Rule that requires two means of disinfection, addition of UV disinfection is planned at this site (see Chapter 6). The facility may also being considered as the site for ammonia addition if the CVA is ever planned to be converted to a chloramine residual. Lab facilities currently housed at Quabbin Reservoir are also expected to be relocated to this facility as part of future facility improvements.

Ludlow Monitoring Station

Ludlow Monitoring Station is located approximately 9 hours of flow travel time downstream of the Ware Disinfection Facility and above the first CVA user (the Wilbraham meter). The facility consists of a small building that encloses sampling and SCADA equipment. The facility monitors chlorine residual and provides the process control feedback that allows Ware Disinfection to dose chlorine properly.

Nash Hill Tanks

The Nash Hill Tanks are two 12.5 MG above ground prestressed concrete storage tanks which were constructed in 1998 to replace an existing open water surface reservoir.
The open reservoir was disconnected and serves only as a detention basin for any overflows.

Nash Hill Service Building

The Nash Hill Service Building is a one story garage type building that is near the entrance of the Nash Hill Tank site. Its purpose is for storage of maintenance equipment associated with buildings and grounds maintenance of the CVA.

Quabbin Reservoir to Wachusett Reservoir

Quabbin Tunnel

The Quabbin Tunnel was constructed in the early 1930's and was initially brought on line for the diversion of Ware River water to the Wachusett Reservoir during that time prior to the completion of Quabbin Reservoir. In addition to access, many of the shaft locations have specific functions as outlined below. At these locations, there are some above-ground facilities. Although there is no redundancy to the Quabbin Tunnel, water could be provided from Wachusett Reservoir for a duration of six months or more during which repairs could be made to the tunnel.

Recommended Project:

- Staff recommend inclusion of the feasibility analysis for a Quabbin Tunnel inspection be included in the Long-term Redundancy study and that the inspection of the Quabbin Aqueduct be included with the inspection of the City Tunnel, Dorchester Tunnel and City Tunnel Extension.

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Quabbin Tunnel Structures and Facilities

Quabbin Intake Structure at Shaft 12

This is the location where flow enters the tunnel for transport to the Wachusett Reservoir. Reservoir water enters the building's intakes, passes through screens and enters the tunnel which is 125' deep at this point. It is a 40' x 30' granite block structure with a concrete substructure and pitched slate roof.

Recommended Project:

- If the water piping in the Oakdale Power Station were to fail, there is currently no way to stop the flow of water. The Shaft 12 structure has stop log bays but it is an intensive process to remove the stop logs to set the shutter valves in the opposite direction and this cannot be done on an emergency basis while flow is moving. A project to design and install a sluice gate at this site is recommended for implementation in the FY 09-13 time period at an estimated cost of $2 million.

Shaft 12 Service Building

This building is located about 240' away from the intake building and is of similar size and construction. The building houses two garage bays, a bathroom and two additional rooms. No major facility work is required.

Shaft 11A Ware River Diversion Discharge

This shaft is used to discharge flow into the Quabbin Reservoir when the Ware River is being diverted towards Quabbin via the Quabbin Tunnel. During normal operation, this shaft acts as a vent and access point for the aqueduct.

Misc. Shaft Structures with no Buildings

At a number of the shaft locations without larger, ancillary facilities, relatively minor improvements in physical hardening are recommended.

Quabbin Aqueduct Shaft 9

The headhouse at this location provides access and pressure relief for the Quabbin Tunnel. Pressure relief is particular important when Shaft 8 is being used for diversion of water from the Ware River. It is a granite block structure approximately 29' x 21' with a concrete substructure and a pitched slate roof. Minor building improvements appear to be required to maintain the integrity of the structure.

Shaft 4

This tunnel shaft serves as an access point and air relief structure for the Tunnel. There is no electrical service or heat in the structure which is approximately 30' x 19' in size. It is a granite block structure with a pitched slate roof. Minor building improvements appear to be required to maintain the integrity of the structure.

Shaft 3

This is the location where the City of Worcester Interconnection Building is located. This allows the City to take water from the Quabbin Aqueduct on an emergency basis with prior notification to MWRA. This facility is the responsibility of Worcester and is in poor condition.

Shaft 2

This shaft provides pressure relief to the Quabbin Aqueduct by allowing overflows and venting air both in and out of the tunnel. Typical operations avoid overflows at this location but they can occur during high volume transfers from the Ware River to either Quabbin or Wachusett Reservoirs. It is an above ground concrete structure and appears to be in poor structural condition. Further investigation of potential deterioration of the structure is planned.

Oakdale Power Station

The Oakdale Power Station is at Shaft 1 of the Quabbin Tunnel and is the terminus of the tunnel where it flows through a 3.4 MW turbine and combines with the Quinapoxet River to flow into the Wachusett Reservoir. Within the structure, flow from the aqueduct rises from Shaft 1 and is split between a generator penstock inlet pipe and a bypass pipeline. A brand new 84-inch butterfly valve provides isolation for the generator. Flow through the bypass is controlled by a new 72-inch butterfly valve and sleeve valve. The structure dates from the construction of the Quabbin Aqueduct and the generator was added around 1950 with limited electrical upgrades done around 1991. Piping and valve rehabilitation was completed in 2006.

Recommended Project:

- Preliminary inspections suggest that additional improvements beyond minor asset protection measures are still required at this facility. Work identified to date has not addressed the need to replace the electrical switchyard and electrical control systems. These facilities both run the turbine and connect the facility to the grid. These facilities are both technologically obsolete but can also present a safety hazard given the specialized antique equipment and localized knowledge necessary to operate the facilities. A new Phase 1A of Oakdale Improvements is recommended for inclusion in the CIP. This phase would study and complete preliminary design of electrical improvements at an estimated cost of $3 million during the FY09-13 time period.

- Phase 2 of the Oakdale project was deleted from a previous CIP and this included $8.625 million to improve hydraulic controls and provide additional transfer capacity to Wachusett Reservoir. This work is still necessary and building repairs to stem deterioration are also required. The turbine does not currently need to be replaced, having been refurbished in the late 1990's but long term replacement of the turbine will be necessary at some future date. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and update the costs of repairs at this station.

Ware River Facilities

Lonergan Intake and Service Building

Shaft 8 (elevation 656') on the Quabbin Tunnel, also known as the Lonergan Intake, is the location where water is withdrawn from the Ware River (seasonally and flow restricted as noted in Chapter 4) and dropped into the Quabbin Tunnel. This facility was constructed in 1931 and was used at that time to supplement the volume of water available from Wachusett prior to the completion of construction at Quabbin. Although flow in the tunnel can be directed in either direction, for water quality reasons, Ware River flows are normally directed to Quabbin (elevation 530') rather than to Wachusett Reservoir (elevation 395). A dam across the Ware River extends from the intake building and the bypass flow to the downstream reach of the river is controlled by the intake building. Flow into Shaft 8 passes through a system of siphons which is primed by the bypass water flow. The facility has an automated control system using floats, pneumatics for siphon priming and hydraulically controlled valves to control the diversion rate but the equipment is old and not normally operated in automatic mode. The building is a granite block superstructure, with a pitched slate roof set on a concrete plant structural steel support system and a reinforced concrete substructure. The building size is approximately 78' x 65' x 29' high at the eave. Although this ingeniously designed system works, in the long term, it is desirable to simplify facility start-up and SCADA controls are planned to allow unstaffed operation and remote monitoring of the facility and replacement of the siphon system. Valves are currently hydraulically actuated using an oil system which should be corrected thus valve and/or actuator replacements may be necessary. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and costs of repairs at this station.

There is no redundancy to these facilities, however, given the seasonal restrictions on taking Ware River water, it is expected that any necessary repairs could be made without impacting the ability to provide water from Quabbin or Wachusett Reservoirs.

The Shaft 8 Service Building is a single story structure containing three garage bays, a maintenance room, an office and bathrooms. The building is approximately 59’ x 37’ and is a granite block structure with a pitched slate roof atop a concrete slab. No major improvements appear to be necessary.

Barre Lower Garage

The Barre Lower Garage is a former textile mill building. It is a large single story structure with brick exterior walls wooden flooring, interior walls and roof system. It was built prior to the 1930’s water supply development of the site. The first floor is supported by a stone and concrete foundation walls and wooden beams and columns resting on concrete piers in the basement. Besides storage, the first floor houses an office, bathroom and lunchroom. A mechanical room in the basement houses the furnace, well water tank and hot water heater. The building is approximately 50’ x 133’ in size. Minor building improvements appear to be required to maintain the integrity of the structure.

The site is dependant upon well water with the well located near the Lower Garage. Further investigation is necessary to determine if this well can adequately meet the needs of the facility.

Wachusett Reservoir Facilities

Cosgrove Intake

The Cosgrove intake building was constructed in 1967 and is the sole active intake from the Wachusett Reservoir. Water passing through the facility enters the Cosgrove Tunnel at Shaft A located near the intake building. Water flows through the intake screens into intermediate wells. It is then controlled through bypass sleeve valves or through one of two 1.7 MW hydroelectric turbines. The water passes into a stilling basin and then through a horizontal tunnel to Shaft A of the Cosgrove Tunnel. The building is approximately 116’ wide x 147’ long but the substructure depth ranges from 70-100’ below the first floor.

In the mid-1990’s this building experienced cracking of wall tiles which may have been associated with some slight movement of the building. Minor water damage due to leakage has also been noted in the structure. In-house and outside experts evaluated these areas and monitoring of these areas was initiated on a regular basis. There does not appear to have been any subsequent movement and the building has been deemed to be fundamentally structurally sound during the inspections.

Recommended Projects:

- The building requires a number of improvements to stabilize and update the facility. Water intrusion at various locations necessitates the need for drainage, roof, ceiling and tile improvements and repairs. Access improvements through new elevator facilities and stairway replacement will improve safety and accessibility. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and costs of repairs at this station.

- The recent work at Cosgrove Intake replaced the bypass valves and refurbished the turbines to bring the mechanical equipment up to good condition. However, the need to operate the stilling basin at a slightly higher level to supply the CWTP has created the need to add downstream turbine and sleeve valve isolation. Although design of these improvements is in the current CIP, the construction funds at $1.9 million are recommended to be added beginning in the FY14-19 time frame.

Algae Control Chemical Feed System

Management of algae at Wachusett Reservoir has always been done manually using application of copper sulfate distributed by boat. This has been very effective for algae species that bloom on the reservoir surface but is less effective when the algae is dispersed in the water column. There have also been infrequent nuisance algae below the surface during winter months when there is an ice cover that doesn't allow copper sulfate dosing.

Recommended Projects:

- Following studies and pilot trials, the construction of an algae dosing system has been proposed. It will consist of piping placed in the reservoir to supply copper sulfate solution to an anchored underwater mixer that will dose the area of concern in front of the intake. This project is in the FY07 CIP at an estimated cost of $450,000 for design and $1.8 million for construction. Work is scheduled to be done in the FY09-13 time period.

Wachusett Reservoir to Shaft 5

Cosgrove Tunnel

The Cosgrove Tunnel was completed in 1967 and is a concrete lined, deep rock tunnel approximately 8 miles in length that extends from the Power Station and Intake to Shaft C in Marlborough. This 14' diameter tunnel is designed to operate under pressure and has a potential capacity of 615 MGD. However, with hydraulic restrictions at Shaft B and the elevation of the CWTP inlet, this capacity cannot be met. At its deepest point, it is over 500 feet below grade. There are three shafts along the alignment with Shaft A at the intake, Shaft B at the midpoint (a hydraulic relief structure to prevent over-pressurization which was raised and rehabilitated in 2003) and Shaft C which is the outlet at the Carroll Treatment Plant site. The tunnel was taken off-line during the winter of 2003 in order to make connections between the tunnel and the new treatment plant. This allowed the tunnel to be inspected using submersible technology in December of 2003.

A Remotely Operated Vehicle (ROV) performed the tunnel inspection using sonar technology to capture detailed information using Shaft B as the point of access in order to be able to go both directions from that location. Results of the inspection indicated circumferential, longitudinal and multiple cracks (a combination of circumferential and longitudinal cracks) were observed throughout the tunnel length. The consultant report (insert footnote) prepared in 2004 concluded that the tunnel was not in imminent danger of collapse, but recommended that structural repairs to the tunnel liner be completed and that a more detailed risk assessment be conducted to focus on tunnel liner stability and to identify potential failure scenarios and the probability of the tunnel lining failing under those scenarios.

As noted previously, there is not full redundancy for the Cosgrove Tunnel at this time. The gravity flow Wachusett Aqueduct can provided up to approximately 240 MGD which is only adequate meet demands during the winter and cannot meet summer demands without pressurization. A further problem is that the delivery gradient at the terminus of the Wachusett Aqueduct is only approximately 280’ which is inadequate to supply water through the CWTP ozone contactors and to directly supply some of the Metrowest communities. Therefore, use of the Wachusett Aqueduct as it exists today would require temporary chlorine disinfection in place of ozonation and temporary pumping to some Metrowest communities as was done during the Cosgrove Tunnel shutdown preceding CWTP start-up. Pressurization of the Wachusett Aqueduct would provide more complete redundancy to a Cosgrove Tunnel failure so that summer flow issues would be eliminated and CWTP could be used under any scenario.

Recommended Projects:

- Given the limitations in capacity and pressure of the Wachusett Aqueduct in providing full redundancy for the Cosgrove Tunnel and the need to take the Cosgrove off-line long term for repairs , it is recommended that funds be added to the CIP for Wachusett Aqueduct pressurization with initial design work to begin in the FY09-13 time frame. The initial cost estimate for this work is $100 million.

Metrowest Water Supply Tunnel

The Metrowest Water Supply Tunnel came on line in November, 2003 as the major transmission facility from the CWTP to the Norumbega Covered Storage Facility and on to the City Tunnel connection at Shaft 5. The tunnel is a 17.6 mile long, 14-foot diameter deep rock tunnel (with a 14-foot diameter connection to the Loring Road Covered Storage Facility) and it was constructed to ensure that there was a redundant means of providing water to the metropolitan area in the event of a failure along the Hultman Aqueduct. Ultimately, the tunnel will work in parallel with the Hultman Aqueduct. Currently, sections of the Hultman Aqueduct are off-line until they can be fully inspected, rehabilitated and new interconnections made with the tunnel and the Norumbega Covered Storage Facility. Metrowest communities previously connected either to the Wachusett Aqueduct (Town of Northborough, Westborough State Hospital) or only to the Hultman Aqueduct (City of Marlborough, Towns of Southborough, Framingham, Weston, Wellesley and Needham) now have either direct connections to the MWWST or indirect connections via new interconnections between the Hultman Aqueduct and the MWWST.

Hultman Aqueduct

The Hultman Aqueduct, a surface aqueduct, was constructed in 1940 and is a pressurized concrete pipeline 18 miles in length extending from the CWTP in Marlborough to Shaft 5 in Weston.

Flow could also be diverted to the Norumbega Open Reservoir (now off-line). The Hultman initially was designed to take water from the Wachusett Aqueduct's open channel. The system was modified in the 1960's when the Cosgrove Tunnel was constructed and was modified again in 2005 with connection to the CWTP. The Hultman was also designed to be able to deliver water to the Low system through the Weston Aqueduct (now on emergency stand-by status) and by using the 7'Branch to supply Loring Road Tanks[1]. The initial Hultman plans called for the construction of a second barrel of the Aqueduct in the same right-of-way for redundancy and operational flexibility. This second barrel was delayed and, ultimately, the MWWST was built to provide that redundancy. The Hultman ranges between 11.5 and 12.5 in diameter but the Southborough Tunnel which is the 3 mile section of the Hultman that transverses under Sudbury Reservoir is a 14 foot diameter deep rock tunnel.

Southborough Tunnel

The Southborough Tunnel section of the Hultman Aqueduct is scheduled to be inspected under an upcoming contract. Results of that inspection will determine the need for rehabilitation. Since the MWWST has been constructed, this section can be taken off line if necessary. The shaft locations would benefit from some additional physical hardening but more extensive structural investigations are required at Shaft 2. There may be significant deterioration of the shaft structure and replacement of the whole structure may be required. Some lesser level of structural repairs may also be required at the Shaft 3 overflow structure. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and costs of repairs at this location.

Southborough Facilities

Most administrative and maintenance activities for Western Operations are centered at the MWRA's Southborough facilities at the Sudbury Dam site. The administrative offices and maintenance shops were constructed in 1996. The water quality lab (see Chapter 8) is expected to get a new roof under the contract to modify existing facilities and additional warehouse space is expected to be provided through conversion of some maintenance space. Some of the trade shops from Southborough will be relocated to the former Interim Corrosion Control Facility which is no longer in use.

Shaft 5 to the East

City Tunnel

The City Tunnel, constructed in 1950, is a 12' diameter deep rock tunnel that extends five miles to Shafts 7 and 7B in Brighton. Shaft 5 is the location where flow enters the City Tunnel from either the MWWST and/or the Hultman Aqueduct. Shaft 5 has experienced significant building and electrical/mechanical deterioration as a result of condensation within the building when the tunnel is venting. Investigations to determine alternative ways to address this problem will be

[1] The Hultman Aqueduct 7-foot branch provides a connection from the Hultman Aqueduct immediately upstream of Shaft 5 to the Weston Aqueduct Supply Main at River Road in Weston and ultimately to the Loring Road Storage Facility.

presented in the facility plans being developed. In addition, due to the alternating wet and dry conditions at this location, it may be necessary to overhaul electrical equipment and to replace motors in order to ensure that valves can be operated. Some physical hardening and improvements to facility access are recommended at the remaining City Tunnel shaft locations.

City Tunnel Extension

The City Tunnel Extension was constructed in 1963 and is a 10' diameter deep rock tunnel that goes from Shaft 7 north to Shaft 9A in Malden. Shafts 8, 9 and 9A each have pressure regulated connections to the Northern Low. Shafts 9 and 9A supply water to the Northern High. As with the City Tunnel, the shaft structures along the City Tunnel Extension are in need of more physical hardening and improved facility access for maintenance. The Shaft 9 building, in particular, is in poor condition both internally and externally, and site security improvements should be made to prevent further vandalism at the site. The Transmission Facilities Engineering Assessment is likely to reflect the potential for substantial repair and/or replacement costs at this facility.

The building at Shaft 9A was previously used to boost chlorine residual through the addition of gaseous chlorine. Due to system improvements, this is no longer necessary and equipment has been removed. This building, located in Malden, is still used for crews to take regular water quality samples. Needed improvements at this site are expected to be minimal and will primarily consist of security upgrades. Shaft 8 structures are below ground and improvements are expected to be minimal.

Dorchester Tunnel

The Dorchester Tunnel is a 10' diameter tunnel that extends southward from Shaft 7B to Shaft 7D in Dorchester. The Dorchester Tunnel was constructed in 1976. Redundancy for the Dorchester Tunnel still requires use of emergency backups like the Chestnut Hill Reservoir and Emergency Pump Station which are expected to require a boil water order if use is required. The planned use of surface mains to allow emergency backup from Shafts 7 or 7B is not complete at this time. Construction of the final phase of the Chestnut Hill Connecting Mains Project (see chapter 8) as previously recommended is necessary to improve and strengthen surface piping to accommodate a problem with the Dorchester Tunnel or with the City Tunnel prior to the Dorchester Tunnel.

7.5 Standby Aqueducts and Facilities

The following section discusses those parts of the system not currently in active use and potentially available for emergency operations.

Wachusett Aqueduct

As part of the preparation for construction of the Metrowest Water Supply Tunnel, rehabilitation of the Wachusett Aqueduct was completed in 2002. The intent was to ensure that the Aqueduct could be the single transmission facility during the winter of 2003-04 when the Cosgrove Tunnel was taken pout of service for connection to the CWTP. In addition to structural rehabilitation of portions of the aqueduct, a pressure reducing structure was constructed at elevation 281.5 BCB to prevent over pressurization of the aqueduct during operation and a shotcrete liner was applied to the inside to reduce head loss as much as possible in order to maximize flows through the aqueduct. The rehabilitated aqueduct was found to be capable of approximately 240 MGD but cannot operate with any internal pressure which limits the delivery water gradient to that of the old Wachusett Aqueduct elevation (around 280'). During the planning of this work, the alternative of aqueduct pressurization was considered as another means to rehabilitate the aqueduct to handle the larger flows. However, this alternative was discarded due to the time limitations to get the aqueduct available in time for the CWTP connection work. However, at that time, the Cosgrove Tunnel had not yet been inspected. That subsequent inspection identified a need for future repair of the Tunnel and the long-term need to have the Wachusett Aqueduct available for use during those times when the Cosgrove Tunnel would not be available. If MWRA experiences a substantial leak from Cosgrove Tunnel or the Shaft C piping to CWTP and has to shut down Cosgrove flow, summer flows cannot be met and treatment at CWTP will be bypassed. This creates a narrow seasonal time frame for repairs where system demands can be adequately met on an average basis. For long-term operational flexibility and for full redundancy of this critical transmission system link, pressurization of the aqueduct is recommended.

Open Channel (see discussion of bridges and roads)

Wachusett Aqueduct Structures and Facilities

Wachusett Dam Upper Gatehouse

This structure is part of the dam structure and is the intake for the former Wachusett Power Station (Lower Gatehouse). The building houses operators for valves at three reservoir intake levels as well as screens and stop logs. The upper two intakes discharge to four 7' diameter vertical wells which are connected to four 48" discharge pipes running horizontally 113' below the floor. These pipes flow directly to the lower gate house for discharge to the Wachusett Aqueduct or to the Nashua River. Some level of repairs to reduce long-term building deterioration will be required.

The Wachusett Power Station and Lower Gatehouse

This facility is located at the base of the Wachusett Reservoir Dam. This is the intake and gate house for the Wachusett Aqueduct and the bypass to the Nashua River. It is a granite superstructure and a concrete substructure with a copper sheet roof. The substructure is separated into 4 main chambers of which 2 feed the Wachusett Aqueduct. The building footprint (105' x 74') includes a three story office area and a large open room with four generators. This facility was retired from active service in the 1960's. Exterior repairs will be necessary to prevent further building deterioration.

Recommended Project:

- In addition to the required asset protection projects to rehabilitate the building, the Consultant is being asked to develop plans that would allow the required water feed to

Lancaster Mills to be separated from the other piping on the site so that when the angle pattern sleeve valve is shut down, flow does not have to be reconfigured to feed Lancaster Mills.

Assabet River Bridge and Siphon

The original Wachusett Aqueduct crossing of the Assabet River was done by use of an aqueduct bridge similar in style to the Echo Bridge on the Sudbury Aqueduct crossing of the Charles River. Due to deteriorated condition and leakage, a siphon was added under the Assabet River and all flow now passes through the siphon. The aqueduct bridge structure remains and require masonry rehabilitation and other remedial work as it ages.

Other Roads and Bridges

The portion of the Wachusett Aqueduct along the open channel includes a number of roads and bridges that were initially constructed by predecessor agencies (see Table 7-4). Besides Wachusett Aqueduct, additional bridges cross within the Sudbury Reservoir system and at the Weston Reservoir. The list of roads/bridges identified by Western Operations is included in Table 7-4 below. MWRA has performed maintenance on some of these structures but ownership and maintenance responsibilities need to be better delineated. To date, costs have generally been absorbed within the CEB expenditures but more significant costs could be incurred over time as the structures age.

Table 7-4

Bridge Location @	***Associated With***
Bridge Near Hultman Intake Dam	Wachusett Aqueduct Open Channel
Carroll Water Treatment Plant	Wachusett Aqueduct Open Channel
Ward Road	Wachusett Aqueduct Open Channel
Route 495	Wachusett Aqueduct Open Channel
Johnson Road	Wachusett Aqueduct Open Channel
Northborough Road	Wachusett Aqueduct Open Channel
Route 30	Wachusett Aqueduct Open Channel
Lynbrook Road	Wachusett Aqueduct Open Channel
Deerfoot Road	Wachusett Aqueduct Open Channel
Parkerville Road	Wachusett Aqueduct Open Channel
Middle Road	Wachusett Aqueduct Open Channel
Stonybrook	Sudbury Reservoir
Route 30	Sudbury Reservoir
Route 9	Foss Reservoir (Framingham #3)
Salem End Road	Foss Reservoir (Framingham #3)
Fountain Street	Brackett Reservoir (Framingham #2)
Winter Street	Stearns Reservoir (Framingham #1)
Ash Street	Weston Reservoir (Open Channel)

Recommendation

- Recommend that staff request clarification from the Law Division on the ownership and maintenance responsibilities for bridges and roads across the Open Channel and at other locations as determined by Western Operations.

Additional structures along the Wachusett Aqueduct include the circular Rattlesnake Hill Access Shaft and the Linden Street Gatehouse. Rattlesnake Hill could formerly be used for personnel access to the aqueduct. The shaft is offset to the side of the aqueduct, which lies approximately 25-30 feet below the building's first floor. The building has deteriorated significantly over time and is currently blocked off for safety reasons.

Weston Aqueduct

The Weston Aqueduct was completed in 1903 and begins at the Sudbury Dam near Shaft 4 and continues from there to the west side of the Charles River in Weston near the intersection of I-128 and the Massachusetts Turnpike. The aqueduct is approximately 12 miles in length and was constructed of concrete and brick masonry. It varies between 9 and 12 feet in height and 10-13 feet in width. The Weston Aqueduct was originally designed to bring water from the Sudbury Reservoir but due to deteriorating water quality conditions in the Sudbury in the 1960's was last operated by a pressure reduced feed from the Hultman or through the hydropower turbine at Shaft 4. The use of the open Weston Reservoir was eliminated in the early 1990's by replacing its flow from pressure reduced connections from the High Service.

The Weston Aqueduct has two main sections, the first intended to get water from the Shaft 4 area to Weston Reservoir and the second being to bring water from the reservoir to the Weston Terminal Chamber where low service distribution begins via the Weston Aqueduct Supply Mains (WASM) lines. In between the two aqueduct sections, the flow has to pass through the open Weston Reservoir. This aqueduct still provides emergency redundancy in a failure scenario which interrupts flow of both Metrowest and Hultman facilities since it can convey water from the Sudbury Dam vicinity all the way to supply the Low Service tanks at Loring Road if necessary. Temporary disinfection and a boil water order would be required in such a scenario

Recommendation

- Staff recommend that a consultant physical inspection and condition assessment report for the Weston Aqueduct be prepared. The estimated cost for such an inspection is between $250,000 and $500,000 and this work should move forward in the short-term.

Weston Aqueduct Structures and Facilities

Also located at Shaft 4 is the Aqueduct transfer power station and connecting piping. The original building was constructed around 1899 and the Weston Aqueduct was fed by three 60-inch diameter pipes from the Sudbury Dam Gatehouse. Around 1985, the facility was modified for hydropower generation. Given that the Weston Aqueduct is no longer in routine operation, this facility is inactive.

In 2004 repair work was undertaken on the Ash Street Bridge in response to a routine inspection conducted by DCR. Repairs included replacement of deteriorated concrete on the underside of the bridge arch, repointing of the stone masonry mortar on one side, and sealing capstone joints under the bridge rail. In addition, a raised bituminous asphalt sidewalk was constructed over the bridge to provide safer access and crossing by pedestrians in the Weston Reservoir area.

Four siphon structures (#1, #2, #3, #4) exist along the Weston Aqueduct. These buildings are all approximately 21’ x 21’ and have no electricity, heating or plumbing. At one of the siphon locations, i.e. the Sudbury River crossing, the aqueduct crosses the river with two barrels, one piped under the river and one which is an 84-inch free standing pipe bridge over the river. These facilities are currently in good condition but may require rehabilitation in the future.

The Weston Reservoir Terminal Chamber is located at the terminus of the Weston Aqueduct where it becomes a section of open channel upstream of the open reservoir. The west wall of the building sets on the Aqueduct arch. Stoplogs can be set in place along the outlet wall to allow maintenance within the part of the aqueduct affected by reservoir backwater.

The Weston Aqueduct Screen Chamber is located on the Weston Reservoir Dam at the beginning of the lower aqueduct section and provids screening of the flow from the Weston Reservoir to the Weston Aqueduct. This is an older facility with some deterioration. The Weston Reservoir Headquarters and Chlorine Building formerly provided chlorine and ammonia storage and delivery equipment for the Weston Aqueduct. This facility is being used for storage of MWRA records and rock cores.

The Weston Aqueduct currently ends at the west side of the Loring Road tanks and is connected via an air gap to the Loring Road piping. This allows use of the aqueduct if necessary to feed the tanks or Low Service pipes in an emergency.

The Weston Aqueduct lower terminal chamber lies at the former discharge end of the Weston Aqueduct just east of the Loring Road tanks. When in operation, the building substructure was normally flooded with water entering from the aqueduct termination point on the west wall of the facility. This facility was disconnected from the active water system when the Loring Road tanks were completed in 2002. The building currently provides storage for site maintenance.

Sudbury Aqueduct and Associated Structures and Facilities

The Sudbury Aqueduct was completed in 1878 and extends from Framingham Reservoir #1 to the Chestnut Hill area in Boston. It is a somewhat smaller diameter concrete and brick masonry gravity aqueduct (with a typical cross section of 7’8” high by 9’ wide). It was primarily constructed using cut and cover methods but has several tunnel segments, two aqueduct bridges and a siphon interspersed to address localized conditions. Surface pipelines connect it to the Chestnut Hill Pump Station and the Chestnut Hill Reservoir. It was designed to carry 90 MGD and was originally used to convey water from Framingham Reservoirs 1, 2, and 3 and indirectly from the Sudbury Reservoir or the Hultman Aqueduct via Reservoir No. 3. Reservoirs 1 and 2 were bypassed in the 1920's for water quality reasons by connecting the Reservoir 3 gateouse to the aqueduct via two 48-inch pipes.

The Sudbury Aqueduct was an essential element of serving the Southern High and Southern Extra High prior to completion of the Dorchester Tunnel in 1974. The water quality of the Sudbury system no longer met standards so routine use was discontinued as soon as the new Dorchester Tunnel allowed, relegating the Sudbury Aqueduct to emergency back-up status. However, it is a particularly significant asset in that regard since it goes all the way into the Chestnut Hill area. In the event of a problem with the City Tunnel or an appurtenant structure, the Sudbury Aqueduct remains the only means to supply the southern metropolitan areas.

MWRA staff most recently investigated the Aqueduct thoroughly in 2002 to determine its physical condition and to determine the location, extent and characterization of sediment in the Aqueduct. ((Sudbury Aqueduct Condition Assessment with Interior Rehabilitation Recommendations, June, 2004). In 2005-2006, consultant staff undertook follow-up investigations for the MWRA of the aqueduct condition with particular effort on the known hazardous waste sites, the clogged Rosemary Brook siphon and the areas where previous examinations had noted structural problems.

External investigations included a walk-over of the entire Aqueduct length and inspection of critical structures including approximately 46 culverts; approximately 45 manholes, two 500-foot bridge structures, one 1,800 foot siphon including two chambers and siphon blow-off valves, four waste weir culverts and all areas identified as having internal defects. Internal inspections focused on those areas identified as having invert heaving and possible undermining and areas identified as having a large aperture crown crack (a particular soft ground tunnel segment).

Crack in Crown

Leak Boil in Floor

The Sudbury Aqueduct has four waste weirs located along its length (A, B, C, D). All of these structures serve as overflow release points for the aqueduct when it is in service and they allow small streams or brooks to transverse the aqueduct. Structures at all four locations are single story granite and brick structures approximately 15' x 20' in size with slate roofs. None of the structures have electricity, heat or plumbing. Waste Weir A is where Course Brook transverses the aqueduct; Bacon's Brook Waste Weir B allows Davis Brook to transverse the aqueduct; Waste Weir C is where Fuller's Brook transverses the Aqueduct and Waste Weir D allows an unnamed drainage way to pass underneath the Aqueduct. When inspected during 1995-96, over $135,000 in recommended deficiencies were identified including significant structural and safety improvements. Some of these deficiencies were fixed as part of more recent sluice gate rehabilitation.

The Rosemary Brook siphon crosses a wide low area by use of pressurized 48-inch pipes. The East and West Rosemary Brook Siphon Chambers are twin facilities that transition Sudbury Aqueduct flow from a normal aqueduct cross section conduit to two pipelines and then back into a normal aqueduct structure. The pipelines have accumulated sediment and require cleaning which is made difficult by the extreme length of the siphon. The siphon chamber facilities are constructed in a similar fashion with the exception being a circular tower within the west Chamber. These structures and the siphon itself have been recently inspected and have significant rehabilitation needs.

MWRA has care and control of the Echo Bridge (1878) which spans the Charles River from Newton Upper Falls to Needham. The structure contains a water conduit and essentially functions as a pipe bridge over the river. The surface has a heavily used pedestrian bridge and is located in Hemlock Gorge, a DCR owned park. Echo Bridge was included on the National Register of Historic Places in 1980, prior to the rest of the Waterworks system. MWRA has repointed the brick surfaces of the structure in the late 1980's and the masonry is currently in good condition.

The handrails along the top of the 500' pedestrian bridge are original, made of cast iron and have been determined to be in poor condition. In 2006, the MWRA installed temporary snow fencing in front of the hand railings on both sides of the bridge as a temporary protective measure. Since the hand rails are historic and must be repaired or replaced, MWRA has offered to work with elected officials and other interested parties to identify potential sources of outside funding. Funding in the amount of approximately $250,000 may be available via legislative appropriation for this project in FY07. Similar to Echo Bridge, Waban Arches Bridge has original cast iron railings that are seriously deteriorated with similar rehabilitation needs as Echo Bridge.

The Farm Pond Gatehouse and Inlet Chamber are located in Framingham and historically, provided access to the Aqueduct. In addition, the Inlet Chamber provided a connection to Farm Pond (stop-logs) and the Gatehouse provided flow control through 4' x 4' sluice gates and screening. These facilities are in seriously deteriorated condition, in danger of collapse and can longer be accessed in any fashion due to safety considerations. Given the poor condition of these structures, a decision should be made whether the sluice gates are necessary at this location and whether access to the aqueduct could be maintained in another manner. The 1995 condition assessment recommended that access to the aqueduct be capped at this location. Although, as all of the Sudbury Aqueduct facilities, these two structures are on the National Register, coordination should occur with appropriate staff to determine if these facilities can be fully documented and taken down.

Southern Sudbury Transfer system

In the 1930's, MDC constructed a temporary water transfer piping system to act as a drought supplement to the existing Sudbury system reservoirs while Quabbin was being constructed. The transfer piping included an open channel and 24" pipe to transfer water from Whitehall Reservoir to Hopkinton Reservoir, a 30" pipe from Hopkinton Reservoir to Sudbury Reservoir, a transfer pumping station for the 30" pipe in Cordaville and a 24" pipe from Ashland Reservoir to Reservoir 1. This system was only needed until Quabbin was completed and was never utilized again. The pump station was demolished and all of the southern Sudbury system reservoirs were transferred to DEM (now DCR). The remaining issue is that the pipelines still exist and may become an issue if there is a collapse in the public way or if the pipeline causes property damage due to inadvertent leakage. MWRA has no plans for reuse but there may be a cost of stabilization (e.g. filling the pipes to prevent collapse) prior to disposition as surplus

Norumbega Facilities

The Norumbega Open Reservoir and associated back-up facilities remains as part of the emergency back-up system. However, structures that were in daily use prior to the construction of the Norumbega Covered Storage Facility coming on line are no longer used or will be phased out as the final interconnections are made between the Hultman and new facilities.. These include the Norumbega Reservoir Gatehouse and Screen Chamber through which the Hultman Aqueduct passes. Ongoing and future work will disconnect this portion of the Hultman and redirect flows around the Gatehouse. It will be possible to reconnect the Hultman to the Open Reservoir in the event of an emergency. The Norumbega Reservoir chlorine storage building is also no longer in use. In the event chlorination is required during an emergency, temporary equipment will be brought to the site. No major expenditures are anticipated at this location during the twenty year planning period.

7.6 Dams

Overview and Responsible Parties

A list of water supply dams is shown in Table 7-5. The original split of dam responsibilities in the MDC/MWRA Memorandum of Understanding was intended to make MWRA responsible for only the dams at distribution reservoirs. The MOU also specifically called out that MWRA would be responsible for Sudbury Reservoir and Reservoir 3 due to the proximity to MWRA offices.

Leakage through Quabbin Spillway face

The MOU was recently amended to make MWRA directly responsible for the water source dams. DCR continues to be responsible for tributary dams and inactive source dams like Reservoirs 1 and 2 in the Sudbury system.

