Metropolitan Tunnel Redundancy
Off-Site Meeting

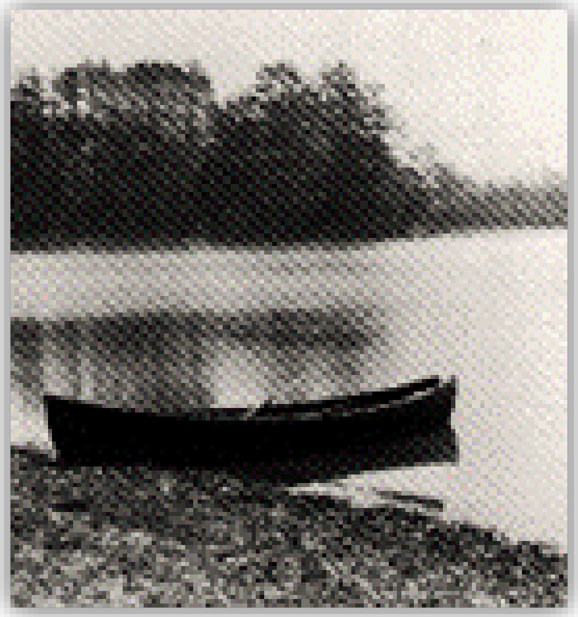
History of the Water System

Frederick A. Laskey
Executive Director

October 6, 2016

Early Boston Water System

- Early Bostonians relied on local wells, rain barrels and a spring on Boston Common for their water
- In 1795 wooden pipes made from tree trunks delivered water from Jamaica Pond to Boston
- By the 1840s, Jamaica Pond was too small and too polluted to provide water to Boston's 50,000 residents
- The pattern of moving continually westward in search of larger water sources began

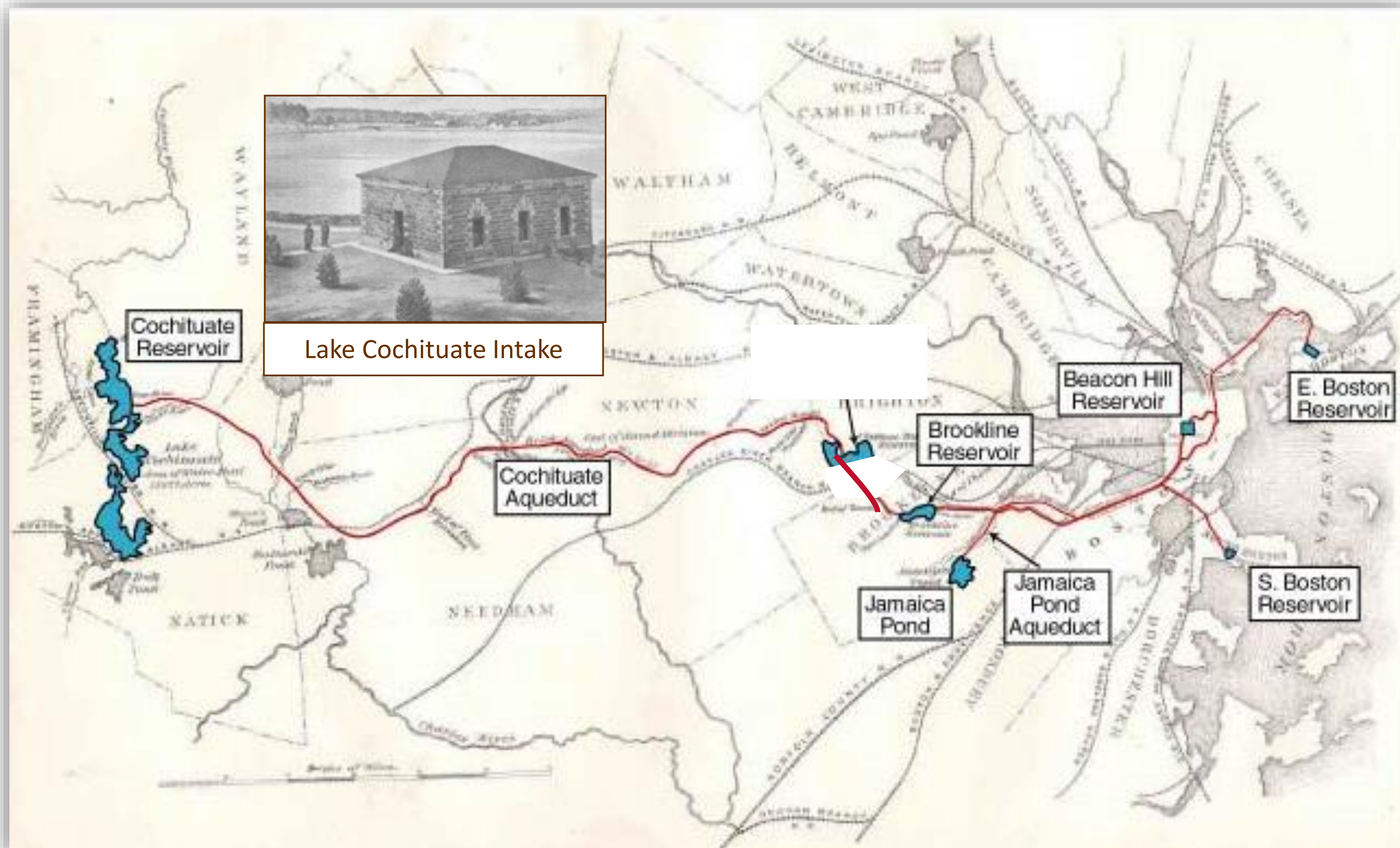


The Cochituate System

- After 20 years of study, the Cochituate System was chosen
- In 1845 construction began on a new distribution system
- The Sudbury River was impounded and Lake Cochituate was formed 14.5 miles from Boston
- The Cochituate Aqueduct transported water to the Brookline Reservoir, which supplied smaller reservoirs all over the City
- Lake Cochituate provided 2 billion gallons of storage and 10 million gallons per day

The Cochituate System

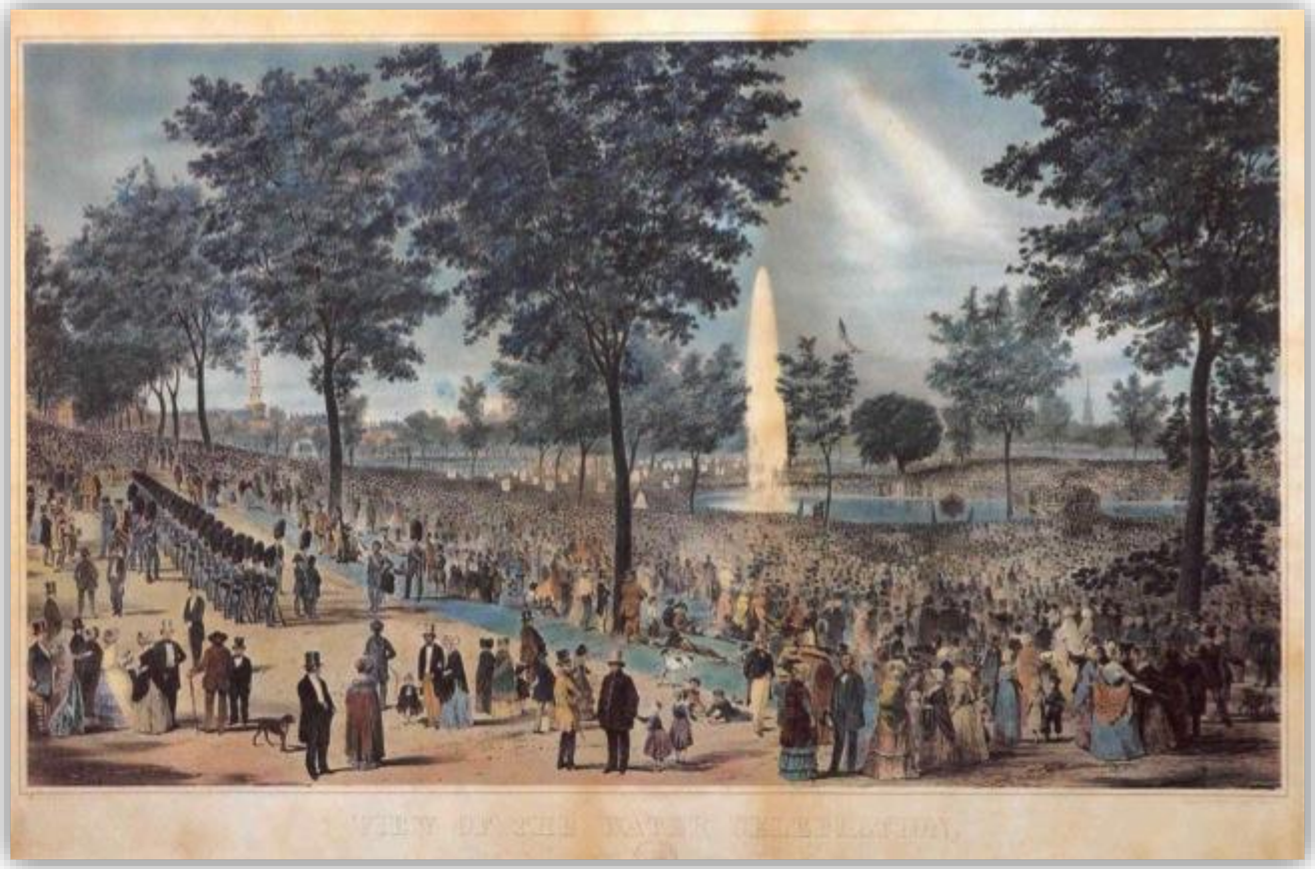
- Long Pond was renamed Lake Cochituate Reservoir
- The system flowed by gravity through a series of distribution reservoirs



Cochituate Reservoir and Aqueduct

The Cochituate System

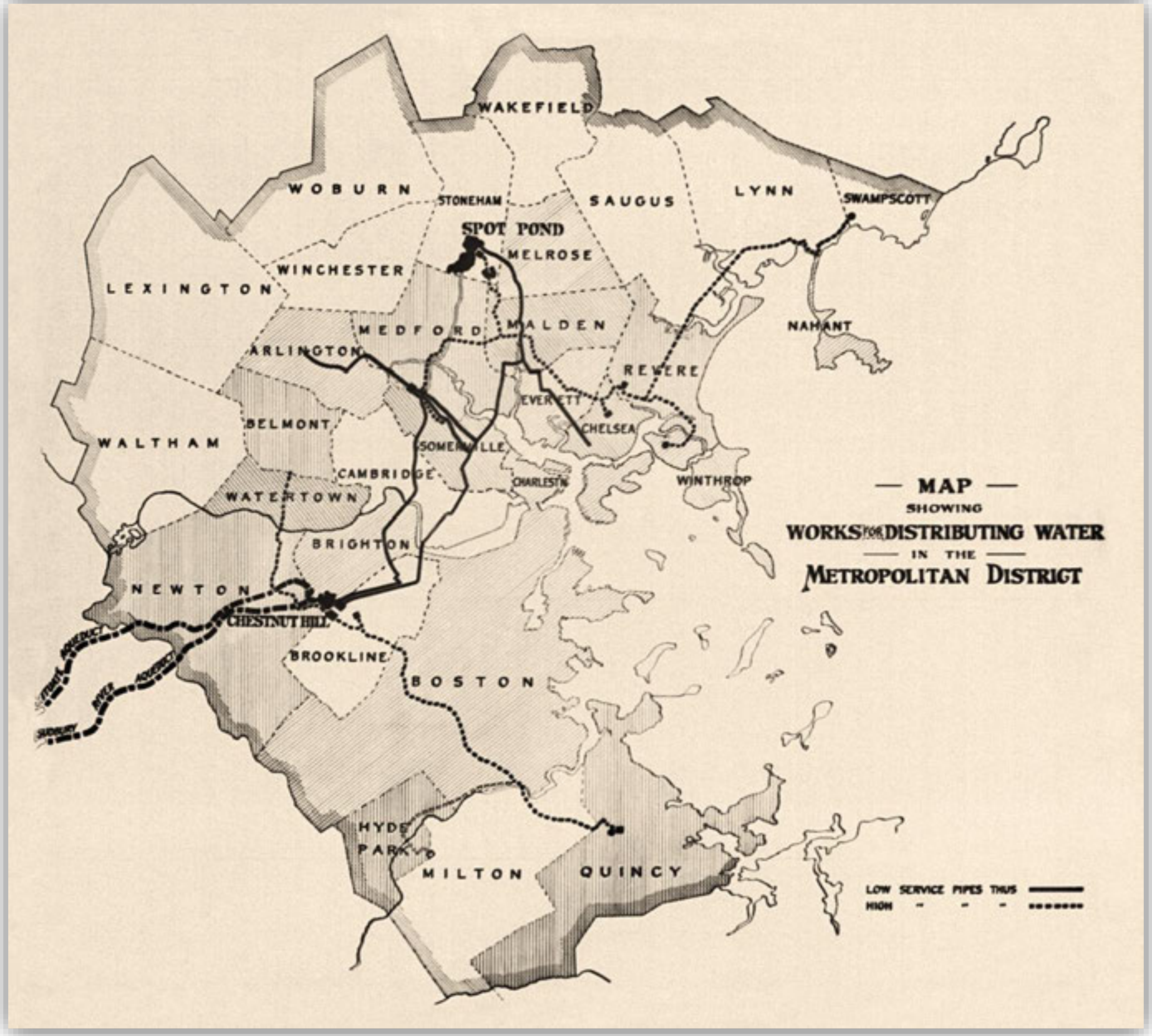
- Water from Lake Cochituate flowed into the Frog Pond on Boston Common in 1848 at a dedication ceremony that drew 100,000