Dam Condition Assessments

Under the Project Prioritization Assessment, there are 19 dams we are responsible for. Seventeen of these are jurisdictional under the Office of Dam Safety regulations 302 CRM 10:00, and two non-jurisdictional. MWRA conducted a number of dam inspections in 2005 and identified several items for incorporation into MWRA's CIP.

Table 7-5
List of water supply dams

	Name	**Description**	Capital Needs
Quabbin area	Winsor Dam	1930s, Earthen dam	**Drain work**
	Goodnough Dike	1930s, Earthen dam	**Drain work**
	Quabbin spllway	1930's, Masonry structure	**Repointing**
Wachusett area	Wachusett Dam	1906 Masonry Dam and spillway	**Spillway work, repointing**
	North Dike	1906 Earthen dam	**Tree clearing**
	South Dike	1906 Earthen Dam	**Tree clearing**
Sudbury System	Sudbury Res	1898 Earthen dam with corewall, masonry spillway	**Riprap resetting, long term repointing**
	Reservoir 3	1898 Earthen dam with corewall, masonry spillway	**Tree clearing, grading, riprap**
	Reservoir 1	1878 Earthen dam with corewall	**DCR responsibility**
	Reservoir 2	1882 Earthen dam with corewall	**DCR responsibility**
Dist. Reservoirs	Norumbega	1940 Earthen with corewall, multiple dikes	**Minimal**
	Schenk's Pond	1940 Earthen with corewall, multiple dikes	**Minimal**
	Weston	1903 Earthen dam	**Tree clearing, emergency spillway construction**
	Spot Pond	1901 Earthen with corewall, multiple dikes	**Tree clearing**
	Fells	1899 Earthen with corewall, multiple dikes	**Tree clearing**
	Chestnut Hill	1868 Earthen dam	**Riprap, grading**
	Waban Hill	1900 Earthen dam	**Riprap, grading**
Ware River	Coldbrook	1931 Masonry dam	**Long term repointing**
Hultman Int.	Forebay channel	1940 Masonry dams	**Minor**
Southboro Open channel	Cascading dams to Sudbury Res.	1898, multiple masonry dams	**Long term repointing, riprap**
Defunct dams	Fisher Hill	Inactive and empty	**N/A**
	Nash Hill	Inactive and empty	**N/A**
	Blue Hills	**Dewatered for tank construction**	**Future maintenance**

In fall 2006, additional dam inspections were conducted and, although many of the dams have received limited maintenance over time, the condition of the structures were generally rated as "good" to "fair". Going forward, the jurisdictional dams will require official inspections every two years by a licensed dam safety inspector. The next inspections are scheduled for FY08, FY10, and FY12. For maintenance reasons and overall project management efficiency, the two non-jurisdictional dams will also be included in the inspection cycle.

Additional pending dam activities include installation of monitoring wells at Wachusett Reservoir North and South Dikes to assess the phreatic surface conditions relative to tree growth on the dikes. This will cost from $50,000 - $100,000. It is anticipated that the monitoring wells will be installed in January 2007. Phreatic surface data will be collected soon after and continue across lowered reservoir elevations in the spring of 2007 for the Wachusett Crest Gates project, and through reservoir elevation recovery in the fall of 2007. The monitoring will continue through the summer of 2008 in order to have a solid period of data at normal operating conditions. At that point additional field work will occur, relative to the monitoring data, to determine if tree clearing is warranted. Should large-scale tree clearing on the dikes be necessary, costs could be expected to increase by $1,000,000 for tree removal on both of these dikes in FY10.


Brush Clearing

Long term dam maintenance activities are largely determined by the type of dam structure. Tree removal and brush control is a factor on all dams but the earthen dams are more likely to require maintenance associated with animal burrows and with erosion which may be associated with clogged drainage outlets. The masonry dams will need repointing at approximately twenty year intervals. Some seepage and leakage is currently visible at some water system dams. All dams may need periodic resetting of riprap as well.

<u>Quabbin Reservoir (Winsor Dam, Goodnough Dike)</u>

At the Quabbin Reservoir, the major dam structures are Winsor Dam and Goodnough Dike which are both over 60 years old. MWRA assumed responsibility for these dams in April 2004. An existing project scheduled for design and construction in the FY06-FY08 time frame will include repairs to the spillways and toe drain as well as piezometer installation.

<u>Wachusett Reservoir (Wachusett Dam, North Dike, South Dike)</u>

At the Wachusett Reservoir, assessment of the entire dam system, which is over 100 years old, is underway. However, initial work has already been identified and is in MWRA's current CIP. In the early 1990's, DCR's predecessor agency, MDC, identified a need for and designed repairs to the spillway and to the North Dike. However, funds for construction were never made available. When MWRA assumed responsibility for capital projects, it was necessary to move forward with this repair work as soon as possible. As part of the same $8 million design contract being used for Winsor Dam improvements, design is under way and work is expected to be completed in

December 2008. Work includes inspection and reassessment of the conditions for the entire spillway (the 100 ft. lower section and 350 ft. higher section) and the North Dike. The old design for the dike repairs and for installation of mechanical gates to replace the old flashboards will be updated for construction. The contract also includes funding for rehabilitation of the 350 ft. long upper spillway section pending the results of the inspection.

Recommended Dam Projects

- Complete the $8.9 million in Wachusett Reservoir spillway improvements and Winsor Dam repairs. This work is funded in the current CIP and is ongoing.

- Complete remaining engineering studies to determine dam risks. An estimated $350,000 to $500, 000 will be required for this study. Monitoring of conditions, including the installation of observation wells as described above, will be included in this work.

- Allocate up to $4 million to make any necessary immediate repairs to dams.

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for earthen dams.

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for masonry dams.

7.7 Summary of Recommended Transmission System Improvements

- Procure Final Design services for the short-term repairs to the Sudbury Aqueduct to allow it to be used in the event of an emergency. A list of critical repairs includes cleaning of the Rosemary Brook siphon and structural repairs at targeted locations identified during the Aqueduct inspection. The estimated cost is $500,000 for design with a start date in FY08.

- Fund the construction of the short-term repairs to the Sudbury Aqueduct using remaining funds available in the CIP. The estimated cost is $2.8 million and work should be initiated immediately following design of the repairs.

- Separately, procure services to conduct an inspection and report on the condition of the Weston Aqueduct. This will provide baseline information on condition and the ability to reactivate the aqueduct in an emergency. Between 4250,000 and $500,000 is anticipated to be required and this should be initiated in FY08.

- Move forward with the construction of the Chestnut Hill Connecting Mains Project at a cost of $5.6 million. Final design work is in the current CIP but construction has not yet been funded. (Described in Metropolitan chapter)

- In anticipation of the need to repair the Cosgrove Tunnel, allocated design and construction funds for the pressurization of the Wachusett Aqueduct. The estimated cost of this effort is $10 million for design and $90 for construction with design recommended to be started in the latter part of the FY 09-13 time period.

- Initiate a new study of long term redundancy alternatives. This study would address the eastern part of the system from Shaft 5 east. It would consider long term use of the Sudbury Aqueduct (pressurization), the tunnel loop alternatives and other possible solutions. This study would also determine the feasibility and develop plans for the inspection of the Quabbin Tunnel, City Tunnel, Dorchester Tunnel and City Tunnel Extension. The estimated cost for this work is $1.5 million and it should be started in the FY09-13 time frame in order to maximize MWRA's ability to coordinate ongoing system improvements with a planned long term solution. Following this study, it is expected that design and construction of recommended redundancy improvements for the Metropolitan portion of the system could cost approximately $100 million.

- Following the above study, move forward with inspections of the Quabbin Tunnel, the City Tunnel, Dorchester Tunnel and the City Tunnel Extension. Although the feasibility studies will further define the costs, $2 million should be added to the CIP for this purpose.

- Increase asset management funds in the CIP to facilitate ongoing repairs of the transmission system facilities. A initial project to address roofs at a proposed cost of $900,000 is proposed for the FY09-13 time period.

- An additional $9 million in asset protection funds to make major repairs to facilities as identified in the Transmission Facilities Engineering Assessment Study. Although cost information has not yet been identified, it is clear from the information below, that some facilities have critical needs. These funds should be available beginning in the FY09-13 time frame but would be used over a twenty year period.

- Improvements at the Winsor Power Station far exceed the routine improvements that could be implemented under FAMP funds. The electrical system for the station is in poor condition and would need improvement whether or not the station is reactivated for hydropower generation. More importantly, the valve intended as the isolation valve for the turbine is currently being used to reduce head at the facility. A project is needed to address this valve and to consider station piping improvements which would allow water to go to the Swift River without going through the valve. Consultant recommendations have not yet been fully developed but it is anticipated that this site will require extensive work and it is recommended that $5 million be allocated in the FY09-13 time period.

- Reactivate the Winsor Hydroelectric facility at an estimated cost of $1.5 million in the FY09-13 time period.

- A new Phase 1A of Oakdale Improvements is recommended for inclusion in the CIP. This phase would study and complete preliminary design of electrical improvements at an estimated cost of $3 million during the FY09-13 time period. Work identified to date has not addressed the need to replace the electrical s switchyard and electrical control systems. These facilities both run the turbine and connect the facility to the grid. These facilities are both technologically obsolete but can also present a safety hazard given the specialized antique equipment and localized knowledge necessary to operate the facilities.

- Phase 2 of the Oakdale project was deleted from a previous CIP and this included $8.625 million to improve hydraulic controls and provide additional transfer capacity to Wachusett Reservoir. This work is still necessary and building repairs to stem deterioration are also required. The turbine does not currently need to be replaced, having been refurbished in the late 1990's but long term replacement of the turbine will be necessary at some future date. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and update the costs of repairs at this station.

- If the Oakdale Power Station were to fail, there is currently no way to stop the flow of water. The structure at Shaft 12 of the Quabbin Aqueduct has stop log bays but it is an intensive process to remove the stop logs to set the shutter valves in the opposite direction and this cannot be done on an emergency basis. A project to design and install a sluice gate at this site is recommended for implementation in the FY 09-13 time period at an estimated cost of $2 million.

- At Cosgrove Intake, the building requires a number of improvements to stabilize and update the facility. Water intrusion at various locations necessitates the need for drainage, roof, ceiling and tile improvements and repairs. Access improvements through new elevator facilities and stairway replacement will improve safety and accessibility. Facility plans prepared under the Transmission Facilities Engineering Assessment contract will further define the alternatives and costs of repairs at this station.

- Long-term, a study to consider the feasibility of the previously recommended Wachusett Bypass should be conducted including alternatives, other than a bypass, to address potential Wachusett Reservoir contamination issues. $1 million is recommended for such a study but it is of a lesser priority than the recommendations above.

- The recent work at Cosgrove Intake replaced the bypass valves and refurbished the turbines to bring the mechanical equipment up to good condition. However, the need to operate the stilling basin at a slightly higher level to supply the CWTP has created the need to add downstream turbine and sleeve valve isolation. Although design of these improvements is in the current CIP, the construction funds at $1.9 million are recommended to be added beginning in the FY14-19 time frame.

- Recommend that staff request clarification from the Law Division on the ownership and maintenance responsibilities for bridges and roads across the Open Channel and at other locations as determined by Western Operations.

- Complete the $8.9 million in Wachusett Reservoir spillway improvements and Winsor Dam repairs. This work is funded in the current CIP and is ongoing.

- Complete remaining engineering studies to determine dam risks. An estimated $350,000 to $500, 000 will be required for this study. Monitoring of conditions, including the installation of observation wells, as described above, will be included in this work.

- Allocate up to $4 million to make any necessary immediate repairs to dams.

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for earthen dams.

- Allocate $3 million in the FY14-48 time period to address rehabilitation needs for masonry dams.

Table 7-6
Water Master Plan - Transmission System
Existing and Future Projects

Last revision 01/04/2007

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
		TRANSMISSION SYSTEM											
7.1	**1**	**Chicopee Valley Aqued. Redundancy**	**NF**	**in, S615**		**5,199**	**FY07-08**	**5,199**					**5,199**
7.2	**2**	**Norumbega Covered Storage**	**NF**	**in, S544**		**1,084**	**FY07-10**	**503**	**581**				**1,084**
7.3	**2**	**MetroWest Tunnel (CP-6)**	**NF**	**in, S604**		**70,995**	**FY07-13**	**19,803**	**51,123**	**69**			**70,995**
7.4	**1**	**Wachusett Res Spill Impr/Winsor Dam Repairs**	**AP**	**in, S620**		**8,925**	**FY07-09**	**6,852**	**2,073**				**8,925**
7.5	**1**	**Sudbury / Weston Aqueduct Repairs**	**Plan/AP**	**in, S617**		**3,199**	**FY07-09**	**3,191**	**8**				**3,199**
7.6	**2**	**Quabbin Transmission System**	**Plan/AP**	**in, S616**		**1,029**	**FY07-10**	**885**	**144**				**1,029**
7.7	**3**	**Waterworks FAMP Cosgrove Valve Seat Replacement Design/Construct**	**AP**	**in, S766**		**600**	**FY08-09**	**75**	**525**				**600**
7.8	**3**	**Waterworks FAMP Cosgrove Turbine Isolation Design**	**Opti**	**in, S766**		**480**	**FY16-18**			**480**			**480**
		SUBTOTAL - Existing - Transmission				**91,511**		**36,508**	**54,454**	**549**			**91,511**
7.9	1	Engineering Studies for Dam Risk	Plan	new	1 year	250	FY08	250					250
7.10	2	Immediate Repairs to Dams	AP	new	4 years	4,000	FY09-12		4,000				4,000
7.11	1	Redundancy Study & Tunnel Inspection Feasibility Assessment	Plan	new	2 years	1,500	FY09-10		1,500				1,500
7.12	1	Winsor Power Station (Pipeline Replacement Ph 1) Design/Construct	AP	prev	5 years	5,000	FY09-13		5,000				5,000
7.13	2	Oakdale Station Phase 1A (Electrical) Study/Preliminary Design	AP	new	3 years	3,000	FY10-12		3,000				3,000
7.14	2	Shaft 12 Quabbin Aqueduct Sluice Gate Design/Construct	Opti	new	2 years	2,000	FY10-11		2,000				2,000
7.15	2	Tunnel Inspections (Quabbin, CTE,CT)	AP	new	1 year	2,000	FY11		2,000				2,000
7.16	1	Wachusett Aqueduct Pressurization Design/Construct	Opti	new	8 years	100,000	FY11-18		10,000	90,000			100,000
7.17	3	Waterworks FAMP Roofs	AP	new	20 years	900	FY09-28		300	300	300		900
7.18	3	Quabbin Lookout Tower (electric highline replacement) Design/Construct	AP	new	2 years	500	FY09-10		500				500
7.19	3	Waterworks FAMP Transmission Facilities Construction	AP	new	10 years	9,000	FY10-19		3,000	5,000	1,000		9,000
7.20	1	Long-Term Redundancy	Opti	prev	10 years	100,000	FY14-23			50,000	50,000		100,000
7.21	3	FAMP Masonry Dam Repointing	AP	new	ongoing	3,000	FY14-48			1,000	1,000	1,000	3,000
7.22	3	FAMP Rehabilitation of Earthen Dams	AP	new	ongoing	3,000	FY14-48			1,000	1,000	1,000	3,000
7.23	4	Oakdale Station Rehab Ph 2 Design/Construct	AP	prev	5 years	8,625	FY14-18			8,625			8,625
7.24	3	Waterworks FAMP Cosgrove Turbine Isolation Construction	Opti	new	3 years	1,900	FY18-20			900	1,000		1,900
7.25	4	Winsor Dam Hydroelectric Design/Construct	AP	prev	5 years	1,534	FY09-13		1,534				1,534
		SUBTOTAL - Future - Transmission				246,209		250	32,834	156,825	54,300	2,000	246,209
		SUBTOTAL - Existing and Future - Transmission				337,720		36,758	87,288	157,374	54,300	2,000	337,720

8 The Metropolitan System

8.1 Chapter Summary

The Metropolitan Water System (also known as the Distribution system) consists of the various components shown in Figure 8-1.

The Metropolitan Water System serves 40 communities and meets an average day demand of approximately 205 MGD. The system is divided into seven (7) "pressure zone" service areas (shown in Figure 8-2) based upon the ground elevation of each zone.

The following are the service areas, and the elevations at which water is generally delivered. All elevations given are in feet, Boston City Base (BCB).

Low Service Area (including Northern Low) (LS) –	185' BCB
Northern High Service Area (NHS) –	280' BCB
Intermediate High Service Area (IH) –	320' BCB
Northern Intermediate High Service Area (NIH) –	330' BCB
Northern Extra High Service Area (NEH) –	440' BCB
Southern High Service Area (SHS) –	280' BCB
Southern Extra High Service Area (SEH) –	400' BCB

The sources of water for the service areas are the tunnel shafts as shown on Figure 8-1. The tunnel shafts are supplied by the Norumbega Covered Storage Facility, which sets the hydraulic grade line for the Metropolitan system. Water from the shafts feed the surface piping system that supplies each of the pressure zones. The NLS, NHS, and SHS all flow by gravity (no pumping required). The IH, NIH, NEH, and SEH all require pumping and storage to provide service.

The "hub" of the Metropolitan Water System is the Operations Control Center (OCC), located within the Chelsea Facility. The OCC operates and monitors the entire Metropolitan system remotely. This includes hydraulic grade line (pressure) at many tunnel shafts; suction and discharge pressure, flow, and basic operation of all of the water pump stations; operating elevation and volume of the water storage tanks; pressure and flow of the supply to the customer communities; and operation of some of the key valves in the MWRA system.

From planning and design through construction and operation and maintenance of the water system, MWRA makes use of standards and manuals developed by organizations

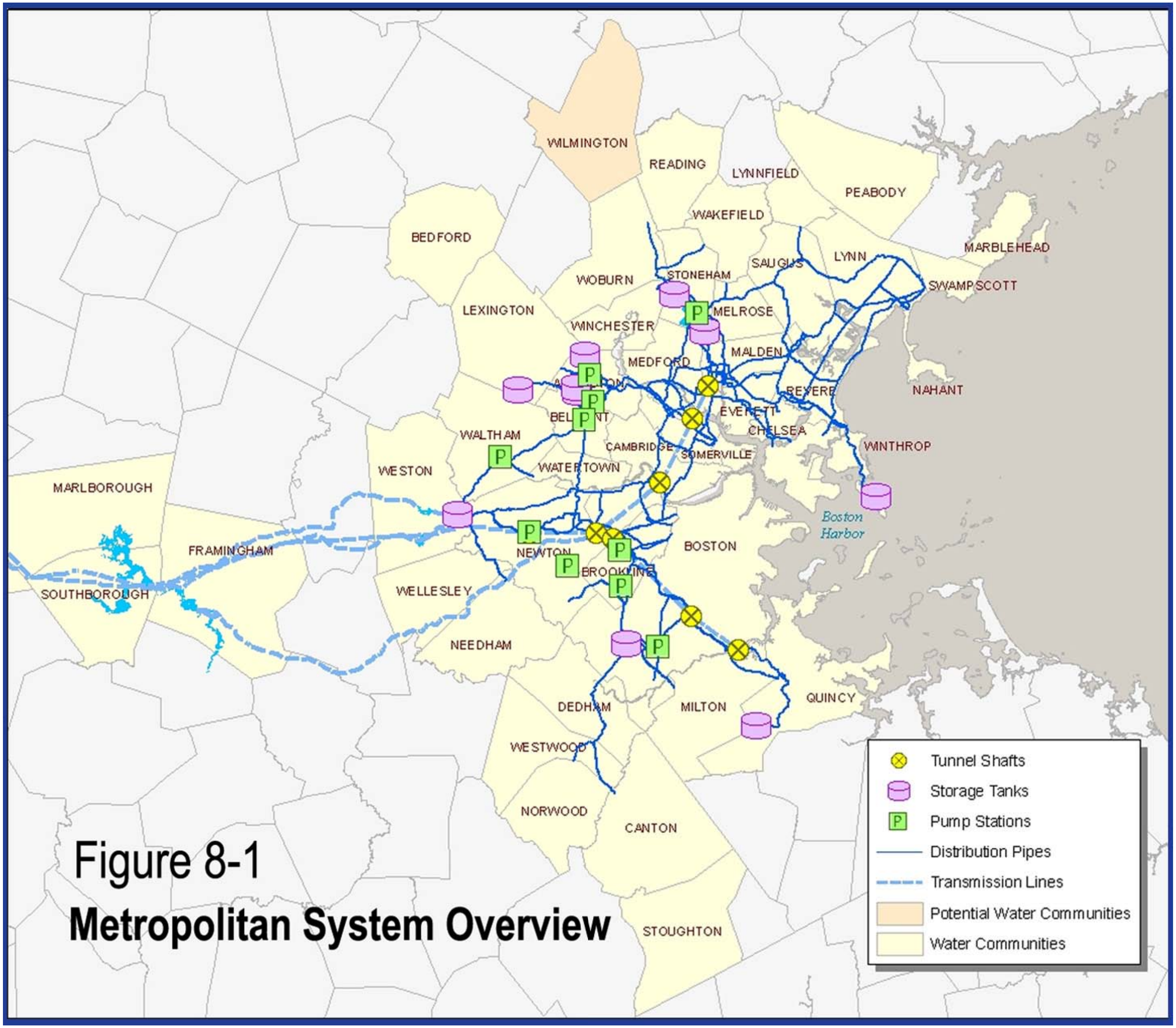


Figure 8-1
Metropolitan System Overview

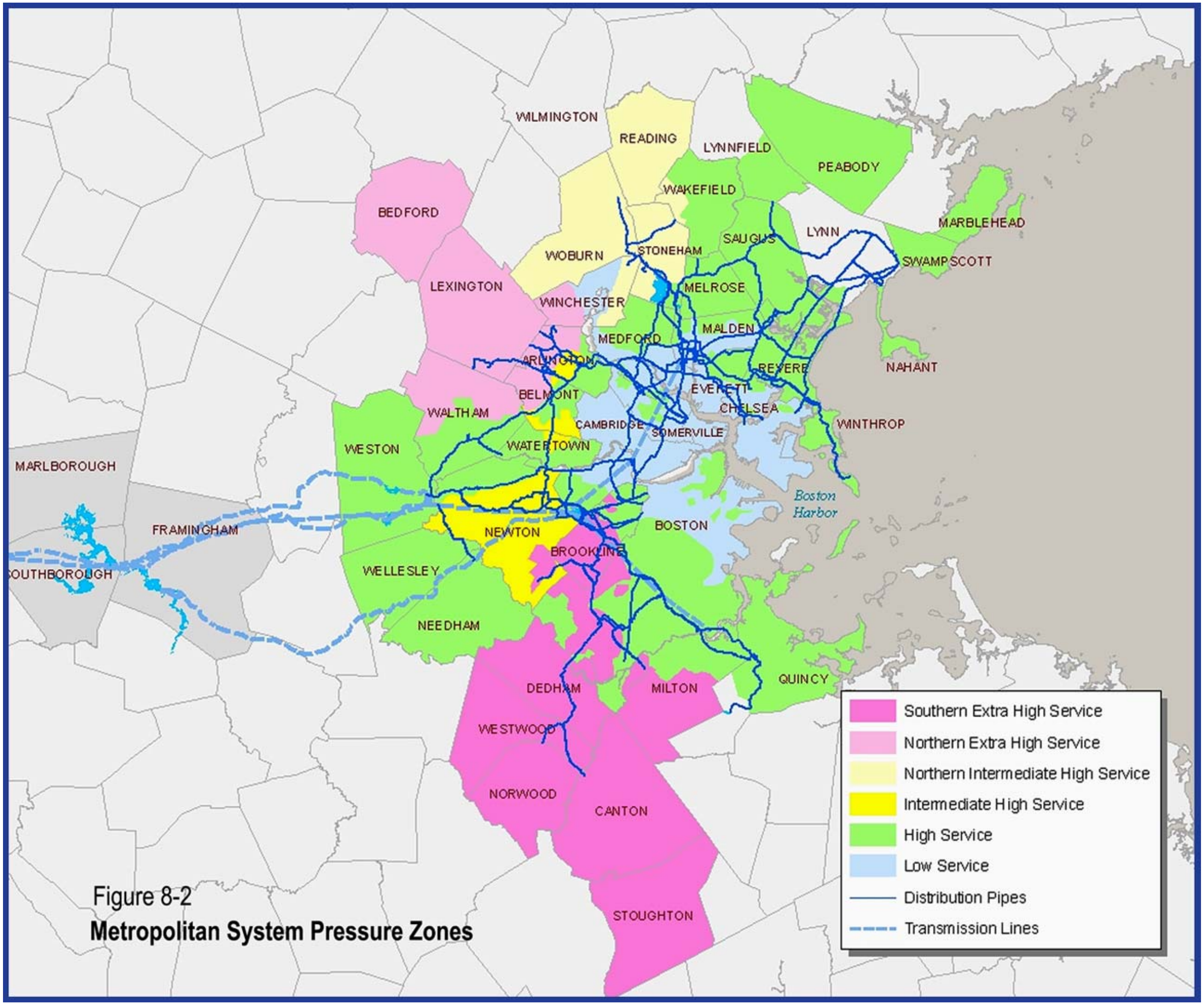


Figure 8-2
Metropolitan System Pressure Zones

such as the American Waterworks Association (AWWA) and the AWWA Research Foundation (AwwaRF). [1]

Chapter Organization This chapter begins with an overview of the major elements (pipelines, valves, pump stations and storage) to provide an overview of MWRA's assets including operational philosophy, condition assessment practices, maintenance practices and performance standards and goals for those assets. This information provides a framework for the individual pressure zone sections that follow. The pressure zone sections allow for an integrated discussion of all of the distribution system assets within a pressure zone since operational flexibility may depend upon the interrelationship between these assets. A "breakdown" in any individual asset may be more or less of a problem depending upon the other assets within that pressure zone (i.e. storage may mitigate the effects of a pipeline break). Each pressure zone section identifies ongoing work within that service area and recommendations for future projects.

Summary of Chapter Recommendations

Projects already in the FY07 CIP**:**

For the FY07-18 timeframe, the FY07 CIP includes the following major projects with significant spending particularly in the FY09-13 and 14-18 timeframes:

- $55.6 million to complete rehabilitation and valve replacements of the Weston Aqueduct Supply Mains (WASMs), FY07-16+, including $5.2 million to rehabilitate Section 28. The WASMs now function below capacity; at completion, they will transmit water to one-third of MWRA customers.

- $49.3 million to complete pipeline rehabilitation/replacement and valve replacements of the Southern Spine Distribution Mains, FY07-16+. Many of the mains now function well below capacity and valves are in poor condition.

- $47.4 million for the Shaft 7-to-WASM 3 Connecting Mains Project, FY07-15. Project completion will allow WASM 3 to be taken off-line for needed rehabilitation.

[1] Two documents that provide a good summary of critical requirements for the effective operation and management of drinking water distribution systems are:

- Distribution Systems Operation and Management (AWWA Standard G200-04), and
- Development of Distribution System Water Quality Optimization Plans (AwwaRF Report 91069)

These documents provide the elements for a water utility to develop and summarize Best Management Plans (BMPs) for water system management. The G200-04 standard describes the critical requirements for the effective operation and management of drinking water distribution systems. The AwwaRF report provides the processes that water utilities can use to improve distribution system operations above and beyond regulatory requirements to improve water quality and to reduce the potential for contamination.

- $34 million for the Blue Hills Covered Storage Project, FY07-10. (Bid price is $37.8 million).

- $24.8 million to rehabilitate five pump stations, FY07-11, completing the modernization program (contract was awarded at $18.2 million).

- $17.2 million for pipeline rehabilitation in the Northern Low service area (S. 8, 37, 38, 97A), FY07-13. Rehab of the 100-year old, cast-iron Section 8 is the primary objective, but strengthening of the East Boston distribution system must occur first.

- $8.2 million to improve pipelines in Revere and Malden, FY07-16, to improve the delivery capacity of major distribution lines serving the Northern High system. Undersized pipes have caused fire-fighting difficulties and extensive corrosion has led to numerous leaks.

- $7.3 million to develop and implement a concept plan and short-term measures to reduce the risk and impacts of a failure of Section 89 or Section 29 in the NIH system, FY07-13[2]. Staff are recommending that funds be added to the FY08 CIP to construct a redundant pipeline, as well as additional storage and redundancy for the Gillis Pump Station (see FY08 CIP recommendations, below).

- $7.1 million for the valve replacement program.

- $5.1 million for pipeline work for a major portion of the NEH system (Sections 34, 36, and 45), to improve hydraulic service and reliability; spending is primarily FY14-18.

- $4 million to replace the undersized 8" main serving the Lynnfield Water District, spending is primarily in FY09-11.

- $1.4 million to complete final design for the Chestnut Hill Connecting Mains Project, FY07-12. If the recommendation to fund construction of this project is endorsed (see FY08 CIP recommendations, below), this project will create a connection between Shaft 7 and the Southern High system to provide emergency back-up to the Dorchester Tunnel.

[2] Section 89 is a three-mile, four-foot diameter PCCP transmission main with no redundancy other than the low capacity, century old Section 29 that parallels its route for a short distance. The 10,500-foot length of Section 89 northwest of Spot Pond is constructed of Class IV wire which has experienced catastrophic failures elsewhere in the country. Section 29 measures 6,300 feet in length and 24 inches in diameter; because of its age and the fact that it is unlined, tuberculation has reduced its carrying capacity to approximately 45% of the original design capacity (C-value: 58). In the event of a shutdown in Section 89, Section 29 may not be able to meet the minimum hydraulic needs of the area and additional chlorination to maintain water quality may be required. Staff are recommending that funds be added to the FY08 CIP to construct a redundant pipeline, as well as additional storage and redundancy for the Gillis Pump Station.

- $900,000 approved at the 11/15/06 Board of Directors meeting to expedite a concept study for redundancy and storage for the SEH service area beginning in FY07.

Projects recommended for consideration in the FY08 CIP:

The following projects with an estimated cost of at least $3 million are recommended for the FY07-18 timeframe:

- $49 million to address redundancy and storage concerns in the NIH service areas, including:

  - $24 million for a pipeline redundant to Section 89, FY09-13

  - $10 million to provide 6 mgd of storage to meet the existing shortfall, FY09-13

  - $10 million for a pump station to provide redundancy to the Gillis station, FY14-18

  - $5 million to rehabilitate Sections 89 and 29, FY14-17

- $35 million to address redundancy and storage concerns in the SEH service areas, including:

  - $25 million for a pipeline redundancy for Sections 77 and 88, FY09-13

  - $10 million to provide 6 mgd of storage, FY13-18

  Rehabilitation of Sections 77 and 88 at a cost of $5 million is recommended for the FY19-23 timeframe.

- $36 million for Low Service Storage at Spot Pond, FY09-15, beginning with a $1 million study/EIR in the FY09-11 timeframe. Project would provide pressure relief and surge control for the Northern Low System.

- $36.7 million ($15.7 million in the FY14-18 timeframe) for rehabilitation of Sections 70, 71 and 79 in the Northern High service area. A $1 million study and condition assessment, FY10-12, would precede this project. As steel pipe ages, it is subject to corrosion and leaks; early rehabilitation intervention postpones the need for replacement.

- $5.6 million to construct the Chestnut Hill Connecting Mains Project (pipeline and facilities rehabilitation). Final design of this project as described earlier in included in the FY97 CIP.

- $29.7 million for the next phase of the Spot Pond Supply Mains project (Sections 66 and 57), including $20 million in the FY14-18 timeframe.

- $8.1 million for the next phase of the Southern Spine Distribution Mains project, FY12-16.

- $10 million, primarily in FY14-18, for the rehabilitation of Sections 30, 40, 44, and 39 in the Southern Extra High.

- $8 million to rehabilitate Sections 33, 49, 49A and 50, smaller-diameter unlined cast-iron mains in the Northern High Service area, FY14-18.

- $7.1 million to rehabilitate Section 80, a pipeline with known water quality problems (pipeline has a tar epoxy lining), FY10-14.

- $4.4 million to extend Section 75, FY13-16. Project will link two pressure zones at same elevation and improve emergency response.

- $15 million for scheduled replacements of meters and related equipment, FY09-16.

Community Financial Assistance – Local Pipeline Assistance Program

This program makes $25 million in loans available annually to MWRA communities for pipeline relining and replacement in proportion to each community's share of total unlined pipe miles. Communities are required to pay back principal for each year's loan during a ten-year period beginning one year after project funding is approved. The Master Plan recommends allocating Local Financial Assistance Program loan repayments to extend community funding similar to a revolving fund. Currently $255.5 million has been approved by the Board of Directors to date, of which $118 million has been distributed to communities for 147 projects. Staff recommends that $125 million in loan repayments be made available to communities for additional Local Pipeline Assistance Program loans in the FY14-23 timeframe.

8.2 Pipelines

Since the 1993 Water Plan, MWRA has made extensive improvements in the distribution network. The Plan cited excessive leakage, hydraulic deficiencies at meters and the lack of redundancy within the distribution system as key issues. Recommendations for pipeline improvements accounted for approximately 46 of 100 projects identified in that plan. The median pipeline age in 1993 was approximately 80 years old and pipes ranged from new to 150 years of age. Since 1993, MWRA has constructed 22 miles of new pipeline and has completed rehabilitation of 63 miles of pipe. As shown in Figure 8-3 below, this has left a remaining 198 miles of pipeline to be rehabbed and, of that, an additional 70 miles of pipeline rehabilitation is either underway or identified in the FY06 CIP. This has left approximately 128 miles of pipeline that are not, at this time, programmed for rehabilitation.

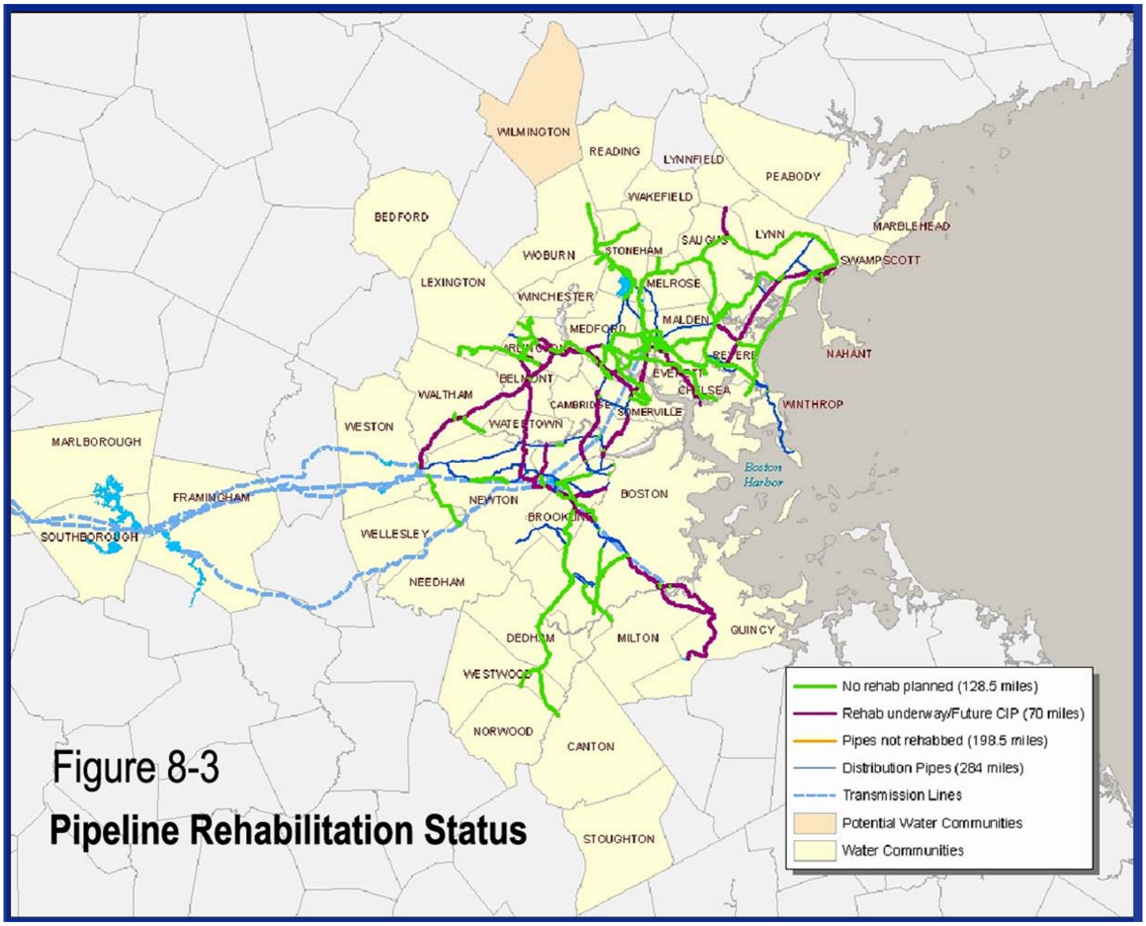


Figure 8-3
Pipeline Rehabilitation Status

In many ways, this remaining pipeline is reflective of typical pipes in the MWRA system. Approximately 48 miles of this pipe was 50 years of age or less in 2006 and 54 miles were between 50 and 100 years in age. However, 26 miles of pipeline were greater than 100 years old. Almost all (25 miles) of this oldest pipe were cast iron.

Water Main Renewal

As part of preparation of this Master Plan, staff reviewed both the industry literature on pipeline rehabilitation and replacement and at the specific experience with the MWRA system in order to determine how to assess the remaining useful life and the relative need for rehabilitation or replacement between the various pipe segments. This analysis focused on the following questions:

1. Which pipelines, if they should fail, have no redundancy to supply customers?
2. Which pipelines have exhibited the most leaks?
3. Which pipelines are located in areas which accelerate pipe deterioration?
4. Which pipelines currently have or have had material problems?
5. How can we best prioritize, using the information we have, pipeline replacement?

Redundancy

The goal of system redundancy has been a significant factor in water supply planning nationwide and at MWRA. Since the events of 9/11/2001, the work completed to assess water system vulnerability has stressed the need for water suppliers to eliminate the "single points of failure" where severe loss of service could occur during a break or other emergency. This is a key element in MWRA's own goals and objectives. Pipelines without redundancy or with less than adequate redundancy were categorized based on whether the lack of redundancy presents a minor, moderate or major problem. These categories considered such factors as available storage and availability of local water supplies. Projects to increase redundancy and/or operational flexibility focused on those areas with "major" single spine problems and are proposed in this plan. The major areas of concern were the Lynnfield Pipeline (already in the FY07 CIP), and single spine lines serving both the Northern Intermediate High and the Southern Extra High pressure zones. More details on proposed projects are discussed in those sections of this plan.

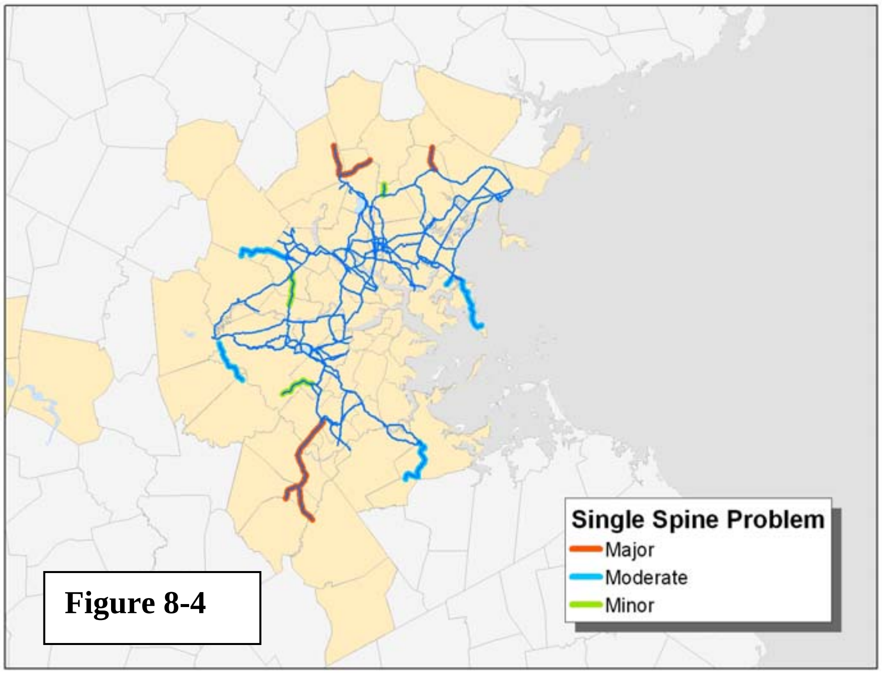
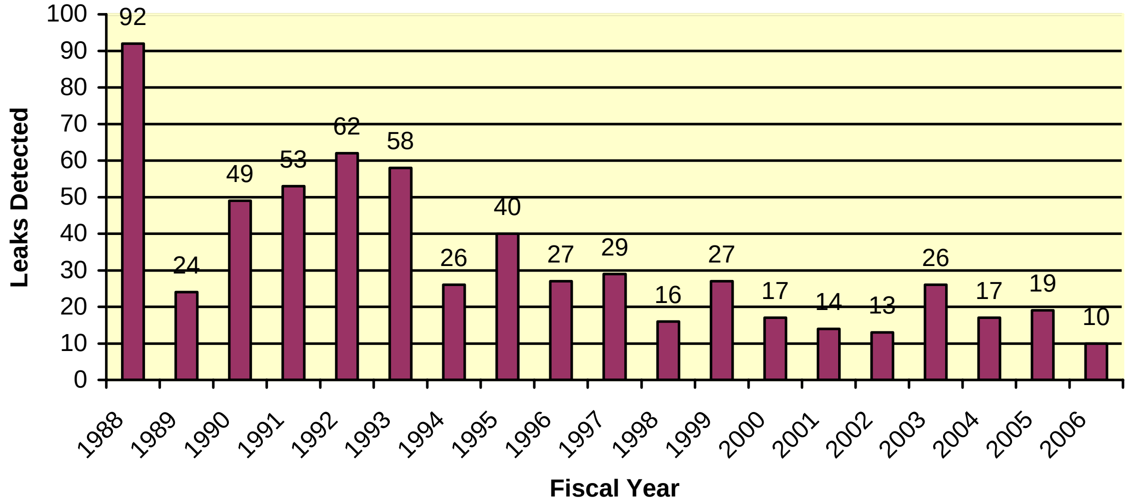


Figure 8-4

Pipe Structural Considerations

The questions of leaks, pipe materials and site conditions are all related. The number of recorded breaks and leaks is a factor used by many utilities as a basis for pipeline rehabilitation and replacement decisions. Leak and break data is most predictive in those large retail systems with many miles of small diameter pipe of various materials where statistical information can appropriately be generated to predict the likelihood of leaks and breaks by pipe material or age. MWRA maintains leak information in our GIS database and this information was analyzed. For the MWRA system, such data is not as good a factor to base rehabilitation decisions on except in very limited circumstances (see steel pipe discussion below). MWRA's relatively smaller number of pipe miles (at 284), means that there may only be a few miles of pipe at most in any single age and material category which makes it harder to draw broad based conclusions about the effects of those pipeline characteristics.

Figure 8-5
Leaks Detected 1988 to 2006

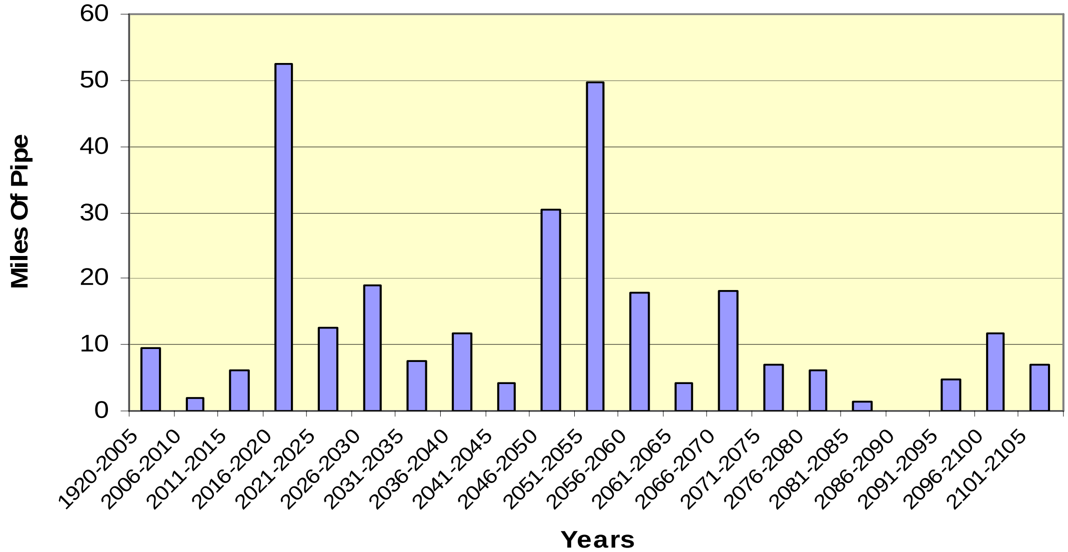


In the 30 year period prior to 1993 there were 17 pipeline sections that had between 10 and > 20 leaks in that timeframe. These pipelines were prioritized for replacement and as a result, overall leak numbers have decreased in the MWRA system. MWRA has also continued aggressive leak detection. The annual goal is for staff to perform leak detection surveys of the entire MWRA system every year, and to survey the steel mains in the system twice each year. Staff has been successful in fulfilling these goals for the last several years. MWRA staff also assist our customer communities with special leak investigations when requested.

The current literature and MWRA experience suggests that pipe age and pipe material have to be examined together to make decisions about rehabilitation or replacement. The historic rule of thumb used in the MWRA system has been that a pipe has an average useful life of 100 years with older cast iron mains lasting even longer due to their thicker pipe walls. Some literature suggests that pipes installed post WWII have an average useful life of 75 years. There can be general deterioration associated with aging pipes and many pipes are subjected to far greater surface loads and stresses than were present when the pipes were installed. However, depending upon location, soil condition and durability of construction, pipes may be quite long-lived. Although there have been many permutations of pipe manufacture in the United States, general pipe materials used in the MWRA system and their general period of installation are reflected in Figure 8-6 which
shows the miles of pipe in the MWRA system and the time periods when those miles of pipe will exceed (or have exceeded) their expected useful life (considering both age and pipe material). This graphic indicates that approximately 10 miles of pipe has currently exceeded its useful life and an additional 92 miles of pipe in the MWRA system will exceed their useful life by 2030. This is useful information in that it illustrates a need to systematically continue pipe rehabilitation to avoid major spikes in capital investments

associated with the need to replace large amounts of deteriorated pipe simultaneously. However, this information alone is not useful in making pipe rehabilitation decisions.

Figure 8-6
Water System Pipe
Exceeding Usefull Life By Year Range



MWRA experience with pipe materials since 1993 has shown that certain steel pipe sections have continued to be significant maintenance problems due to leaks associated with corrosion. Although use of appropriate pipe coatings and pipe bedding materials can mitigate the impact of the soil corrosion, these have not always been installed historically and this information is inconsistently noted in MWRA's records, limiting the predictability of such leaks. When these pipelines are located in areas of wet soils, particularly in former and present salt marsh areas, riverbanks, wetlands and floodplains, leaks appear to be more common and appear to recur more frequently once corrosion has begun to affect the pipe. There are some pipelines in areas associated with salt storage facilities that also tend to show recurring leaks. Specific problem locations include the Neponset River marsh near the Southeast Expressway, the banks of the Charles River in Weston, the Belle Isle Marsh in Revere, and salt storage facilities in Arlington. Areas with significant stray current from transportation facilities or other utilities can also be a catalyst for pipe corrosion.

Of seven leaks during the summer of 2006, six were in steel mains. However, it is worth noting that these leaks in steel mains, while requiring repair, are usually not catastrophic failures and are often repaired while the pipes remain in service. Cast iron mains tend to have more significant circumferential or longitudinal cracking and thus are more likely to fail catastrophically.

<u>Interior Pipe Condition: Hydraulics and Water Quality Considerations</u>

In addition to the exterior condition of a pipe, another issue related to pipe materials is whether a pipe is lined or unlined. Unlined pipes (primarily older cast iron or steel) are far more susceptible to tuberculation, corrosion and pitting than more recent materials. This can impede water flow and impair water quality. Since the 1940's, pipe materials have primarily included lined steel pipes, lined ductile iron and reinforced concrete cylinder pipe. In 1993, approximately 80% of MWRA's pipe network was unlined cast iron or steel. That percentage has dropped and will continue to drop as projects identified in the current CIP move forward.

Hydraulic deficiencies caused by tuberculated pipes might also be a reason to prioritize a pipe for replacement. The measure of a pipe's carrying capacity is determined by the pipe's diameter and resistance to flow, otherwise known as the pipe's "C" value.[3] C-values for new pipe are typically in the 130-140 range; C-values between 70 and 100 are indicative of pipe in poor condition and C-values below 70 are generally associated with pipes in bad condition. A C-value of 70 can deliver only about 50 percent of the amount of water that it was designed to carry. MWRA has determined C-values for all of its pipe segments and this information was also factored into the renewal analysis. In MWRA's experience, a poor C-value is not necessarily a good predictor of potential pipe failures but it is an indicator of hydraulic inefficiencies which may impact the level of service at specific locations. MWRA modeling can identify potential areas within the communities where the target hydraulic gradeline may not be met under max day conditions. Many of these locations reflect development on hills at a grade higher than that served by the MWRA's pressure zone so the most common means of addressing such deficiencies is community construction of local booster pumping stations.

Besides being hydraulically inefficient, tuberculated cast iron pipe may be a source of water quality problems. The accumulation of metallic salts and rust (tubercules) on interior pipe surfaces can lead to water quality complaints related to discolored water which, in some instances, can result in staining of fixtures or laundry items. In addition, the presence of tubercules may also lead to opportunities for bacterial growth along the pipe walls. Industry practices suggest that it is preferable to replace such pipe from the inner core of the system outward. Most water quality complaints relative to "colored" water are related to work in community systems where flow is disrupted or changes direction. This tends to break off or scour rust from the pipe interior and transport to the service lines. However, concerns about potential bacterial growth are very relevant to both the MWRA and community systems and as noted in Chapter 5, future regulatory actions will likely address the need to maintain water quality within the distribution system.

[3] The friction coefficient of a pipe is used as the measure of flow resistance. Standard waterworks design uses the "C" value in the Hazen-Williams pipe flow formula as the parameter of resistance. Higher "C" values correlate with better conditions and lower flow resistance.

Methods of Pipeline Rehabilitation

Pipelines can be renewed, rehabilitated or replaced depending upon the location and circumstances. Each of the strategies below yields different benefits in terms of extending the life of the asset.

Cleaning & Lining: This is a process which cleans and resurfaces the interior of an old pipe to make it comparable to a new pipe's interior. The old pipe must be structurally sound and expected to remain intact for another 50 years for a pipe to be a candidate for this technology. The pipes are cleaned, lined with cement mortar and valves or other appurtenant structures are replaced. This can be approximately 40% less expensive than the cost of pipeline replacement and based, on industry literature can extend the life of the old pipe by up to fifty years. Water quality benefits may also be gained by the cleaning and lining of cast iron pipe.

"Sliplining": This technology involves inserting a smaller diameter pipe within the existing pipe and either expanding the insert or filling the annual space with grout. There is an associated loss of hydraulic capacity which must be closely reviewed to determine if such loss is acceptable. This is less expensive than conventional replacement due to the use of smaller pie. It is most often considered when the loss of capacity is not problematic and where conventional construction methodologies are extremely difficult due to access or construction impacts.

Replacement: This technology entails the removal of the pipe segment and the replacement of it with a new pipe segment generally of the same size (depending upon capacity needs). Typically, this is used where a pipe is structurally in poorer condition and ongoing maintenance of the existing pipe would not be cost-effective or would pose risks to service.

Parallel Piping: This methodology entails the installation of a new pipeline in parallel with the existing pipeline. The old pipe may not remain in service depending upon the specific conditions and needs in that service area. This approach can be preferred where additional service objectives must be met by the project, where pipe replacement is excessively costly or disruptive or where additional capacity or redundancy may be needed.

MWRA has used all of these technologies over time depending upon the site specific circumstances. Based on work done to date, staff generally assumes for the purposes of preliminary cost estimates that two-thirds of the pipeline length can be rehabilitated through cleaning and lining and that one-third of the pipeline will require replacement. Actual determinations are made during design for most projects. Sliplining may also be evaluated as an alternative during the design process depending upon site specific conditions. However, for some projects, initial recommendations specifically call for parallel piping. This is generally because the pressure zone evaluations have identified a need for pipeline redundancy or for additional capacity to serve a specific area. Selection of pipe materials is also dependent upon review of the project by engineering, operations and construction staff and includes consideration of soils, location and specific pipe design characteristics (for example, long straight sections versus many bends and turns). In addition, for those areas where record drawings are not available or are inaccurate, there may be a need to change or fabricate piping connections in the field, resulting in materials such as steel, which are more suitable for such modifications. Consultation with local officials provides an opportunity for their input into project design.

Pipeline Prioritization

The water mains renewal methodology is summarized in Attachment 8-2. Based on the analyses, scores were generated for the 508 identified pipe segments. The scores were considered in developing projects for the Master Plan and most of the pipeline sections recommended for rehabilitation are also supported by the analyses. However, additional factors were also used to make the recommendations contained in the Master Plan. Redundancy projects, particularly for the NIH and SEH systems ranked very highly towards maintaining reliable service with the Metropolitan system. Additional projects that remedy other system vulnerabilities and/or increase operational flexibility during emergencies are also highly ranked.

The continued systematic removal of unlined cast iron and steel mains is also recommended. Remaining unlined cast iron, although it may have the greatest longevity of pipe materials, can create hydraulic inefficiencies and water quality problems and, for this reason many of these pipe sections were also identified in the renewal analyses as requiring rehabilitation or replacement. It is expected that future distribution system regulatory requirements will also focus on the need to remove unlined pipes. In addition, when cast iron pipes fail, they often fail catastrophically, resulting in damage to homes, businesses and roadways. For steel pipes, recent literature suggests a life expectancy of approximately 75 years and MWRA experience suggests that once corrosion begins, steel pipes begin to experience leaks and leak frequency begins to accelerate over time. Although these can often be fixed "live", (with the line in service), depending upon their location, these lines create a greater and greater drain on maintenance staffs.

Recommended Actions and Capital Improvements-Pipelines

The pressure zone sections of this plan identify the specific pipe sections recommended for rehabilitation and the proposed cost and schedule. However Figures 8-7 and 8-8 below provide an overview of the recommended cast iron and steel pipe rehabilitation work that is proposed. Figure 8-9 graphically shows compiled leak information by pipe section. Although these leaks have been repaired, it shows that the majority of pipes that have experienced leaks will be addressed either by projects in the current FY07 CIP or by projects proposed in the Master Plan. Some pipes sections of varying ages are not proposed for rehab in the Master Plan. The pipes may be newer or, if older, may be proposed for abandonment. Leak information for these pipes was reviewed to determine if additional pipe sections should be considered for renewal.

Figure 8-7
Cast Iron Mains Proposed for Rehabilitation or Replacement

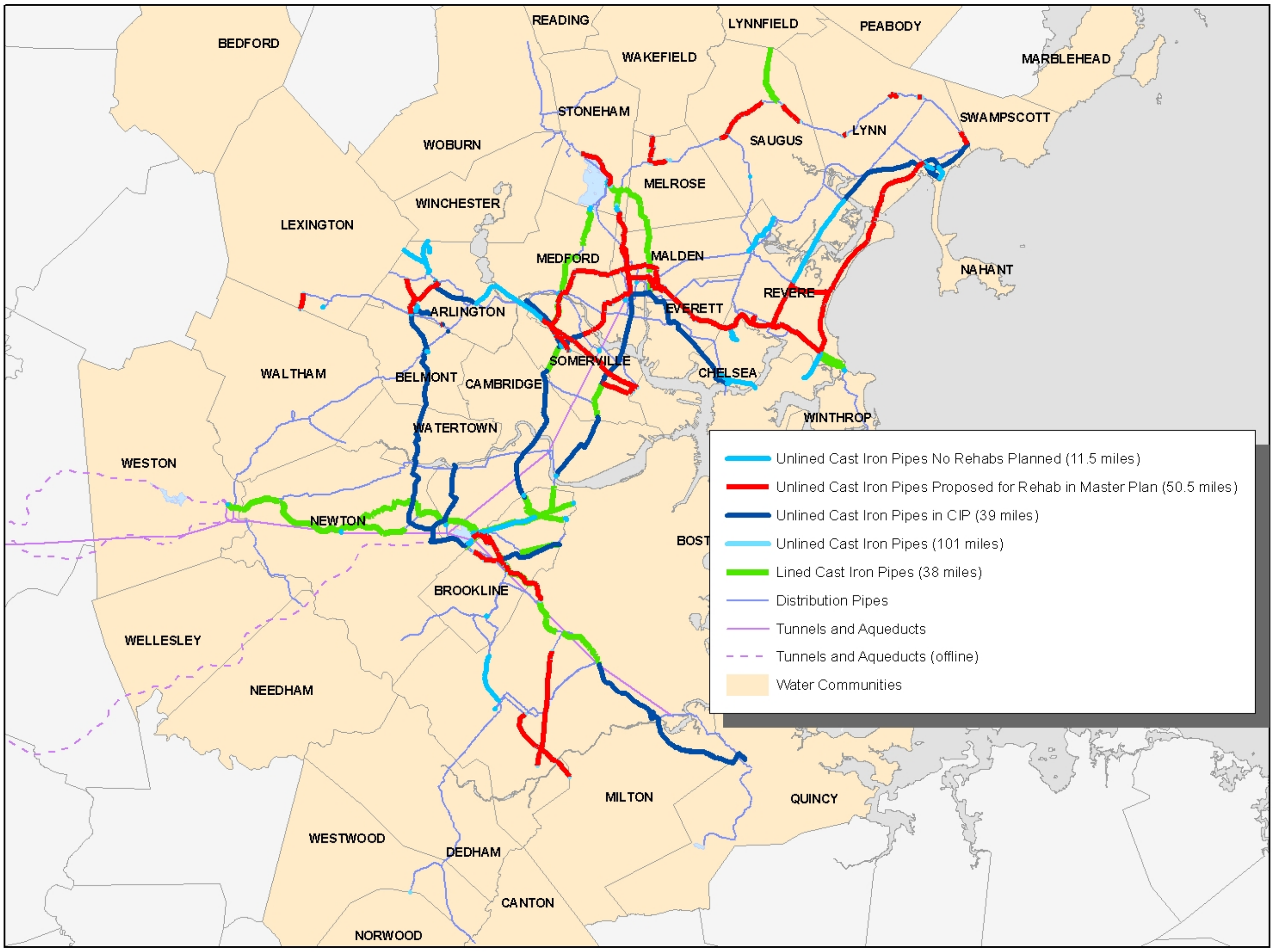


Figure 8-8
Steel Mains Proposed for Rehabilitation or Replacement

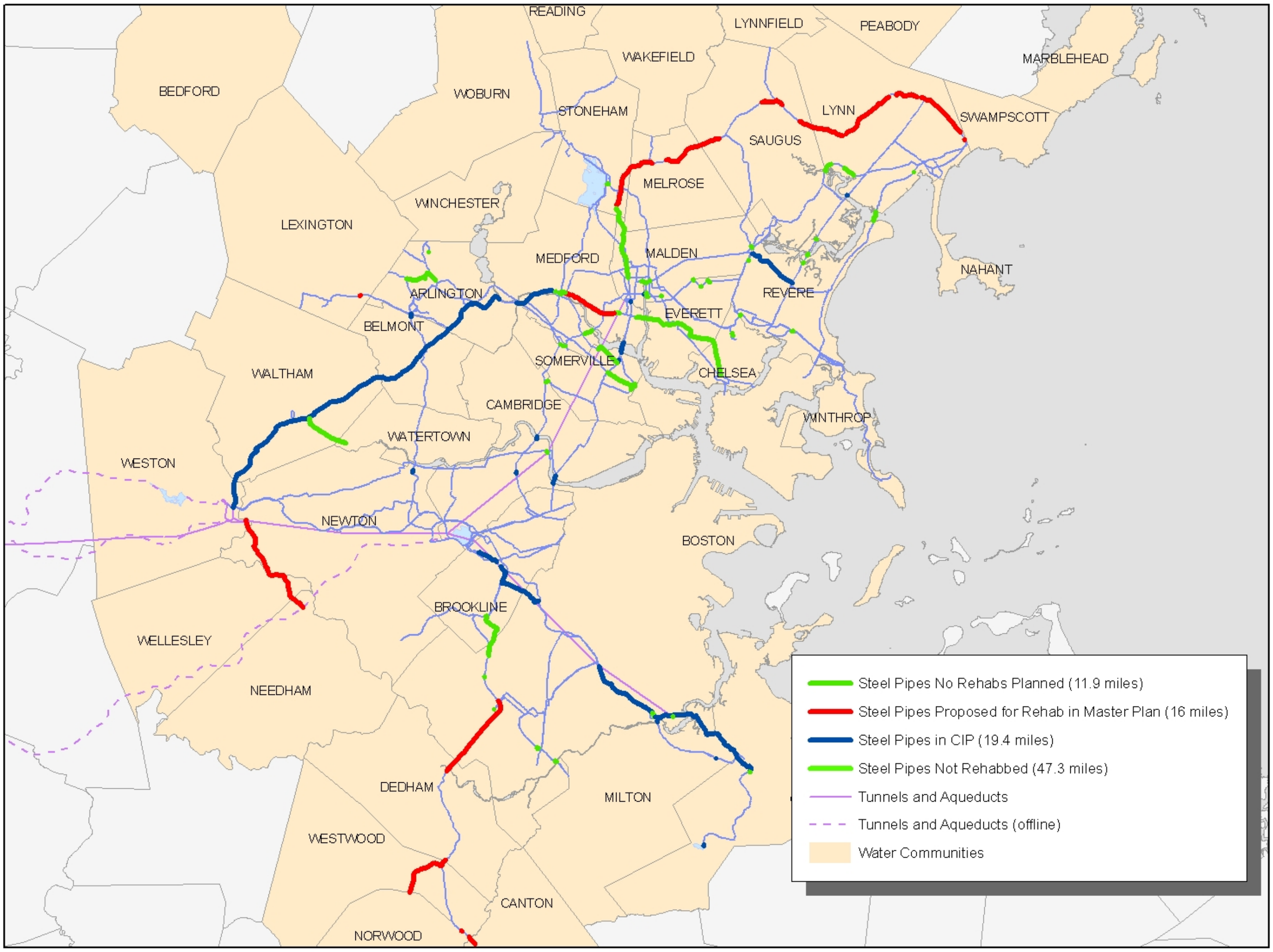
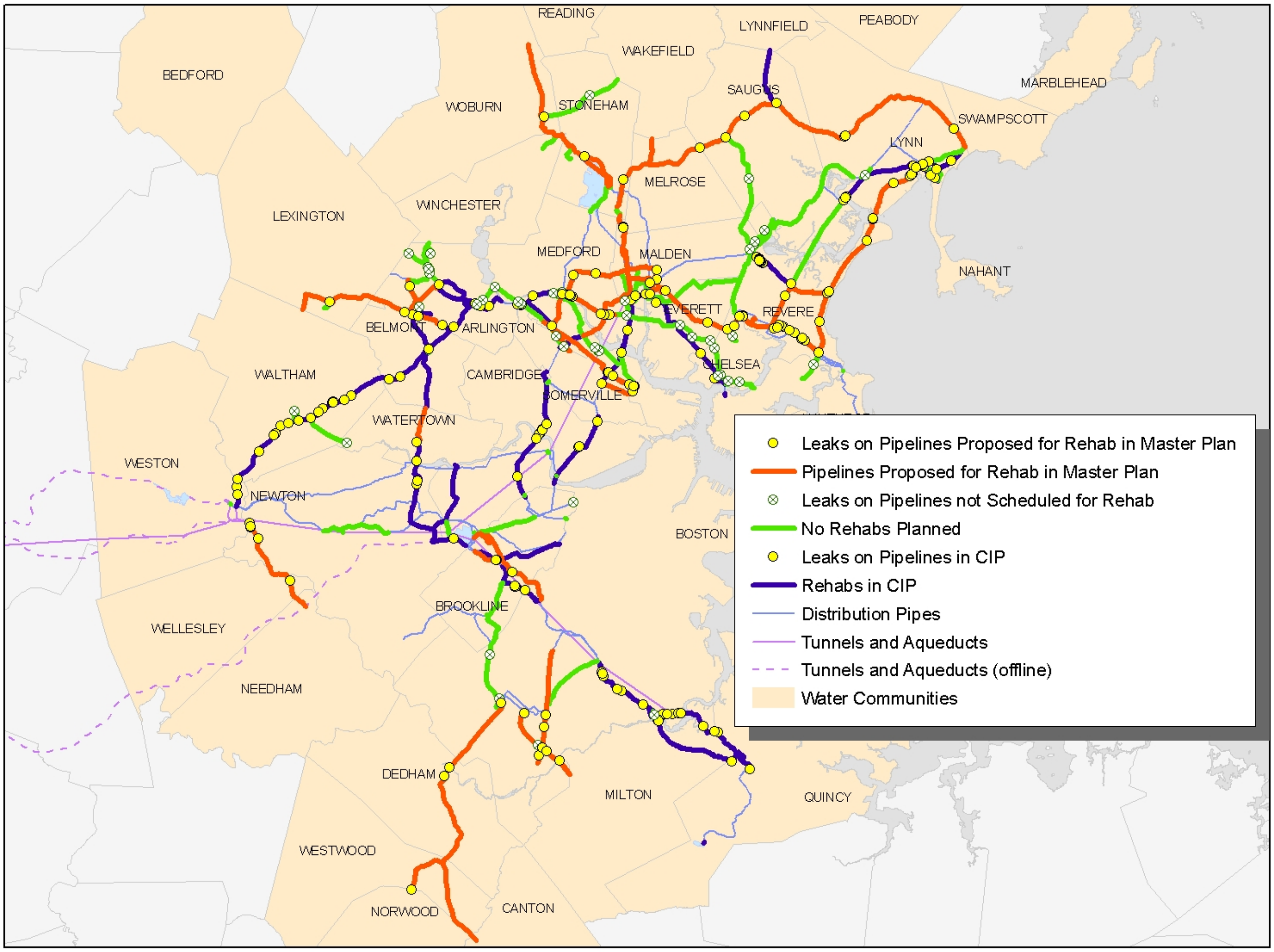


Figure 8-9
Leak History and Pipeline Renewal



8.3 Valves

There are over 4700 valves in the MWRA Metropolitan water system. Valves provide the means to control the flow of water in the pipes, and their operability is critical. Valves provide the means to isolate leaking or broken water mains, control the flow of water in redundant piping systems, reduce pressure depending upon service area needs, and to allow pipes to be shut down (isolated) and drained so that new or rehabilitated water mains can be connected to the existing water system.

<u>Types of Valves</u>
The following are the types and numbers of each of the valves that are currently in the Metropolitan water system.

Table 8-1		
Valve Type	#	What it does
Main Line	1251	Control water flow in the distribution pipelines and isolate flow in and around pump stations, tanks and reservoirs.
Meter	574	Control water flow to the community meters.
Cross Over	88	Control water flow in the distribution system between pipelines of similar pressure (within pressure zones).
Division Gate	17	Control water flow in the distribution system between pipelines of different pressure (normally closed).
Emergency Connection	96	Allow water to flow from the MWRA system to the community system without metering (normally closed).
Control-Check Valves	109	Allow flow in only one direction and are normally installed immediately up or downstream of a community meter. Contains water in the community system in event of a major MWRA break.
Control-Pressure Reducing	53	Reduce the Norumbega gradient (270' BCB) to the Northern Low gradient (185') to prevent over pressurization.
Blow Off	1118	Allow water to be released from the distribution pipelines to drain lines, provide for flushing or for disinfection preparation.
Air Release	1321	Allow air to enter or leave distribution pipelines during filling or draining of lines.
Bypass	75	Small diameter gate valves installed on piping around newer, large diameter butterfly valves

Valves of particular importance include the pressure reducing valves (PRV) that reduce the hydraulic grade line from Norumbega Covered Storage Tank (NCST) to the Northern Low Service (NLS) pressure zone. PRV are located at most of the tunnel shafts, and at many meter connections to customer communities. The OCC monitors the performance of the PRV to confirm that they are operating within the required parameters. Blow off valves are notable in that they are used to dewater the MWRA pipelines for a variety of reasons and were originally designed to flow into drainage lines, sewer lines, or direct discharges to surface water bodies (primarily small streams). The Massachusetts Department of Environmental Protection (DEP) determined that the direct connections constituted a cross connection condition, and need to be severed in order to eliminate the potential health hazard.

Valve Database and Performance Standards for Valves

All maintenance done at the MWRA is managed through the use of a computerized maintenance management system (CMMS). The specific software package used is MAXIMO and all water system maintenance work is captured on work orders within MAXIMO. This database allows for reports to be run on demand to determine the current valve operability for any of the valve types in our system. The database contains all of the pertinent valve information, such as age, material, manufacturer, number of turns to open or close, and maintenance history. Valve operability is reported on a monthly basis, as a part of our overall maintenance management reporting.

The MWRA has established criteria with associated codes to define the operability of the valves in our system. The following are the codes and their definitions as used to define valve operability.

Code	Definition	Meaning
OE	Operable/excellent	Full number of turns achieved
OA	Operable/adequate	Enough turns achievable for an adequate shut down in an emergency
PI	Partially Operable	Partial closure achievable but inadequate to shut down in an emergency
FO	Frozen open	
FC	Frozen closed	
FU	Frozen in unknown position	
AB	Abandoned	
BA	Broken Air Valve	Air valve inoperable, do not operate
RE	Removed	Valve removed from the system
SP	Special Status	Position and operability never checked “Do Not Touch”
UN	Unknown position	Presently unknown, due to inaccessibility & operability
Not Visit	Not yet visited	Valve has not been visited by crew

The MWRA considers the valves in the OE and OA categories as those that are operable. All others are considered inoperable, except for those that are abandoned or removed.

Valve Operability-2006

Valve Type	Total	Operability
Main Line	1251	86%
Air Release	1321	90%
Blow Off	1118	90%
Control-PRV	53	92%
Total All Others	979	N/A

The physical condition of most of the valves in the MWRA system is good to excellent which is a significant improvement over the situation in 1993 where the Plan said "Operational experience with mainline valves indicate that many valves are inoperable or only partially operable due to a general lack of maintenance for many decades" . It is difficult to make a gross assessment of valve condition, however, and individual reporting, using valve operability statistics provides a much better method of valve conditions. Capital construction projects, in-house valve replacement, and valve maintenance programs (discussed below) have made a great improvement in the overall condition of the valves.

Valve Maintenance Program

Pipeline and Valve crews are dedicated to water system maintenance. Pipeline crews replace broken or inoperable valves, repair leaks, retrofit blow off valves, and perform a variety of other tasks. The valve maintenance program includes the goal setting and tracking stressed in the standards set by the AWWA.[4] The goal is to exercise all main line

[4] Valve exercise program. The utility shall have a valve exercising program. This program shall include at least the elements:

a. A goal for the number of transmission valves to be exercised annually based upon the percentage of the total valves in the system.
b. A goal for the number of distribution valves to be exercised annually.
c. Measures to verify that the goals are met and written procedures for action if the goals are not attained.
d. Critical valves in the distribution system shall be identified for exercising on a regular basis. Potential quality and isolation concerns shall be recognized. The program shall track the annual results and set goals to reduce the percent of inoperable valves.

valves once every two years. However, some valves cannot be exercised as it would cause a loss of supply in the system. This is the case when a redundant line is out of service due to a construction project, leak repair, or some other maintenance activity. Closing of the valves on the active line would cause a disruption in service. Valve exercising can drop to as low as 10% of the work load in the summer months, as the majority of the time is spent on construction support and the other activities.

Work to date

There have been dramatic improvements in system performance in the last 10 to 15 years, due to the success of the combined program. The "selected" CIP valve contracts (five have been completed to date) have replaced 69 valves, with more currently under design. In-house valve replacements need to remain in place to keep pace with the maintenance of a water system of this size. Phase 6 construction is scheduled to start in July 2006 and includes 4 blow-off valve retrofits, 16 main line valve replacements, 9 globe valves for tank isolation, one check valve and rehabilitation of one meter. The cost for Phase 6 is approximately $2.2 million. Phase 7 construction is scheduled to start in October 2008 at approximately the same cost. To date, MWRA has spent approximately 35% of the $4 million allocated for equipment purchases to support ten phases (with 20 main line valves per phase) of in-house valve replacement work. Valve replacement that occurs through the pipeline rehabilitation program must also remain in place. Over 200 valves have been replaced by MWRA staff as a part of the program.