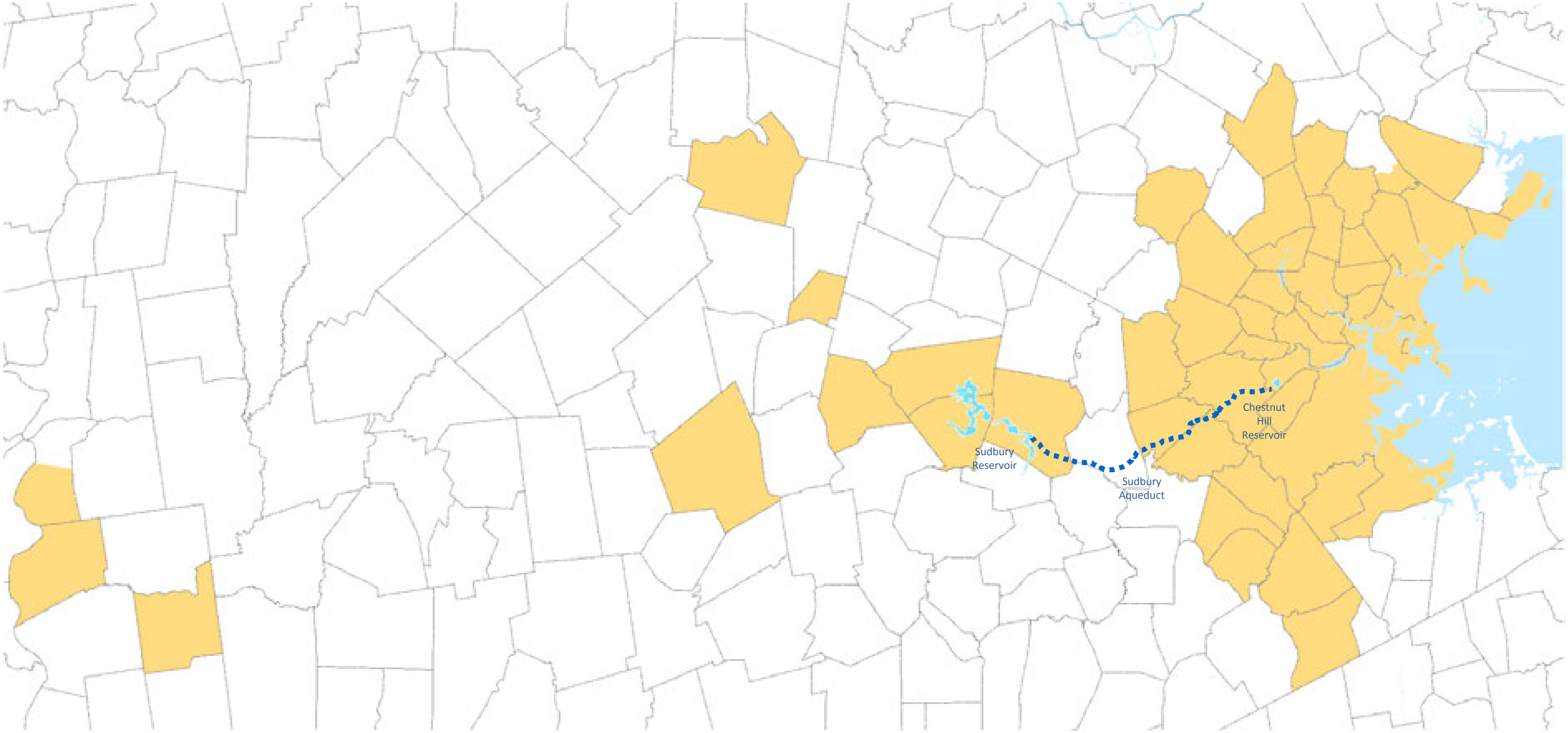
But Boston Needed More Water

- By the early 1890s, Boston's water supply was deemed unsafe and inadequate
- Governor Russell proposed a water district including the development of a large water supply for a number of communities
- In 1895, the Metropolitan Water Act called for the taking of water from the south branch of the Nashua River, the Boston Waterworks at Chestnut Hill and Spot Pond
- This system would supply water to the cities and towns within 10 miles of the State House that wanted it

Metropolitan Water District



The Sudbury System



The Sudbury System

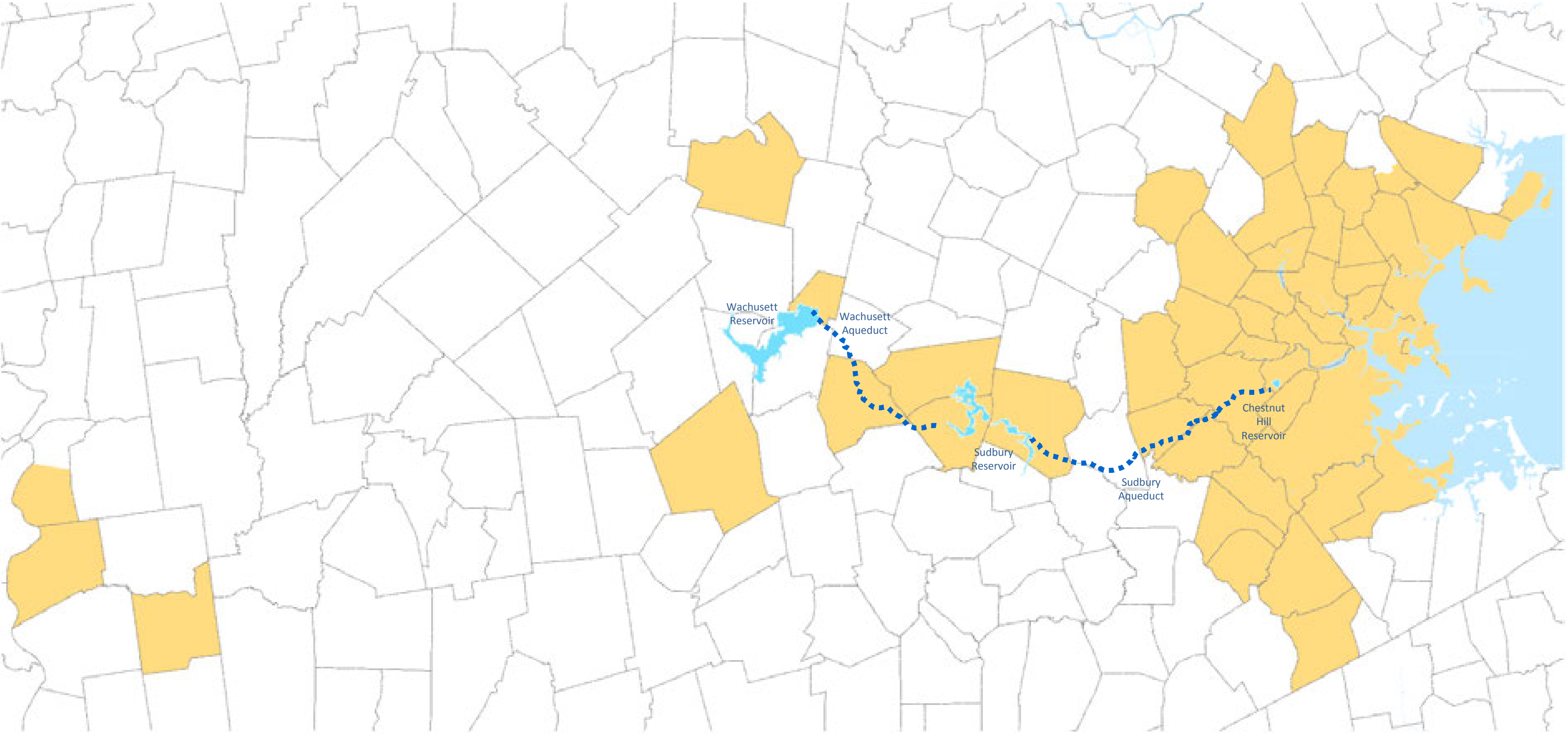
- In 1878, the Sudbury River, 18 miles from Boston, was diverted through the Sudbury Aqueduct to the Chestnut Hill Reservoir

- By 1898, the Fayville Dam and the Sudbury Reservoir were completed

A Regional Solution Was Needed

- Boston continued to grow rapidly in the 1880s and 1890s
- And planners had not foreseen the advent of indoor plumbing
- New water sources were considered: the Nashua River, the Merrimack River, Lake Winnipesaukee and Sebago Lake

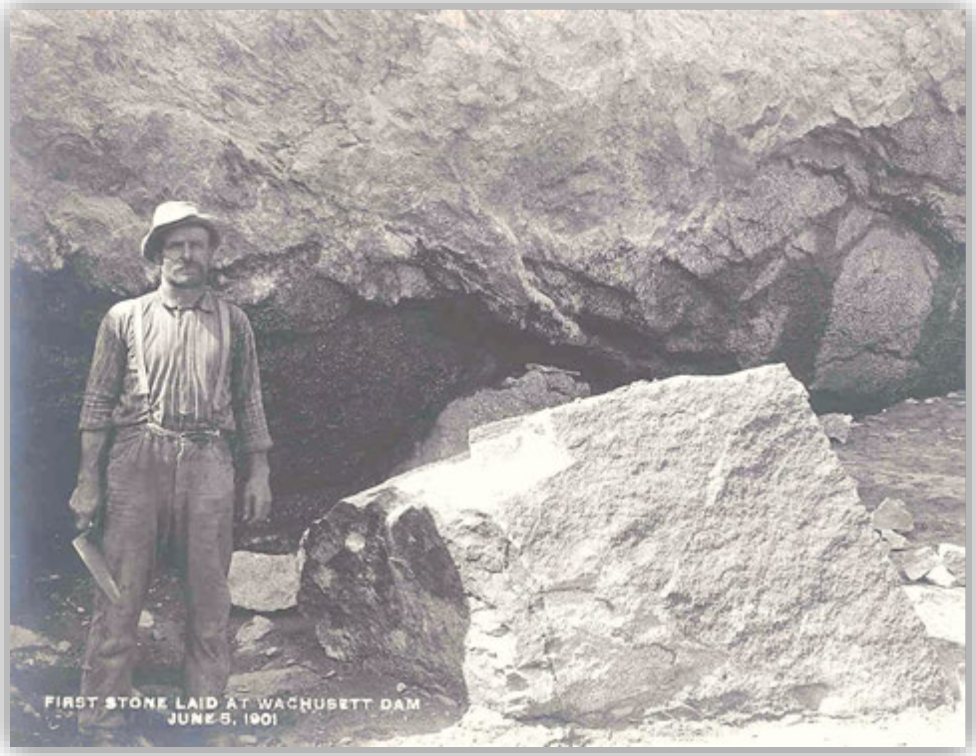
The Wachusett Reservoir - 1897



The Wachusett Reservoir

- Chief Engineer Frederick Stearns planned a water source that would be gravity-operated and not require filtration

- The Nashua River was impounded by the Wachusett Dam, 38 miles from Boston



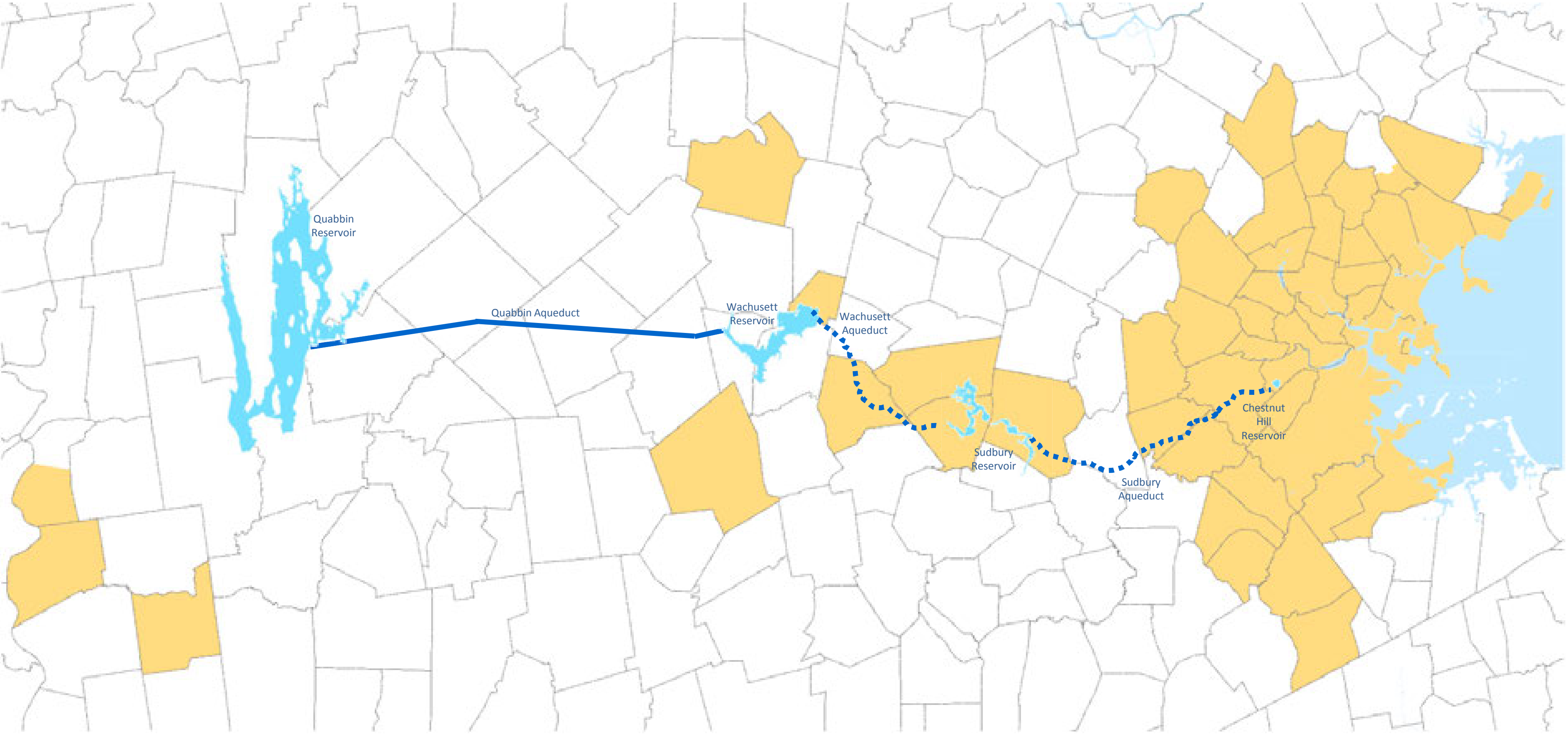
The Wachusett Reservoir

- At the time it was constructed, the Wachusett Reservoir was the largest man-made water supply reservoir in the world
- Its 65 billion gallons supplied 118 million gallons per day

Wachusett Aqueduct

- The Wachusett Aqueduct was constructed to bring water from the Wachusett Reservoir to Sudbury Reservoir

The Quabbin Reservoir



The Quabbin Reservoir

- Construction of the Quabbin required the impoundment of the Swift River and the takings of four towns

- The Quabbin Reservoir, 60 miles from Boston, was another source that could be gravity-operated and not require filtration

Enfield

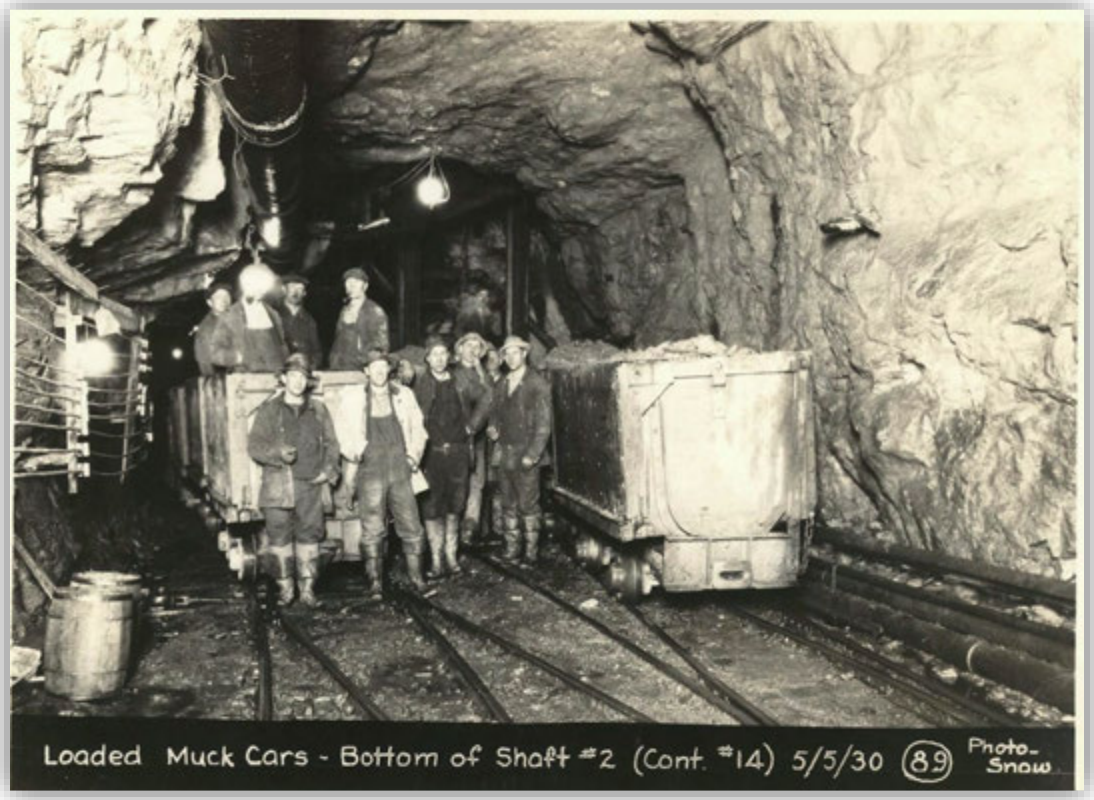
The Quabbin Aqueduct

- Construction of the Wachusett-Colebrook Tunnel (now the Quabbin Tunnel) began in 1926, carrying surplus flow from the Ware River to the Wachusett Reservoir