Recommended Actions and Capital Improvements-Valves

- Two additional phases of valve replacement are recommended at a cost of $6 million ($3 million per phase) with a start date of FY 09. Valve operability goals are not yet fully met although great improvements have been made. In order to increase the percentage of operable valves and to address valves that fail during the next 10 year period, work will need to continue using both the proposed CIP project and in-house design services. In addition, it is expected to take 5-10 years more to complete the blow off valve retrofit program with 50% of the blow-offs still needing to be completed. The mix of in-house and CIP work on all phases of the MWRA valves has been the key to operational success of the system and staff recommend that Phase 8 and Phase 9 be added to the valve replacement program with $6M to be spent between FY 09-18.

- Recommend monitoring the maintenance needs for the butterfly valves that have replaced gate valves over the past 15 years. Gate valves have routinely had an expected life in the MWRA system of 50-75 years and there is some concern that

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The AWWA also publishes a series of Manual of Water Supply Practices. One of these manuals is M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance. This manual provides the following for guidance in the planning of a maintenance schedule for valve exercising:

- Inspections should be made of each valve on a regularly scheduled basis (annually if possible) and at more frequent intervals for valves with a 16" diameter and larger.
- All gate valves should be cycled from full open to full close and back to open at least once every two years.

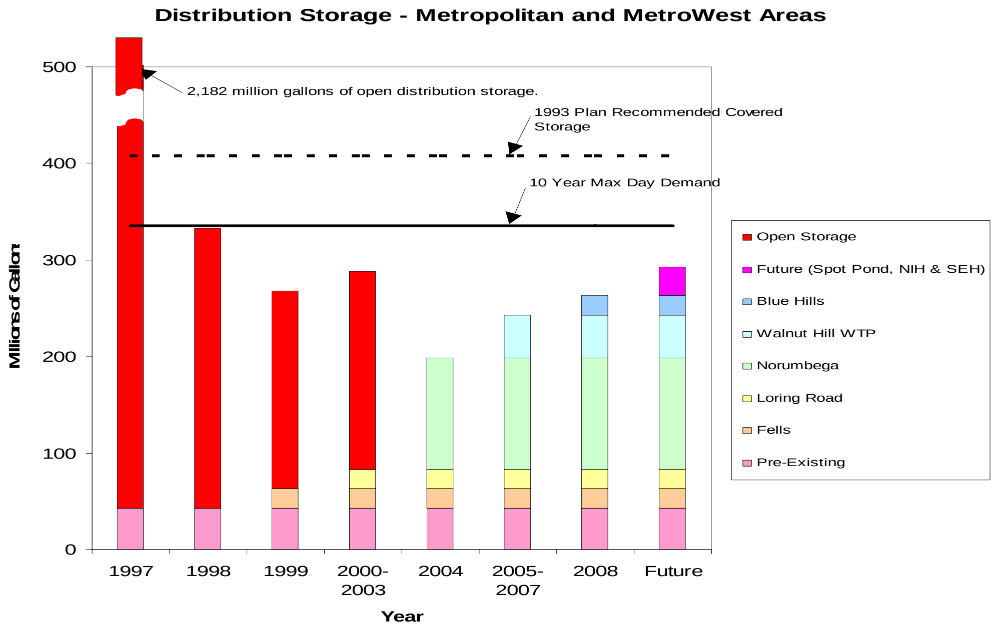
the butterfly valves may not be as resilient and more prone to breakage and misalignment. For the next master plan update, review this information and complete a revised life cycle cost analysis if appropriate.

8.4 Storage

The majority of the water (81%) delivered in the Metropolitan area is done by means of gravity. The remaining 20% is delivered through the use of pumping stations and the 11 water storage tanks. In 1993, MWRA had approximately 2,182 MG of open distribution storage in Eastern Massachusetts. MWRA had initiated efforts to comply with the regulatory requirements to eliminate uncovered storage. Although work was in the early stages, MWRA accepted that the requirement would greatly reduce the storage volume available. Based on generally accepted standards, MWRA's planning assumptions were based on the need to provide a storage quantity equal to a max day demand for the system. The 1993 Master Plan enumerated the projects identified by the 1993 *Water Distribution System Storage Study* and noted that by 2017 covered storage within the distribution system should approach 345 MG (including Nash Hill in the Chicopee Valley Aqueduct (CVA) system but not including planned storage of 50 to 100 MG at the proposed water treatment plant). This would get MWRA close to the 1993 conservatively projected goal of having storage for a max day demand of 460 MG.

Since 1993, significant covered storage has become operational as Fells, Loring Road, Norumbega and the storage at the Carroll Water Treatment Plant has come on line. At some locations, the storage volume that has been or is proposed to be constructed may be less than the volume initially proposed in 1993. Siting and mitigation issues at specific locations have resulted in decisions to downsize volumes in order more readily fit the storage on the selected sites. Four facilities recommended in 1993 have not been constructed. Additional storage has not been constructed for the Northern Intermediate High service area, the Southern Extra High service area, the Low service area and in the Lynn/Saugus area (Northern High). The 1993 report also noted that additional long-term storage could be constructed in the Fells to supplement both the Northern High and the Low service areas. However, since 1993, major uncovered reservoirs at Norumbega, Weston, and Spot Pond have been disconnected from the system. MWRA now has 243 MG of available storage in the Metropolitan system (excludes Nash Hill in the CVA system). An additional 20 MG of storage is being constructed at Blue Hills. The 263 MG of storage to be provided by the above facilities is still less than MWRA's current max day demand. Overall system demands have dropped significantly. In 2005, max day for the MWRA system was 287 MG. However, this leaves a continuing shortfall in storage within the MWRA Metropolitan System and specifically, within certain pressure zones.

Figure 8-10



<u>Recommendations for Additional Storage</u>

Staff looked at each pressure zone to determine where there may be remaining needs. Needs can be driven either by the inadequacy of the existing volume of storage in each pressure zone or by the location of the existing storage within the zone relative to where the demands are within that pressure zone. Staff has also looked at community owned storage. Although most community storage serves small localized areas, in some cases, the elevation or location of community storage may be appropriate to consider in thinking about the regional system's ability to meet max day demand in the event of an emergency.

- Additional distribution storage should be constructed in both the NIH and SEH pressure zones where storage shortfalls were identified in 1993 and where shortfalls remain. These service areas also happen to be where additional communities have recently (Reading in NIH; Stoughton and Dedham-Westwood in SEH) or are expected (Wilmington in NIH) to join the MWRA system. More detailed information is provided in the pressure zone sections but it is estimated that approximately 6 MG of storage is required in the NIH and up to 10 MG in the SEH.

- MWRA should proceed with the construction of the previously recommended 20 MG of Low Service Storage in the general vicinity of Spot Pond. This is estimated to cost approximately $35 million dollars and will need to be preceded by a study and environmental review.

Purpose of Storage

Distribution storage tanks serve two important functions in a water system: they provide equalization flows to dampen the effects of daily flow variations and they provide emergency storage in the event of a short-term supply disruption[5]. Thus, it is necessary for a distribution storage tank to have an elevation high enough to provide adequate pressure throughout the system served.

However, the MWRA system may present some flexibility in terms of emergency storage. Although, ideally, most system emergencies should be handled transparently to the communities and end consumers with system operations automatically or unobtrusively shifting to the use of emergency storage, MWRA has not lost the ability to use the large uncovered reservoirs in the event of a significant system problem. This type of shift would not be transparent and would be accompanied by water restrictions, boil orders etc. but a level of service could be maintained. The ability to use the uncovered reservoirs in an extreme emergency can be considered in determining the right amount of new covered storage for the MWRA system.

Locating Storage

The ideal location for distribution storage is affected by many factors but should reflect where demands are located within the pressure zone. This set-up results in minimal head losses and pressure fluctuations, since, on average, the water travels the shortest distance from its storage location to the consumer. Distribution storage should be relatively proportional to water demand in each of the service areas. The original open reservoirs at Norumbega, Fells Reservoir and Blue Hill Reservoirs were laid out in such a way to meet this objective and these locations are now the site of the key covered storage reservoirs (including the future Blue Hills Covered Storage facility). The remaining smaller covered

[5] **Equalization storage** is the amount of water necessary to supply peak water usage at times when the demand exceeds the system's delivery capacity. The availability of sufficient equalization storage keeps the elevation of stored water within an acceptable range, thereby preventing excessive reductions in pressure. During times of maximum demand, water flows from the distribution storage facility to the consumers. When demand drops off, the flow refills the reservoir. The volume of equalization storage required for an area is a function of the magnitude and variability of water usage and the capacity of the water delivery system.

Emergency storage is the quantity of storage required to maintain water service in the event of an interruption in supply due to circumstances such as a pipeline break or a mechanical malfunction. The amount of emergency storage required depends upon the magnitude of water usage and the anticipated response times for emergency repair operations. It is common practice to design water systems to have enough overall distribution storage to meet at least one day's maximum demand. To appropriately serve a large region with variable land elevations, individual distribution storage facilities must be appropriately sized and located relative to the needs of each service area.

The sum of equalization and emergency storage volumes equals the total useable storage. A relatively small volume of water is also necessary to provide a buffer depth at the bottom of a storage facility to maintain the water quality of the water leaving the tank. This amount is called reserve volume.

storage, which receive pumped water from the MWRA system, are located on hilltops in the areas served.

Storage Facility Condition Assessment

The 11 active storage facilities in the Metropolitan system range in actual age from 6 to 91 years old (excluding Norumbega which is west of the Metropolitan system). Blue Hills Covered Storage is expected to come on line in 2010. Generally, prestressed storage structures have expected lives of 50 years while cast-in-place concrete structures have expected lives of approximately 100 years. For the purpose of the asset value analyses done in 2004, MWRA assumed that overall, MWRA's storage facilities had an average useful life of 80 years. Internal piping and appurtenant structures are expected to last approximately 50 years. In addition, for those facilities significantly rehabbed, the 2004 analyses reset the clock at 80 years of useful life. The age, material and operating condition of each of MWRA's storage facilities is found on the table below.

Table 8-2

Storage Facility	Year Built	Year Rehabbed	Years to Next Rehab
Arlington Covered Reservoir (active)	1937		11
Arlington Heights Standpipe (standby)	1922	1999	73
Bear Hill Tank (active)	1986		60
Bellevue Standpipe #1 (standby)	1915	1999	73
Bellevue Standpipe #2 (active)	1955	2000	74
Deer Island Tank (active)	1994		68
Turkey Hill Tank (active)	1945	2000	74
Walnut Hill Tank (active)	1961	1999	73
Fells Covered Storage (active)	1999		73
Loring Road Covered Storage (active)	2000		74
Blue Hills Covered Storage (in design)	2010 (expected)		80 (in 2010)

*Years to Next Rehab-Remaining Useful Life from MWRA asset replacement analysis

Routine maintenance practices do need to be applied to storage facilities to ensure that structural features are secure. Catastrophic failure is not generally a concern but gradual problems can include cracks in side walls, internal and/or external ice damage, loose or fractured welds, broken control valves or other appurtenant piping, damaged overflow weirs and malfunctioning instrumentation. However, the "failure mechanism" would likely be rusting, followed by weeping, followed by leaking.

AWWA recommends that finished water storage facilities undergo an in-depth inspection every 3 to 5 years. The MWRA started an inspection program in 1999. Five water tanks were cleaned and painted in 1999-2000 and all others were inspected in 2000-2001 with two requiring cleaning. All tanks were re-inspected in 2006, keeping with the 5 year inspection cycle. No major deficiencies were found. One tank (Bellevue 2) was found to have a small area of interior paint failure, which will be corrected. No large expenditures are anticipated within the Master Planning time frame for most of these facilities. Although the Arlington Covered Reservoir (constructed in 1937) would appear to need rehabilitation in the FY14-23 time frame, it has been inspected and been determined to be in good condition.

Water Storage Tank Operation and Maintenance

The operation and maintenance of water storage tanks requires that attention be paid to tank level monitoring, operating ranges, turnover rates, mixing process, and water quality. Maintenance has to consider activities required on a routine, annual, and detailed inspections basis. Security issues, including fencing, inspection frequency, and access have become a significant issue for both MWRA and for the community-owned storage facilities.

The OCC monitors the water storage tanks, pump stations, pressure reducing valves, community meters, and tunnel shafts. The individual water storage tanks are controlled using programmable logic controllers (PLCs) at the pump station that is the tank's source of water. Normal operation is managed by the OCC remotely. In the event of a loss of communications from the OCC, the PLC is capable of operating the pumps and the tank levels on a local/remote basis. All of the tanks have high and low level alarms to alert the operator at the OCC if there is a problem.

<u>Maintaining Water Quality</u>

Maintaining the best quality of water possible is accomplished by monitoring the turnover rates, mixing process, and water quality of each of the water storage tanks. This provides for the lowest water age, and in turn, the highest water quality.[6] The turnover rates calculated for the MWRA tanks were determined to be between 1.3 and 2.4 days (which equate to daily rates of 40% to 77%). Another element to promote the optimum water quality in storage tanks is through the mixing process. This can also help to minimize water age, and to minimize stagnant zones in the tank. The mixing of the water in the tank is encouraged by a more aggressive or turbulent flow into the tank. Confirmation of water age and water quality is through weekly water quality samples taken at each water storage tank. MWRA samples each tank every week to confirm water quality[7]. If water quality

[6] The AWWA Research Foundation (AwwaRF) published a report titled "Maintaining Water Quality in Finished Water Storage Facilities" (AwwaRF report 90763, 1999), The study recommends water in storage tanks should be turned over an average of every 2.5 days to minimize water age and maximize water quality. A 2.5 day turnover rate translates to a 40% daily turnover in tank volume.

[7] Field Operations coordinates with the OCC staff so that the tanks are at the appropriate elevations to allow for a sample to be taken. Crews radio the OCC while driving to each tank, to confirm that water is leaving the tank. This way the sample is sure to be from the tank, and not inbound system water. If the tank is

sampling and testing continue to show a drop in chlorine residual, despite operational changes, then more drastic measures, such as draining the tank, may be required.

8.5 Pump Stations

Since 1993, the initial work to rehabilitate the Spot Pond (now the James L. Gillis P.S.), Commonwealth Avenue, Lexington Street and Newton Street pump stations has been completed, as well as work to construct the Chestnut Hill emergency pump station, and the remaining older pump stations at Brattle Court, Reservoir Road, Hyde Park, Belmont and Spring Street are scheduled to be rehabilitated beginning in FY07. Work will include installation of new mechanical, electrical, instrumentation and security systems with building and site refurbishment. A fast track contract completed in 2001, installed SCADA systems at each station and all stations are now remotely operated. The Dudley Road Pump Station in Newton was recently (2006) rehabilitated by in-house staff. Please also see Pressure Zone discussion.

<u>Recommended Projects</u>

- Staff recommends that funds be added to the CIP for replacement of instrumentation, electrical and mechanical systems at the pump stations with $2 million to be added in the FY14-18 time period; $4 million to be added in the FY 19-28 time period. It is expected that up to $50 million will be required in the twenty year period following 2028 for another significant facility rehabilitation project.

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filling, the OCC notifies the crew to wait anywhere from 15 to 30 minutes to make sure that the pumps are disabled, and water is flowing out of the tanks. The crew performs a field chlorine residual test, and radios the results to the OCC. Sample bottles are taken to the lab for bacteria testing. Results are published in the weekly and monthly operations reports. The sample results are plotted and are monitored by Metropolitan Operations staff, and Quality Assurance staff. A threshold level of 1.0 mg/l is used to review water quality, and determine if operational changes should be made, such as increasing the operating range to move more water in the tank. The specifics of each tank is considered, such as the existence of separate inlet and outlet piping, configuration, and volume and the disinfection methods used must also be considered. The use of chloramines suggests that testing for ammonia and nitrification needs to be done in the warmer months.

Broken down by component, pump stations have an average useful life of 10-50 years. Computer control systems, generally used as a part of the Supervisory Control and Data Acquisition (SCADA) systems have a useful life of between 10 and 15 years. This is due to the nature of the computer industry, and the pace at which technology changes. Routine condition assessment of pump station equipment has been initiated in order to identify any equipment or instrumentation issues.

Table 8-3
Pump Station Overview

Pumping Station	Pressure Zone Serviced	Capacity (mgd)	Year Built	Year Rehabbed
Gillis, Stoneham	Northern High Northern Int. High	35	1900	1998
Brattle Court, Arlington	Northern Extra High	12	1907	2010
Spring Street, Arlington	Northern Extra High	20	1958	2010
Lexington Street, Waltham	Northern Extra High	2	1949	1998
Belmont	Intermediate High	6	1937	2010
Commonwealth Ave., Newton	Southern Extra High	20	1952	2000
Hyde Park Ave., Hyde Park	Southern Extra High	8	1912	2010
Reservoir Road, Brookline	Southern Extra High	5	1936	2010
Newton Street, Brookline	Southern Extra High	19	1954	1998
Dudley Road, Newton	Southern Extra High	1	1954	2006
Chestnut Hill Emergency P.S.	Southern High	90*	2001	

* The Chestnut Hill Emergency Pump Station was constructed to supply the Southern High and Southern Extra High in an emergency by taking water from the Sudbury Aqueduct via the Chestnut Hill Reservoir or by taking water from the Low Pressure system. The 90 mgd capacity reflects the station taking non-potable water from the Chestnut Hill Reservoir.

Please see Table 9-1 in Chapter 9 for recommended SCADA equipment replacements and upgrades.

Although recent and ongoing rehabilitation projects have addressed the major capital needs of these facilities, the useful life of certain components including equipment such as pumps and instrumentation are generally within the 20-25 year time range and equipment replacement is expected to be necessary within the Master Planning period. In addition, Field Operations continually evaluates opportunities for facility optimization. As part of this, VFDs have been installed in a number of pump stations and this will continue as part of the remaining rehabilitation work. For this reason additional VFDs are also likely to be installed in Gillis Pump Station.

Maintenance Practices

There are a variety of maintenance activities that are performed at the pump stations. Theses preventative maintenance (PM) tasks are performed on a monthly, quarterly, semi-annual, and annual schedule, depending upon the type of equipment. The following are examples of the equipment that are maintained at the pump stations:

- Emergency Generators
- Motors
- Pumps
- Motor Control Centers
- Surge Control Valves
- Diesel Engines
- Gate and Butterfly Valves

8.6 Water Local Pipeline Assistance Program

The goal of the $255.5 million Local Pipeline Assistance (loan) Program is to assist MWRA member water communities in improving local water system pipeline conditions to help maintain high water quality to customers as water passes through local pipes and to promote the use of distribution system best management practices. This program is a critical element of MWRA's Integrated Water Supply Improvement Program and was a component of the Board's October 1998 treatment technology decision for the John J. Carroll Water Treatment Plant. It continues the effort of the two-year, $30 million "pilot" program that provided grants and loans for local distribution system rehabilitation projects during FY98 and FY99. On November 12, 1999, the MWRA Board of Directors approved funding of the Local Pipeline Assistance Program to provide $250 million ($25 million per year over a ten-year period) in interest-free loans to water system communities for pipeline cleaning and lining projects or replacement of unlined water mains. Funds were allocated to member water communities based on their percent share of unlined water pipe. MWRA's partially supplied communities received pro-rated shares based on their percentage use of MWRA water during fiscal years 1995 through 1998. Interest-free loans are repaid to MWRA over a ten-year period beginning one year after the date the funds are distributed. After initiation of the $250 million Program, $5,517,500 was added to fund new MWRA water communities – Lynnfield ($320,000), Stoughton ($4,480,000), Reading ($710,000), and Dedham/Westwood ($7,500).

Funding of local projects began in August 2000 (FY01). Through December 2006, $118 million in interest-free loans have been distributed to finance 147 projects that will help maintain high water quality in the local distribution systems. The remaining $137 million in loans will be distributed to communities through FY13. Table 8-4 provides a summary of funds allocated and distributed to each eligible community through December 2006. This Table is updated periodically and available on the MWRA web site. Table 8-5 provides detail on the miles of community water mains lined and remaining unlined through December 2006. Since FY98, a total of about 278 miles of community water mains have been replaced or rehabilitated via the MWRA pilot program, the current MWRA interest-free loan program, and community funded projects. Project costs have averaged about $100 per foot ($530,000 per mile). Projecting this unit cost through completion of the program, about 2000 miles of community water main will remain unlined, representing a future community water main replacement/rehabilitation cost of over $1.0 billion.

Recommended Projects-Local Pipeline Assistance Program

- Given the greater than one billion dollars anticipated to be needed at the local level to continue to eliminate unlined water pipe, staff recommend that a systematic approach be considered to maintaining continued MWRA financial assistance. The Master Plan recommends allocating Local Financial Assistance Program loan repayments to extend community funding similar to a revolving fund. Currently $255.5 million has been approved by the Board of Directors to date, of which $118 million has been distributed as loans to communities and is being repaid. Staff recommends that $125 million in additional loan funds be made available to communities for additional Local Pipeline Assistance Program financial assistance in the FY14-23 timeframe.

Table 8-4

MWRA LOCAL PIPELINE ASSISTANCE PROGRAM

ALLOCATION AND FUND UTILIZATION BY COMMUNITY

THROUGH DECEMBER, 2006

Community	Community Total Allocation for 10 years	Community Max Annual Allocation	Allocation To Date (7 years)	Funds Distributed Thru Nov 06	Percent Distributed (7 years)	Total Remaining Funds 10 years
Arlington	$9,723,620	$972,362	$6,806,534	$1,638,000	24%	$8,085,620
Bedford*	$1,018,610	$500,000	$1,018,610	$1,018,610	100%	$0
Belmont	$4,213,570	$500,000	$3,500,000	$650,000	19%	$3,563,570
Boston	$61,571,330	$6,157,133	$43,099,931	$43,099,931	100%	$18,471,399
Brookline	$625,090	$500,000	$625,090	$0	0%	$625,090
Canton*	$2,080,380	$500,000	$2,080,380	$0	0%	$2,080,380
Chelsea	$5,023,870	$502,387	$3,516,709	$292,680	8%	$4,731,191
Dedham/Westwood* ##	$7,500	$7,500	$7,500	$0	0%	$7,500
Everett	$5,429,020	$542,902	$3,800,314	$2,695,101	71%	$2,733,919
Framingham	$8,681,800	$868,180	$6,077,260	$5,184,460	85%	$3,497,340
Lexington	$1,539,570	$500,000	$1,539,570	$153,957	10%	$1,385,613
Lynnfield Water District	$320,000	$320,000	$320,000	$320,000	100%	$0
Malden	$10,244,520	$1,024,452	$7,171,164	$5,653,645	79%	$4,590,875
Marblehead	$6,320,350	$632,035	$4,424,245	$0	0%	$6,320,350
Marlborough*	$1,166,200	$500,000	$1,166,200	$450,000	39%	$716,200
Medford	$9,723,620	$972,362	$6,806,534	$3,889,448	57%	$5,834,172
Melrose	$6,586,590	$658,659	$4,610,613	$3,296,018	71%	$3,290,572
Milton	$6,771,800	$677,180	$4,740,260	$4,063,080	86%	$2,708,720
Nahant	$1,331,210	$500,000	$1,331,210	$802,242	60%	$528,968
Needham*	$1,286,520	$500,000	$1,286,520	$257,304	20%	$1,029,216
Newton	$25,860,190	$2,586,019	$18,102,133	$15,516,114	86%	$10,344,076
Northborough*	$97,180	$97,180	$97,180	$0	0%	$97,180
Norwood	$5,139,630	$513,963	$3,597,741	$3,597,741	100%	$1,541,889
Peabody*	$838,030	$500,000	$838,030	$251,409	30%	$586,621
Quincy	$15,835,600	$1,583,560	$11,084,920	$6,334,240	57%	$9,501,360
Reading* ##	$710,000	$500,000	$710,000	$0	0%	$710,000
Revere	$5,371,140	$537,114	$3,759,798	$1,000,000	27%	$4,371,140
Saugus	$9,029,070	$902,907	$6,320,349	$5,414,535	86%	$3,614,535
Somerville	$9,480,530	$948,053	$6,636,371	$6,636,371	100%	$2,844,159
Southborough	$81,030	$81,030	$81,030	$0	0%	$81,030
Stoneham	$1,736,360	$500,000	$1,736,360	$0	0%	$1,736,360
Stoughton* #	$4,480,000	$560,000	$2,800,000	$0	0%	$4,480,000
Swampscott	$5,602,660	$560,266	$3,921,862	$3,921,330	100%	$1,681,330
Wakefield*	$2,524,950	$500,000	$2,524,950	$0	0%	$2,524,950
Waltham	$13,636,210	$1,363,621	$9,545,347	$0	0%	$13,636,210
Watertown	$1,736,360	$500,000	$1,736,360	$0	0%	$1,736,360
Wellesley*	$1,279,280	$500,000	$1,279,280	$516,957	40%	$762,323
Weston	$127,330	$127,330	$127,330	$127,330	100%	$0
Winchester*	$665,190	$500,000	$665,190	$665,190	100%	$0
Winthrop	$4,167,260	$500,000	$3,500,000	$0	0%	$4,167,260
Woburn*	$3,454,330	$500,000	$3,454,330	$1,100,000	32%	$2,354,330
TOTAL	**$255,517,500**		**$186,447,205**	**$118,545,693**	**64%**	**$136,971,808**

*** Partially Served Communities**

 # Stoughton's total allocation is for eight years; the Town was not an MWRA member water community for the first two years of the Program.

Reading's and Dedham/Westwood's total allocations are for five years; the Towns were not MWRA member water communities for the first five years of the Program.

Table 8-5
MWRA LOCAL PIPELINE ASSISTANCE PROGRAM
LOCAL COMMUNITY UNLINED WATER PIPE
THROUGH DECEMBER 2006

Community	Total Miles of Pipe	Miles of Lined Pipe	Miles of Unlined Pipe	Percent Unlined	Replacement Pipe Pilot Program (miles)	Clean & Line Pipe Pilot Program (miles)	Replacement Pipe LPAP (miles)	Clean & Line Pipe LPAP (miles)	Replacement / Clean & Line Community (miles)
Arlington	131	54.9	76.1	58%	1.1		2.9		
Bedford*	83	74.2	8.8	11%			0.4	3.3	
Belmont	91	56.8	34.2	38%			1.1		
Boston	1182	775.5	406.5	34%	14.8	19.8	31.1	32.7	
Brookline	140	140.0	0.0	0%	0.4	5.0			
Canton*	121	87.3	33.7	28%	0.2				
Chelsea	62	21.3	40.7	66%	1.3	0.8	0.4		
Dedham/Westwood*	194	188.0	6.0	3%					
Everett	67	24.6	42.4	63%	0.5		4.0		
Framingham	250	191.1	58.9	24%	4.0	0.3	2.5	6.3	
Lexington	157	144.9	12.1	8%			0.2	1.0	
Lynnfield W.D.	25	23.0	2.0	8%	0.2		0.6		
Malden	118	36.3	81.7	69%	0.6		6.3		
Marblehead	78	26.4	51.6	66%		0.8			
Marlborough*	168	154.5	13.5	8%	1.1	1.7	0.6		
Medford	120	42.9	77.1	64%	0.4		5.0		
Melrose	80	32.4	47.6	60%	0.5		4.7		
Milton	126	74.8	51.6	41%	1.1		6.0		
Nahant	23	13.0	10.0	43%			1.5		
Needham*	133	90.1	43.2	32%	0.2		0.7		
Newton	316	111.8	204.2	65%	1.7	6.3	13.7	10.2	
Northborough*	65	61.2	3.8	6%	0.8				
Norwood	125	57.7	66.9	54%		1.5	0.9	8.4	
Peabody*	170	52.7	117.3	69%			0.1	1.6	
Quincy	240	139.5	100.5	42%	2.6	1.6	10.9		
Reading*	101	54.0	47.0	47%					
Revere	91	47.9	43.2	47%	0.4	1.7	1.2		
Saugus	120	49.0	71.0	59%	1.0		6.0		
Somerville	119	26.9	92.1	77%	0.8		6.4	2.4	
Southborough	84	83.4	0.6	1%	0.5				
Stoneham	75	66.6	8.4	11%	2.8				
Stoughton*	142	42.6	99.4	70%					
Swampscott	55	13.1	41.9	76%			2.8	3.7	
Wakefield*	114	88.0	26.0	23%	0.8				
Waltham	157	41.3	115.7	74%	2.1				
Watertown	80	65.0	15.0	19%					
Wellesley*	136	62.0	74.1	54%			0.7		
Weston	105	105.0	0.0	0%			1.9		
Winchester*	105	105.0	0.0	0%					11.6
Winthrop	45	10.0	35.0	78%	1.0				
Woburn*	182	93.3	88.7	49%	1.1			3.0	
TOTAL	**5,976**	**3,628**	**2,349**	**39%**	**41.9**	**39.4**	**112.4**	**72.7**	**11.6**

*** Partially Served Communities**

Pressure Zone Issues and Recommendations

8.7 Boston Low and Northern Low Service Areas

The Low Service area accounts for approximately 25% of MWRA use and provides water to low lying areas of Boston (Boston Low) and seven suburban communities to the north (Northern Low). The Low system includes over 35 miles of 36-inch to 48-inch cast iron pipe (not including WASM 1 and WASM 2) and is the oldest part of the metropolitan system. As such, it has been the focus of much pipeline renewal work, particularly in the vicinity of Chestnut Hill. The Boston portion of the service area is normally supplied from Loring Road Covered Storage (elev.200') by two of the large diameter Weston Aqueduct Supply Mains (WASM 1 & 2). In addition, Operations can feed one of the Boston meters from the Spot Pond Supply Mains from the Shaft 8 PRV. The Northern Low Service (NLS) area is supplied by high service tunnel water which is reduced in pressure and distributed through the Spot Pond Supply Mains extending north from Chestnut Hill to meters in the northern part of the Low system. Shafts 7, 7B, 8, 9, and 9A all have pressure reducing valves (PRVs) which provide for the noted pressure reduction. The NLS PRV provide for great redundancy due to the number of pressure reducing valves, and their location throughout the service area. Because the Low service area includes those areas at the lowest elevations, hydraulic deficiencies in this area are rare. The Nonantum Road PRV will allow the Northern Low to also be fed from WASM 4. The PRV has been installed but is not yet on-line. There is no MWRA storage within the Low system east of the Loring Road covered Storage Facility.

Figure 8-11

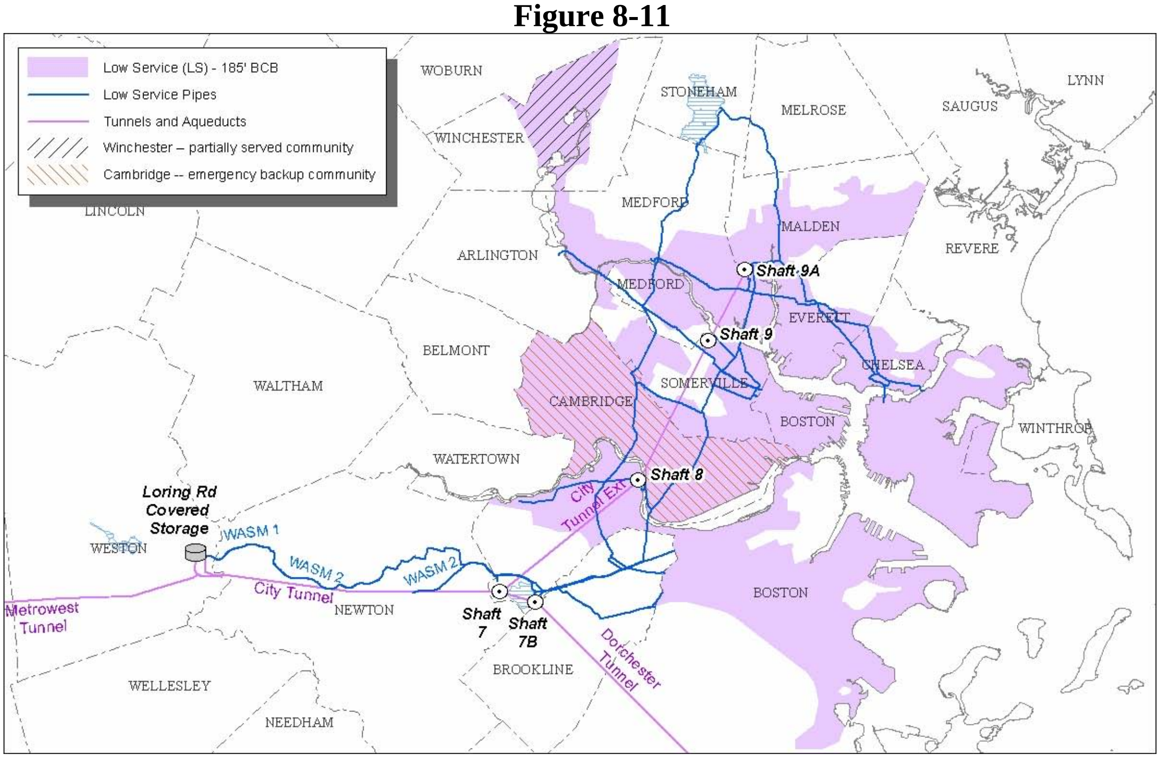


Figure 8- shows the communities and key infrastructure of the Low System. MWRA serves as an emergency back-up for the City of Cambridge. This section of Winchester also can be partially supplied through a metered connection from Spot Pond.

Delivery System Condition and Ongoing Work:

The pipes in this service area include the oldest sections owned by the Authority including some pipes that date to the 1840's. Much of the pipe rehabilitated to date has been is old unlined cast iron and some sections that have deteriorated to the point of removal from service due to the risk of breaks are scheduled for replacement or abandonment. Approximately 18 miles of unlined cast iron remain in this pressure zone with 11 miles scheduled for future rehabilitation.

WASM 1 is a 48-inch diameter cast iron pipeline initially constructed in 1904 and WASM 2 is a 60-inch cast iron main constructed in 1916. These pipelines, as most pipelines in the Low Service, were constructed when there was substantially less traffic (less surface loading) and adjacent construction activity and prior to the construction of MBTA facilities. This is particularly apparent in the Cleveland Circle area which has been problematic in terms of pipe leaks for a number of years. These lines have been a focus for rehabilitation due to their age, extensive tuberculation, inoperable valves and concern over the potential for joint failures. Contracts to rehabilitate WASM 1 and 2, primarily through cleaning and lining, are substantially complete and supply the Boston Low mains in Clinton Road, Beacon Street and Boylston Street which were rehabilitated (and part of the Beacon Street line abandoned) as part of the Boston Low Service Rehabilitation Project. Section 31 (48-inch) and the Spot Pond Section 2's (2 East and 2 West-both 48-inch) parallel the Beacon Street Line and were rehabbed under the Boston Low Project. The Low Service supply to the downtown Boston area has no significant pressure problems when fully in service.

The MBTA's Green Line occupies Beacon Street and presents an ongoing source of stray current that could impact the three 48-inch mains in the vicinity. A temporary fix to reduce this risk was provided but ongoing monitoring is necessary to ensure that the pipe remains protected. A 48-inch cast iron section of the Beacon Street Line installed in 1870 and previously repaired in the 1950's and 1970's, failed in June, 2006. The location was adjacent to Borland Street in Brookline. The Green Line tracks had to be removed for the pipeline to be repaired. This portion of the Green Line was out of service for 2 days during the incident with the normal 20 MGD flow shifted temporarily to other Northern Low Service pipelines.

Additional work is underway in the Northern Low including the rehabilitation of the 100 year old East and West Spot Pond Supply Mains (approximately 75% complete). These mains serve as distribution mains to the eight communities in the Northern Low system and can provide emergency back-up to the Gillis Pump Station. The East Spot Pond Supply Main is 61,000 linear feet of mostly 48" diameter pipe and the West Spot Pond Supply Main is approximately 53,000 linear feet of 48-inch and 60-inch pipe. Section 57 which connects the east and west mains is also in need of rehab and 1,200 linear feet are being rehabilitated as part of the SPSM work. This includes High Street and a portion of Riverside Avenue in Medford. The eastern portion was rehabbed in the 1980's from Middlesex Avenue in Medford to the eastern end of the pipeline in Chelsea.

In September 2006, the Shaft 9A PRV in Malden malfunctioned to allow the discharge hydraulic gradient in the Northern Low to rise from a normal of about 180 feet to a brief spike reaching over 220 feet. This pressure spike and additional ones that followed caused over forty breaks in the five communities of Chelsea, East Boston, Medford, Malden and Everett. A second PRV at Shaft 9A was brought on line and experienced similar fluctuations. An alternate PRV was brought on line at Shaft 9 and has performed well. This illustrates the value of the operational flexibility provided by the redundant PRVs at the tunnel shafts.