- In the 1930s, the Tunnel was extended to the Swift River

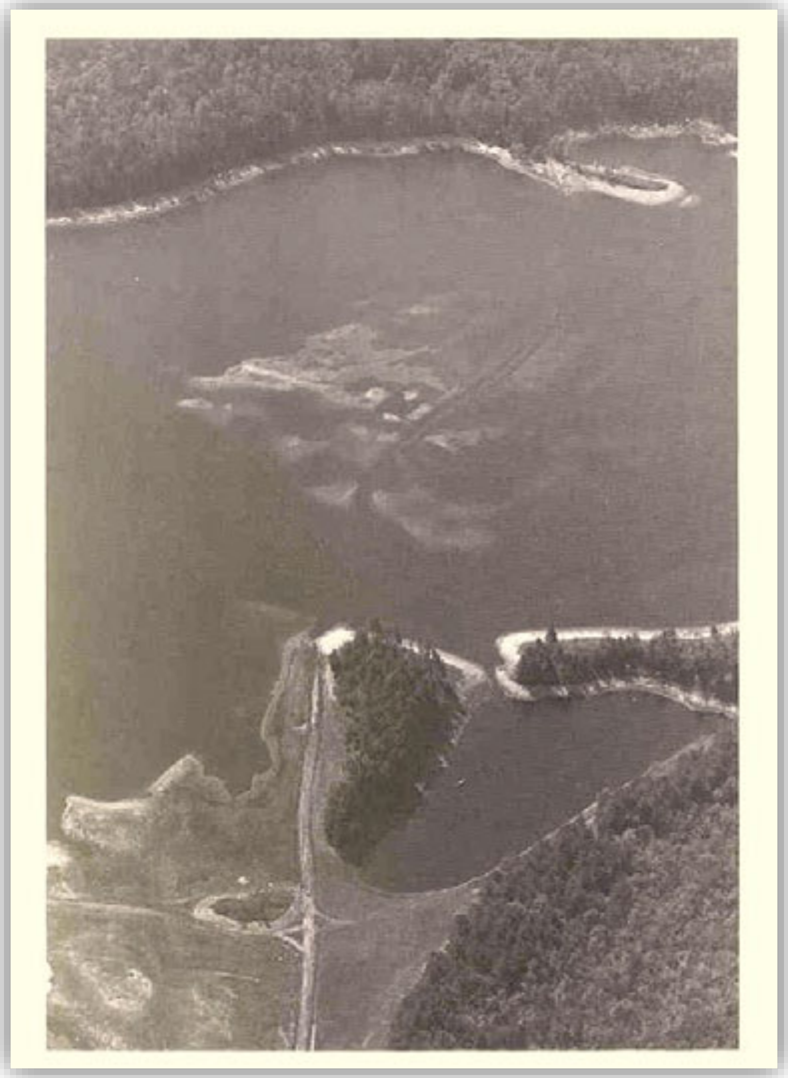
- This two-way tunnel carries flows east and west, depending on time of year

- In 1936, construction of the reservoir began



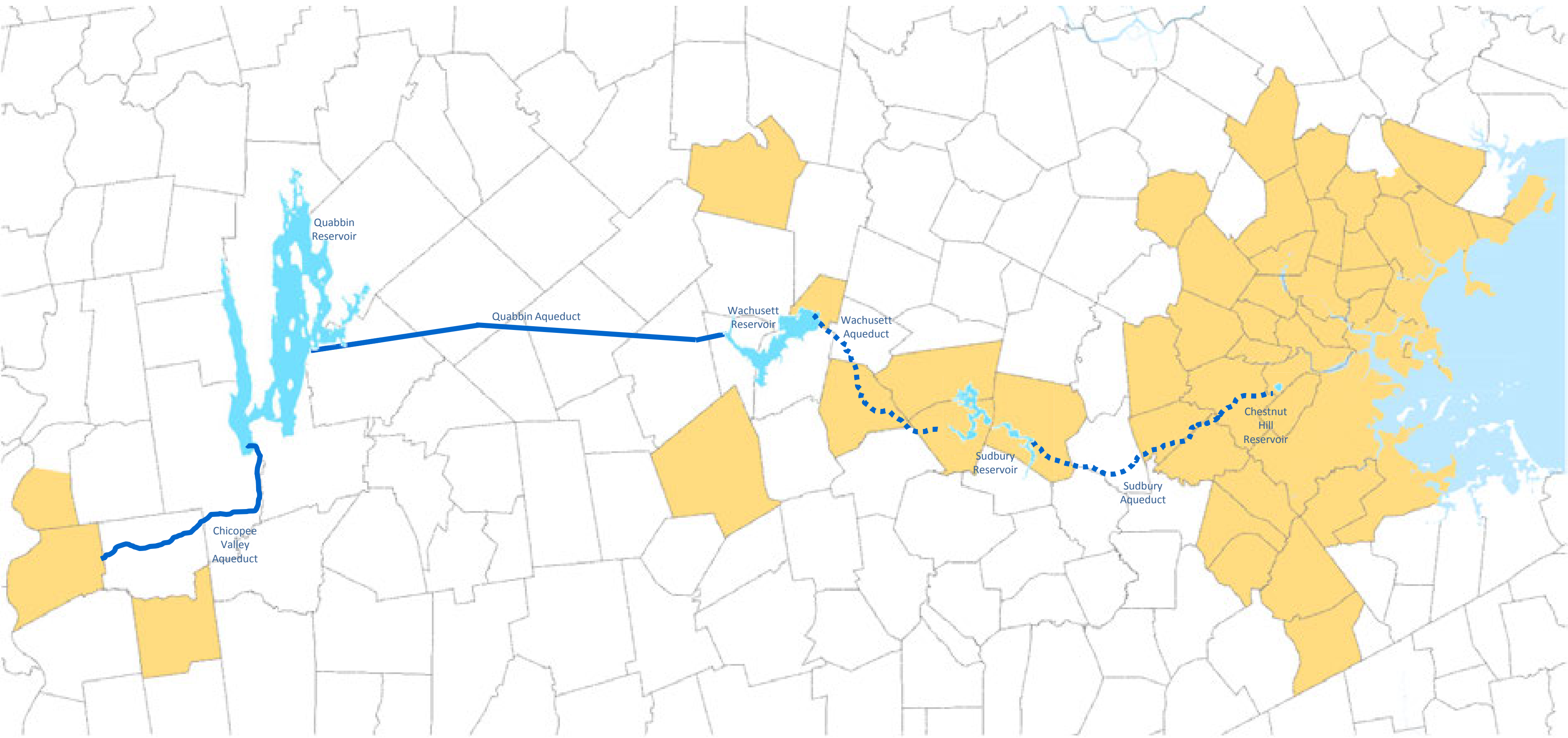
The Quabbin Reservoir

- The reservoir was filled with water from the Swift River and the Ware River
- Filling began in 1939 and was completed in 1946
- At the time, the 412 billion gallon reservoir was the largest man-made reservoir in the world



Road still visible beneath surface of water

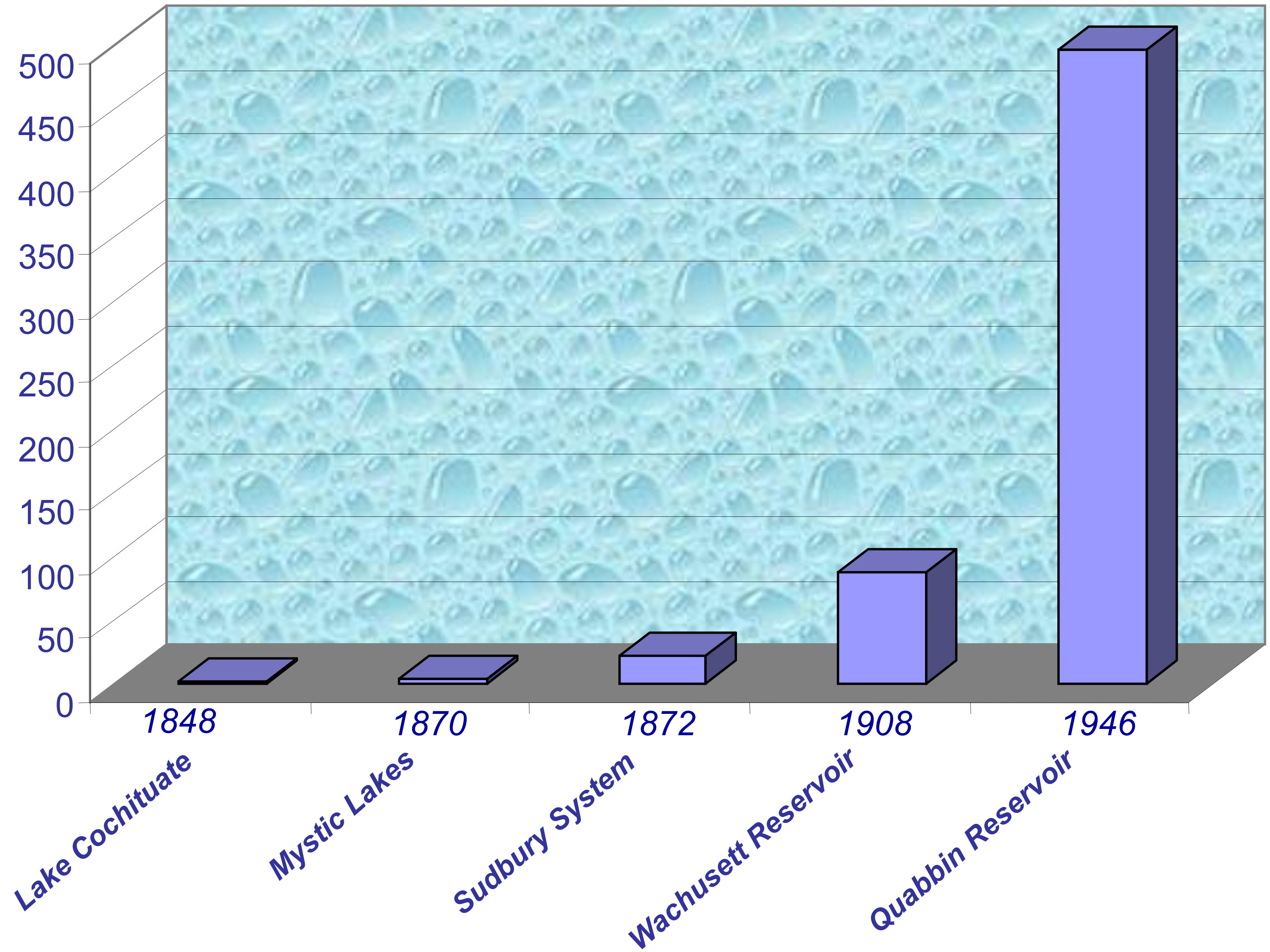
The Chicopee Valley Aqueduct - 1949



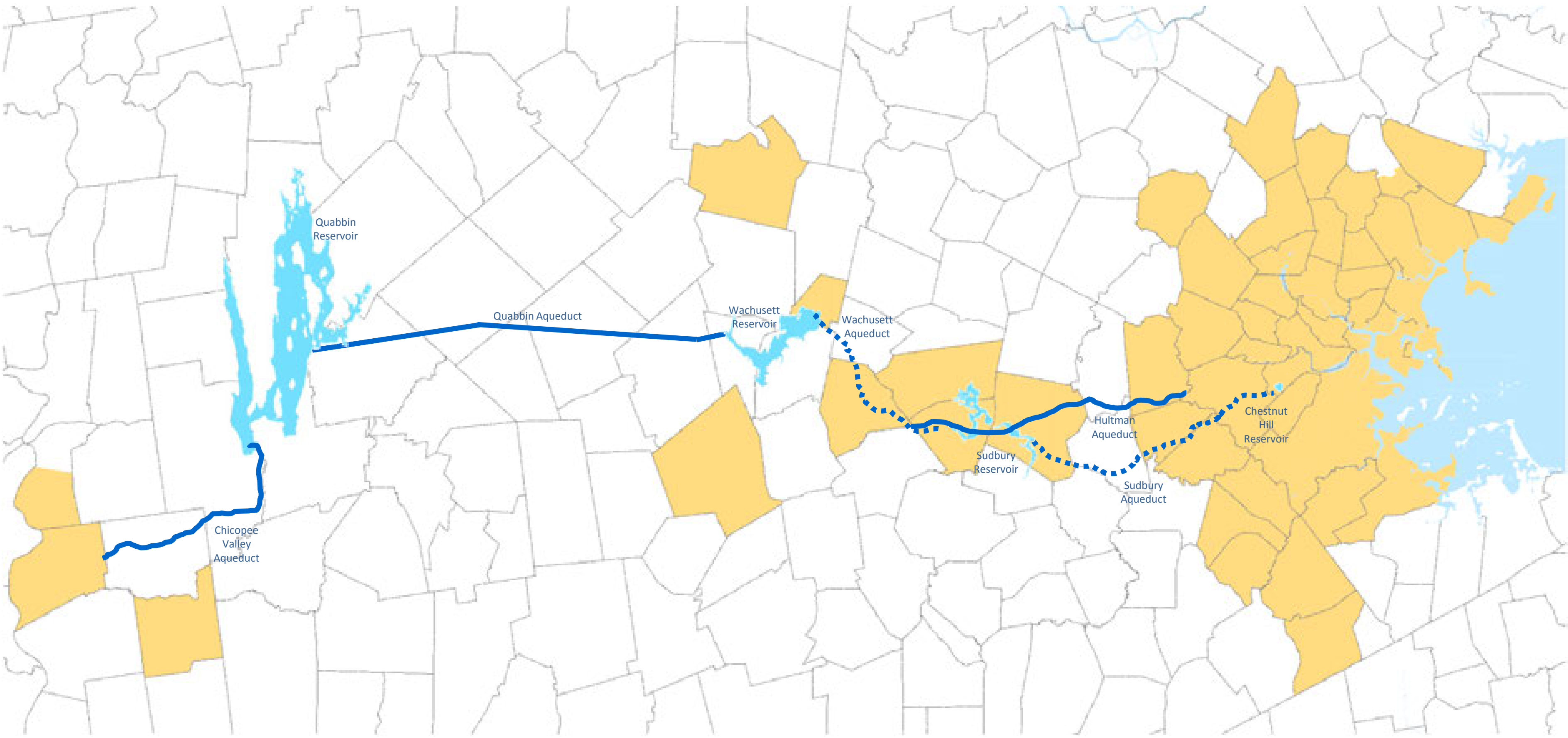
The Chicopee Valley Aqueduct

- The Chicopee Valley Aqueduct is a 14.8 mile, 4-foot diameter steel and concrete pipeline that supplies Chicopee, South Hadley FD 1 and Wilbraham from the Quabbin Reservoir

Cumulative Water Supply Capacity



The Hultman Aqueduct - 1940



The Hultman Aqueduct

- In 1936, the Legislature approved the construction of a two high-pressure aqueducts to deliver water to the greater Boston area

- The two aqueducts would carry water from the Wachusett Reservoir to the new Norumbega Reservoir in Weston

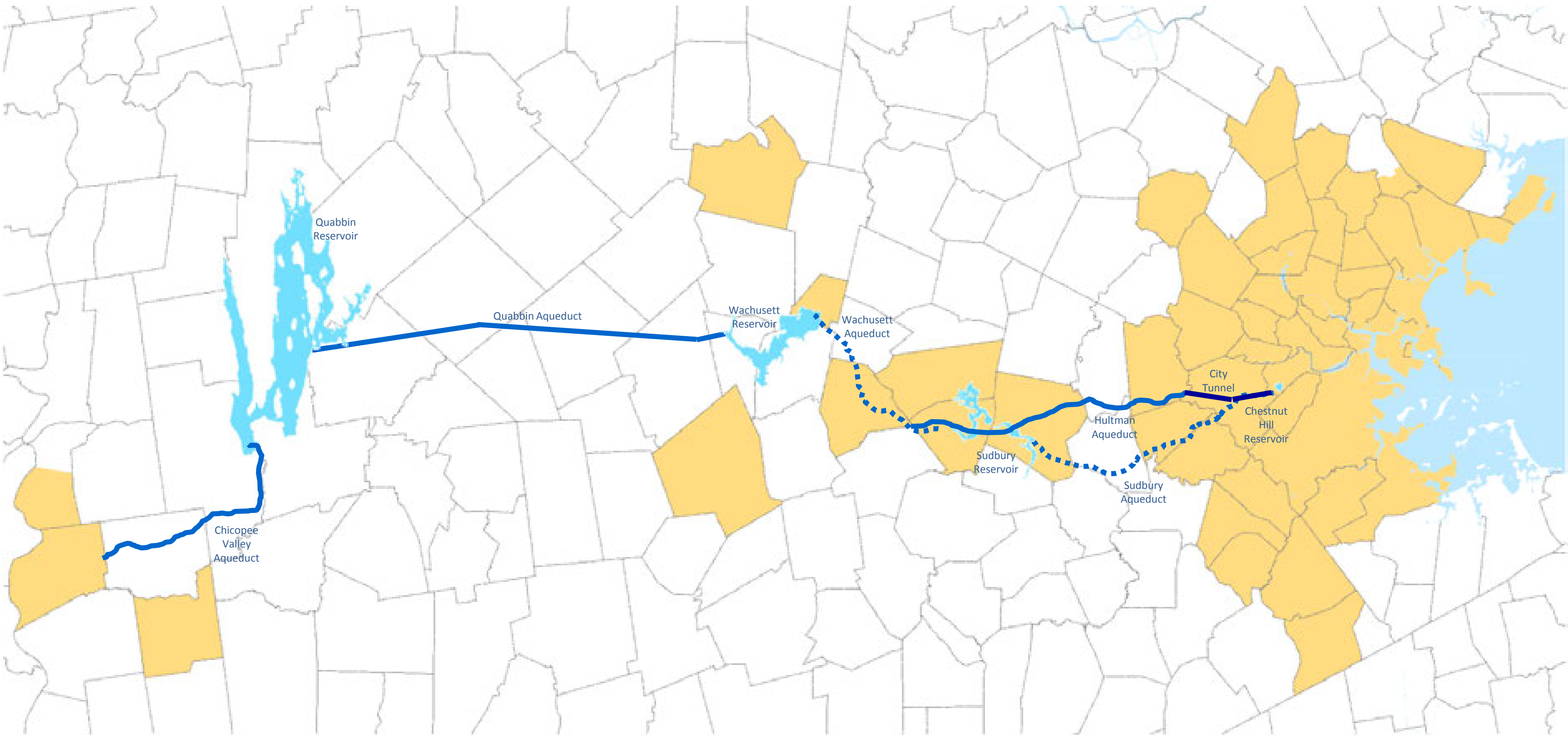
The Hultman Aqueduct

- One barrel of the aqueduct system - the Hultman Aqueduct - was completed
- But work on the second barrel did not resume after World War II
- Until 2003, 85% of Boston's water supply was provided without redundancy

The Metropolitan Tunnel System

- By the 1950s, tunnels were used to bring better pressure deeper into the distribution system

The City Tunnel - 1950

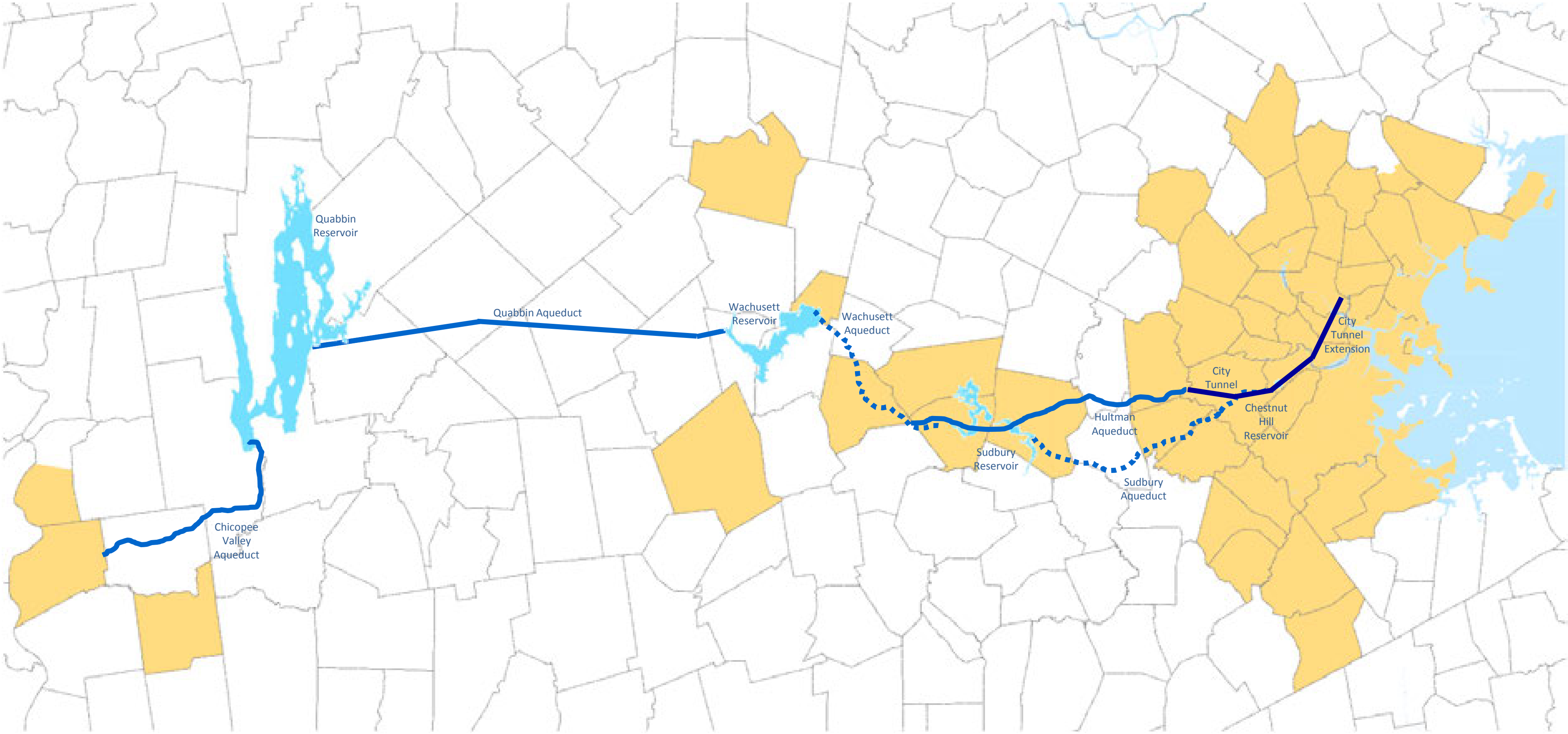


The City Tunnel

- The City Tunnel is a 12-foot deep rock tunnel that goes from Shaft 5 in Weston to Shaft 7/7B in Brighton

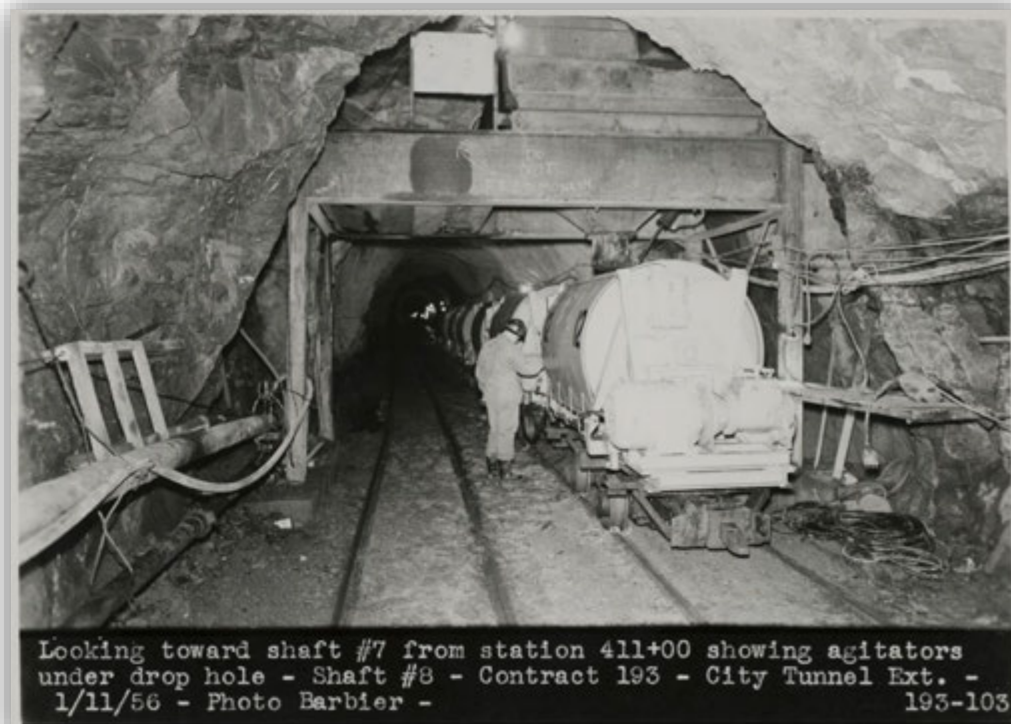
- It was constructed to meet increased demand, followed by the City Tunnel Extension to the north and the Dorchester Tunnel to the south

The City Tunnel Extension - 1963

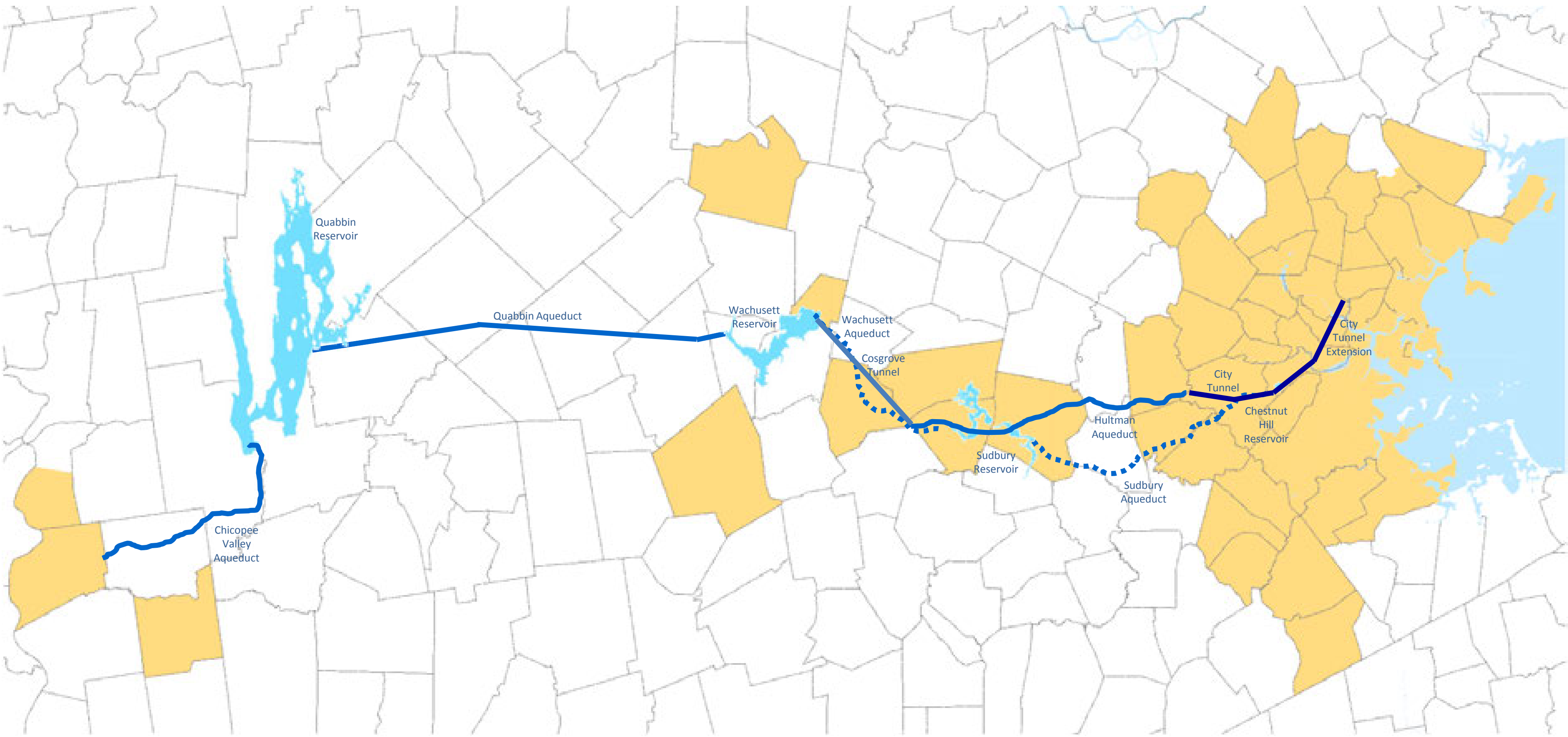


City Tunnel Extension

- The City Tunnel Extension is a 10-foot diameter deep rock tunnel that goes from Shaft 7 north to Shaft 9A in Malden