Another older pipeline in this pressure zone requiring a mix of replacement and cleaning and lining work is Section 8 in Malden and Everett. Section 8, a 48" cast iron main, in excess of 100 years old, had a catastrophic failure in October, 2002. A 22 ½ degree bend failed along its length, causing extensive damage to the street. Service to the NLS was temporarily affected until the break was isolated. As part of the existing CIP, the pipeline will be cleaned and lined and all defective or inoperable valves replaced in the 7,500 feet of 48-inch pipe and new 36-inch ductile iron main will replace 9,722 feet of the 42-inch deteriorated cast iron main in Everett to the Mystic River Bridge in Chelsea. Construction is scheduled to start in August, 2009 but work will commence in 2008 to rehabilitate and strengthen Sections 37 and 38 which provide service to East Boston. In addition, redundancy to East Boston will be provided through the installation of 2,000 linear feet (Section 97A). A new PRV will allow this line to provide redundant service to East Boston including Logan Airport, although it will operate normally as part of the Northern High system.

A small leak was more recently identified on a coupling on Section 4 in Central Square in Cambridge. Section 4 is partially rehabbed and will be completed by the Spring, 2008. The portion of the pipe where the leak was identified will be rehabilitated next year and the leak was small enough to leave as is in the short term.

<u>Recommended Projects: Low Service</u>

The existing CIP project to rehabilitate Section 8 must be completed prior to these two projects being done.

- Design and Construction for replacement and rehabilitation of 5,000 linear feet of 36-inch pipe on Section 66 and replacement and rehabilitation of 5,000 linear feet of 30-inch pipe with 36-inch pipe on Old Mystic Main. Abandonment of 14,000 linear feet of 150 year old 24-inch cast iron main. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $8.2 million and, in conjunction with the project below, should be scheduled in the FY15-22 time period.

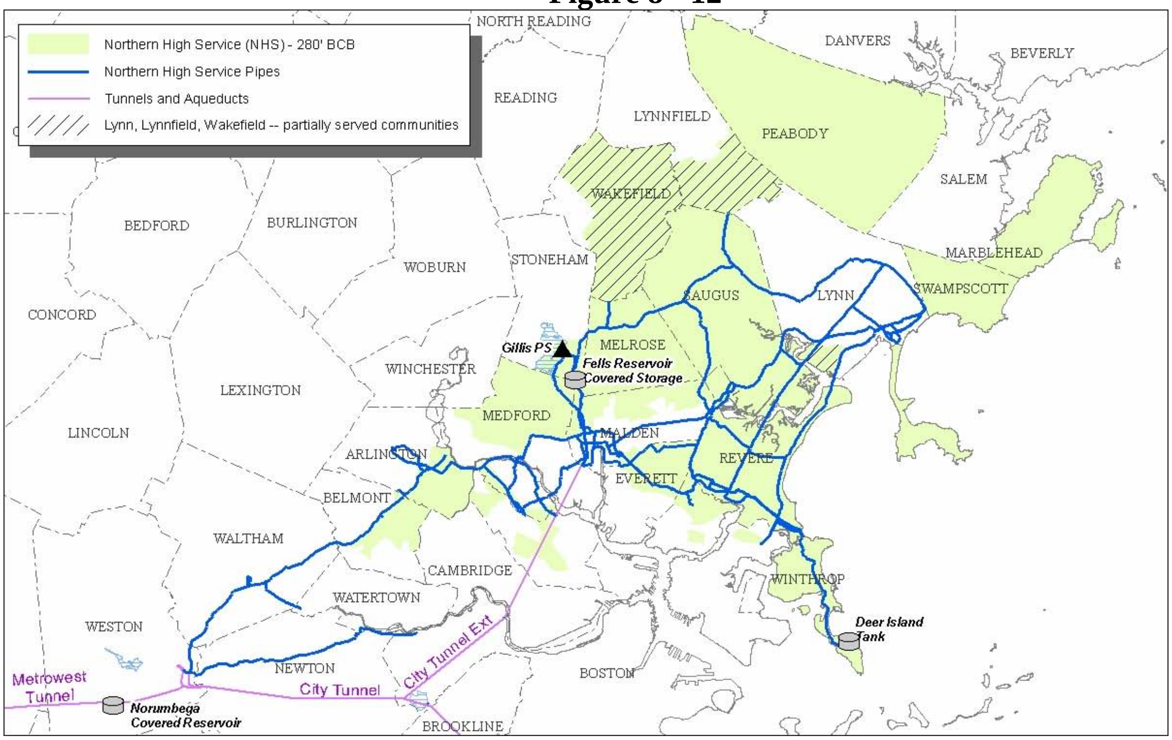
- Design and Construction for rehabilitation of the remaining portion of Section 57 in Riverside Avenue along with rehabilitation of 8,000 feet of sewer that must be done as part of the same project. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $21.4 million.

- Low Service Storage at Spot Pond. This 20 MG storage facility was identified as part of the original *Water Distribution System Storage Study* and carried forward in the 1993 Master Plan. This project adds storage to the overall system and to the Low system which has no storage east of Loring Road. In addition, this storage facility could help to provide pressure relief and surge control in an event similar to what occurred in 2006 when the PRVs at Shaft 9A malfunctioned. The estimated cost is approximately $35 million. This project is recommended for implementation in the FY12-15 time period. This work should be preceded by a study/environmental review phase which should start in FY09 and last two years at a cost of approximately $1 million.

8.8 Northern High Service

The Northern High Service zone is the largest geographical service zone and is located north of Boston. Water is supplied from Norumbega Covered Storage Facility (elev. 282') via the City Tunnel and City Tunnel Extension and distributed to 17 communities by gravity flow. The remaining three communities, Melrose and portions of Stoneham and Wakefield, are supplied from the Gillis Pumping Station by pumping to the Fells Reservoir Covered Storage (elev. 270'). This system also provides service to MWRA facilities on Deer Island.

Figure 8- 12



<u>Delivery System Condition and Ongoing Work</u>:

Since this service is so large and distant from Norumbega reservoir, it has historically experienced the widest pressure fluctuations during summer peak flows. The northeastern corner of the service area, which feeds Marblehead, Swampscott and Nahant, was significantly strengthened by the completion of Section 91 through Lynn. The southern part of the Northern High, including Chelsea, Everett, Orient Heights and Winthrop, has already been improved since the 1993 Master Plan by the addition of reinforcing pipelines. Previously marginal areas are no longer a factor. The Deer Island tank came on line in 1995 and has improved the reliability of service to Winthrop and on Deer Island.

MWRA's target gradeline analyses determined that potential hydraulic deficiencies may still be a factor at several meters in six communities (Boston-Orient Heights, Chelsea, LWD, Medford, Melrose and Saugus). In Medford, Melrose, and, in particular, Saugus, these communities have high ground elevations which are difficult to serve by gravity. Specifically, Saugus has experienced hydraulic deficiencies due to continued housing development at higher elevations in the northwest part of town. Typically, it is the responsibility of the local community to address these deficiencies through booster pumping (as Melrose has recently done). However, in Saugus, MWRA has adjusted operation of our system to better accommodate the Town's needs. Meter 205, at the intersection of the Lynn Fells Parkway and Main Street is now fed from Section 70 (Fells gradient) and Section 72 (NHS gradient). The normal supply to Meter 205 is from Section 70, which is the higher gradient (pressure). In Chelsea, it appears that any potential deficiency is mitigated by local storage. Service to Orient Heights is expected to be improved through the 97A work scheduled in MWRA's current CIP.

For Lynnfield, planned improvements will address the insufficient capacity of the existing 8-inch MWRA line feeding the District. The 7,000 linear feet of pipeline has experienced problems meeting summertime demands. MWRA consultants have recently completed a "Concept" plan which looked at alternative routes for construction of a new, larger diameter pipeline. The next step would involve the procurement of design engineering services to move forward with a preliminary design. This work is anticipated to start in 2007. An interim improvement project is currently under design with construction scheduled to be completed in 2007. This interim connection will provide adequate relief until the primary project is complete.

Gillis Pumping Station is one of the oldest stations in the system but it was substantially overhauled and upgraded in the 1990's. In addition a new suction pipeline to the Station from the City Tunnel shaft in Malden was installed which provides water at a higher head than was provided by Spot Pond (which now serves only as an emergency back-up). These improvements have facilitated the ability to transfer water between the low and high service systems and allow the full use of the 20 MG Fells Reservoir Covered Storage facility which came on line in Fall, 1999.

The 1993 Master Plan repeated the *Water Distribution System Storage Study* recommendation that a new storage tank with a useable volume of 24 MG be constructed in the vicinity of the Lynn/Saugus border in order to improve hydraulics and reliability for the Northern High system. In general, as noted above, construction of Section 91 resolved major hydraulic concerns for this part of the Northern High system and the construction of the Fells Covered Storage Facility also alleviated some of the concerns relative to reliability. It was also envisioned long-term that more storage (in addition to the 20 MG constructed to date) would be built at the Fells Reservoir site. This storage was proposed, in part, because it would work in concert with the previously proposed Northern Tunnel Loop. At this point, these projects are not being recommended. However, it may be useful to revisit these storage recommendations at each update of the Master Plan.

The Northern High Service has a wide range of pipe ages and materials. Overall, this area has 116 pipe miles of which 14 miles are greater than 100 years old. Of the 116 miles of pipe, 26 miles have been rehabbed to date and another 26 miles are planned for rehab, leaving 66 miles of pipe with no work planned. Of particular concern are the remaining unlined cast iron mains and the larger diameter steel mains which serve as major transmission mains for this service area. The Northern High contains 42 miles of remaining unlined cast iron pipe of which 10 miles is programmed in the current CIP but 32 miles is not. These mostly small diameter unlined cast iron pipe can be a contributor both to water quality problems as well as pressure problems. MWRA's initial capital budget focused on rehabilitation of larger pipes and on resolving immediate, known piping problems. Many previously identified Northern High pipeline rehabilitation projects were removed from the CIP due to budgetary concerns. Longer term changes in water quality regulations (see Chapter 5) will clearly focus on the distribution system and this unlined, highly tuberculated pipe needs to be systematically replaced.

The Northern High also contains some of the remaining steel pipe constructed approximately 70 years ago which has tended to corrode and leak frequently. Although some sections, as mentioned above, have been replaced in this service area, Sections 70 and 71, and 79 remain to be addressed. A recent leak in August, 2006 was repaired on Section 70 in Stoneham.

Work ongoing or completed to date to address older pipelines includes initial work to complete Revere and Malden pipeline improvements. This work includes the significantly corroded 18,900 linear feet of steel pipeline (Section 53) in Malden and Revere. Early work was completed in 1994 on Section 53 in Malden but the Revere section remains to be completed. Additionally, the undersized Section 53A will be reinforced by a new 3,000 linear feet 60-inch diameter pipeline and Section 68 will be reinforced with 850 feet of 48-inch pipeline. The Shaft 9A-D Extension will provide a more reliable connector to the Section 99 pipeline that serves as the suction line to the Gillis Pump Station.

Section 27 is a 12-20-inch cast iron main (108 years old) that serves the communities north of Lynn. This line will be rehabilitated or replaced with construction scheduled to start in September 2013.

Section 97A is currently in final design. This project will install approximately 2,000 feet of 20-inch water main, a rehabilitated metering station and a new PRV. As noted above, this project will also address existing pressure deficiencies in the Orient Heights area. The PRV will also allow this line to serve critical parts of the Boston Low (Logan airport) in emergencies. Construction is anticipated to start in October 2007. The completion of 97A will assist the MWRA's operational flexibility for moving ahead with the Section 8 work in the Northern Low system.

Recommended Projects: Northern High Service

The recommendations for the Northern High system address the need to continue the systematic cleaning and lining of old cast iron mains and the rehabilitation of steel pipe nearing the end of its expected life. The following projects were all identified in earlier MWRA CIP's but were eliminated for budgetary reasons. The projects are configured geographically as previously identified. However, as in the past with NHS improvements, project groupings and/or schedules can be modified to address local community issues or paving concerns. It is expected that Water Engineering will review these project groupings prior to initiating design work on any of these projects and regroup them as necessary to reflect other project schedules. The key, however, is the continued progress to eliminated older unlined mains.

- Pipeline rehabilitation of the small diameter unlined cast iron along the coastline from East Boston north to Lynn. This includes Sections 54, 55, 56 and 69. Although these cast iron pipes are not as old as some of the other pipes in this service area (1932 and 1951 for Section 69), the C-values associated with these pipelines are estimated to range from 67-73 indicating that the 20-24-inch mains are severely corroded. The cost of this work is estimated to be $16.3 million. This is recommended for the FY24-28 time period.

- Pipeline rehabilitation of NHS Sections 13-18 and 48-unlined cast iron (except Section 48 which is unlined steel) with identified hydraulic restrictions. Sections 13-18 were generally constructed in the 1896-1903 time period and have C-values estimated to be as low as 57 along much of the area but ranging higher in other areas. Based on the analyses completed to rank pipelines, portions of Sections 14, 15, 17 and 18 were all in the top twenty of worst ranked sections. During design, the mix of cleaning and lining versus replacement of any seriously deteriorated segments can be determined. Section 48 is 30-38-inch diameter steel pipe constructed in 1930 with C-values of approximately 75. The estimated cost for design and construction is $18.4 million. This work is recommended for the FY 19-23 time period.

- Pipeline rehabilitation of NHS Sections 33, 49, 49A, 50 at a cost of $8 million. These are smaller diameter unlined cast iron mains ranging in age from 81-97 years in age and with C-values in the 60-70 range. Based on historical leak information and C-value, portions of Section 33 ranked in the top ten worst pipe segments in the analyses completed. This work is recommended for the FY 14-18 time period.

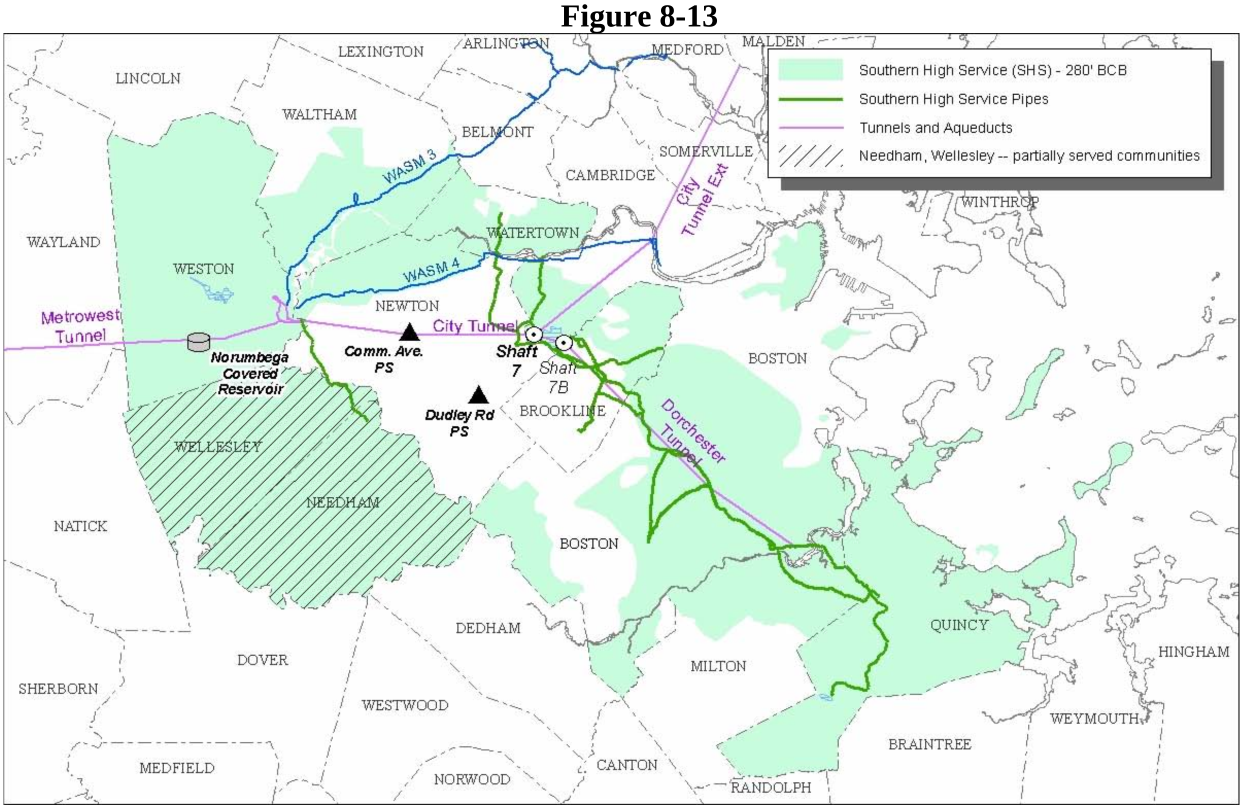
- Rehabilitation of the major unlined steel mains that serve the Northern High. This includes NHS Sections 70 and 71 and 79 which consists of more than 10 miles of corroded pipeline in Stoneham, Saugus, Melrose and Lynn. These pipes did not score highly in the analyses that were done, however, the frequency of leaks seems to be increasing over time and this is expected to accelerate during the 10-20 year period required to complete design and construction. Moving forward with rehabilitation is expected to extend the life of the pipe and postpone need for more costly pipe replacement. Given that these pipes act as transmission mains for this part of the system, staff recommends that the design and construction phases be preceded by a planning study that would assess the sequencing of the work. The estimated study costs are $1 million and it is recommended that the study be completed and design initiated in the FY10-12 time frame. The estimated design and construction costs for the rehabilitation work is $35.7 million and should be done in the FY 15-24 time period.

8.9 Southern High Service

The Southern High Service Area has the greatest average daily water demand at 72.7 MGD. Due to its configuration, the Southern High can be characterized in two sub-areas. One sub-area is served off of the Norumbega Supply lines. This includes Waltham, Watertown, Weston, Newton, Needham and Wellesley. Service is provided via WASM 3 and WASM 4 and Newton is also supplied from Shaft 6 to the Commonwealth Avenue Pump Station and then to Newton's Covered Reservoir. A smaller service area inside of the Newton system is supplied by the Dudley Road Pumping Station. The 2005 average day demand for this area was 18.1 MGD.

The second sub-area includes that area served off of the Dorchester Tunnel. This includes parts of Boston (Brighton, downtown Boston, Dorchester and Roxbury), Brookline, Milton and all of Quincy. The older pipes in this system were constructed to work with the earlier aqueduct systems, the Cochituate and Sudbury, and thus, piping in the Chestnut Hill Vicinity is both complicated and, given its age, in need of extensive rehabilitation. The 2005 average day demand for this area was 54.6 MGD. This second area of the Southern High system can only be served off of Shaft 7B on the Dorchester Tunnel. If the Dorchester Tunnel were to go out of service, it would be necessary to activate the Sudbury Reservoir system, transport water via the Sudbury Aqueduct to the Chestnut Hill Reservoir and use the new emergency pump station at Chestnut Hill to pump non-potable water to the Southern High system.

Figure 8-13



Delivery System Condition and Ongoing Work:

For the area served off of the Norumbega Supply lines, the major issue is that Section 80, which supplies Needham and Wellesley, was constructed with a tar epoxy lining. Since the communities it serves primarily rely on local supplies, the line is not in regular use. Flushing of the line by the local communities prior to its activation is necessary to reduce the potential for customer complaints. This main has also recently experienced several leaks.

For the second sub-area of the Southern High (served off of the Dorchester Tunnel), pressures generally have not been a problem since the completion of the tunnel in the 1970's. However, Quincy has experienced peak hourly pressure problems at higher elevations (Hospital Hill, Penns Hill and the vicinity of Nut Island) and pressure complaints are common from Quincy during periods of high demand or pipeline maintenance. Pressures at Meter 166 fluctuate greatly during peak flows. Construction of the Blue Hills Covered Storage Facility has been delayed due to permitting issues and appeals but the benefits of this project to Quincy are significant. Storage will increase pressures during peak flows and provide stored treated water closer to the demand.

The Southern High has a significant amount of deteriorated steel pipelines and old cast iron pipelines and a number of projects to begin to address these issues have been identified or implemented since the 1993 Master Plan. This includes the Nonantum Road portion of WASM 4 and initial phases of work for the pipelines near Heath Hill Road. These were areas with excessive leakage over many years. Rehabilitation of the western portion of WASM 4 was completed in 2001 and rehabilitation of the eastern section was recently completed. WASM 4 will continue to operate as a high service main from the Hultman Aqueduct Branch Connection to Shaft W of the MetroWest Tunnel up to the PRV at Nonantum Road.

Another steel pipe, Section 22, (56 years old), goes from Boston through Milton and into Quincy and has continued to be a major maintenance problem with ongoing leaks. This is exacerbated by those parts of the pipeline that travel through saltmarsh. Several leaks have occurred recently. One leak required repair in the south bound, high speed lane of Interstate 93 (Southeast Expressway) immediately adjacent to the Granite Ave exit. The other occurred in the salt marsh in July, 2005. Section 22 North is proposed to be rehabilitated as part of the Southern Spines Distribution Mains work. Construction is scheduled for the FY12-14 time period at an approximate cost of $12 million.

The Southern Spines project also includes construction of 4,400 linear feet of new 48-inch main from East Milton Square to Furnace Brook Parkway in Milton and Quincy and replacement of Sections 21 and 43 with 11,000 linear feet of new 48-inch water main from Dorchester Lower Mills in Boston to East Milton Square.

The Chestnut Hill Connecting Mains project included several major elements:

- A new emergency pump station was completed in 2001. The new station was designed to provide 90 mgd of non-potable water to the Southern High system from Chestnut Hill Reservoir or, potable water from the Low system
- Cross connections between the active water system and Chestnut Hill Reservoir were eliminated.
- A new pressure reducing chamber at Shaft 7B was constructed with new piping.
- All low service piping near the historic pump station was either replaced or rehabilitated.

However, as discussed below, Phase 2 of this work to allow full utilization of these systems in an emergency, has yet to be completed. Design of Phase 2 improvements is in the current CIP but construction is not.

Commonwealth Avenue Pump Station was upgraded as part of the initial series of improvements during the 1990's and the Dudley Road Pump Station was recently rehabilitated by in-house staff. Dudley Road is used when the PRV that functions as the control valve to Newton's Oak Hill tank is unavailable.

Additional projects that are ongoing or that are in the FY 07 CIP include:

Heath Hill Road Pipe replacement: These pipelines supply water to Brookline, Boston and to the SEH system and have been subject to severe corrosion as noted above. Work was completed on Sections 58, 20 and 19 which entailed rehabilitation of approximately 11,000 feet of 48-inch diameter and 10,000 feet of 36-inch diameter segments. Work was also completed on the replacement of 820 feet of Section 52 with a new 48-inch diameter pipe. The remaining work on Section 52 entails the cleaning and lining of 11,500 feet of 54-inch steel pipeline as well as associated valve replacement. Section 52 is a 79 year old steel main extends from the Chestnut Hill Pump Station to Sections 19, 20 and 58 and provides suction to the Newton Street Pump Station.

Walnut Street Pipeline Rehabilitation: This project includes the rehabilitation of approximately 7,900 feet of 48-inch unlined cast iron main which is some of the oldest pipe in the system. The hydraulic carrying capacity has been greatly reduced and C-values are estimated to be very low (C-value of 60). The hydraulic gradeline at Meter 5 in Boston is not adequate under max day demands (the Parker Hill area). Along with the rehabilitation of the Walnut Street Line, the project includes relocating Meter 5 to the Boston line (currently in Brookline) and installing a PRV upstream of Meter 5's new location which will connect the Walnut Street Line to the Boylston Street Line. This will allow service to Meters 244 and 245 in Boston in the event that the Boylston Line is shut down for any reason. Construction is scheduled to start in FY 07.

<u>Recommended Projects: Southern High Service</u>

- The Fisher Hill Pipeline was initially proposed to be rehabilitated with the Walnut Street Pipeline but was removed from the CIP. This project involves the design and rehabilitation of approximately 3,200 linear feet of 36-inch pipe; 3570 linear feet of

30-inch pipe; and 1,190 linear feet of 42-inch cast iron mains. These mains are all in excess of 100 years old and have limited carrying capacity due to tuberculation with C-values in the 58-60 range. The estimated cost for construction of this project is $2.7 million and this work is proposed for the FY16-18 time period.

- The remaining part of the Chestnut Hill Connecting Mains Project should be completed. This work, which would be a key element of MWRA's emergency response capabilities, would create a connection between Shaft 7 of the City Tunnel and the Southern High system in order to provide redundancy along the Dorchester Tunnel. It would also enable the MWRA to provide raw water to the Chestnut Hill Reservoir via the Sudbury Aqueduct and to the Southern High system via the Emergency Pump Station in the event the City Tunnel needs to be taken off line. Although design is currently in the CIP, this project allow MWRA to move forward with the construction of new pipelines, additional rehabilitation of older pipelines, sliplining of the Cochituate Aqueduct and modification and repairs to existing facilities at the Chestnut Hill Reservoir complex. The cost estimate is $5.6 million. Construction duration is expected to take two years and work should start in the FY 09-13 time frame as soon as design is complete.

- Southern Spines Distribution Mains-Rehabilitation of Section 19. This project would include the design and construction of 13,000 linear feet of 48-inch main. Rehabilitation is expected to be cleaning lining and replacement of main line valves, blow-off valves and appurtenances. This project was previously dropped from the CIP due to budgetary concerns. However, Section 19 was constructed in the 1890's and has C-values in the 60's. The estimated cost for design and construction is approximately $8.1 million (June 97 dollars). This project should be started in the FY09-13 time frame but most of the work would be done in the FY14-18 time period.

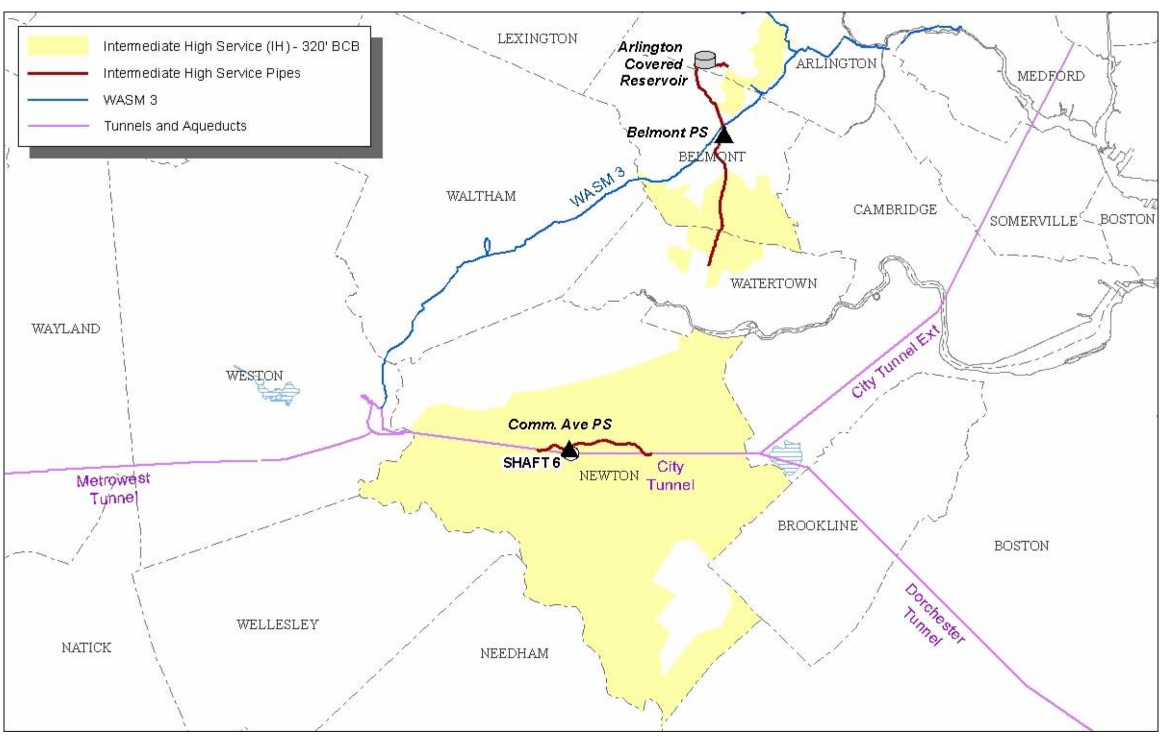
- Section 80 Rehabilitation-This project entails the design and construction to clean and line 16,200 linear feet of pipeline through Newton, Wellesley and Needham along Route 128/95 to remove tar epoxy lining. This lining will reduce the level of phenols and mitigate public health concerns and maintain consumer confidence. As the new distribution system rules are developed (See Chapter 5), it may become more important to rehabilitate this pipe if new contaminant monitoring or reporting requirements are identified. A temporary transmission main would need to be provided during construction because Section 80 would need to be taken off line for the duration of the construction phase. Design and construction is a five year duration and staff recommend that it be done within the FY10-14 time period at an estimated cost of $7.1 million.

8.10 Intermediate High Service

The Intermediate High Service zone consists of two geographically distinct and hydraulically unconnected areas served at similar grade lines (elev. 320') approximately 50 feet higher than high service. The southern area is a portion of Newton lying south of the Massachusetts Turnpike supplied by the Commonwealth Ave. pumping station which takes suction from Shaft 6 of the City Tunnel and pumps to the City owned Newton Covered Storage Reservoir on Waban Hill. The second area is further north and consists of portions of three communities served by water from Norumbega Covered Storage Facility which is transported via WASM 3 and then pumped from the Belmont Pump Station to the Arlington Covered Reservoir (elev. 320'). This area had a 2005 average day demand of 1.8MGD.

Delivery System Condition and Ongoing Work: The northern part of this area is served by a small diameter, single north/south pipe (Section 59) which is in poor condition with low C-values. From a redundancy standpoint, this system is vulnerable. MWRA staff installed a PRV in the vicinity of the Arlington Covered Reservoir which can provide Northern Extra High water if the Belmont Pumping Station fails or needs to be taken out of service. The major vulnerability is the single pipeline service, and the fact that the covered storage is not at an optimal location. Section 75 serves the southern part of this zone. This is a concrete pipe approximately 50 years old.

Figure 8-14



The eleven mile long, steel WASM 3 pipeline remains a significant concern due to corrosion. The pipe, which was built in the 1920's, requires frequent repairs (most recently in July 2006) and rehabilitation is critical. This supply line carries high service water from the 7-foot diameter branch of the Hultman Aqueduct to community connections and MWRA pumping stations serving the Intermediate High, the Northern High and the Northern Extra High pressure zones. It extends from the Hultman branch to Shaft 9 in Medford and supplies approximately 230,000 customers over all. Rehabilitation cannot occur until the Shaft 7 to WASM 3 Connecting Mains project is complete. This latter project will provide sufficient redundancy to allow WASM 3 to be taken off line and rehabilitated in phases. The current schedule proposes that rehabilitation would commence in January 2010.

WASM 3 also has 13 cast iron insulation joints, all of which had repairs (bell joint clamp installation) done in 1962. In April, 2005, one of the joints developed a leak while the parallel supply main was out of service due to CIP work. A repair coupling was purchased on an emergency basis. The coupling was installed on the leaking joint over the bell joint clamp, while the line remained in service. Two additional repair couplings were purchased in December 2005 in the event that another of the 12 remaining joints develops a leak.

The pipes are generally unlined cast iron with C-values in the 70's. The replacement or rehabilitation of Sections 59 and 60 pipe remains as a subphase (~$3.6 million) of the Shaft 7 to WASM 3 connecting main project but because that project has undergoing redesign, the ability of the connecting mains to provide redundant service to this area while Sections 59 is being cleaned and lined is no longer possible. It is possible still to rehabilitate Section 60. Another subphase of the Connecting Mains project is the design and construction for the replacement of Section 25 which entails 4,800 linear feet of 16-inch diameter pipe at a projected cost of $2.1 million with construction to start in July 2011.

Belmont Pump Station: This pump station is part of the $29 million project to upgrade the five remaining older pump stations in the system. The Belmont station was built in 1937 and has occasionally been out of service for extended periods due to fire damage or the need to replace equipment. This rehabilitation will include installation of new mechanical, electrical, instrumentation and security systems but will also include building and site renewal.

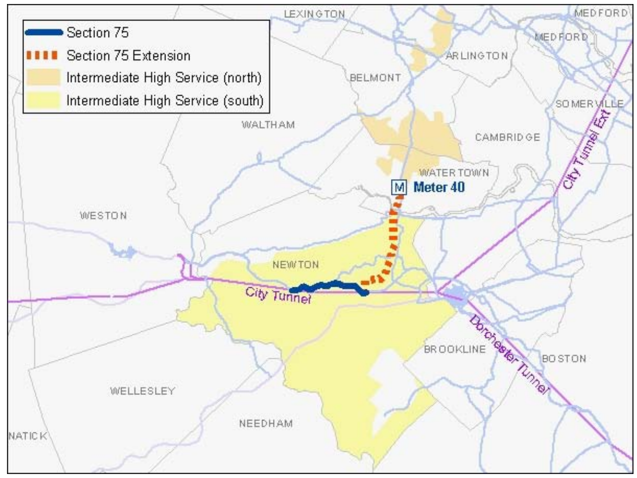
Recommended Projects: Intermediate High Service

One project is recommended in this pressure zone. It has been previously submitted for consideration.

- Section 75 Extension-Section 75 delivers water to the Newton Covered Reservoir (owned and operated by Newton) from the Commonwealth Ave. P.S. but Section 75 does not extend the full distance to the Reservoir with the last 6,000 feet being Newton pipe. A new 30-inch diameter pipe would permit Sections 23, 24 and 47 to be operated at the head of the Intermediate High system. In conjunction with the

Section 25 replacement (noted above) it would permit the two geographically distinct areas to be connected and operated as one system. This project would also allow Section 59 to be taken out of service for rehabilitation. This eliminates the need to build a replacement pipeline for Section 59 which had been estimated to cost $10 million. This proposed project would have the additional benefit of increasing pressure to Boston Meter 120 (Notting Hill area). This project has an estimated cost of $4.4 million and should be completed in the FY13-16 time period.

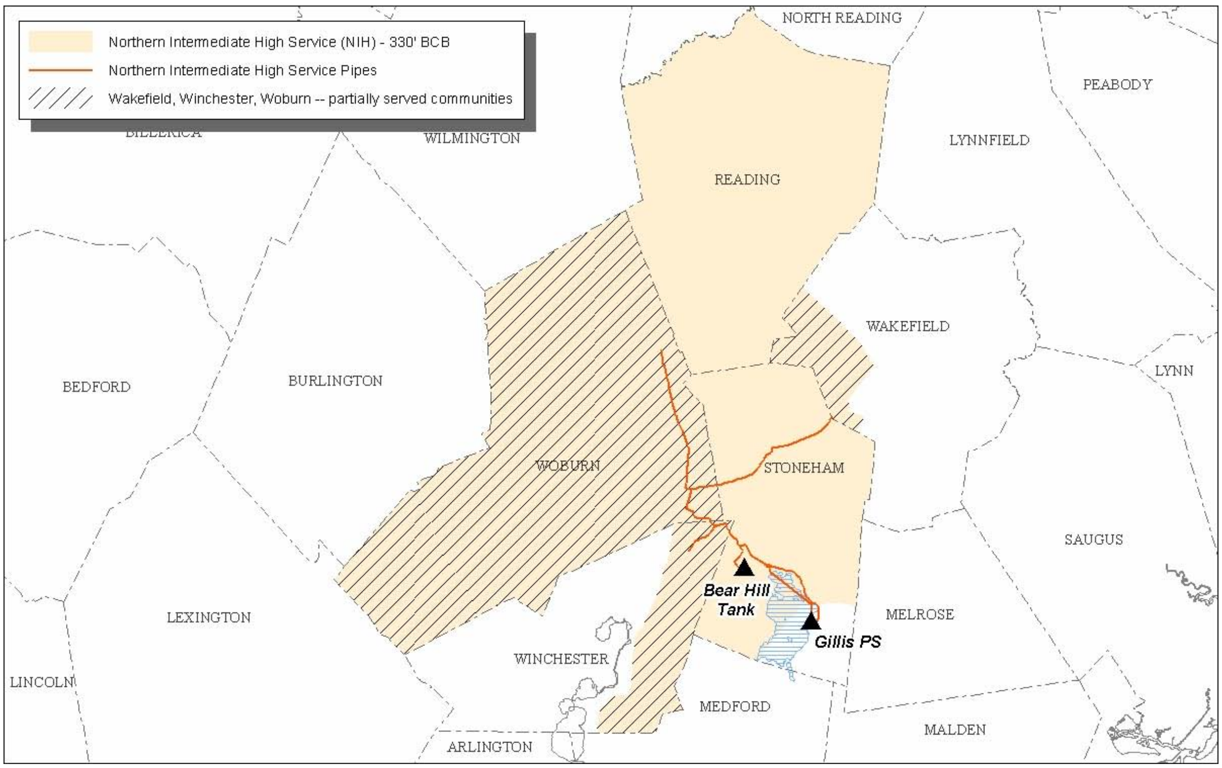
Figure 8-15



8.11 Northern Intermediate High Service

The Northern Intermediate High Service zone is one of the smaller pressure zones and was once considered part of the Northern High Service area. It is supplied by water pumped from the Gillis Pump Station to the Bear Hill Tank (elev. 330'). Water is distributed to 5 communities north of Spot Pond and a sixth community, Wilmington, is expected to submit an application for admission to the MWRA system as a partially supplied community.