The Cosgrove Tunnel

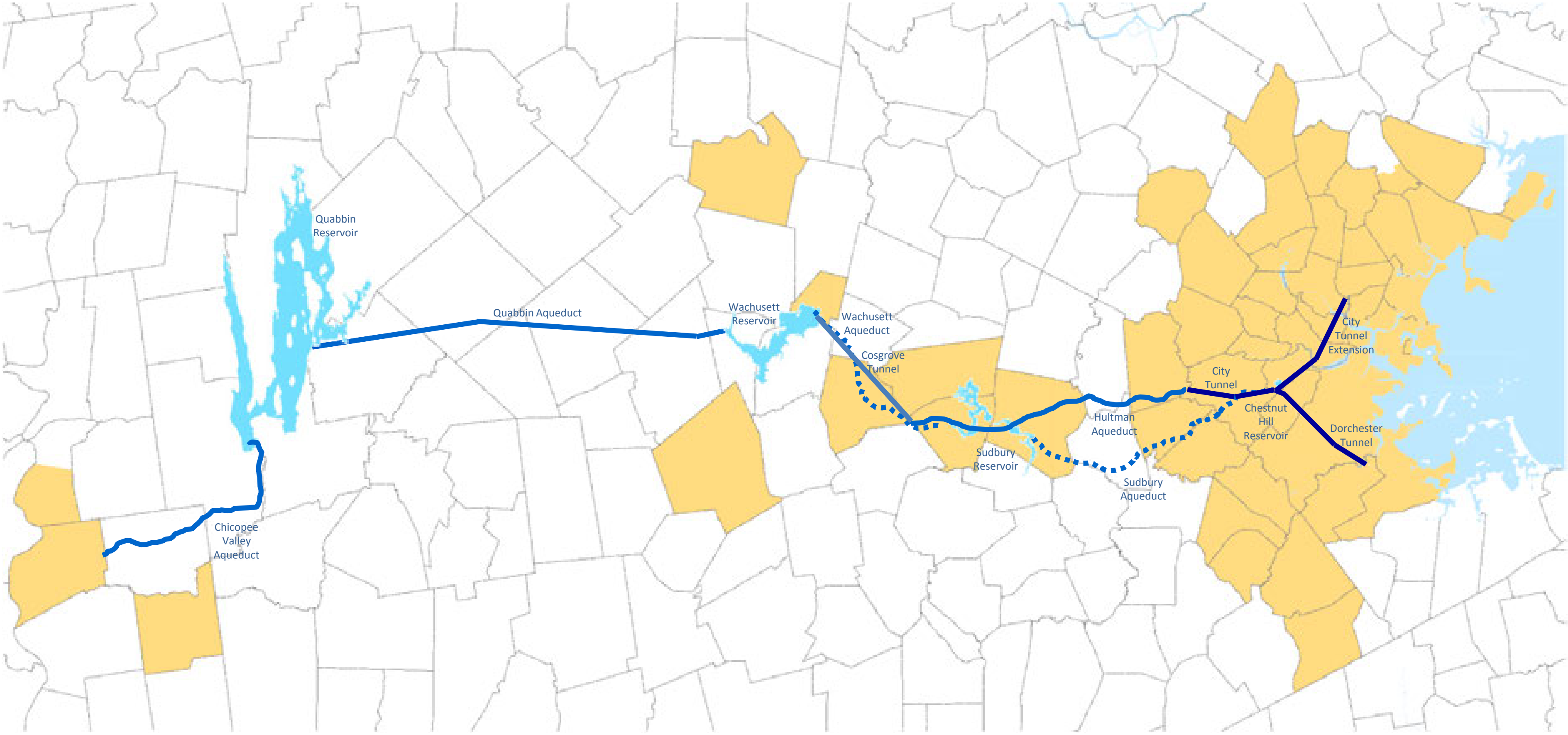


Cosgrove Tunnel - 1967

- The Cosgrove Tunnel carries water eight miles from the Wachusett Reservoir to the Carroll Treatment Plant
- It is 14 feet in diameter and was constructed to replace the Wachusett Aqueduct with a pressurized tunnel


Small drill jumbo which carries four drills - Photo taken at sta. 198+99 - Looking towards Shaft "A" - Wachusett-Marlboro Tunnel - Cont. 284 - 3/24/60 - Photo Barbier - 284-160

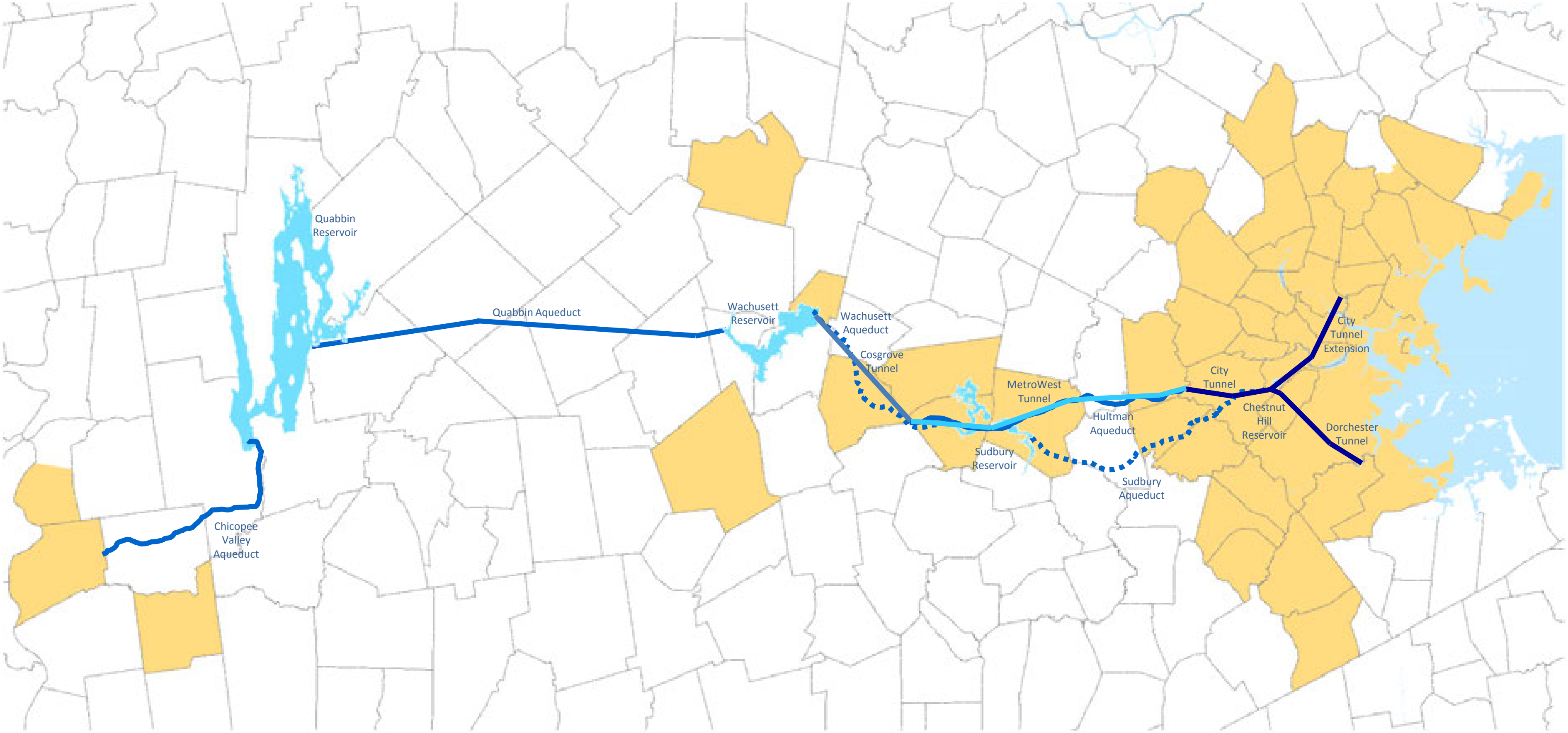
The Dorchester Tunnel



Dorchester Tunnel - 1976

- The Dorchester Tunnel is a 10-foot diameter deep tock tunnel that was needed to serve the Southern High and Southern Extra High zones when the Sudbury Reservoir system no longer met water quality standards

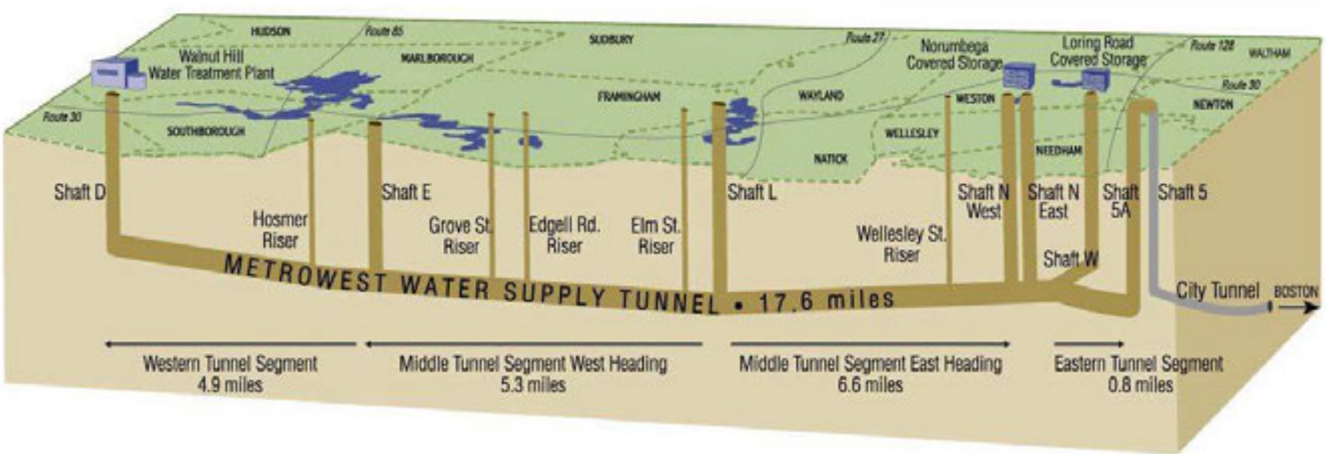
The MetroWest Water Supply Tunnel - 2003



MetroWest Water Supply Tunnel

- The 17.6 mile, deep rock MetroWest Water Supply Tunnel was brought on-line in November 2003

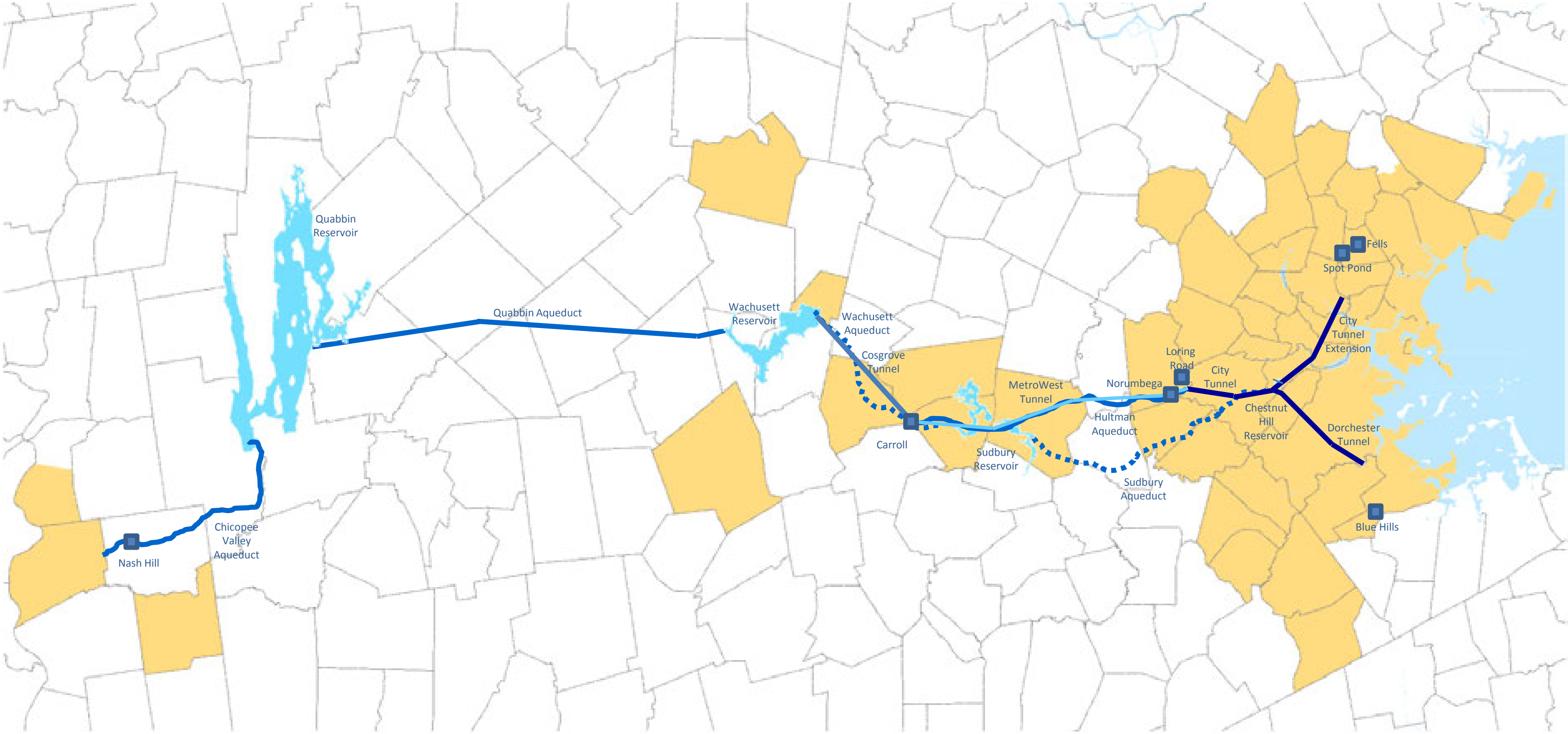
- By March 2004, the Tunnel was being fully utilized allowing the shutdown of the Hultman Aqueduct for repair



Hultman Aqueduct Rehabilitation

- Since 2013, for the first time since originally planned in the 1930s, the Metropolitan Water System has redundancy for the Hultman Aqueduct from Marlborough to Weston

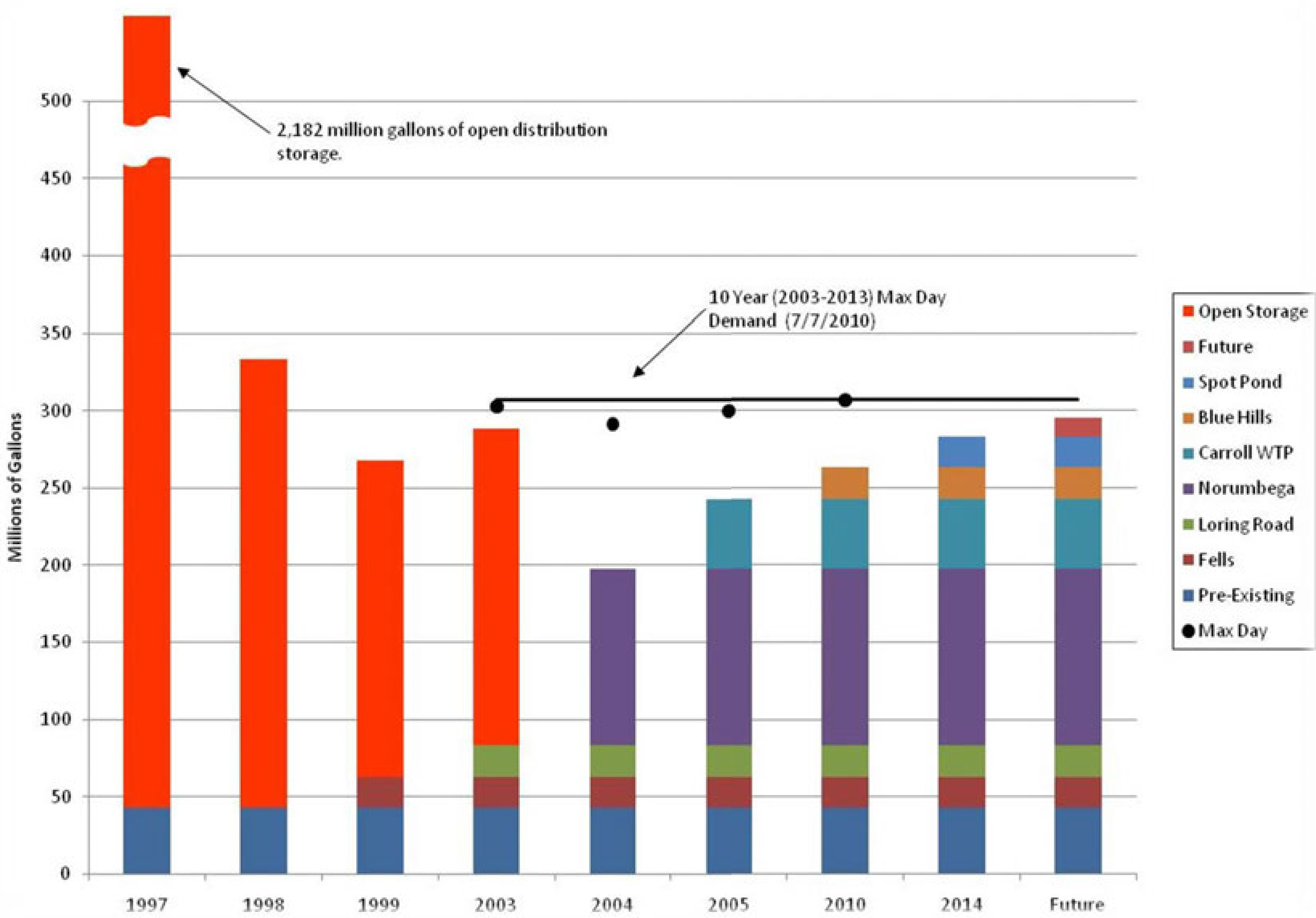
Covered Water Storage - 1992-2015



Norumbega Covered Storage Facility

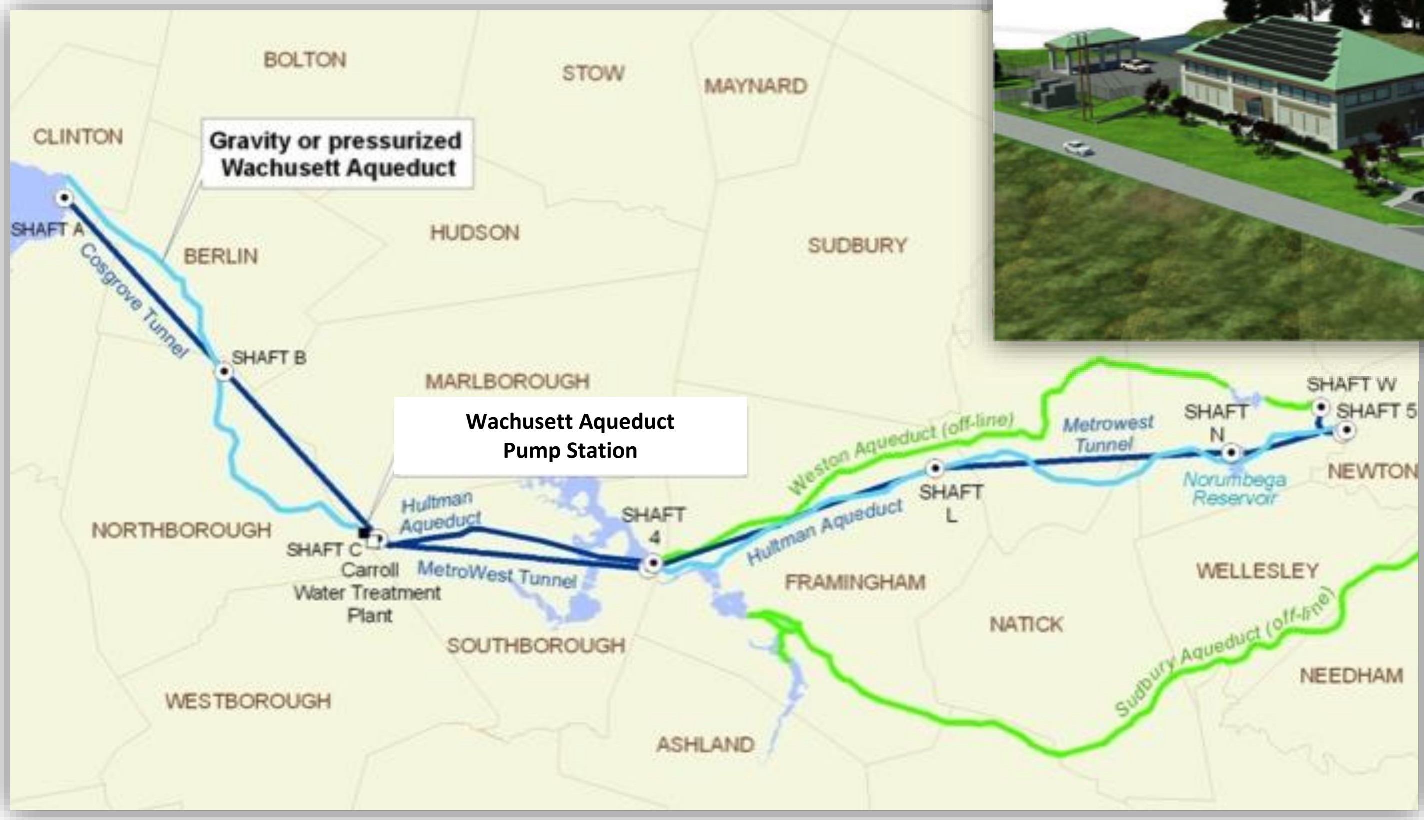
- The tank was completed in May 2004
- It provides 115 million gallons of storage for metropolitan Boston

MWRA Metropolitan Area Storage Capacity Over Time

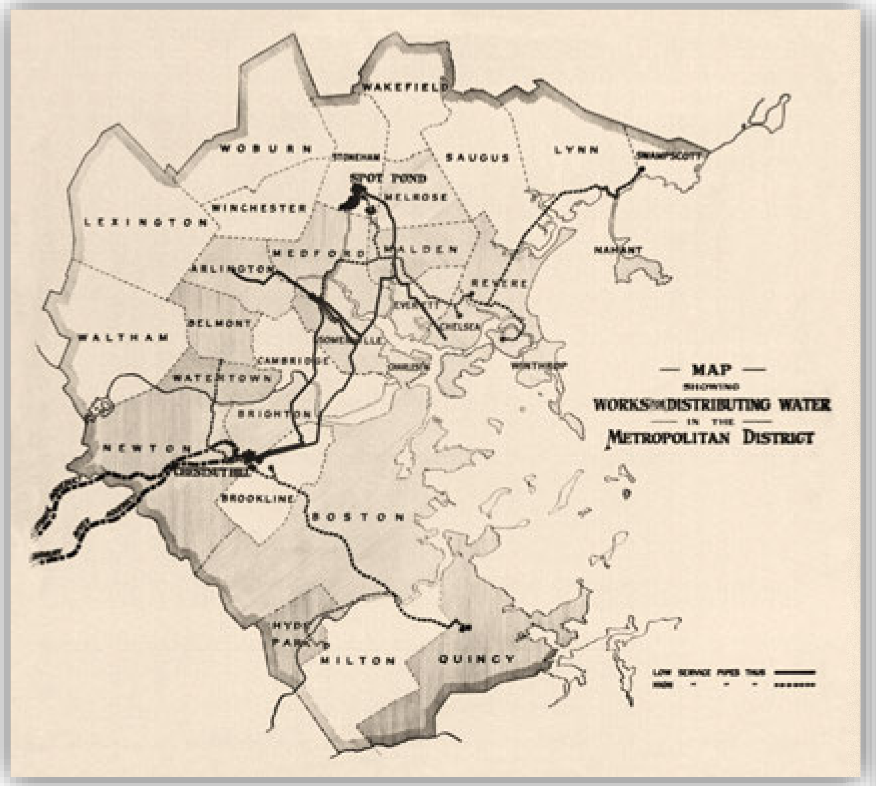


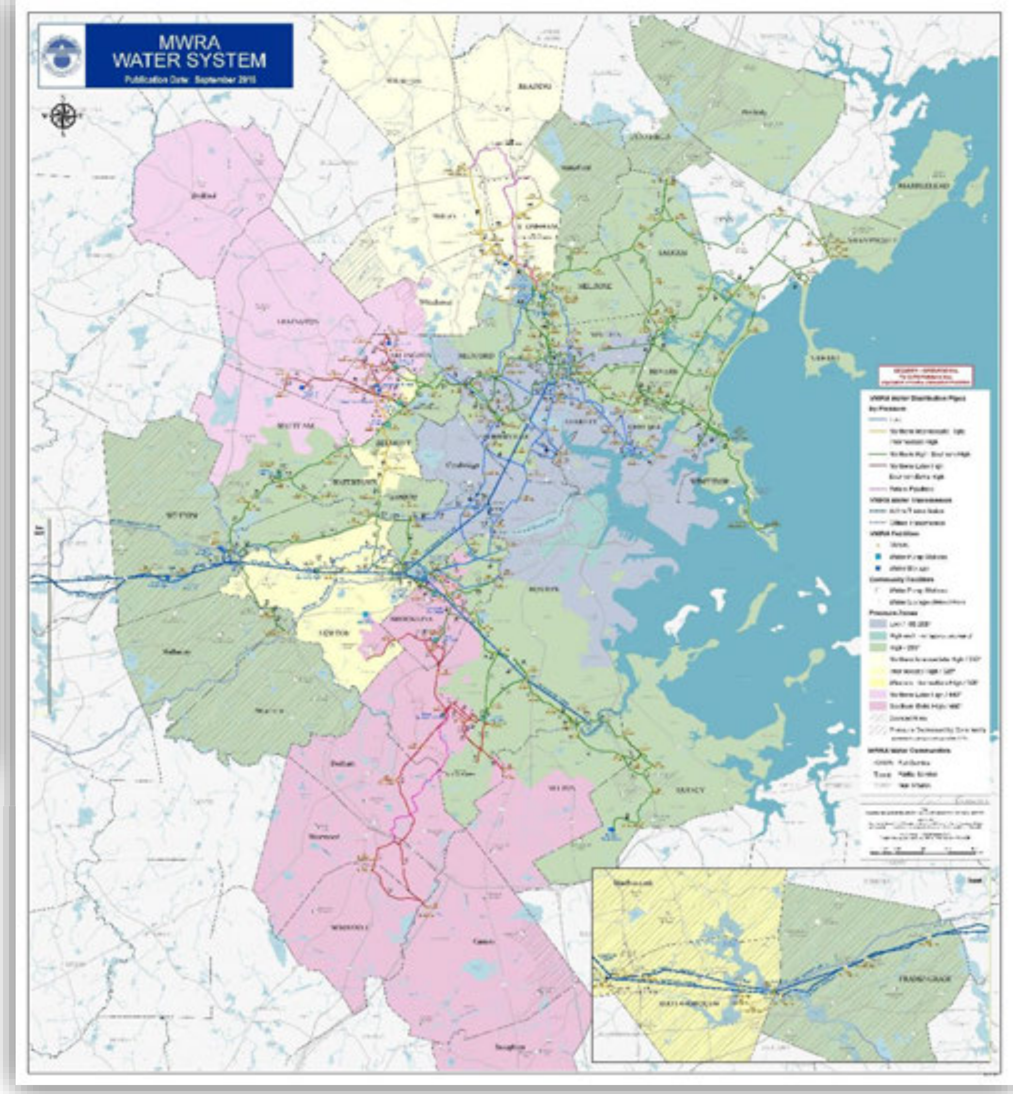
New Wachusett Aqueduct Pump Station Under Construction

- Will provide redundancy for the Cosgrove Tunnel, from the Wachusett Reservoir to the Carroll Treatment Plant