Figure 8-16



<u>Delivery System Condition and Ongoing Work</u>: From a redundancy standpoint, the NIH service area has a single supply point and a single tank which limits repair or maintenance opportunities as well as increasing the impact if a failure were to occur. Stoneham, in particular, has no local storage or other connections to rely on during a system problem. Concern over the potential for a catastrophic failure of Section 89 increased when in-house research showed that a 10,000 foot portion of this pipeline was a Prestressed Concrete Cylinder Pipe (PCCP) that was constructed by a particular manufacturer with a Class IV wire that has been prone to embrittlement and failure elsewhere in the country. Because of this, the NIH Assessment and Concept Plan was initiated to assess short-term risk reduction

measures that might be undertaken to limit the effects of a pipe failure and develop conceptual level plans for the provision of a redundant pipe, a redundant pump station and additional storage. Work is ongoing and the full Concept Plan is expected to be complete in 2007.

Example of a brittle wire

The one section of Section 89 that has redundancy is a small part underneath Spot Pond which is backed up by Section 29 north of the Pond. However, Section 29 is an old, unlined cast iron main which is severely corroded and has limited carrying capacity. Emergency repair parts for Section 89 have been purchased, and are kept at the Chelsea facility if needed.

In addition, this service area is entirely dependent on the Gillis Pumping Station. The rehabilitation of this pumping station substantially improved the reliability of providing flow from the station to Bear Hill, however, a redundant pump station would improve the flexibility and reliability of operations. The Concept Plan will also identify a location for a redundant pump station.

The single storage facility, Bear Hill Tank, has a capacity of 6 MG and is located near Gillis Station. The 1993 *Water Distribution System Storage* study recommended placement of additional storage at the Bear Hill site. Given the shift in demand to the north, the Bear Hill site could be considered as a potential location for some additional storage, but ideally, new storage capacity would also be located further north in the service area. The Bear Hill tank was built in the 1980's and is in good physical condition but it is not able to be taken off-line for cleaning. Mechanical cleaning while the tank is in operation has been used but major rehabilitation work, if necessary, is not currently possible.

The Concept Plan work includes an analysis of how much additional volume of storage should be constructed. Average and max day demands from both the MWRA and local community systems will be defined and local storage also will be identified. The intent is to determine what level of storage deficit exists including consideration of available local storage. Table 8-6 shows the initial analysis completed by MWRA staff. This indicates a storage deficit of 6 MG when the capacity of Bear Hill is accounted for. This analysis also includes Wilmington. Although Woburn has 8.7 MG of storage (6.2 MG useable) and Winchester 0.8 MG, those areas within those communities operate at a lower gradeline than the other communities in the NIH System so their storage will only be useful locally. Stoneham and Wakefield whom do not have community storage in this service zone would be completely dependent upon the Bear Hill tank during an emergency.

Table 8-6
Northern Intermediate High System 2005 Demand and Storage Summary

Community	DEMAND (mgd) MWRA Supply Avg	Max	Local Supplies Avg	Max	Total Community Demand Avg	Max	STORAGE (mg) Total	Est. Usable	Local Community Storage Deficit (mg)	Storage Deficit relative to MWRA Supply (Local Supply Active) (mg)
Woburn	2.6	6.9	2.8	2.9	5.4	9.8	8.7	6.2	-3.6	-0.7
Stoneham	3.1	4.6	0.0	0.0	3.1	4.6	0.0	0.0	-4.6	-4.6
Winchester(1)	0.4	1.6	0.0	0.0	0.4	1.6	0.8	0.8	-0.8	-0.8
Wakefield(2)	1.7	2.4	0.0	0.0	1.7	2.4	0.0	0.0	-2.4	-2.4
Reading(3)	2.6	3.7	0.0	0.0	2.6	3.7	1.8	1.2	-2.5	-2.5
Wilmington(3)	1.5	2.7	2.0	2.7	2.1	3.1(4)	5.2	4.1	-1.0	-1.0
SUBTOTAL	**12.0**	**21.8**	**4.8**	**5.6**	**15.3**	**25.1**	**16.4**	**12.2**	**-14.9 w/Wilmington -13.9 w/o Wilmington**	**-12.0 w/Wilmington - 11.0 w/o Wilmington**
TOTAL, includes MWRA storage @ Bear Hill 6 mg								18.2	-8.9 w/Wilmington - 7.9 w/o Wilmington	-6.0 w/Wilmington - 5.0 w/o Wilmington

(1) Includes Meter 234 Only
(2) Includes Meter 229 Only
(3) Supply from MWRA is based on Contracts, no data available
(4) Wilmington purchased water from Burlington and Woburn to meet max day demands.

MWRA Storage Bear Hill 6.0 mg

Recommended Projects: Northern Intermediate High Service

- Redundant pipeline for Section 29/89-The Concept Plan will develop new cost estimates. In the interim, staff recommends that $24 million be allocated for design and construction with design to start in FY09.

- Additional Storage-The Concept Plan will develop new cost estimates. In the interim, staff recommends the inclusion of $10 million for the design and construction of 6 MG of storage for the NIH system with design to start in tandem with the redundant pipeline recommended above.

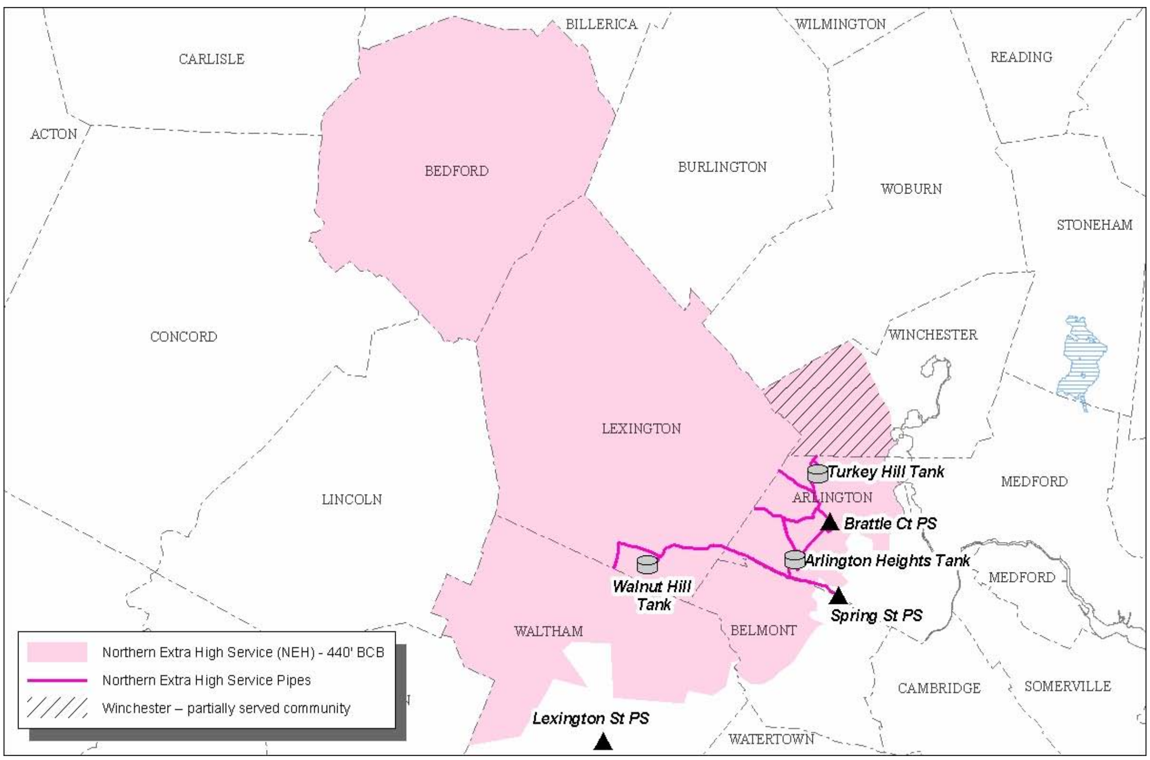
- Repair of Section 89/29, once the new pipeline and the additional storage have been completed. Rehabilitation of Sections 89 and 29 is required so that with the new pipeline, there is sufficient redundancy in the service area. However, depending upon the selected route of the redundant pipeline, it is possible that a portion of Section 29 could be rehabilitated as part of that project or it is possible that Section 29 could be abandoned. Rehabilitation is estimated to cost $5 million and is recommended to start in FY14.

- Redundant Pump Station. A redundant pump station for the Gillis Station is recommended. The Master Plan recommends the inclusion of $10 million for this facility with design to start in FY14.

8.12 Northern Extra High Service

The Northern Extra High zone provides water to the highest gradelines in the system. Six suburban communities in the hilly region northwest of the Boston are supplied by water from the Norumbega Reservoir via WASM 3 which is pumped to three MWRA owned tanks and one community owned tank. The elevations of the MWRA tanks range from 442' to 445'. The Brattle Court and Spring Street Pumping Stations discharge directly into the Northern Extra High while the Lexington Street Pumping Station discharges directly into Waltham's Prospect Hill service area.

Figure 8-17



<u>Delivery System Condition and Ongoing Work</u>**:** Sections 34, 36, 45, 63 and 83 provide service to this system. As was noted in 1993, the original pipelines were not large enough to meet maximum day demands plus fire flow service goals. To address this issue, Section 45, a 16-inch diameter pipe installed in 1920 was partially rehabilitated but 2,600 linear feet remain to be done. Approximately 3,400 linear feet of Section 63 was rehabilitated and Section 83 was reinforced with a parallel main. The remaining work will address Sections 34 and 36 and the last 2,600 linear feet of Section 45. Section 34 is an undersized (12-inch) unlined cast iron main (built in 1911) and may be the source of localized water quality problems. This line is required to provide service between the Brattle Court Pump Station and the distribution system. Section 36, also constructed in 1911 is just under a mile in

length is also undersized at 16-inches and this main is part of the Brattle Court discharge piping.

Overall, while some of the 16-inch pipe on Sections 36 and 45 will be rehabilitated, most of the distance will be replaced with 20 or 24-inch diameter pipes in order to improve reliability, pressure and flows. This should result in better fire protection and reduced pumping costs. Design will be in-house and construction is scheduled to start in FY14. Although it does not affect capacity, Section 83 was constructed to specification that required an additional metal fitting inserted into the top of the pipe (dropholes) along the 4-5 mile length. These have a tendency to fail and result in leakage and require frequent maintenance.

The Lexington Street Pumping Station was rehabilitated in the 1990's and the Brattle Court Pumping Station and Spring Street Pumping Stations are scheduled for rehabilitation beginning in FY07. This work includes new mechanical, electrical, instrumentation and security systems as well as building and site renewal. SCADA installation at all stations was completed under a fast track contract in 2001.

The storage tanks in the service area vary from the old Arlington Heights Standpipe to the more recently constructed Walnut Hill and Turkey Hill tanks. Tank location also prevents good circulation of water in Arlington Heights. Current inspection and maintenance programs are meeting needs in this area and no major expenditures are anticipated.

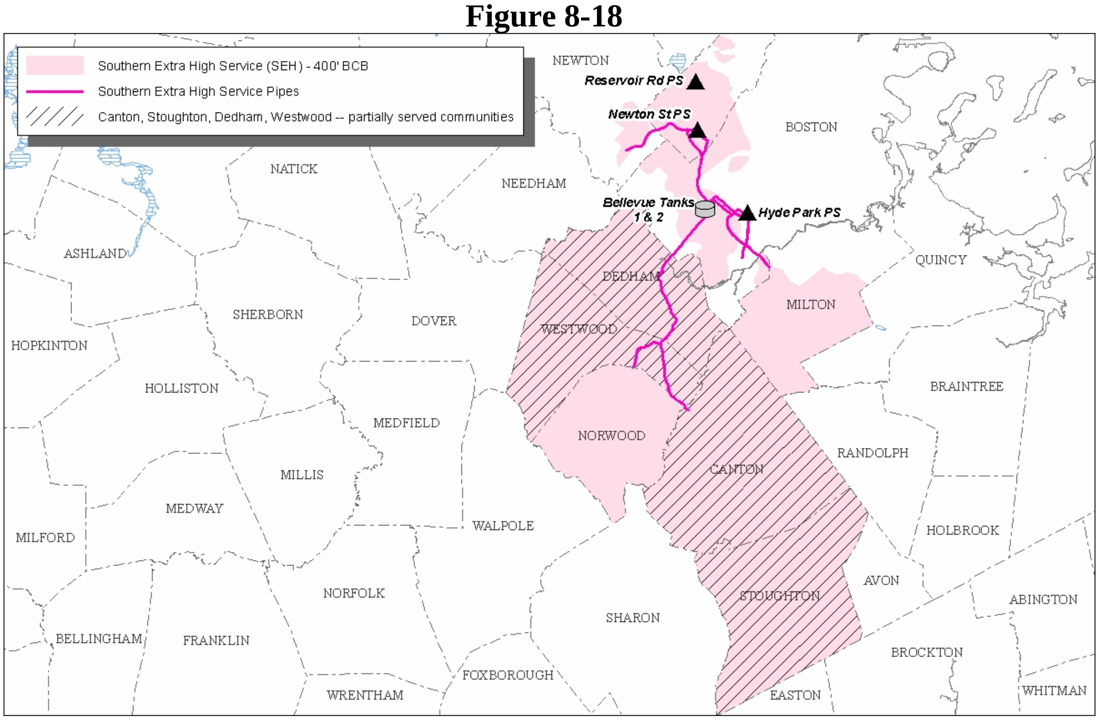
<u>Recommended Projects: Northern Extra High</u>

- Rehabilitation of the Section 83 Dropholes. Staff recommend that a design and construction contract to eliminate these dropholes (using vacuum excavations to locate them) be done at an estimated cost of $3 million in FY16-18.

8.13 Southern Extra High Service

The Southern Extra High zone includes the Roslindale and West Roxbury sections of Boston, a portion of Brookline and six suburban communities to the south of Boston. This zone is supplied by water pumped from the Southern High system to Bellevue standpipe No. 2 (elev. 400') and to several community owned elevated tanks The Newton St. (Brookline), Hyde Park and Reservoir Road Pump Stations serve this area. Newton St. and Hyde Park Pump Stations pump to the Bellevue tanks, while the Reservoir Road Pump Station pumps to the Singletree Tank, owned by the Town of Brookline. In the event of a power failure or some other service disruption that takes Reservoir Road out of service, there is a PRV that opens automatically at the Newton St. Pump Station to supply the Singletree service area. The SEH service area has grown in the past several years with the addition of the partially supplied Town of Stoughton and the Dedham-Westwood Water District. As discussed below, this further exacerbates concerns about the lack of redundancy and limited storage in this pressure zone.

Figure 8-18



<u>Delivery System Condition and Ongoing Work</u>: Lack of redundancy is the major issue within the SEH system. Sections 77 and 88 are single spine mains serving Canton, Norwood, the Dedham-Westwood Water District and Stoughton. Although four of these communities are partially supplied and may be able, in part, to provide some level of service in the event of a pipeline leak, break or other failure, Norwood is fully supplied by MWRA.

The Bellevue tanks consist of a newer 3.7 million gallon tank having a 400' elevation and an older 2.5 million gallon tank having a 375' elevation. The older tank stagnates since it can not contribute unless there is a 25 foot drawdown on the higher tank. It has been valved off due to concerns that the stagnant water may accidentally be drawn back into service. There is a plan to use a recirculation unit to better maintain water quality within the older tank.

The volume of storage in the SEH is small in proportion to demand such that there is little storage dampening on a summer day. In past summers, there have been 35' fluctuations in tank levels over the course of a peak day. In addition, like the NIH system, the SEH service area has geographically expanded and the growth has been concentrated to the south meaning that the existing Bellevue tanks are at the upper periphery of the service area. Additional storage to the south (closer to the center of demand) would be of great benefit.

At the November 2006 Board of Directors meeting, the Board approved inclusion of $900,000 in the CIP for development of a Concept Plan for the Southern Extra High service area. This study is expected to develop a recommended route for a redundant pipeline and to identify potential sites to locate additional storage.

The Concept Plan work also includes an analysis of how much additional volume of storage should be constructed. Average and max day demands from both the MWRA and local community systems will be defined and local storage also will be identified. The intent is to determine what level of storage deficit exists including consideration of available local storage. Table 8-7 shows the initial analysis completed by MWRA staff.

This indicates a storage deficit of approximately 10 MG when the capacity of the Bellevue tanks is accounted for. Although Stoughton has a significant volume of local storage, not all of that volume is useable and what can be used is only available to Stoughton.

Other pipes in the service area are typically smaller diameter and not as old as in some other parts of the system. Sections 41 and 42 are unlined cast iron 20-inch pipe built in 1914 and Section 74 was built in 1951 of PCCP. These mains connect the Hyde Park Pump Station and the Newton Street Pump Station discharge pipeline (Section 77) to Bellevue Tanks 1 and 2. These pipes were initially installed prior to the construction of Bellevue 2 which is 25 feet higher than Bellevue 1. Thus, these pipes were not designed to withstand the higher pressures associated with the use of Tank 2 and the result was that the Pump Station could not be operated at full capacity without limiting the volume of water in Tank 2 which subsequently led to problems in meeting peak demands. To fix this, construction was completed in 2003 to replace Sections 41 and 42 with 8,000 feet of new 24-inch diameter pipe and to a portion of Section 74 with about 2,700 feet of new 24-inch diameter pipe. An additional 6,400 feet of Section 74 was rehabilitated.

The remaining small diameter unlined cast iron mains (Sections 30, 40, 44 and 39) range in age from 97 to 104 years old (with a small part of Section 44 only 49 years old). Sections 30 and 44 serve Boston and Milton. Section 39 provides suction to the Hyde Park Pump

Table 8-7

Southern Extra High System 2005 Demand and Storage Summary

Community	DEMAND (mgd)						STORAGE (mg)		Local Community	Storage Deficit relative to MWRA
	MWRA Supply		Local Supplies		Total Community Demand		Total	Est. Usable	Total Storage Deficit	Supply (Local Supply Active)
	Avg	Max	Avg	Max	Avg	Max			(mg)	(mg)
Boston	4.0	5.8	0.0	0.0	4.0	5.8	0	0	-5.8	-5.8
Brookline (1)	1.9	3.1	0.0	0.0	1.9	3.1	1.7	1.7	-1.4	-1.4
Canton	2.0	3.0	0.4	1.1	2.4	3.3 (3)	6	5.4	None	None
DWWD	0 (2)	0.0	4.4	6.3	4.4	6.3	4.8	3	-3.3	-3.3
Milton	1.0	2.0	0.0	0.0	1.0	2.0	1.4	1.3	-0.7	-0.7
Newton (1)	0.7	1.4	0.0	0.0	0.7	1.4	0.4	0.4	-1.0	-1
Norwood	3.2	4.9	0.0	0.0	3.2	4.9	4.5	2.5	-2.4	-2.4
Stoughton	0.5	0.9	2.3	Not Avail.	2.3 (4)	3.6 (4)	14.2	14.2	None	None
SUBTOTAL	**13.3**	**21.1**	**7.1**	**7.4**	**19.9**	**30.4**	**33.0**	**28.5**	**-15.6**	**-15.6**
TOTAL, includes MWRA Storage 6.2 mg @ Bellevue 1 and 2								34.1	10	10

(1) Assumes supply to all areas in communities
(ie Single Tree in Brookline off-line; Oak Hill in Newton off-line)
(2) MWRA Contract Avg Day Demand = 0.1 mgd
(3) Total max day is not the sum of MWRA supply max day and local max day since they do not typically occur on the same day
(4) Data source - 2004 DEP Annual Statistical Report

MWRA Storage	Bellevue 1	2.5 (available)
	Bellevue 2	3.7 (useable)
		6.2 Total

Station. These lines are tuberculated and have low C-values. Meters 55 and 68 are served by a single line and all of Milton cannot be fed off of Meter 55 due to tuberculation. Milton is installing a PRV to allow the Town's low service system to be fed off of the high system in the event that it is necessary. A parallel main would improve service to the meters.

Newton Street was one of the pumping stations included in the initial round of upgrades in the 1990's. Reservoir Road and Hyde Park Pumping Stations (built in 1936 and 1912 respectively) are included in the upgrade project scheduled to start in FY07. All major building systems will be replaced and building and site refurbishment will be done.

<u>Recommended Projects: Southern Extra High</u>

- Concept Study for Pipeline Routing and Storage Alternatives-This remains one of two areas without adequate redundancy. If Sections 77 or 88 were to fail, SEH communities would be severely impacted. It is recommended that MWRA move forward in the immediate short-term with a study to assess storage and pipe routing options. Some non-destructive testing of the existing pipes should also be conducted during the study to help assess their condition and to set an appropriate schedule for achieving redundancy. $1 million should be allocated for this purpose with work to be initiated in FY07.

- Redundancy for Sections 77 and 88-A cost estimate for pipeline redundancy will be developed during the Concept Study. Previous estimates have varied depending upon route evaluated but staff recommends that approximately $25 million be allocated for design and construction of a redundant pipeline. Design should commence in FY11.

- Based on preliminary analyses, including looking at available community storage, this service area continues to have a storage shortfall. An estimated $10 million should be added to the CIP for design and construction for additional storage with the location and volume to be determined by the Concept Study. Design should begin in FY13.

- Design and Construction for Sections 30, 40, 44 and 39. The design and construction costs are estimated to be $10 million. These pipelines should also be considered during the planning work proposed above in order to determine whether any concept plan alternatives would change or delete any of the proposed rehabilitation work. The current cost estimate for design and construction is $10 million.

- A parallel line to serve meters 55 and 68 in Milton should be considered in conjunction with the above project. The estimated cost is $5 million.

- Following construction of a redundant service for Sections 77 and 88, these lines should be rehabilitated as necessary. It is recommended that the SEH Concept Plan include funds for some level of non-destructive testing of the existing mains to better determine their condition. The scope of the design and construction work for the proposed rehabilitation would be based on these investigations. This work should be initiated in the FY19-23 time period and is estimated to cost $5 million.

8.14 Summary of Recommended Metropolitan System Improvements

- Two additional phases of valve replacement are recommended at a cost of $6 million ($3 million per phase) with a start date of FY 09. Valve operability goals are not yet fully met although great improvements have been made. In order to increase the percentage of operable valves and to address valves that fail during the next 10 year period, work will need to continue using both the proposed CIP project and in-house design services. In addition, it is expected to take 5-10 years more to complete the blow off valve retrofit program with 50% of the blow-offs still needing to be completed. The mix of in-house and CIP work on all phases of the MWRA valves has been the key to operational success of the system and staff recommend that Phase 8 and Phase 9 be added to the valve replacement program with $6M to be spent between FY 09-18.

- Recommend monitoring the maintenance needs for the butterfly valves that have replaced gate valves over the past 15 years. Gate valves have routinely had an expected life in the MWRA system of 50-75 years and there is some concern that the butterfly valves may not be as resilient and more prone to breakage and misalignment. For the next master plan update, review this information and complete a revised life cycle cost analysis if appropriate.

- Staff recommends that funds be added to the CIP for replacement of instrumentation, electrical and mechanical systems at the pump stations with $2 million to be added in the FY14-18 time period; $4 million to be added in the FY 19-28 time period. It is expected that up to $50 million will be required in the twenty year period following 2028 for another significant facility rehabilitation project.

- Given the greater than one billion dollars anticipated to be needed at the local level to continue to eliminate unlined water pipe, staff recommend that a systematic approach be considered to maintaining continued MWRA financial assistance. The Master Plan recommends allocating Local Financial Assistance Program loan repayments to extend community funding similar to a revolving fund. Currently $255.5 million has been approved by the Board of Directors to date, of which $118 million has been distributed as loans to communities and is being repaid. Staff recommends that $125 million in additional loan funds be made available to communities for additional Local Pipeline Assistance Program financial assistance in the FY14-23 timeframe.

- Design and Construction for replacement and rehabilitation of 5,000 linear feet of 36-inch pipe on Section 66 and replacement and rehabilitation of 5,000 linear feet of 30-inch pipe with 36-inch pipe on Old Mystic Main. Abandonment of 14,000 linear feet of 150 year old 24-inch cast iron main. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $8.2 million and, in conjunction with the project below, should be scheduled in the FY15-22 time period.

- Design and Construction for rehabilitation of the remaining portion of Section 57 in Riverside Avenue along with rehabilitation of 8,000 feet of sewer that must be done as part of the same project. This work was previously in the CIP as part of the Spot Pond Supply Mains project. The estimated cost is approximately $21.4 million.

- Low Service Storage at Spot Pond. This 20 MG storage facility was identified as part of the original *Water Distribution System Storage Study* and carried forward in the 1993 Master Plan. This project adds storage to the overall system and to the Low system which has no storage east of Loring Road. In addition, this storage facility could help to provide pressure relief and surge control in an event similar to what occurred in 2006 when the PRVs at Shaft 9A malfunctioned. The estimated cost is approximately $35 million. This project is recommended for implementation in the FY12-15 time period. This work should be preceded by a study/environmental review phase which should start in FY09 and last two years at a cost of approximately $1 million.

- Pipeline rehabilitation of the small diameter unlined cast iron along the coastline from East Boston north to Lynn. This includes Sections 54, 55, 56 and 69. Although these cast iron pipes are not as old as some of the other pipes in this service area (1932 and 1951 for Section 69), the C-values associated with these pipelines are estimated to range from 67-73 indicating that the 20-24-inch mains are severely corroded. The cost of this work is estimated to be $16.3 million. This is recommended for the FY24-28 time period.

- Pipeline rehabilitation of NHS Sections 13-18 and 48-unlined cast iron (except Section 48 which is unlined steel) with identified hydraulic restrictions. Sections 13-18 were generally constructed in the 1896-1903 time period and have C-values estimated to be as low as 57 along much of the area but ranging higher in other areas. Based on the analyses completed to rank pipelines, portions of Sections 14, 15, 17 and 18 were all in the top twenty of worst ranked sections. During design, the mix of cleaning and lining versus replacement of any seriously deteriorated segments can be determined. Section 48 is 30-38-inch diameter steel pipe constructed in 1930 with C-values of approximately 75. The estimated cost for design and construction is $18.4 million. This work is recommended for the FY 19-23 time period.

- Pipeline rehabilitation of NHS Sections 33, 49, 49A, 50 at a cost of $8 million. These are smaller diameter unlined cast iron mains ranging in age from 81-97 years in age and with C-values in the 60-70 range. Based on historical leak information and C-value, portions of Section 33 ranked in the top ten worst pipe segments in the analyses completed. This work is recommended for the FY 14-18 time period.

- Rehabilitation of the major unlined steel mains that serve the Northern High. This includes NHS Sections 70 and 71 and 79 which consists of more than 10 miles of corroded pipeline in Stoneham, Saugus, Melrose and Lynn. These pipes did not score highly in the analyses that were done, however, the frequency of leaks seems to be increasing over time and this is expected to accelerate during the 10-20 year period required to complete design and construction. Moving forward with rehabilitation is expected to extend the life of the pipe and postpone need for more costly pipe replacement. Given that these pipes act as transmission mains for this part of the system, staff recommends that the design and construction phases be preceded by a planning study that would assess the sequencing of the work. The estimated study costs are $1 million and it is recommended that the study be completed and design initiated in the FY10-12 time frame. The estimated design and construction costs for the rehabilitation work is $35.7 million and should be done in the FY 15-24 time period.

- The Fisher Hill Pipeline was initially proposed to be rehabilitated with the Walnut Street Pipeline but was removed from the CIP. This project involves the design and rehabilitation of approximately 3,200 linear feet of 36-inch pipe; 3570 linear feet of 30-inch pipe; and 1,190 linear feet of 42-inch cast iron mains. These mains are all in excess of 100 years old and have limited carrying capacity due to tuberculation with C-values in the 58-60 range. The estimated cost for construction of this project is $2.7 million and this work is proposed for the FY16-18 time period.

- The remaining part of the Chestnut Hill Connecting Mains Project should be completed. This work, which would be a key element of MWRA's emergency response capabilities, would create a connection between Shaft 7 of the City Tunnel and the Southern High system in order to provide redundancy along the Dorchester Tunnel. It would also enable the MWRA to provide raw water to the Chestnut Hill Reservoir via the Sudbury Aqueduct and to the Southern High system via the Emergency Pump Station in the event the City Tunnel needs to be taken off line. Although design is currently in the CIP, this project allow MWRA to move forward with the construction of new pipelines, additional rehabilitation of older pipelines, sliplining of the Cochituate Aqueduct and modification and repairs to existing facilities at the Chestnut Hill Reservoir complex. The cost estimate is $5.6 million. Construction duration is expected to take two years and work should start in the FY 09-13 time frame as soon as design is complete.

- Southern Spines Distribution Mains-Rehabilitation of Section 19. This project would include the design and construction of 13,000 linear feet of 48-inch main. Rehabilitation is expected to be cleaning lining and replacement of main line valves, blow-off valves and appurtenances. This project was previously dropped from the CIP due to budgetary concerns. However, Section 19 was constructed in the 1890's and has C-values in the 60's. The estimated cost for design and construction is approximately $8.1 million (June 97 dollars). This project should be started in the FY09-13 time frame but most of the work would be done in the FY14-18 time period.

- Section 80 Rehabilitation-This project entails the design and construction to clean and line 16,200 linear feet of pipeline through Newton, Wellesley and Needham along Route 128/95 to remove tar epoxy lining. This lining will reduce the level of phenols and mitigate public health concerns and maintain consumer confidence. As the new distribution system rules are developed (See Chapter 5), it may become more important to rehabilitate this pipe if new contaminant monitoring or reporting requirements are identified. A temporary transmission main would need to be provided during construction because Section 80 would need to be taken off line for the duration of the construction phase. Design and construction is a five year duration and staff recommend that it be done within the FY10-14 time period at an estimated cost of $7.1 million.

- Section 75 Extension-Section 75 delivers water to the Newton Covered Reservoir (owned and operated by Newton) from the Commonwealth Ave. P.S. but Section 75 does not extend the full distance to the Reservoir with the last 6,000 feet being Newton pipe. A new 30-inch diameter pipe would permit Sections 23, 24 and 47 to be operated at the head of the Intermediate High system. In conjunction with the Section 25 replacement (noted above) it would permit the two geographically distinct areas to be connected and operated as one system. This project would also allow Section 59 to be taken out of service for rehabilitation. This eliminates the need to build a replacement pipeline for Section 59 which had been estimated to cost $10 million. This proposed project would have the additional benefit of increasing pressure to Boston Meter 120 (Notting Hill area). This project has an estimated cost of $4.4 million and should be completed in the FY13-16 time period.

- Redundant pipeline for Section 29/89-The Concept Plan will develop new cost estimates. In the interim, staff recommends that $24 million be allocated for design and construction with design to start in FY09.

- Additional Storage-The Concept Plan will develop new cost estimates. In the interim, staff recommends the inclusion of $10 million for the design and construction of 6 MG of storage for the NIH system with design to start in tandem with the redundant pipeline recommended above.

- Repair of Section 89/29, once the new pipeline and the additional storage have been completed. Rehabilitation of Sections 89 and 29 is required so that with the new pipeline, there is sufficient redundancy in the service area. However, depending upon the selected route of the redundant pipeline, it is possible that a portion of Section 29 could be rehabilitated as part of that project or it is possible that Section 29 could be abandoned. Rehabilitation is estimated to cost $5 million and is recommended to start in FY14.

- Redundant Pump Station. A redundant pump station for the Gillis Station is recommended. The Master Plan recommends the inclusion of $10 million for this facility with design to start in FY14.

- Rehabilitation of the Section 83 Dropholes. Staff recommend that a design and construction contract to eliminate these dropholes (using vacuum excavations to locate them) be done at an estimated cost of $3 million in FY16-18.

- Concept Study for Pipeline Routing and Storage Alternatives-This remains one of two areas without adequate redundancy. If Sections 77 or 88 were to fail, SEH communities would be severely impacted. It is recommended that MWRA move forward in the immediate short-term with a study to assess storage and pipe routing options. Some non-destructive testing of the existing pipes should also be conducted during the study to help assess their condition and to set an appropriate schedule for achieving redundancy. $1 million should be allocated for this purpose with work to be initiated in FY07.

- Redundancy for Sections 77 and 88-A cost estimate for pipeline redundancy will be developed during the Concept Study. Previous estimates have varied depending upon route evaluated but staff recommends that approximately $25 million be allocated for design and construction of a redundant pipeline. Design should commence in FY11.

- Based on preliminary analyses, including looking at available community storage, this service area continues to have a storage shortfall. An estimated $10 million should be added to the CIP for design and construction for additional storage with the location and volume to be determined by the Concept Study. Design should begin in FY13.

- Design and Construction for Sections 30, 40, 44 and 39. The design and construction costs are estimated to be $10 million. These pipelines should also be considered during the planning work proposed above in order to determine whether any concept plan alternatives would change or delete any of the proposed rehabilitation work. The current cost estimate for design and construction is $10 million.

- A parallel line to serve meters 55 and 68 in Milton should be considered in conjunction with the above project. The estimated cost is $5 million.

- Following construction of a redundant service for Sections 77 and 88, these lines should be rehabilitated as necessary. It is recommended that the SEH Concept Plan include funds for some level of non-destructive testing of the existing mains to better determine their condition. The scope of the design and construction work for the proposed rehabilitation would be based on these investigations. This work should be initiated in the FY19-23 time period and is estimated to cost $5 million.

Table 8-8 (page 1)

Water Master Plan - Metropolitan System
Existing and Future Projects

Last revision 01/09/2007

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
		METROPOLITAN SYSTEM											
8.1	1	Weston Aqueduct Supply Mains (WASMs)	AP	in, S730	10 years	55,564	FY07-16+	3,241	30,852	21,471			55,564
8.2	1	Chestnut Hill Connecting Mains-6995 Final Design CA/RI	NF	in, S719	6 years	1,404	FY07-12	140	1,264				1,404
8.3	1	NIH Redundancy & Covered Storage	Plan/NF	in, S722	7 years	7,264	FY07-13	824	6,440				7,264
8.4	2	Blue Hills Covered Storage	NF	in, S545	4 years	34,166	FY07-10	18,815	15,351				34,166
8.5	2	Valve Replacement-Ph 6&7, equipment	AP	in, S677	5 years	7,095	FY07-11	3,528	3,567				7,095
8.6	2	Walnut St. Pipeline Rehabilitation	AP	in, S732	3 years	3,303	FY07-09	2,008	1,295				3,303
8.7	2	Heath Hill Road Pipe Replacement	AP	in, S683	3 years	7,394	FY07-09	7,126	268				7,394
8.8	2	Southern Spine Distribution Mains	AP	in, S721	10 years	49,316	FY07-16+	3,462	28,191	17,663			49,316
8.9	2	Rehab of Other Pumping Stations	AP	in, S704	5 years	24,775	FY07-11	12,982	11,793				24,775
8.10	2	James L. Gillis Pump Station Rehab.Final Hazmat	AP	in, S689	2 years	741	FY07-08	741					741
8.11	2	Spot Pond Supply Mains - Rehabilitation	AP	in, S713	4 years	9,885	FY07-10	9,131	754				9,885
8.12	2	New Connecting Mains - Shaft 7 to ..	NF	in, S702	9 years	47,320	FY07-15	8,839	37,513	968			47,320
8.13	2	Lynnfield Pipeline	NF	in, S731	4 years	4,000	FY07- 10	425	3,575				4,000
8.14	2	Nor Extra High Serv - New Pipelines	AP/NF	in, S708	10 years	5,115	FY07-16+	3	33	5,079			5,115
8.15	2/3	Nor Low Service Rehab-- Secs. 8/37/38/97A	AP	in, S723	9 years	17,210	FY07-15	1,200	11,800	4,210			17,210
8.16	3	NHS - Section 27 Improvements - Construction	AP	in, S692	9 years	2,578	FY07-15	2	16	2,560			2,578
8.17	3	NHS - Revere & Malden Pipeline Improvements	AP	in, S693	10 years	8,191	FY07-16	1,674	1,057	5,460			8,191
8.18	3	Waterworks FAMP Walnut Hill Tank Design/Construct	AP	in, S766	2 years	1,300	FY09-12		1,300				1,300
8.19	4	Waterworks FAMPMeter Vault Manhole Retrofits	AP	in, S768	4 years	1,417	FY15-18			1,417			1,417
8.20	5	Cathodic Protection Of Distr.Mains-Install 2,3&4	AP	in, S712	3 years	1,268	FY19-28				1,268		1,268
		SUBTOTAL - Existing				289,306		74,141	155,069	58,828	1,268		289,306

Table 8-8 (page 2)

Water Master Plan - Metropolitan System
Existing and Future Projects

Last revision 01/09/2007

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
								2 years	5 years	5 years	10 years	20 years	
8.21	1	SEH Concept Study/EIR	Plan	new	2 years	1,000	FY07-09	750	250				1,000
8.22	1	NIH Redundant Pipeline Design/Construct	NF	new	5 years	24,000	FY09-13		24,000				24,000
8.23	2	NIH Storage Design/Construct	NF	new	7 years	10,000	FY09-16		7,000	3,000			10,000
8.24	2	SEH - Sections 77/88 Redundancy Design/Construct	NF	new	5 years	25,000	FY11-16		7,000	18,000			25,000
8.25	2	Chestnut Hill Connecting Mains (Final Pipe & Facilities Rehab. Ch 149 & 30)	NF	prev	2 years	5,600	FY10-12		5,600				5,600
8.26	2	NH - Sections 70, 71, and 79 Study and Condition Assessment	Plan	new	2 years	1,000	FY10-12		1,000				1,000
8.27	2	Valve Replacement Phase 8 & 9	AP	new	10 years	6,000	FY09-18		3,000	3,000			6,000
8.28	3	Section 80 Rehabilitation Design/Construct	AP	prev	5 years	7,119	FY10-14		6,000	1,119			7,119
8.29	3	Northern High (sections 70, 71 and 79) Design/Construct	AP	prev	10 years	35,670	FY15-24			15,670	20,000		35,670
8.30	3	Waterworks FAMP Meters- Venturi Tubes	AP	new	10 years	10,000	FY09-18		5,000	5,000			10,000
8.31	2	NIH - section 89/29 Rehabilitation Design/Construct	AP	new	4 years	5,000	FY14-17			5,000			5,000
8.32	2	NIH - Gillis Redundancy	NF	new	5 years	10,000	FY14-18			10,000			10,000
8.33	2	SEH Storage	NF	new	5 years	10,000	FY13-18		500	9,500			10,000
8.34	3	SEH - Sections 30, 40, 44 & 39 Design/Construct	AP	new	4 years	10,000	FY15-18			10,000			10,000
8.35	3	Fisher Hill Pipeline Rehabilitation Construction	AP	prev	2 years	2,711	FY16-18			2,711			2,711
8.36	3	NHS - Sections 33, 49, 49A & 50 Design/Construct	AP	prev	5 years	8,000	FY14-18			8,000			8,000
8.37	3	Spot Pond Supply Mains (Sections 66 & 57) Design/Construct	AP	prev	7 years	29,671	FY15-22			20,000	9,671		29,671
8.38	3	Southern Spine Distribution Mains (Section 19) Design/Construct backs up Heath Hill	AP	prev	5 years	8,088	FY12-16		1,500	6,588			8,088
8.39	3	Section 75 Extension Design/Construct	NF	new	4 years	4,400	FY13-16		1,000	3,400			4,400
8.40	4	Section 83 DropHole Rehabilitation Design/Construct	Opti	new	3 years	3,000	FY16-18			3,000			3,000
8.41	2	SEH Sections 77/88 Rehabilitation Design/Construct	AP	new	5 years	5,000	FY19-23				5,000		5,000
8.42	3	Northern High Service Pipeline Rehabilitation Design/Construct Sections 54, 55, 56, 69	AP	prev	5 years	16,288	FY23-28				16,288		16,288
8.43	3	Northern High Service Pipeline Rehabilitation (Sections 13-18 & 48) Design/Construct	AP	prev	5 years	18,363	FY19-23				18,363		18,363
8.44	4	Waterworks FAMP Pump Station Instrumentation/Electrical/Mechanical	AP	new	ongoing	56,000	FY16-48			2,000	4,000	50,000	56,000
8.45	4	Parallel Main to Meters 55 & 68	NF	new	4 years	5,000	FY21-24				5,000		5,000
8.46	2	Low Service Storage near Spot Pond Study/EIR	NF	prev	2 years	1,000	FY09-11		1,000				1,000
8.47	3	Low Service Storage Design/Construct	NF	prev	4 years	35,000	FY12-15		17,500	17,500			35,000
		SUBTOTAL - Future - Metropolitan System				352,910		750	80,350	143,488	78,322	50,000	352,910
		SUBTOTAL - Existing and Future - Metropolitan System				642,216		74,891	235,419	202,316	79,590	50,000	642,216

Table 8-9

Water Master Plan - Community Assistance
Existing and Future Projects

Last revision 01/12/2007

Prioritization

1 Critical
2 Essential
3 Necessary
4 Important
5 Desirable

Project Types

NF	New Facility/System
RF/IC	Replacement Facility/Increase Capacity
Opti	Optimization
AP	Asset Protection
Plan	Planning/Study

FY07 CIP Notes

in	included in FY07 CIP (bold)
new	new project, not previously in CIP
prev	included in prior CIP, but deleted

Line No	Priority	Project	Project Type	FY07 CIP	Project Duration	Cost ($1000)	Schedule	FY07-08	FY09-13	FY14-18	FY19-28	FY29-48	Total Cost ($1000)
		COMMUNITY ASSISTANCE											
8.48	**3**	**Water Local Pipeline Assistance Program**	**AP**	**in**	**12 years**	**(96,500)**	**now-FY18**	**15,500**	**22,000**	**(100,000)**	**(34,000)**		**(96,500)**
		SUBTOTAL - Existing - Community Assistance				**(96,500)**		**15,500**	**22,000**	**(100,000)**	**(34,000)**	**0**	**(96,500)**
8.49	3	Water Local Pipeline Assistance Program	AP	new	10 years	0	FY14-23			50,000	(31,000)	(19,000)	0
		SUBTOTAL - Future - Community Assistance				0		0	0	50,000	(31,000)	(19,000)	0
		TOTAL - Existing and Future - Community Assistance				(96,500)		15,500	22,000	(50,000)	(65,000)	(19,000)	(96,500)

Attachment 8-1

Hydraulic Modeling and Target Gradelines

MWRA's initial assessment of C-values for the distribution system were developed for the *Water Distribution Model Study*, completed in 1990 using field measurements, hydraulic modeling and flow and pressure readings from revenue meters. In 1998, MWRA developed and calibrated a new hydraulic model which was built directly from the current GIS database. The goal was to improve MWRA's modeling capabilities to accurately analyze and predict the current and future operating conditions of its water transmission and distribution system. Another important goal was to reduce model maintenance and data storage redundancy by developing automated transfer links (integration) between its modeling software and the various data systems that are maintained by the MWRA. By 2001 the model was rebuilt using current GIS data and was successfully calibrated based on travel time. The Authority is currently utilizing Infowater developed by MWHSoft for all of its modeling needs.

This updated model was utilized to update and evaluate the hydraulic deficiencies within the Authority's system that were identified in the 1993 plan. A maximum daily demand of 320 mgd was used for this analysis. This demand includes all demands east of the CWTP. The model was run for three consecutive days to stabilize the model and to simulate peak periods of the day (peak hour). However, prior to running the model an evaluation was completed to determine minimum target grade lines for each meter.

<u>Determination of Target Hydraulic Gradelines</u>

Massachusetts standards for water distribution are set by the Guidelines and Policies for Public Water Systems published by the DEP. These standards state that, at the highest point of land served, the minimum allowable pressure at street level in a water distribution system must exceed 35 psi under maximum day flow conditions. The standard further states that ISO required fire flows must be delivered at a residual pressure of at least 20 psi under maximum day demand. To enable our communities to meet these standards, the Authority maintains a minimum head at our meters of 40 to 45 psi above the high ground in the community system supplied by the meter. This allows for 5 to 10 psi loss through the meter and the community pipe network from the meter to areas of high ground it supplies (the range accounts for the variations of distance from the meter to the high found). Typical head losses in community systems during maximum day demand conditions are in the range of 2.5 feet per 1,000 feet. If the community distribution system is in reasonable conditions, areas of high ground up to 9,000 feet away from the meter should be properly served. Head losses higher than 10 psi over this distance indicate that the community system should be improved. This minimum head at the meter allows for 25 psi of loss under fire flow conditions.

The attached table shows the estimated target grade lines for each community, separated in pressure zones where applicable. Please note that the targets are estimates since detailed analysis of each community distribution system was not done. In several communities high ground elevations are above the recommended maximum ground elevations served by the MWRA to that particular service area, as noted in the table. In these cases, the communities may use booster pumping to ensure adequate pressures within the local distribution system.

The Authority's hydraulic model was run for three consecutive days with the June 1999 maximum day demands. Current system conditions were simulated. Appendix A compares the resulting minimum hydraulic grade line at each meter with the calculated target grade line. As shown in red, there are several areas considered deficient, these areas are discussed in further detail in the individual pressure zone sections. However, it should be noted that these areas identified may in fact not be deficient, Community systems are not included within the MWRA model and in particular, communities with multiple meters hydraulically connected within the community, may find that flow adjusts to meet local needs.

Target Minimum Hydraulic Gradelines at Meters For Review						
Community	**Service Area**	**Meters**	**High Ground Elev (ft BCB)**	**Streeet Name/Area**	**Target Minimum HGL (ft BCB)**	**Existing Minimum HGL (ft BCB) under Max Day Demands**
Arlington						
	Norumbega Supply Lines	171	84	Pelham Terr (1/2 mi)	188	245
	Intermediate High	121	193	Endicott/Gray St (1/2 mi)	297	316.5
	Northern Extra High	***86,128,135***	***380***	***Park Circle (150 ft)***	***466 (1)***	***427***
Belmont						
	Norumbega Supply Lines	88	104	Kilburn Rd (1700 ft)	208	246
	Intermediate High	110,111	173	Fieldmont Rd	277	309
	Northern Extra High	62	301	Cumberland Rd (1000 ft)	405	427
Boston						
	Boston Low	44, 60, 75, 244, 245, 101	56	Various locations	160	178 - 185
	Northern Low					
	East Boston	3, 64	74	Brooke St/High School (550ft)	160	181.5
	Charlestown	78, 48	65	Near Monument (1 mi)	169	173
	Northern High	***99***	***153***	***Seaview Ave (1/2 mi)***	***239 (3)***	***222***
	Southern High	***120, 9, 71***	***202***	***Nottinghill Rd (1/2mi)***	***306 (1)***	***253***
	Southern High	***5, 6, 94***	***193***	***Parker Hill Area (500 ft from 5)***	***284 (1)***	***248***
	Southern High	***8, 195, 7***	***173***	***Elm Hill Ave***	***277 (1)***	***248***
	Southern High	167, 209, 51	143	Codman Hill Ave (1000ft)	234	249
	Southern Extra High	68	242	Prospect St (2000 ft)	346	377
	Southern Extra High	73, 161, 170, 188 (PRV)	291	Bellevue Hill Rd	382	390.4
Brookline						
	Southern High	98, 151	133	Various sm locations	237	250
	Southern Extra High	***157***	***310.65 (1)***	***Single tree tank area***	***392 (1)***	***388***
Canton						
	Southern Extra High	194	PRV		321	354
Chelsea						
	Northern Low	11, 102, 192	65	Beacon St	156	182
	Northern High	***10, 139***	***143***	***Summit Ave***	***234 (2)***	***229***
Everett						
	Northern Low	15, 118, 201	55		159	183
	Northern High	***13, 119***	***163***	***Garland St (2000 ft)***	***254 (1)***	***234***
Lexington						
	Northern Extra High	***47, 136, 181, 183***	***350***	***Several area***	***454 (1)***	***425***
Lynnfield WD						
	Northern High	***169***	***PS, Req. Suction***		***180 (3)***	***140***
Malden						
	Northern Low	18, 19, 20, 21	73	Lebanon Terr (sm area)	164	184.5
	Northern High	***16, 17, 82, 140, 153, 232A***	***173***	***off of E Border Rd (1300ft)***	***264 (1)***	***243***
Marblehead						
	Northern High	149, 150	BPS (system grade 181' BCB)			224
Medford						
	Northern Low	24, 25, 97, 227	74		178	175 - 180
	Northern High	***22, 23, 65, 129, 159, 197***	***183***	***Several areas (1/2 mi)***	***275 (1)***	***236***
Melrose						
	Northern High	***26, 144***	***173***	***Boston Rock Rd (over 1 mi)***	***277 (1)***	***260***
Milton						
	Southern High	27, 107	133	Adams St (1500 ft, 10inch)	219	247
	Southern Extra High	55	232	Hilltop St	336	376
Nahant						
	Northern High	28	84	Several areas	188	226
Norwood						
	Southern Extra High	163	PRV 334		334	363

(1) High ground elevation exceeds highest elevation which can be served by that particular service area. For example ground elevation above 160 ft BCB in the NHS will not typically meet DEP standards during peak hour on a max day.
(2) Community storage is available to provide adequate pressures during peak hours.
(3) Current CIP includes project(s) to alleviate deficient

Community	Service Area	Meters	High Ground Elev (ft BCB)	Streeet Name/Area	Target Minimum HGL (ft BCB)	Existing Minimum HGL (ft BCB) under Max Day Demands
Peabody						
	Northern High	168	163	Several areas	267	228
Quincy						
	Southern High	***28, 85, 199, 334, 166***	***163***	***Reservoir Rd close to m85***	***250 (1)***	***246***
Reading						
	Northern Intermediate High	230				316
Revere						
	Northern High	30 (Fenno Hill High)	BPS (115) 183	Fenno's Hill	75	228.5
		93 (Young's Hill High)	124	Young's Hill (800 ft)	215	224
		106, 126, 175(low)	104	High Street	208	225
Saugus						
	Northern High	***205 (Fells System)***	***172***	***Blacksmith Way***	***262 (1)***	***258***
	Northern High	***174, 198, 185, 134, 233***	***152***	***Cliffter St***	***242***	***229***
Somerville						
	Northern Low	33, 35, 37, 80, 91	74	Fisk Ave (1/2 mi)	166	175 - 180
	Northern High	31,32	133	Hospital (3/4 mi)	237	242
Stoneham						
	Northern High	70, 141	Inactive ?			
	Northern Intermediate High	53, 138	224	Rivers Ln (1/2 mi)	315	317
	Northern Intermediate High	***228***	***224***	***Cowdrey St (1/4mi)***	***315 (4)***	***311 (4)***
Stoughton						
	Southern Extra High	336	Community	Tank Overflow @ 395 ft BCB	BPS need curve	354
Swampscott						
	Northern High	115, 158			BPS need curve	225
Wakefield						
	Northern High	172	BPS to 295.82 ov			250
	Northern Intermediate High	229	212	Cowdry Lane (4000 ft)	303	307
Waltham						
	SH, Norumbega Supply Lines	131, 137, 148, 202	114	Turner St	218	255
	Northern Extra High	206 CWPS	CW area operates @ 360' BCB - BPS		245	259
		132, 238 LSPS	440 (tank overflow)	Prospect Hill Area	240 @ LSPS	253
		182 NEH	440 (tank overflow)	Prospect Hill Area		434
Watertown	***Intermediate High***	***2***	***232***	***Mtg House Hill/Oakley Club***	***323***	***300***
	SH, Norumbega Supply Lines	40, 81, 92, 103	133	Rose/Grandview (less 1 mi)	237	252
Winchester						
	Northern Extra High	***130***	***340***	***Berkshire Dr (1 mi)***	***444***	***424***
	Northern Intermediate High	***234***	***222***	***Ledgewood Ave (2 mi)***	***326***	***317***
Winthrop						
	Northern High	41, 235	94	Overflow of tank 201.5	198	220
Woburn						
	Northern Intermediate High	200, 230	PRV @ 280		280	316

(1) High ground elevation exceeds highest elevation which can be served by that particular service area. For example ground elevation above 160 ft BCB in the NHS will not typically meet DEP standards during peak hour on a max day.

(2) Community storage is available to provide adequate pressures during peak hours.

(3) Current CIP includes project(s) to alleviate deficient

(4) The MWRA's hydraulic model is limited in that it does not include community piping. Stoneham is served by three separate meters that are hydraulically connected with the community distribution system. This would cause the grade lines at each meter to remain fairly equal by increasing or decreasing the flow through each meter. The model does not account for this, the model results show two of the meters consistently remaining above the target grade line with one dropping below during peak periods.

Attachment 8-2

Water Mains Renewal Methodology

Background

The MWRA's water distribution system consists of approximately 284 miles of pipes. . Over the past 15 years the Operations Division has made significant strides to better understand our system from both a physical and operational standpoint. MWRA staff has a good understanding of its distribution system based on many technological investments such as: Geographical Information Systems (GIS), metering, hydraulic modeling (H_2ONET), leak detection, and Work Order Management (MAXIMO).

Planning Department staff has access to descriptive information of each pipe segment and valves as well as geographic information system information. All of these technological components have been considered in developing a pipeline renewal strategy.

Introduction

The objective of the water mains renewal strategy is to ensure that the MWRA meets its' drinking water conveyance responsibilities without service disruptions. This task should be performed with minimal costs and attention to preserving and extending the useful life of our built assets.

This analysis focused around the following questions:

6. Which pipelines have exhibited the most leaks?
7. Which pipelines, if they should fail, have no redundancy to supply customers?
8. Which pipelines currently have or have had material problems?
9. Which pipelines are located in areas which accelerate pipe deterioration?
10. How can we best prioritize, using the information we have, pipeline replacement?

This report will address these questions and prioritize the order in which existing pipe sections should be rehabilitated/replaced.

Strategy

The approach for this analysis was similar to that of the Sewer Interceptor Renewal Project. The incidence of leaks as recorded in the leaks data base and the pipe roughness factor (C-value) used in the hydraulic model were used as predictors of pipe condition.[8]

[8] Staff performed a state-of-the art review of the prioritization methodologies. All of them utilized leaks. For retail systems, particularly in Europe, there was sufficient leak data to estimate a probability distribution function to characterize the interval between leaks. MWRA, being a wholesaler with a limited amount of leak data, does not lend itself suitably to this type of analysis.

For this analysis, data from across the organization was gathered, parsed, and compiled into a single database. This resulting database provided pipe information including section data, pipe attributes (material, age, size, c-value, etc.), leak data, and special concern data. The complete database is shown in Appendix A.

The water mains with special concerns are those pipes with previously identified areas that require special attention. These areas can be divided into three categories.

1. Configuration
   a. Single spine lines are pipelines that solely serve a complete or portion community or portion of a community that could not be supplied from a local source.
   .
2. Mechanical Defects
   a. Section 89 is a pre-stressed concrete cylinder pipe installed in the 1970's The steel bands imbedded in the concrete have been identified as defective and break without any warning.
   b. Section 80 is a steel pipe that was lined with a bitumastic coating. This situation is troublesome when the flow in the pipe is stagnant as the chemical from the lining leaches into the drinking water causing a potential public health risk.
3. Location
   a. Several pipe sections are located near road salt storage facilities. Salt leaching salt from facilities accelerate the deterioration of pipe in these areas.
   b. Pipe located in salt marshes also have accelerated deterioration concerns.

<u>Analyses</u>
The following methodology was used to perform prioritization analysis.
All available data was evaluated from a statistical and an engineering judgment perspective. The data was analyzed using Microsoft Excel, Microsoft Access and SPSS. The data was analyzed to determine what pipe factors/characteristics could be used to predict future pipe failure.

Correlation Analyses
A bivariate correlation analysis was performed to determine the degree of relationship between the pipe leaks and the other pipe information listed above. Appendix B contains the full results of the correlation analyses. The analysis showed a small significant correlations for leaks per mile and diameter for concrete pipes ($r=0.13$ with a p-value of 0.034 at the 0.05 significance level).

GIS Analyses

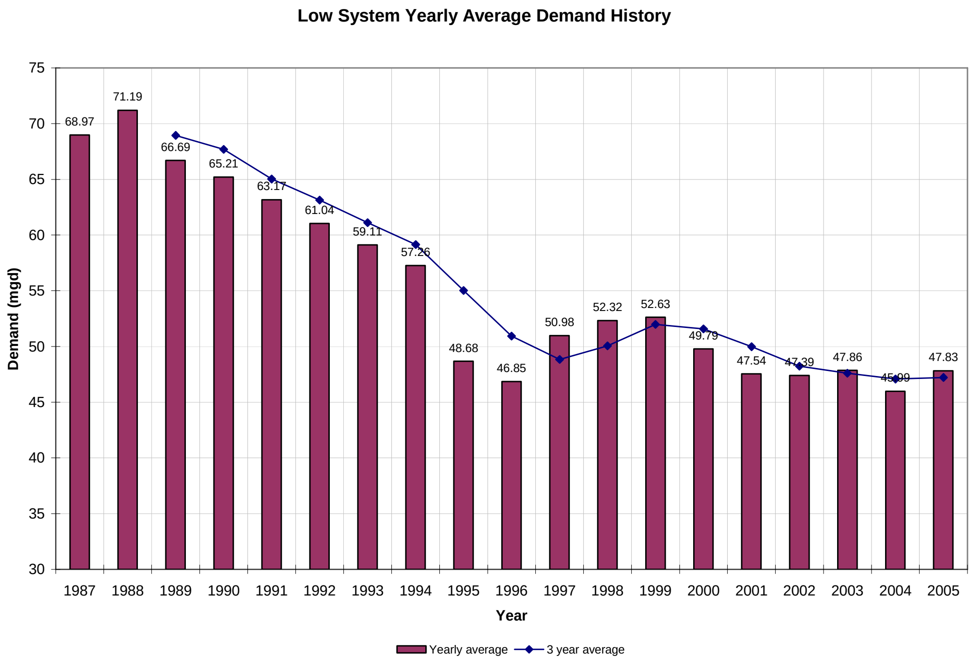
The pipes needed to be reordered to identify upstream and downstream segments. Unlike the sewer collection system the water distribution system has no manholes which made it difficult to break up individual sections. In order to accomplish this task code was written to break the sections into workable segments. Sections were broken based on line branches within the section, change of material category, age category, and size category. In addition once the length of a segment exceeded 2,000 feet, the line was broken at the next available node. Ideally, the segments would be a consistent and easily managed length of 2000-2500 feet. However, the varied nature of the systems design as well as the need to apply the analysis to segments of like material, size, and age resulted in varied segment lengths. This resulted in the distribution system broken up into 508 segments. Once the scoring system has been applied, and construction hierarchy determined, the segments will need to be split and/or joined based on construction requirements.

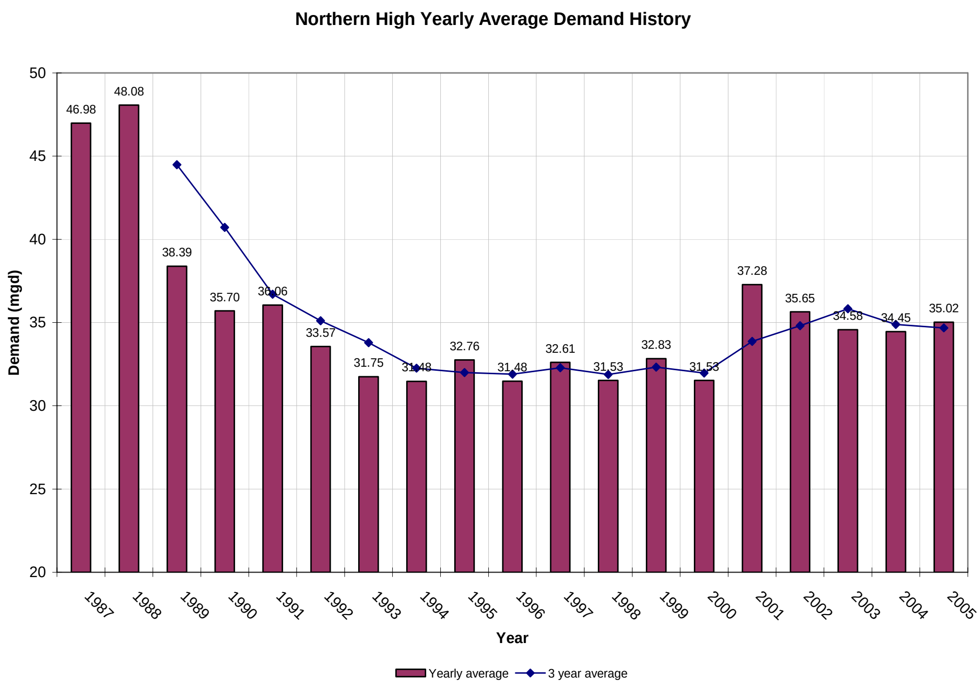
Scoring Methodology

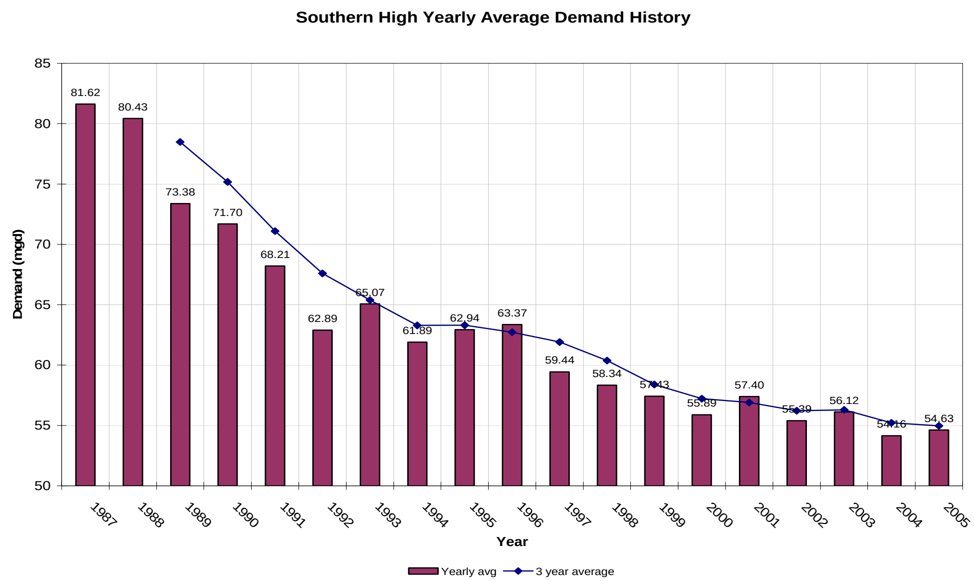
Once the sections were parsed, the scoring methodology was developed using the data. As mentioned previously, data was analyzed against the leaks in the system. The data was weighted by total length, total leaks and leaks/mile average, then normalized to a 10 points scoring system. These three weights were averaged to obtain one weighted score for each category. The method was applied to age, material, size, and remaining useful life data. C-Value, material defect, and salt corrosion data was weighted based on institutional knowledge. It was determined that single spine pipelines issues would be assigned priority outside of this analysis as these concerns are based in system design as apposed to system condition. Then multipliers were assigned to each category of data based on priorities derived from institutional knowledge. The resulting scores from this analysis will be considered as part of the prioritization for the rehabilitation of water mains.

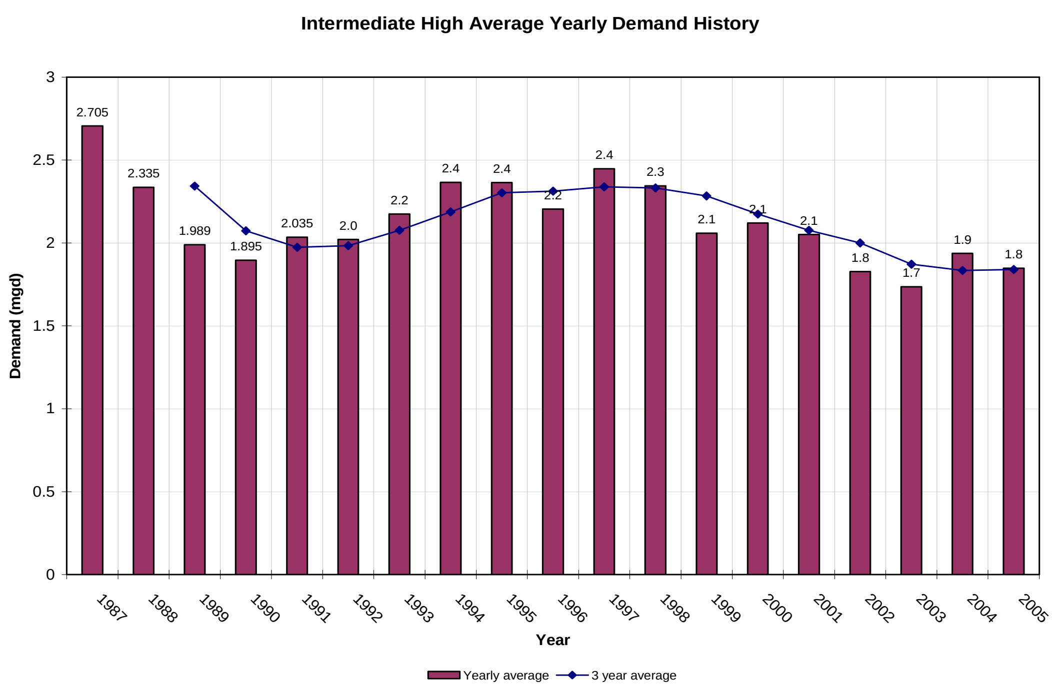
Attachment 8-3

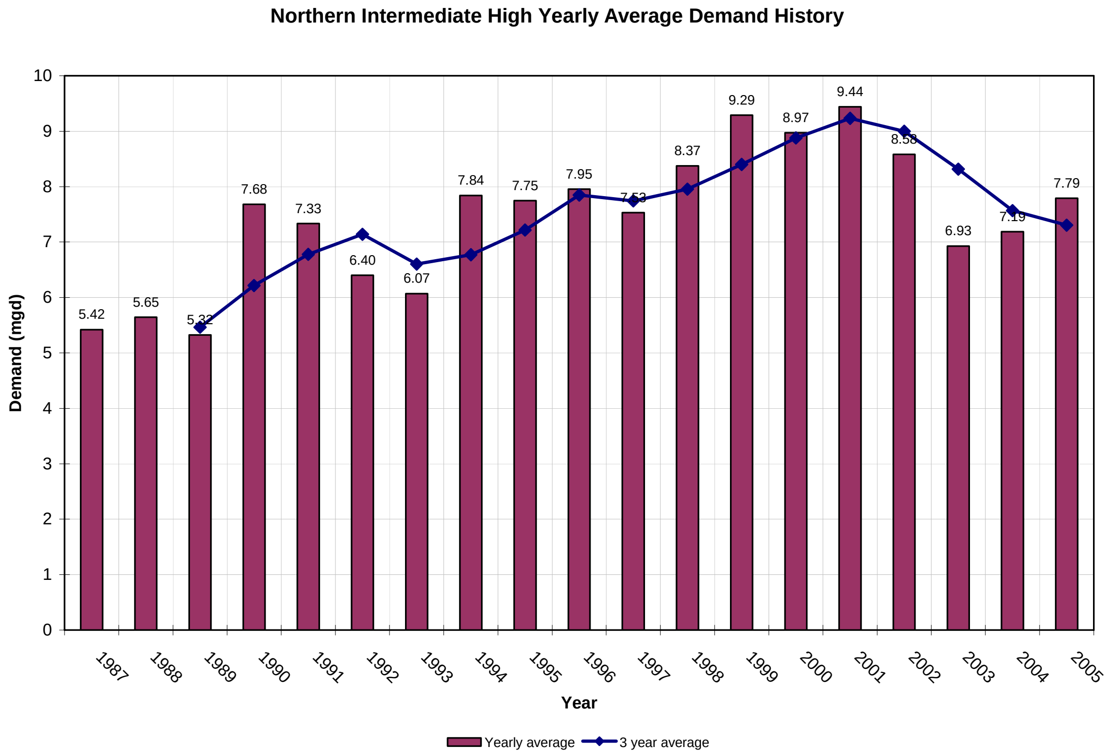
Demand by Pressure Zone over time






Southern High Yearly Average Demand History
Demand (mgd)
Year
81.62
80.43
73.38
71.70
68.21
62.89
65.07
61.89
62.94
63.37
59.44
58.34
57.43
55.89
57.40
55.39
56.12
54.16
54.63
Yearly avg
3 year average


Intermediate High Average Yearly Demand History
Demand (mgd)
Year
2.705
2.335
1.989
1.895
2.035
2.0
2.2
2.4
2.4
2.2
2.4
2.3
2.1
2.1
2.1
1.8
1.7
1.9
1.8
Yearly average
3 year average


Northern Intermediate High Yearly Average Demand History
Demand (mgd)
Year
5.42
5.65
5.32
7.68
7.33
6.40
6.07
7.84
7.75
7.95
7.53
8.37
9.29
8.97
9.44
8.58
6.93
7.19
7.79
1987
1988
1989
1990
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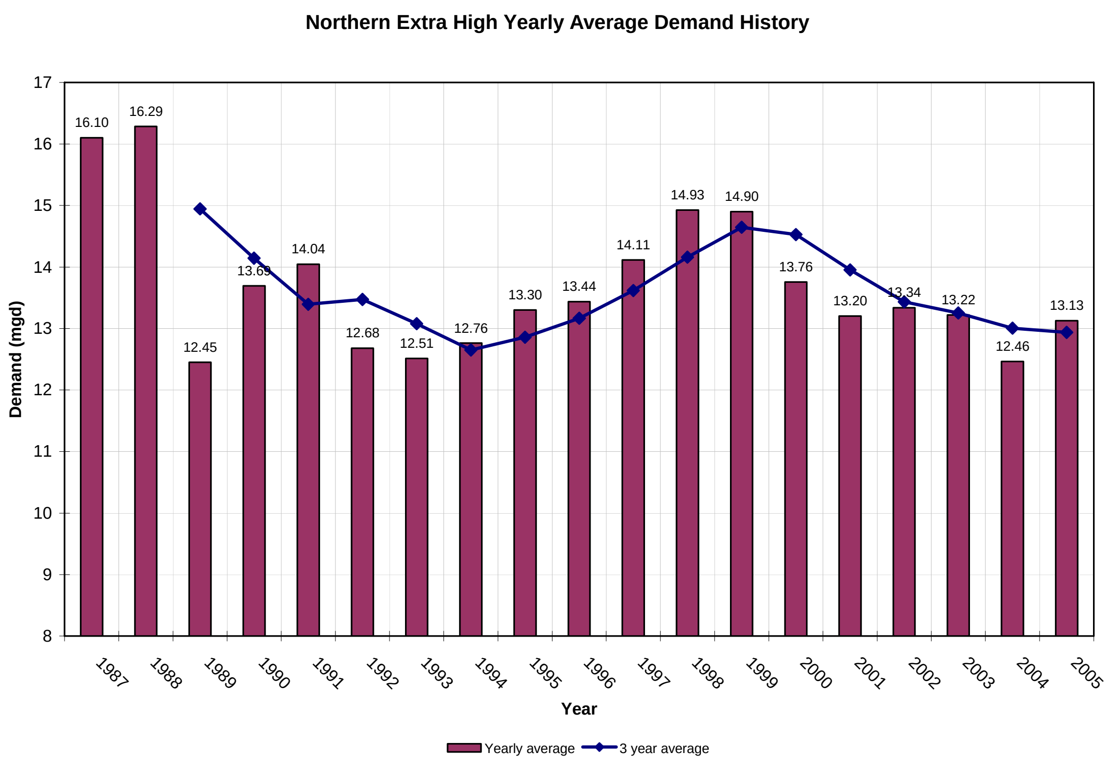
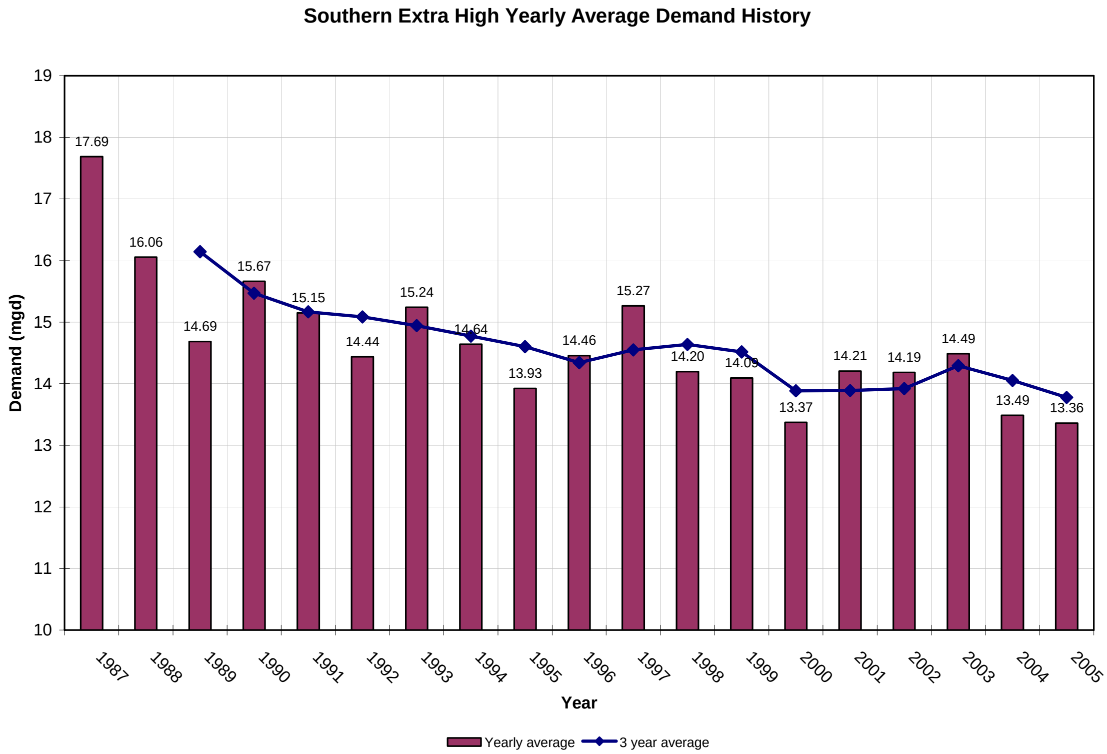
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Yearly average
3 year average


Northern Extra High Yearly Average Demand History
Demand (mgd)
Year
16.10
16.29
12.45
13.69
14.04
12.68
12.51
12.76
13.30
13.44
14.11
14.93
14.90
13.76
13.20
13.34
13.22
12.46
13.13
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Yearly average
3 year average


Southern Extra High Yearly Average Demand History
Demand (mgd)
Year
17.69
16.06
14.69
15.67
15.15
14.44
15.24
14.64
13.93
14.46
15.27
14.20
14.09
13.37
14.21
14.19
14.49
13.49
13.36
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Yearly average
3 year average

9 Ancillary Services

9.1 Chapter Summary

The operation and maintenance of the water supply and wastewater systems are supported by an array of processes, systems, and equipment. These include meters for flow measurement, telecommunications to monitor remote facilities, informational maps and records for locating existing underground mains and documenting changes to the system, laboratories for performing water quality tests and a work coordination tracking system. The current conditions and needs of each functional group are discussed below along with corresponding recommendations for each group. Detail on wastewater SCADA and the wastewater metering system are provided in Chapter 12 of the Wastewater Master Plan.