We've Come A Long Way





Special Meeting of the Board of Directors

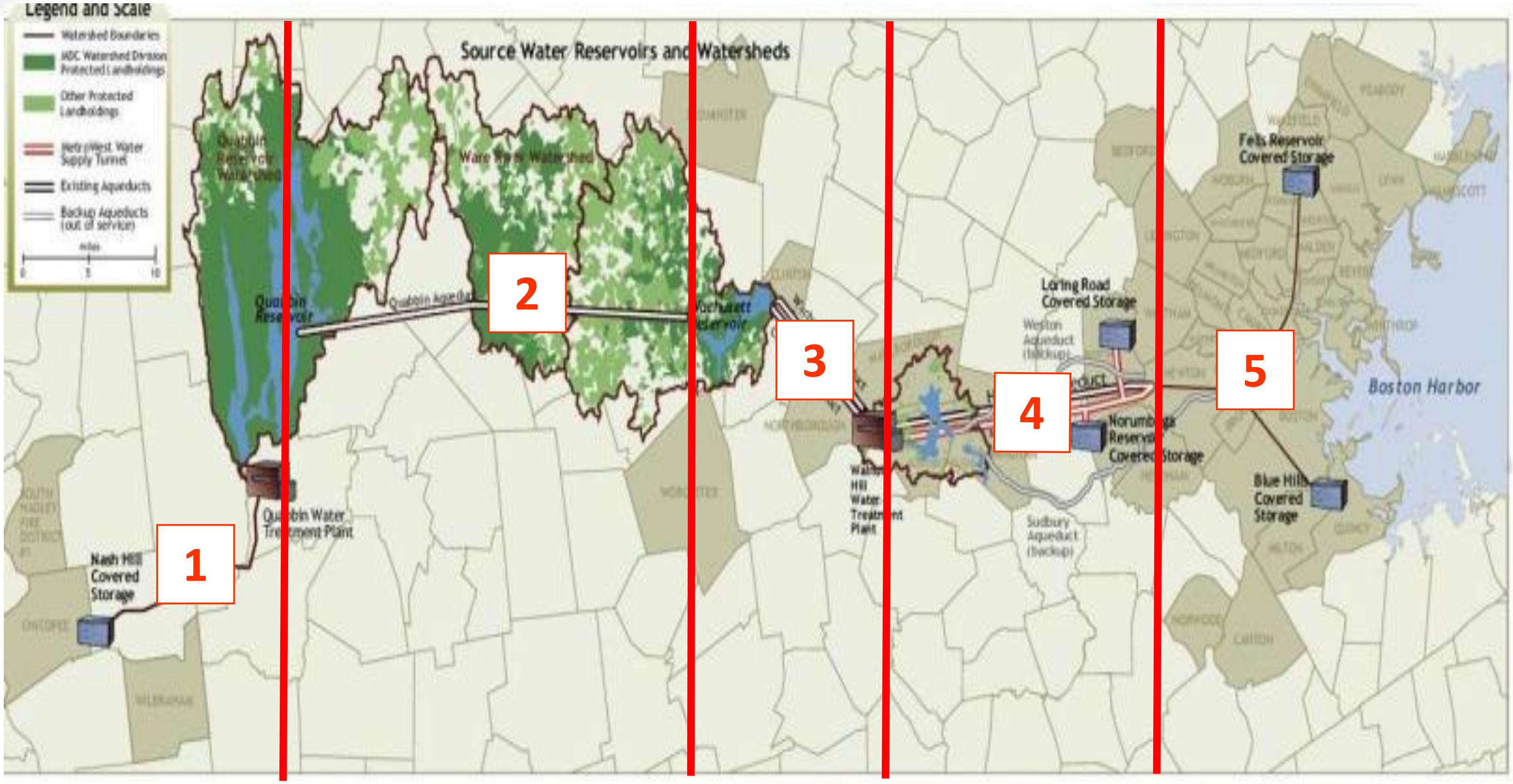
on

Metropolitan Tunnel Redundancy

October 6, 2016

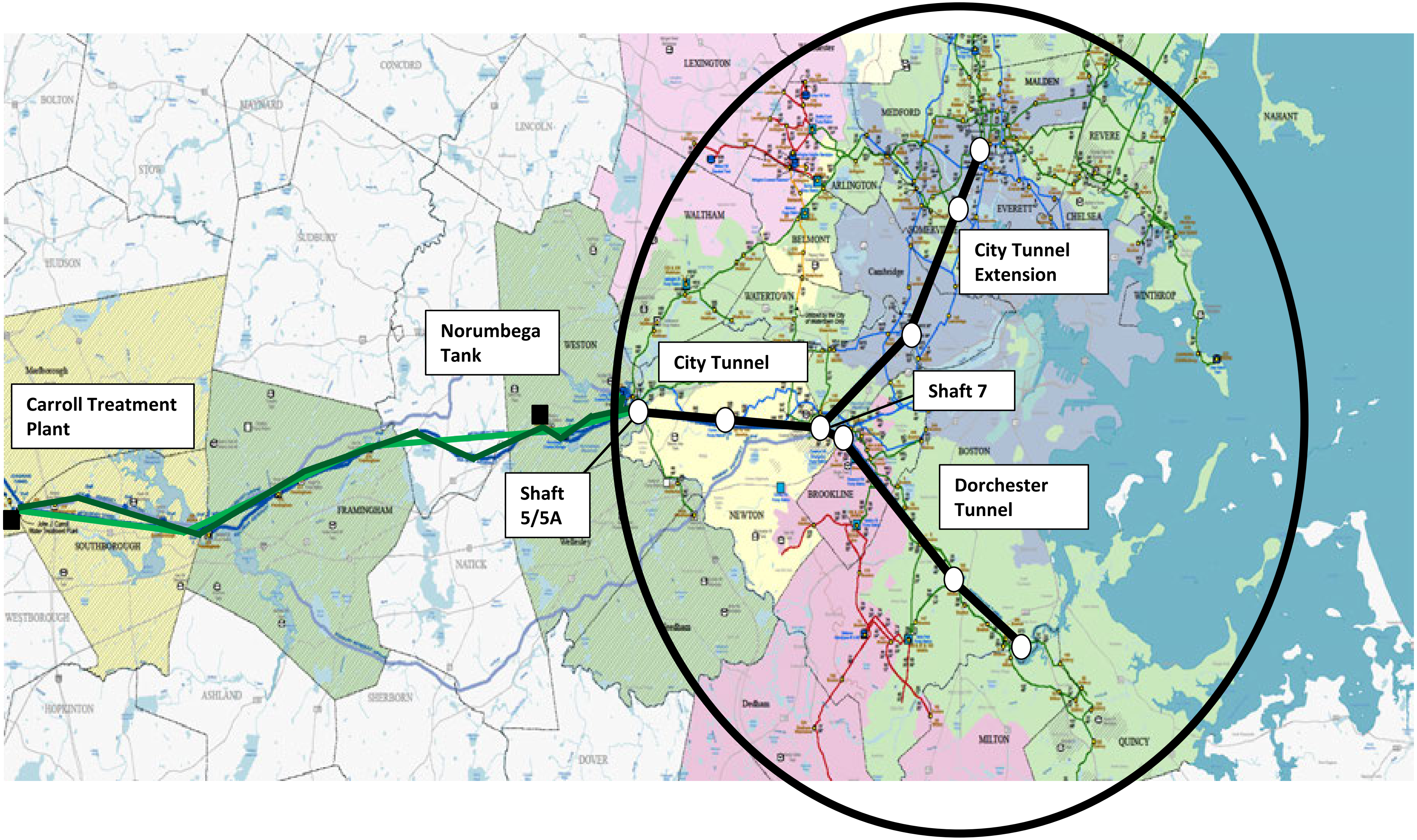
Status of Existing Transmission System Facilities

MWRA Water Transmission System

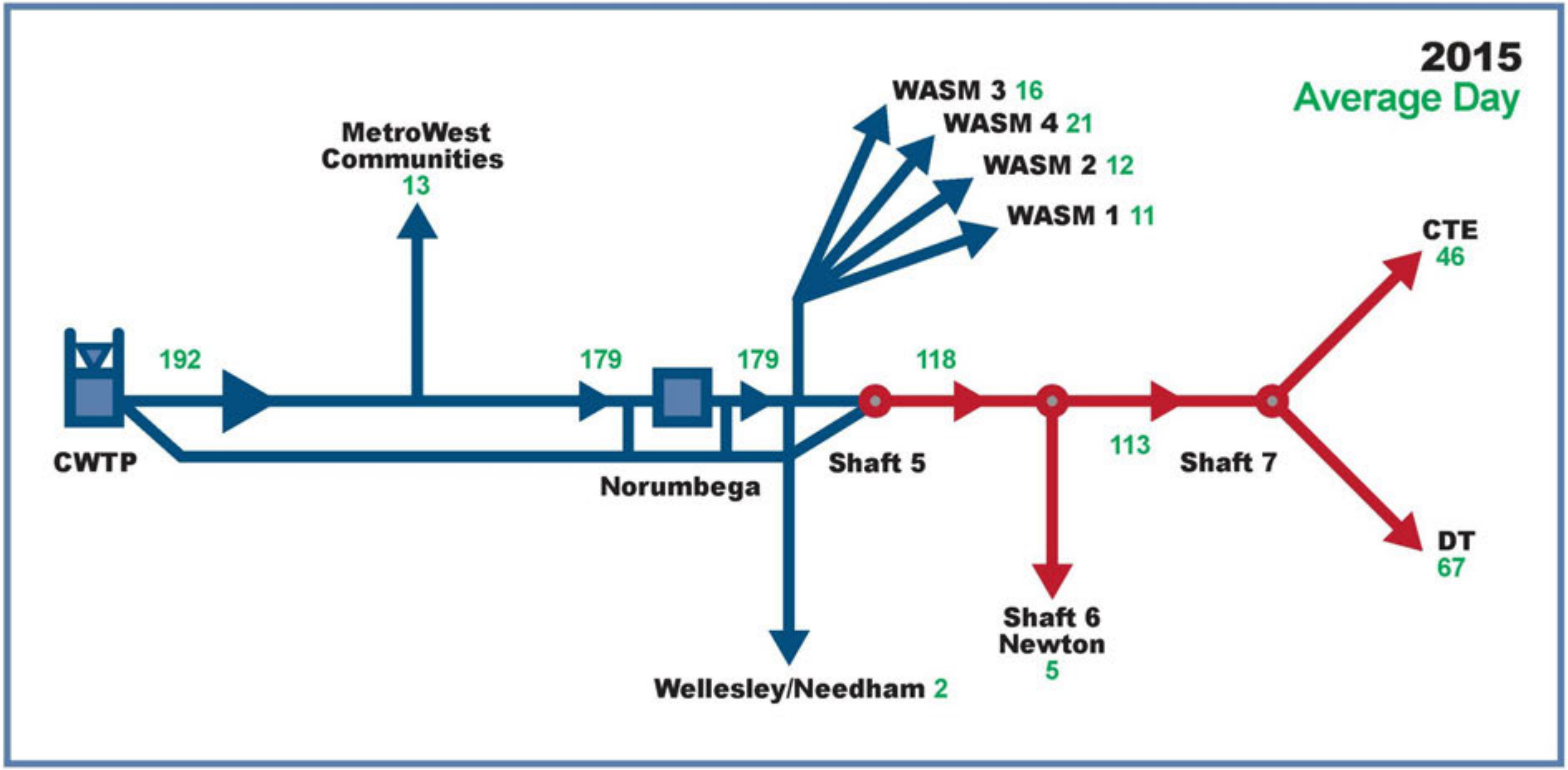


1.	Chicopee Valley Aqueduct	2007 Improvements
2.	Quabbin Aqueduct	Inspection planned
3.	Cosgrove Tunnel / Wachusett Aqueduct	Project underway
4.	MetroWest Tunnel / Hultman Aqueduct	2003/2013 Improvements
5.	Metropolitan Tunnels	Significant Needs

Metropolitan Tunnel System



Service Provided to a Large Percentage of MWRA Customers



Approximately 60% of total system flow is carried through the Metropolitan Tunnel System

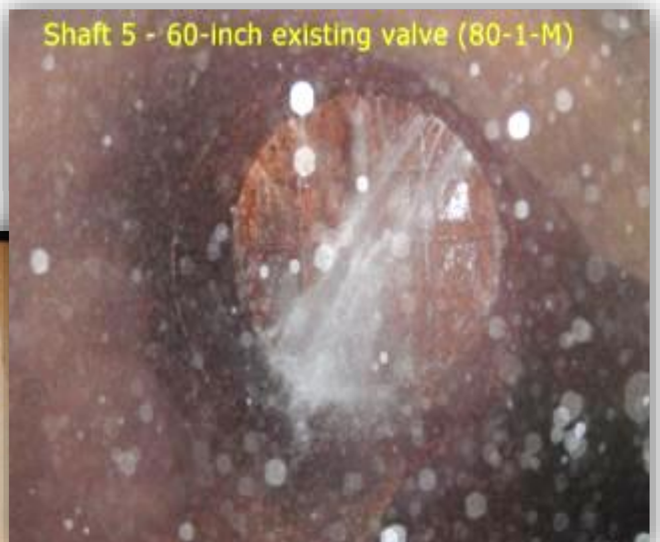
Condition of Metropolitan Tunnel System

- Tunnel system:
  - Concrete-lined deep rock tunnels
  - Steel and concrete vertical shafts
  - Surface pipe, valves and appurtenances
- Little maintenance required for tunnels and shafts. **Little risk of failure**.
- Pipe, valves and appurtenances need maintenance, replacement, rehabilitation

Valve Reliability Concern

- Valves that don’t work
- Valves we can’t exercise

Cone Valve at Shaft 7B



54-inch Shaft 7 Valve

20-inch Shaft 7 Valve

Valve Reliability Concern

- Valves that don't work
- Valves we can't exercise

60-inch gate valve Shaft 5

Cone Valve at Shaft 7B

Gear box on valve at Shaft 8

Valve Reliability Concern

- Valves that don't work
- Valves we can't exercise

Shaft 8 PRV Chamber

Shaft 8

Shaft 8

Access Can Be Difficult

- High ground water table
- Standing water in some chambers
- Corrosion is a concern

Shaft 7C connection to Section 58

Chamber at Shaft 7C

Chamber at Shaft 7D

Access Can Be Difficult

- High ground water table
- Standing water in some chambers
- Corrosion is a concern

Shaft 7D located near salt marsh at Neponset River Reservation

Shaft 8 near Storrow Drive and the Charles River

Shaft 7D connecting pipe air valve chamber

Appuntenances Can Be Liabilities

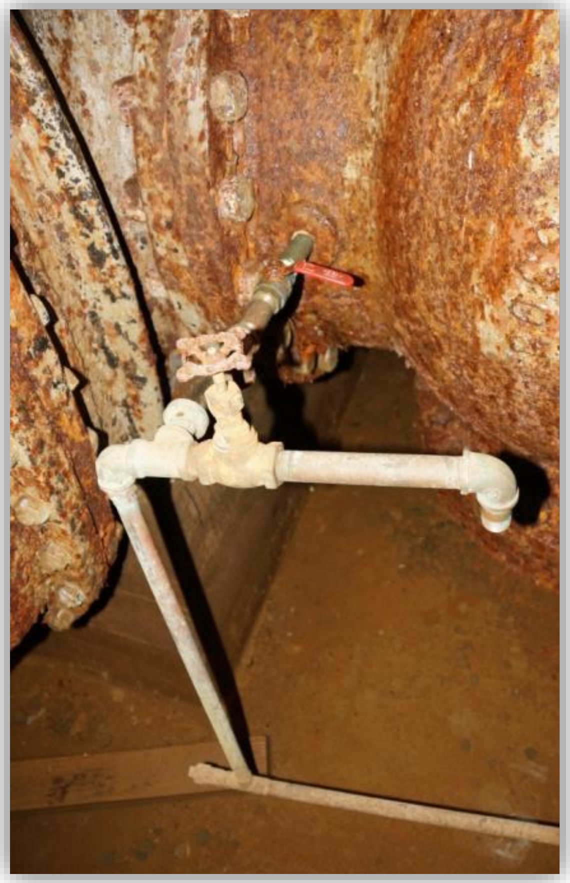
- Small pipe failures can lead to shut downs