9.2 Metering

There are essentially two kinds of meters, master meters and revenue meters. The approximately 68 master meters measure flow at key locations within the water transmission system and wastewater interceptors. These meters are tested every three years to ensure they are working properly. Water revenue meters measure delivered flow to the communities and institutional customers while wastewater revenue meters measure wastewater flowing from the communities into MWRA's system. There are between 160 and 180 water revenue meters and 180 and 200 wastewater revenue meters. The water revenue meters have an expected useful life of approximately 10 years and have generally been replaced during adjacent pipeline or valve projects. If a new community comes on-line, staff will put together an in-house design and construction project to install a new meter. New wastewater revenue meters were installed throughout the system in 2004 and 2005 and these meters, given the harsher conditions under which they operate, are expected to have a useful life of approximately 7 years.

A key theme for metering is the need for periodic replacement of the meters to ensure the most accurate information is being transmitted back to the Authority. There are two main components to metering that can be significantly affected by technology changes; the instrumentation which includes the meters and associated computers, and the SCADA system which receives and manages the data transmitted from the meters. The role of new technology is a critical element in how the meters are managed and when they are replaced. The Authority strives to stay on top of new metering technology and anticipate new technology changes.

Since the wastewater meters were just replaced, the next focus is on the replacement of water revenue meters and the associated Venturi tubes and meter enclosures. While electronic components are expected to last a minimum of ten years, Venturi tubes are expected to last at least fifty years. The tubes only become a problem when the inside becomes tuberculated, changing the calibration relationship. Significant meter rehabilitation work was done at the largest community meters by the MDC in the mid-1980's but this work primarily involved the replacement of secondary equipment (new transmitters and steel chambers). In the early 1990's, MWRA replaced the remaining 70 or so smaller community meters and for these, the Venturi tubes were also replaced

leaving approximately 53 meters that were pre-1992. However, a number of Venturi tubes installed in 1903 remain in operation and the size and condition of these tubes is in question. Although 15 of the pre-1992 meters are included in other scheduled scopes of work, it may now be appropriate to initiate new contracts to replace the remaining meter equipment and Venturi tubes independent of other ongoing work. Replacing the remaining Venturi tubes will cost about $10 million. It would cost approximately $5 million to replace the water meters.

Specific to MWRA's wastewater metering system, there are a lot of battery controlled wastewater meters and this can be problematic in that a battery powered meter does not provide uninterrupted data because the battery dies too quickly. The MWRA should consider whether these data interruptions are significant enough to warrant investigations into the feasibility and design of providing power at wastewater metering locations.

Recommendations:

- Continuously review metering technology to stay abreast of changes to the technology.
- Proceed with meter and Venturi tube replacement already included within the scope of current pipeline and/or valve projects.
- Replace remaining water meters in the FY15-16 time period at a cost of $5 million.
- Replace the remaining Venturi tubes through a dedicated contract in the FY09-18 time frame at an estimated cost of $10 million.
- Evaluate the pros and cons of providing dedicated power lines to more wastewater meters.

9.3 SCADA (Supervisory Control and Data Acquisition)

The SCADA system is a powerful process control technology used to monitor and control facilities and equipment from a remote central location. It also provides a continuous record of facility operations. The SCADA system consists of four main components: 1) field instruments and equipment, 2) input/output devices, 3) communication devices and media, and 4) host computers. The existing Water SCADA System is maintained by MWRA staff.

Five water pump stations are scheduled to be rehabilitated over the next 4 years and the SCADA system will be upgraded at these stations. Most of MWRA's SCADA upgrades in the next several years will be made to the wastewater SCADA system.

In addition to the water SCADA systems in the facilities and in the field, there are microwave towers and associated equipment at the area commonly known as MDC Hill in Southborough. These towers last about 75 years and the lifespan of the microwave equipment is approximately 15 to 20 years. MWRA will need to replace the radio feed line and antennae in the next ten years at a cost of approximately $1 million.

Additional recommendation as shown below reflect the need to regularly review available communications technology and to update and replace equipment as new features are determined to be beneficial to MWRA operations or as existing equipment becomes obsolete or where vendor support is no longer available.

Future issues for SCADA include using it for other applications such as energy use management and monitoring hydrogen sulfide concentrations throughout the MWRA's wastewater system. Another key issue is whether MWRA should switch field meters to wireless technology. Wireless is cheaper than using a phone line and it can get places that wires can't, but going wireless means dependency on the Internet.

Recommendations:

- Evaluate the need for and timing of microwave equipment replacement at MDC Hill.

- Replace radio feed line and antennae in FY15 at a cost of approximately $1 million.

- Replace Waterworks SCADA PCs every five years to support the desired operating systems at an estimated cost of $50,000 per five-year timeframe beginning in FY11.

- Replace or upgrade Waterworks PLCs every 15 years or when a significant enhancement in security architecture is released. Replacement or upgrade costs will depend on the level of reconfiguration and reprogramming required. For planning purposes, an equipment upgrade cost of $2 million during the FY19-28 timeframe has been assumed.

- Replace modems as needed over a five year time period (FY09-13) at an estimated cost of $200K.

- Replace Waterworks data radios in the FY09-13 time period at an estimated cost of $100K.

- Continue to explore other applications for SCADA including energy use management and hydrogen sulfide monitoring system-wide.

9.4 Laboratory Services

MWRA's laboratory services are client based. Clients include Deer Island, ENQUAD, TRAC and Drinking Water Programs (including MWRA communities). To accommodate the range of program needs, the geographic range of the MWRA system and types of samples to be analyzed requires multiple facilities and MWRA operates laboratory facilities in Chelsea, Clinton, Quabbin, Southborough and the Central Lab, located on Deer Island.

Samples are generally taken by staff within various programs and submitted to the appropriate lab for analyses in compliance with a range of regulatory requirements. For example, TRAC staff sample industrial discharges for permit compliance and Quality Assurance staff obtain samples from the Carroll Water Treatment Plant to ensure proper plant performance and compliance with federal and state drinking water regulations. To provide a sense of the magnitude of work, the Central Lab analyzes more than 300,000 samples per year and the Chelsea Lab analyzes approximately 2,000 total coliform samples per month for 37 MWRA communities. This latter work, for the communities, allows MWRA to both ensure sampling consistency and to be in a position to recognize patterns of bacterial contamination that could potentially occur in the system. Overall, 85% of the analyses conducted in the Chelsea laboratory are done for the communities. MWRA also analyzes all DCR's samples in accordance with the MOU between MWRA and DCR.

Given the magnitude of the work effort, Laboratory Services continues to be proactive in identifying current and emerging issues. Staff safety while handling and analyzing samples must be protected through training and use of well maintained laboratory equipment. Staff resources must be efficiently allocated to the ongoing work while thinking ahead to the potential regulatory changes that may occur, particularly the identification of emerging contaminants. The lab must work closely with other MWRA departments to try to anticipate which contaminants might actually become a problem in order to focus limited resources on the relevant contaminants. Key questions to be answered when considering which contaminants to gear up for include: 1) how probable is it that a particular contaminant will become a problem, 2) will the concern be short-lived or a long-term problem, and 3) how much training and equipment are involved? A second issue relative to staff resources is the need to staff lab services seven days a week in order to accommodate various sampling needs and requirements. This is a particular issue at those laboratory sites with limited staff overall. Finally, data management tools must keep pace with both the lab work load and significant advances in technology. Projects identified for Laboratory Services address these challenges.

Facility needs generally include the need to periodically reconfigure space for gains in efficiency or to adapt to new test and/or equipment requirements. This is of particular importance at the Central Lab and an ongoing means to accomplish such reconfigurations should be addressed jointly by Laboratory Services, appropriate Deer Island managers, Operations and Finance.

Laboratory facilities at Quabbin Reservoir are currently housed in the DCR facilities at the Reservoir. As part of the Concept Design for future improvements at the Ware Disinfection Facility, the plan includes construction of new laboratory facilities to replace the facilities used by MWRA staff at Quabbin.

In addition, periodic replacement of analytical or safety equipment is necessary. Ventilation equipment is particularly critical in this regard. Fume hoods at the Central lab are now recommended for replacement both to address worker safety and to preserve sensitive analytical equipment. The fume hoods in the metals lab need to be replaced because they have corroded due to acid used in the test. This is a recurring expense approximately every 15 years.

Data management needs are being addressed in the short-term through the replacement of the Laboratory Information Management System (LIMS). This system has not been upgraded since 1993 and significant improvements in software options and functionality have occurred since then. A competitive bid is expected to be released in FY07 with an award recommendation to the Board in early FY08. The benefits of a new LIM System are more automation, consolidation of data, and the ability to automate responses to DEP regarding reporting requirements. There will likely be a need for reprogramming of other linked in-house databases once a new LIMS system is selected, and this work will be addressed by MIS. Any additional data management tools necessary to more fully utilize and interface with an updated LIMS system will be identified and coordinated between MIS and laboratory staff and identified as part of the LIMS procurement or as a subsequent capital project.

Recommendations:

- Move forward as planned in 2007 with the LIMS upgrade and any ancillary in-house data management improvements. Discuss with MIS how the proposed purchase of a Chromatography Data Management Server, or a more global instrument data management system (which could include a server-based approach to managing instrument data and interfacing with LIMS), fits into the LIMS procurement. Laboratory Services has identified a need for this type of system at an estimated cost of $250,000 to be spent in FY09.

- Replace the fume hoods at the Central Lab at a cost of $270,000.

- Operations staff including Lab Services, Deer Island and Chelsea facilities staff and Operations Administration should discuss whether a system can be developed to efficiently and quickly reconfigure laboratory space as needed to accommodate new sampling requirements or new equipment. This will allow the lab to maintain high levels of efficiency with minimum disruptions to ongoing work by staff. As part of this effort, Laboratory Services staff should identify any technological changes or equipment that will assist in improving staff efficiency.

- Purchase major laboratory instrumentation, such as high resolution GC-MS (gas chromatography-mass spectrometry) or LC-MS (liquid chromatography-mass spectrometry) to facilitate laboratory operations at a cost of $1 million in FY09-10.

9.5 Information Management

MWRA owns and operates many dozens of facilities, miles of tunnels, interceptors and pipelines, dams, treatment facilities and thousands of ancillary structures (manholes, valves, meters etc.). This results in an extensive number and range of documents and records to be maintained and continually updated. Tools for organizing and accessing this information are critical to allow information to be accessed both quickly in emergency situations and in an organized manner to facilitate long-term rehabilitation and replacement of MWRA assets and to design new system components. Information must also be available to document permit or regulatory compliance, protect MWRA assets from damage by outside contractors or utilities, and for responding to litigation, if necessary. Given decreased staffing levels, it is important that procedures and tools for information management be developed and used to facilitate access to the most accurate information in the most efficient manner. This includes the need to ensure that "baseline" information systems at MWRA are brought up to date and include all of the agency's current information and, equally important, that subsequent updates can be systematically added both to the baseline and to all of the other MWRA databases that rely on that baseline information.

Record drawings are the major category of information maintained by MWRA and these also provide the basis for MWRA's GIS-based mapping and modeling systems. In addition, MWRA uses MAXIMO as a work order-based maintenance system which can provide useful information on asset condition and the need to plan for rehabilitation or replacement of equipment. Individual facility sites often have specific facility handbooks on site and this type of information should also be kept up to date as facility changes are made. Each type of information resource is discussed below and recommendations focus on ways to improve the access to and accuracy of key MWRA asset and facility information to ensure its availability when needed. In contrast to other sections of the Master Plan, while there may be need for consultant support to facilitate initial document control system improvements, the recommendations below focus on the need to develop and use standard procedures both for information provided by consultants and for information obtained by in-house staff. At the start of FY07, MIS initiated a MWRA-wide steering committee to address GIS priorities and data related improvements. The goal is to develop an Information Management Business Plan by staff representing Planning, Field Operations, Water and Wastewater Engineering and MIS. This Data Resources committee will be expanded to include records drawing data standards, priorities, and plans in late FY07.

Record Drawing Management

Authority record drawings exist on hardcopy and film, and are located in the Records Center, as well as at a number of MWRA and DCR facilities. A survey of these locations estimates the total number of drawings referencing MWRA infrastructure at 75,000. A subset of 45,000 of those drawings has been electronically scanned to the network. Record drawings at these locations vary from complete sets on recent contracts, to incomplete sets on pre-MWRA contracts, and partial sets for others. Design Information

Systems Center (DISC) staff in Wastewater Engineering are involved in a review of these drawings in order to secure the latest revision for MWRA use. Drawings secured by DISC are chronicled in a number of pre-MWRA logbooks, recent departmental databases, and/or the Authority-wide document control system.

Organized drawing collections include the Records Center drawing archive, Chelsea water and sewerage microfilm archive, the Western Operations files, Metro Operations files, and the Wastewater Engineering Unit compilation of recent construction projects, along with other miscellaneous collections. When a request for record drawings is made by staff or by outside consultants or contractors, staff search these sources first. InfoStar, acquired through the Boston Harbor Project, is used as the indexing tool. Minor changes will be made in FY07 by MIS to expand the capability to address waterworks drawings but this is only a short-term solution. InfoStar requires replacement since the product is obsolete and there is no vendor support. Newer technology would provide improved efficiency and management control.

- The Data Resources committee will develop plans, process improvements, data standards and recommendations to address a number of needed changes, work backlog and system replacement. The committee will make specific recommendations that may lead to CIP projects, CEB spending, and/or in-house staff tasks. These plans will also be included in the MIS Master Plan.

Mapping and Modeling

MWRA sewer and water infrastructure data is created from Record Drawings and Detail Records and stored in GIS. GIS is then used to update the hydraulic model. A change in the field brought about by a capital improvement or an in-house project causes a chain reaction of updates: record drawings and detail records need to be updated and finalized, then submitted to GIS so the GIS and hydraulic model can be updated. An up-to-date GIS and hydraulic model facilitate flow of accurate information during emergencies, future project planning, and even master planning efforts. Thus, many of the recommendations for ensuring updated mapping and modeling data are the same as for ensuring that accurate record drawing information is available.

In considering mapping and modeling information, the flow of information is as follows:

Project →Project doc. mgmt. →Digital doc. Mgmt. →Digital info. mgmt. →Info. surfing
(hardcopy) (electronic copy)

The digital information management includes both a spatial and a non-spatial component. The spatial component includes the GIS information such as pipes, parcels, manholes, etc. and the non-spatial component is the connection to programs such as MAXIMO and LIMS. There, the Data Resources committee will address needed improvements. Examples include:

1) Standardizing nomenclature (e.g. W12 or 12W, Spring Street P.S. or Arlington P.S.), data formats (e.g. Excel vs. Access, upper case vs. lower case) and data to be collected across all projects.

2) Data maintenance and version control (e.g. to ensure intermediate, final and official Authority versions are delineated for all to use).

Recommendations for Records Management and Mapping and Modeling:

- As previously indicated, the Data Resources committee will identify recommendations and additional CIP budget needed to evolve records management, mapping and modeling into a more integrated resource. For Master Planning purposes, staff has included $930,000 in Table 9-1 for the planning and implementation of these improvements. Additionally, the committee will consider enhancements to MWRA's data use, such as new potential applications and consider pilot projects to demonstrate them (e.g. pollution tracing, call center, etc.). Over the longer term, expansion of modeling efforts beyond hydraulic modeling to encompass other types of modeling would appear to be beneficial. Examples include water quality modeling, modeling of the behavior of water and wastewater while in the pipes, and modeling of potential releases to the wastewater or water system. No funds are proposed at this time for system enhancements.

- The Committee should also provide guidance on the Distribution Systems Facilities Mapping-Records Development. This project will create record drawings and detail records for high priority areas of the water distribution system where such records do not currently exist. Funds are programmed in the FY07 CIP with expected costs of $1.268 million in the FY07-13 time period.

Work Order Management-MAXIMO:

MAXIMO is currently used as a work order maintenance system and it is designed to provide the planning function for the Maintenance Group. The Work Coordination staff regularly use MAXIMO for planning and scheduling work and reporting on labor utilizations hours and percentage of work orders completed. MWRA staff also use MAXIMO to manage asset repair costs and to evaluate that cost in the determination of further equipment repair or replacement. The data are also used for specialized analyses.

Use of MAXIMO is always being reviewed and refined. Some next steps for wider use of MAXIMO include how to better schedule staff activities based on time they've spent on those activities in the past, prioritizing work and assigning criticality, and using it more to support proactive asset management. For example, MWRA can use MAXIMO to better track equipment use as well as the occurrence of problems with each piece of equipment in order to optimize our assets. In addition, MAXIMO could be the repository for condition information that then could be used to provide critical information to other programs, such as GIS, SAMS, and the hydraulic modeling program. For example, the hydraulic model could obtain from MAXIMO the current position and operability of valves.

Recommendations for Work Order Management:

- Establish a project manager position to manage the preventative maintenance and asset management piece and to provide QA/QC support to the program. In addition, this staff person could function as the asset manager in the Work Coordination Center using MAXIMO to produce reports and analyze data concerning equipment use and failure, frequency and types of maintenance performed, and infrastructure behavior. The creation of this position was recommended by an internal audit done in September 2005.

- Integrate MAXIMO with other programs such as GIS, SAMS, and the hydraulic model to assist in the management and operation of the water and sewer system.

- Implement the use of wireless handheld devices so information can be made readily available in the field.

10 Energy Management

10.1 Chapter Summary

Utility costs are the second largest component of MWRA's direct expense budget, exceeded only by labor costs. In FY07, the MWRA budgeted approximately $23.1 million for electricity, $4.0 million for diesel fuel and $1.1 million for natural gas. These represent about 13.3% of total FY07 direct expenses. As MWRA has placed new facilities into service, demand for energy has grown. Growth in demand, coupled with the sharp rise in the cost of energy in recent years, has made energy management an increasingly important element of MWRA's overall rates management strategy. The key energy management strategies for the Authority should be to diversify its energy sources, include renewable energy in its portfolio, and reduce energy use whenever possible. Strategies are broken into demand-side strategies and supply-side strategies for the purpose of this chapter. Demand-side strategies focus on opportunities to implement additional energy conservation measures as well as to maximize the use of existing and potential new base-load self-generation assets to reduce or offset MWRA's need for purchased energy. Supply-side strategies focus on the operational and economic feasibility of enrolling additional back-up generation assets in load reduction programs and evaluating opportunities to shave peak demand thereby reducing demand charges. If a capital project identified in this chapter is associated with a particular facility (e.g. Deer Island or Winsor Power Station), cost and schedule information for that project can be found in the respective chapter of the Water System or Wastewater Master Plan. For projects not identified with specific facilities, please see Table 9-1 of the Water System Master Plan.

10.2 Energy Use

Collectively, MWRA facilities use approximately 185.5 million kilowatt hours (kWh) of electricity each year which translates into an average load of approximately 21,700 kW. The bulk of MWRA energy consumption is used for the pumping and treatment of wastewater. Energy consumption within the water system is much less since over 80% of the water supplied by MWRA to its customer communities is delivered by gravity. The Carroll Water Treatment Plant, however, is a significant electrical load requiring 15.5 million kWh per year, largely consumed in the generation of ozone, which is the plant's primary water disinfectant. Electricity consumption within the MWRA system by asset class is presented in Table 10-1.

Table 10-1 Summary of MWRA Electricity Demand		
Asset Class	**Annual Consumption (kWh)**	**Percent Share**
Wastewater Treatment	130,815,000	70.5%
Wastewater Pump Stations	7,617,000	4.1%
Headworks	9,442,000	5.1%
CSO Facilities	2,895,000	1.6%
Subtotal – Wastewater	*150,768,000*	*81.3%*
Water Treatment	15,448,000	8.1%
Water Pump Stations	12,314,000	6.6%
Storage/Transmission	3,093,00	1.7%
Subtotal Water	*30,856,000*	*16.6%*
Support Facilities	3,898,000	2.1
Total	**185,523,000**	**100.0%**

The Deer Island Treatment Plant is, by far, the largest consumer of energy resources within the MWRA system, accounting for over 69% of Authority-wide demand for purchased electricity (128.7 million kWh). Eight large accounts, which are presented in Table 10-2, account for almost 90% of MWRA demand for purchased electricity.

Table 10-2 Largest MWRA Electric Accounts		
Facility	**Annual Consumption (kWh)**	**Percent Share**
Deer Island Treatment Plant	128,716,000	69.4%
Carroll Water Treatment Plant	15,448,000	8.1%
Nut Island Headworks	5,294,000	2.9%
Chelsea Maintenance Facility	3,534,000	1.9%
Newton St. Water Pump Station	3,247,000	1.8%
Braintree/Weymouth Intermediate Wastewater Pump Station	3,000,000	1.6%
Spring St. Water Pump Station	2,321,000	1.3%
Clinton Treatment Plant	2,099,000	1.7%
Subtotal	*163,659,000*	*88.2%*
Other Facilities	21,864,000	11.8%
Total	**185,523,000**	**100.0%**

10.3 Energy Management Strategy

MWRA's approach to managing energy costs consists of both demand-side management (strategies to reduce the quantity of purchased power) and supply-side management (strategies to reduce the cost of purchased power).

Demand-side Management

MWRA has implemented a wide-range of projects and operational changes to reduce energy consumption at its facilities. For example, MWRA has made extensive use of energy efficient variable frequency drives ("VFDs") to control the operation of pumps and other large equipment at its water and wastewater facilities. The continuing rise in energy costs will reduce payback periods and enhance the economic feasibility of further investment in energy conservation measures. Therefore, MWRA should pursue the following recommendations:

- Undertake new audits and revisit old audits to identify cost effective energy conservation strategies. The cost of energy audits may be subsidized by Local Distribution Companies (NSTAR and NGrid). This initiative would also include other energy conservation efforts such as optimizing operation of HVAC systems in MWRA headworks facilities

- Examine the benefits of using performance contracting for the implementation of demand-side management projects (MGL Chapter 25A Section 11C Contracts for Procurement of Energy Management Services).

- Prioritize energy conservation during the design of new facilities and rehabilitation of existing facilities, including installation of VFDs to control pumps and other large equipment.

In pursuing demand-side management strategies, it is important to recognize that MWRA manages large, complex industrial process facilities which involve a wide range of operational considerations, including worker health and safety, security, system reliability and environmental compliance. These issues must be carefully considered when evaluating energy conservation measures.

The second element of MWRA's demand-side management approach is to maximize the use of existing base-load self-generation assets and promote the development of new base-load self-generation assets to reduce or offset MWRA's need for purchased energy. MWRA has five principal base-load self-generation assets which are summarized in Table 10-3

Table 10-3 MWRA Base-load Self-Generation Assets			
Asset	**Rated Capacity (kW)**	**Annual Output (kWh)**	**Comment**
Cosgrove Hydroplant	2,500	7,000,000	Portion of output is behind the meter – offsets Western Operations demand. Balance of output is sold into the ISO-NE grid at real time prices
DITP Hydroplant	2,500	4,380,000	Behind the meter – offsets DITP demand
DITP Steam Turbine Generator	18,500	26,280,000	Behind the meter – offsets DITP demand. Renewal assets receives RPS credits
Oakdale Hydroplant	3,500	10,000,000	Operates seasonally based on transfer of flow from Quabbin to Wachusett. Output sold to West Boylston with revenue offsetting DCR watershed management costs
Winsor Dam Hydroplant		-	Not in service

The Deer Island Steam Turbine Generator (STG) is the MWRA's most significant base-load self-generation asset. It generates the largest amount of electricity; the electricity generated is "behind the meter" (i.e. the power generated is consumed on-site thus avoiding not only the cost of electric energy but the transmission and distribution charges assessed by NSTAR to deliver the energy to Deer Island); and it is a renewable energy source (the STG is fueled by digester gas) making it eligible for renewable energy credits which provide approximately $1.0 million in annual revenue to MWRA. The Deer Island thermal plant and the STG are, however, oversized relative to the thermal load of the treatment plant. As a result the STG operates at a fraction of its rated capacity and is relatively inefficient, particularly in summer, when excess steam which could be used to generate electricity is dumped into the outfall tunnel. Therefore, MWRA should undertake the following:

- Evaluate the economic and engineering feasibility of replacing the existing steam turbine generator with a smaller more efficient design to maximize electricity production from Deer Island digester gas output.

The Cosgrove, Deer Island and Oakdale hydroplants are also important self-generation assets and MWRA should seek to optimize their operation to the extent permitted by operational considerations. Therefore, MWRA should:

- Seek to optimize performance of its existing hydroplants by insuring that equipment is adequately maintained to insure operational availability, and that flow through the facilities is maximized to the extent feasible without compromising other critical operational criteria.

The Winsor Dam hydroplant is inoperative due to a fire in 1991 that destroyed the electrical switchgear. At the time the fire occurred, hydropower re-development was not a priority given the low price for which electricity from the hydroplant could be sold into the regulated utility market and the capital costs of station rehabilitation (in addition to switchgear replacement, turbine/generator repairs were also required). Another factor that forestalled repair of the hydroplant was concern over potential licensing/permitting issues that could severely limit electricity output and adversely affect MWRA's ability to perform its key mission of supplying water. However, the need for valving and electrical work at Winsor Power Station is moving forward and this initial work will examine the feasibility of installing of a smaller turbine in the hydroplant. Assuming such work is feasible, MWRA expects to initiate any required permitting with the goal of resuming hydropower production at the station.

In addition to hydropower already being produced at Cosgrove, Oakdale, and Deer Island; there is a new technology that uses the water pressure present in water pipes to produce energy. Gravity fed water systems use pressure release valves to reduce pressure resulting from the change in elevation between the water source and the customer. This new technology puts a micro hydroturbine onto these pressure release valves to harness the energy that would otherwise be lost when it dissipates through the friction of the valves. This energy is then sold back into the grid. Initial installations of this technology reveal that a typical system can generate around $25,000 per year in energy. Therefore, the MWRA should:

- ♦ Evaluate the feasibility of installing micro hydroturbines on pressure reducing valves in MWRA's water transmission system, and if applicable, install a micro hydroturbine at a test location in MWRA's water system to determine the applicability and reliability of these types of turbines.

MWRA's most significant demand-side management initiative is the development of new large-scale on-site self-generation assets to further reduce the demand for purchased electricity. Specifically MWRA is evaluating the economic and engineering feasibility of installing wind turbines at MWRA sites. Wind turbines have several key features which make the attractive: they are proven, cost-effective technology capable of generating significant amounts of electricity; they are quite, safe and avoid production of greenhouse gases; and wind turbines are classified as a renewable energy source and, therefore, eligible to receive renewable energy credits.

As discussed above, it will generally be most advantageous for MWRA to site wind turbines in locations with large, steady electricity loads (e.g. Deer Island Treatment Plant, Carroll Water Treatment Plant, and Nut Island Headworks) so the power can be consumed on-site and thereby avoid not only the cost of the electricity itself but the transmission and distribution charges assessed by the Local Distribution Companies (NSTAR and NGrid) to deliver the electricity as well. These transmission and distribution charges account for a significant share of the delivered cost of electricity and thus behind the meter applications generally have more attractive economics. As a result, these are the sites where MWRA will focus its efforts, plus possibly other sites where multiple turbines could be installed and generate sufficient electricity to make it cost effective to sell into the grid. Therefore, MWRA should undertake the following:

- Continue pursuing development of wind turbines on Deer Island and undertake studies to determine the economic, engineering and environmental feasibility of siting wind turbines at other MWRA facilities with a focus on those facilities with large loads and high load factors which could consume the generated power on site. This effort should also seek to maximize use of MTC’s Large On-Site Renewables Initiative (LORI) program to provide funding for a portion of project implementation.

Supply-side Management

The bulk of MWRA demand for purchased electricity is addressed through the procurement of competitive supply agreements in which the pricing for a portion of total demand is fixed and the balance is purchased in the hourly variable rate market at market clearing prices. This approach, coupled with the structure of MWRA fixed-price contracts, result in MWRA consistently purchasing electric power at rates below those charged by Local Distribution Companies under Basic Service. MWRA has been purchasing competitive supply for the Deer Island Treatment Plant since November 2001. MWRA plans to continue this approach for procuring electric power for the foreseeable future.

While this approach results in lower average electricity costs, it does expose MWRA to greater price volatility. An important strategy used to limit this volatility on Deer Island is to enroll the plant’s significant back-up generation assets (Combustion Turbine Generators or CTGs) in load reduction (Price Response) programs managed by ISO-New England (operator of the regional electric grid). Under this program, Deer Island self-generates electricity and removes itself from the grid when ISO-New England declares a Price Response event. MWRA then receives a payment from ISO-New England based on the market price of power and avoids the high cost of peak market rate electricity as well as NSTAR transmission and distribution changes. These revenues and savings are partially offset by the cost of operating the CTGs (primarily diesel fuel), but the net result is significant economic benefit to MWRA while operating the CTGs on a fairly limited basis (e.g. less than 300 hours per year). Additionally, participation in these programs can result in significant reductions or elimination of capacity charges assessed by ISO New England on all customers and these charges are expected to increase over time.

Almost all MWRA operating facilities have back-up generating capability which could similarly be enrolled in load reduction programs. In particular, the John Carroll Water

Treatment Plant has significant back-up generation capability, already permitted for non-emergency operation that could be utilized in this manner. Additionally, DEP has relaxed some restrictions on non-emergency operation of back-up generators to allow participation in these programs. Therefore, MWRA should undertake the following:

- Evaluate the operational and economic feasibility of enrolling the John Carroll Water Treatment Plant and other MWRA facilities with back-up generation capacity in ISO-New England load reduction programs.

Similarly, these self-generation assets could also be used for “peak shaving” to reduce transmission and distribution charges paid to Local Distribution Companies. These charges are generally calculated based on the total amount of electricity consumed (in kilowatt hours) and the monthly peak demand for electricity (in kilowatts). The latter “demand charges” can significantly increase the unit cost of electricity for facilities that may have relatively low average consumption, but whose demand can peak sharply, such as wastewater pump stations during a wet weather event. To potentially minimize these costs, MWRA should undertake the following:

- Evaluate the operational and economic feasibility of utilizing back-up generation capacity at MWRA facilities to shave peak demand and reduce demand charges. Also, review schedules for pump testing and other routine test procedures and evaluate the feasibility of performing testing during off-peak periods and modifying test procedures to limit peaks in demand.

Finally, certain MWRA facilities, such as water pump stations, have some degree of operating flexibility which may be used to smooth demand and shift electricity consumption to lower cost off-peak hours. To potentially reduce electricity costs, MWRA should undertake the following:

- Evaluate the operational and economic feasibility of modifying operation of water pump stations and other facilities to smooth electric demand, improving load factors, and shift electricity consumption to off-peak periods.

10.4 Summary of Energy Recommendations

- Undertake new audits and revisit old audits to identify cost effective energy conservation strategies. The cost of energy audits may be subsidized by Local Distribution Companies (NSTAR and NGrid). This initiative would also include other energy conservation efforts such as optimizing operation of HVAC systems in MWRA headworks facilities.

- Examine the benefits of using performance contracting for the implementation of demand-side management projects (MGL Chapter 25A Section 11C Contracts for Procurement of Energy Management Services).

- Prioritize energy conservation during the design of new facilities and rehabilitation of existing facilities, including installation of VFDs to control pumps and other large equipment.

- Evaluate the economic and engineering feasibility of replacing the existing steam turbine generator with a smaller more efficient design to maximize electricity production from Deer Island digester gas output.

- Seek to optimize performance of its existing hydroplants by insuring that equipment is adequately maintained to insure operational availability and that flow through the facilities is maximized to the extent feasible without compromising other critical operational criteria. Move forward with evaluation and rehabilitation of the hydroplant at Winsor Power Station.

- Evaluate the feasibility of installing a micro hydroturbine at a test location in MWRA's water system to determine the applicability and reliability of these types of turbines.

- Continue pursuing development of wind turbines on Deer Island and undertake studies to determine the economic, engineering and environmental feasibility of siting wind turbines at other MWRA facilities with a focus on those facilities with large loads and high load factors which could consume the generated power on site. This effort should also seek to maximize use of MTC's Large On-Site Renewables Initiative (LORI) program to provide funding for a portion of project implementation.

- Evaluate the operational and economic feasibility of enrolling the John Carroll Water Treatment Plant and other MWRA facilities with back-up generation capacity in ISO-New England load reduction programs.

- Evaluate the operational and economic feasibility of utilizing back-up generation capacity at MWRA facilities to shave peak demand and reduce demand charges.

- Also review schedules for pump testing and other routine test procedures and evaluate the feasibility of performing testing during off-peak periods and modifying test procedures to limit peaks in demand.

- Assess how energy related projects get prioritized, especially in relation to construction or engineering projects. These types of project could improve the efficiency of our facilities and save significant dollars in the long term, but whose immediate, tangible benefits are less obvious.