Shaft 8 PRVs

Top of Shaft 8

Appurtenances Can Be Liabilities

- Small pipe failures can lead to shut downs



Control piping at Shaft 8

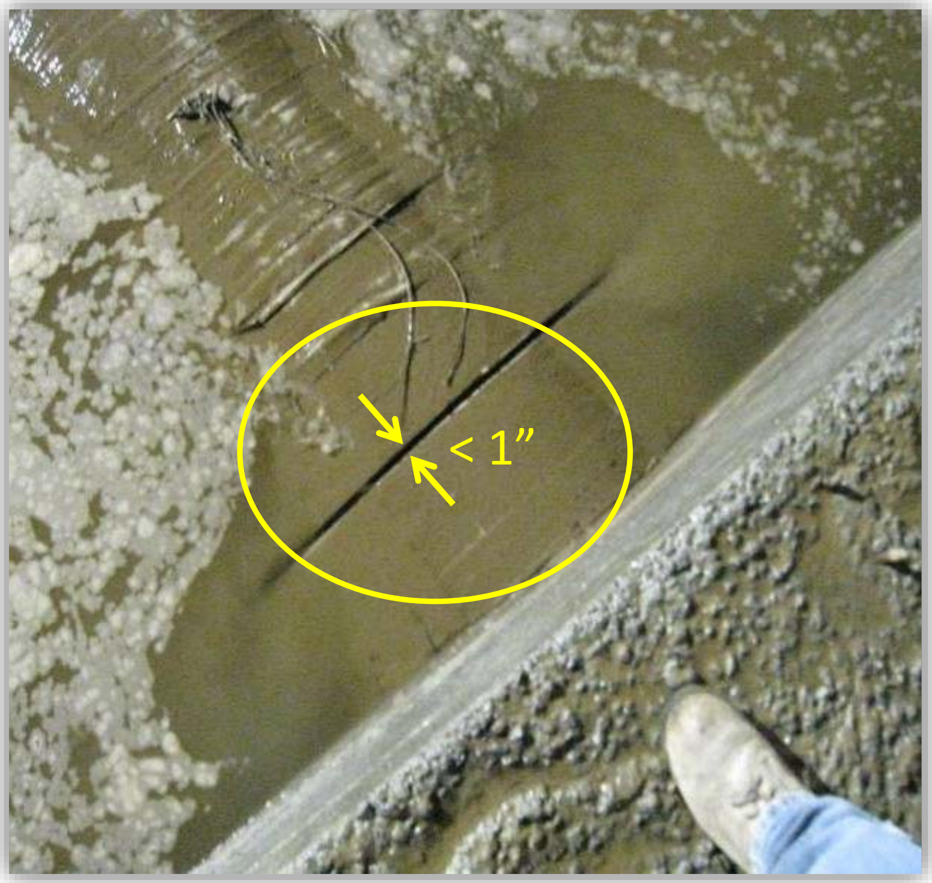
Air valve at Shaft 9A

Shaft 8 PRV Chamber

Appuntenances Can Be Liabilities

- Small pipe failures can lead to shut downs

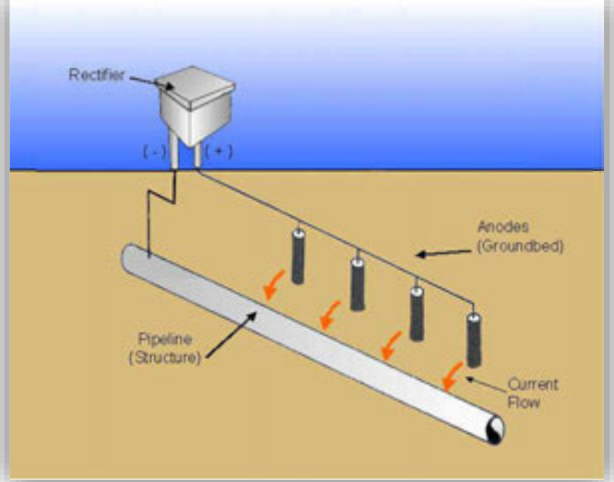
250 MGD flow at Shaft 5 break….



…came from a small gap in the pipe

Shaft Pipeline Improvements to Reduce Risk

- Replace corroded bolts
- Metal thickness evaluation
- Wrap or coat pipe segments
- Replace air valves
- Cathodic protection
- Heat tracing

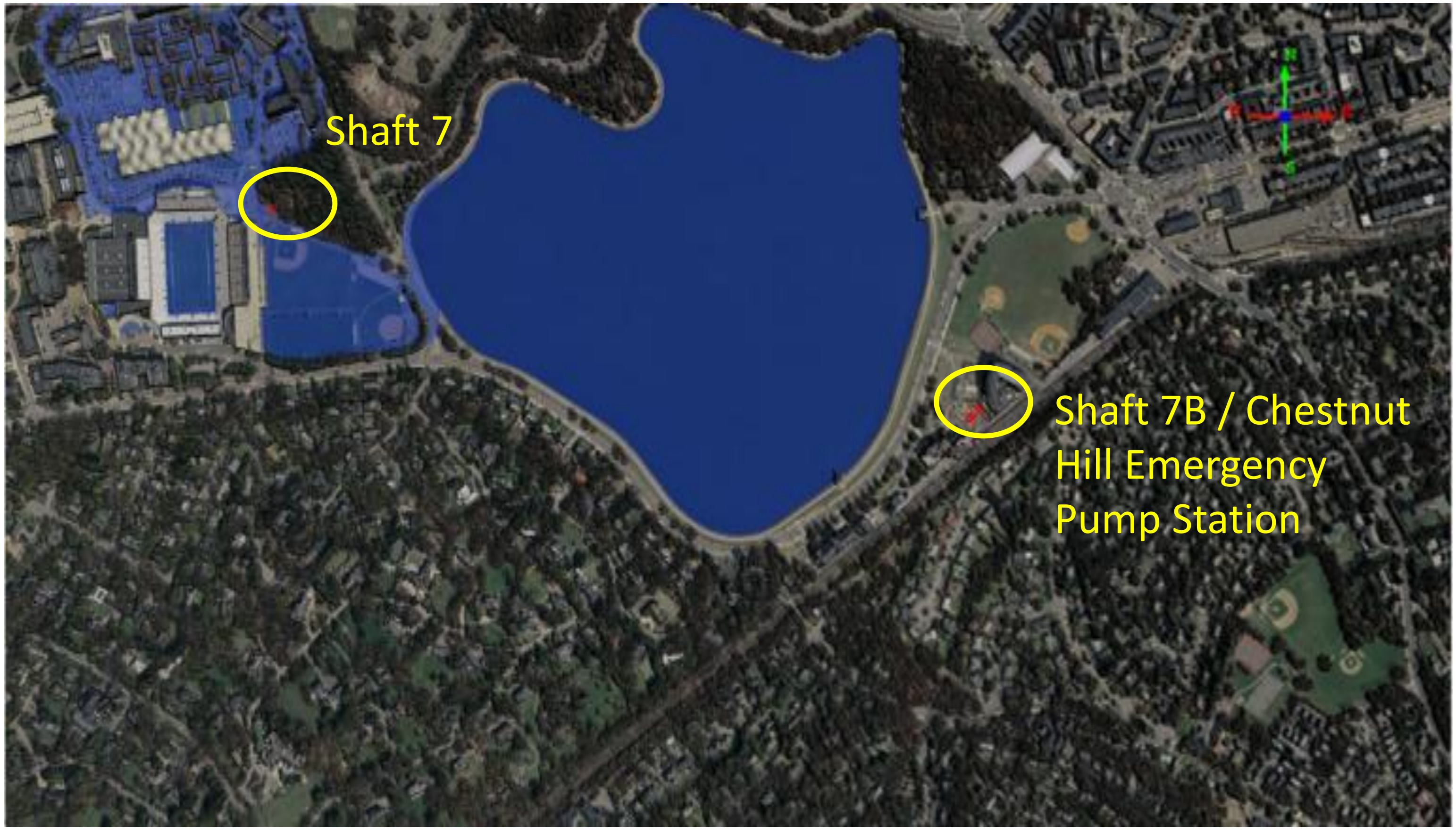


Location of Concern – Shaft 7

- Six 54-inch hydraulically actuated Dow Disc valves
- Junction point of all three tunnels
- Valve operability uncertain
- Small diameter piping and valves

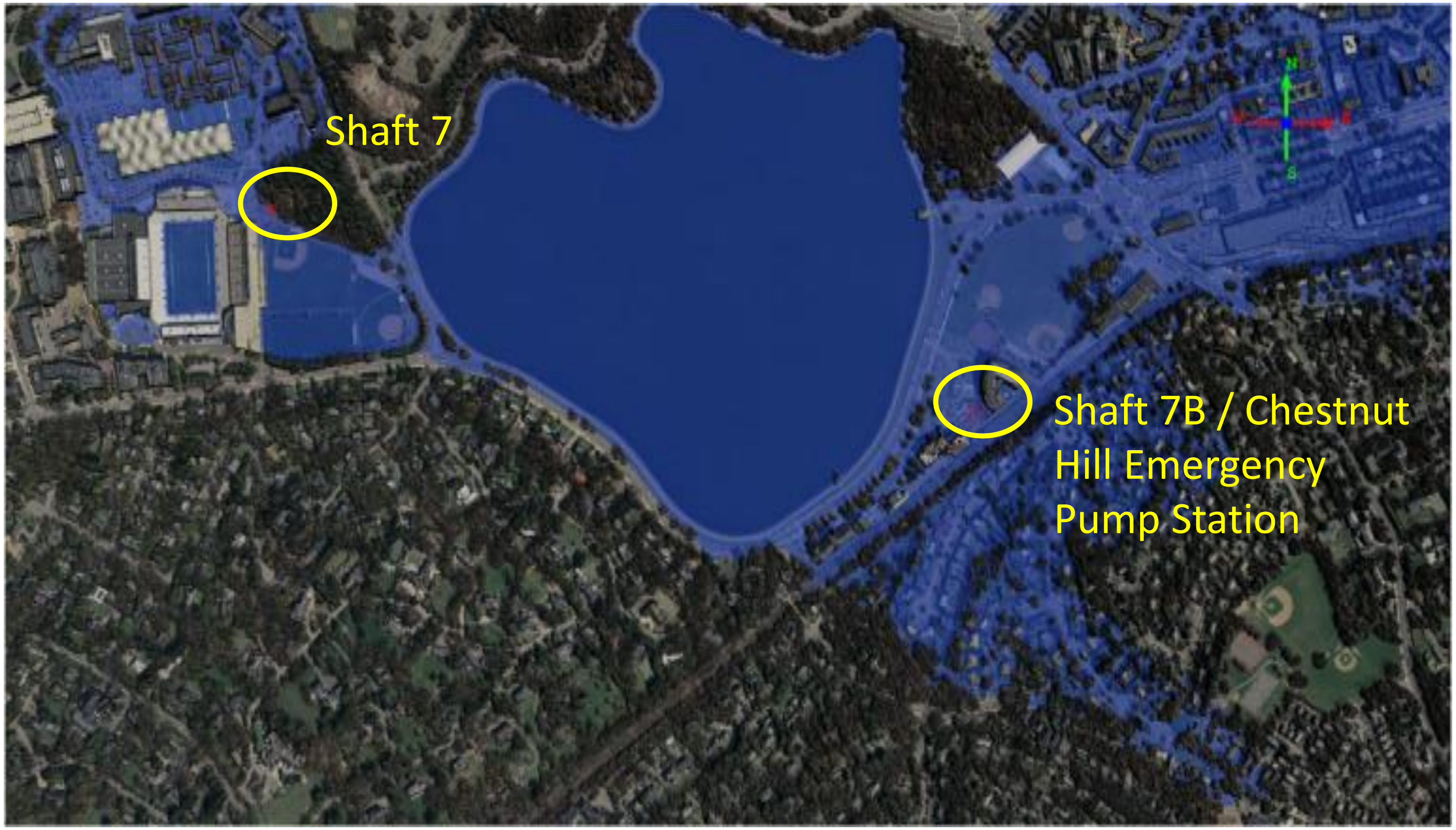
Shaft 7 – Boston College

- Flooding of Boston College

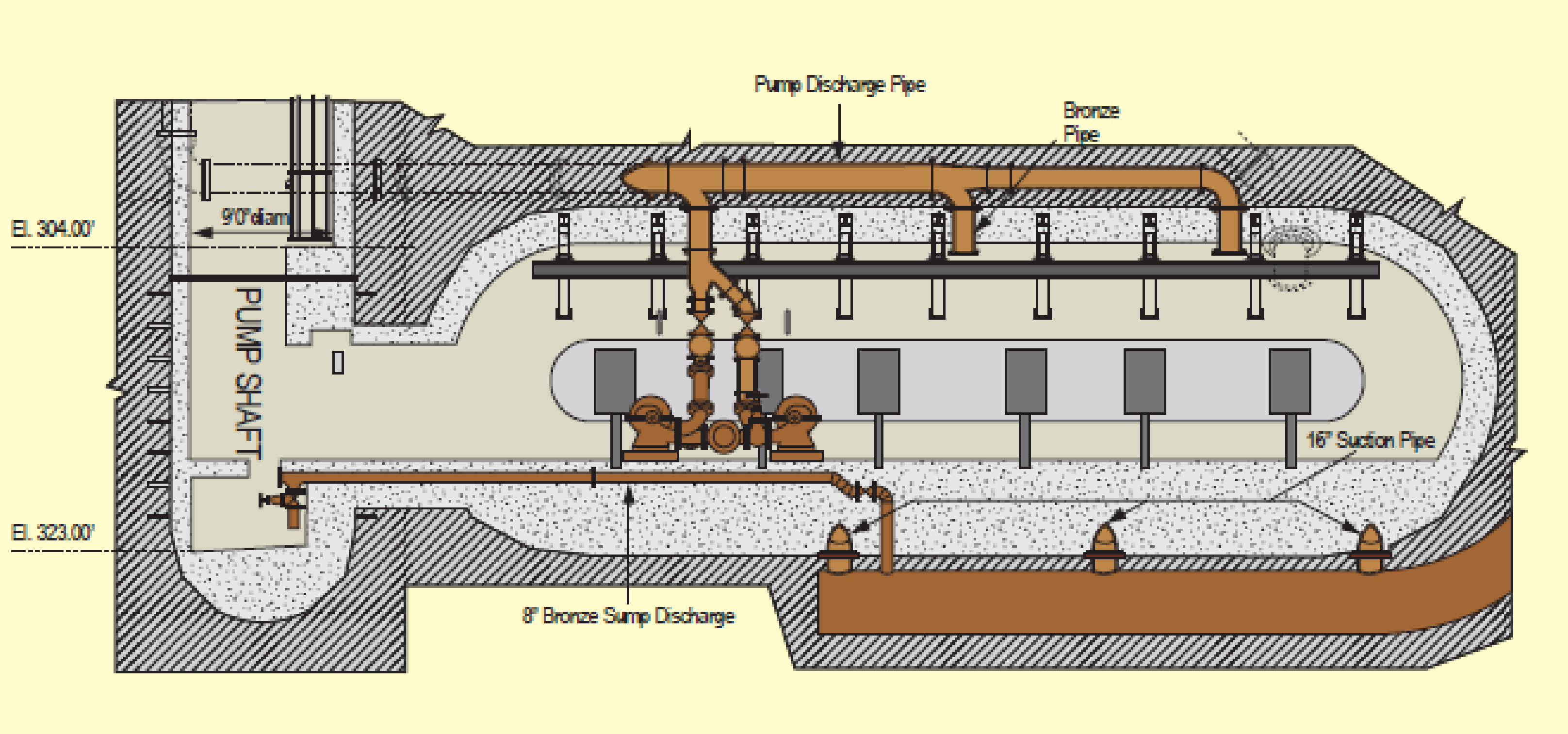


Shaft 7 – Boston College

- Impacts to Chestnut Hill reservoir to Shaft 7B and Cleveland Circle

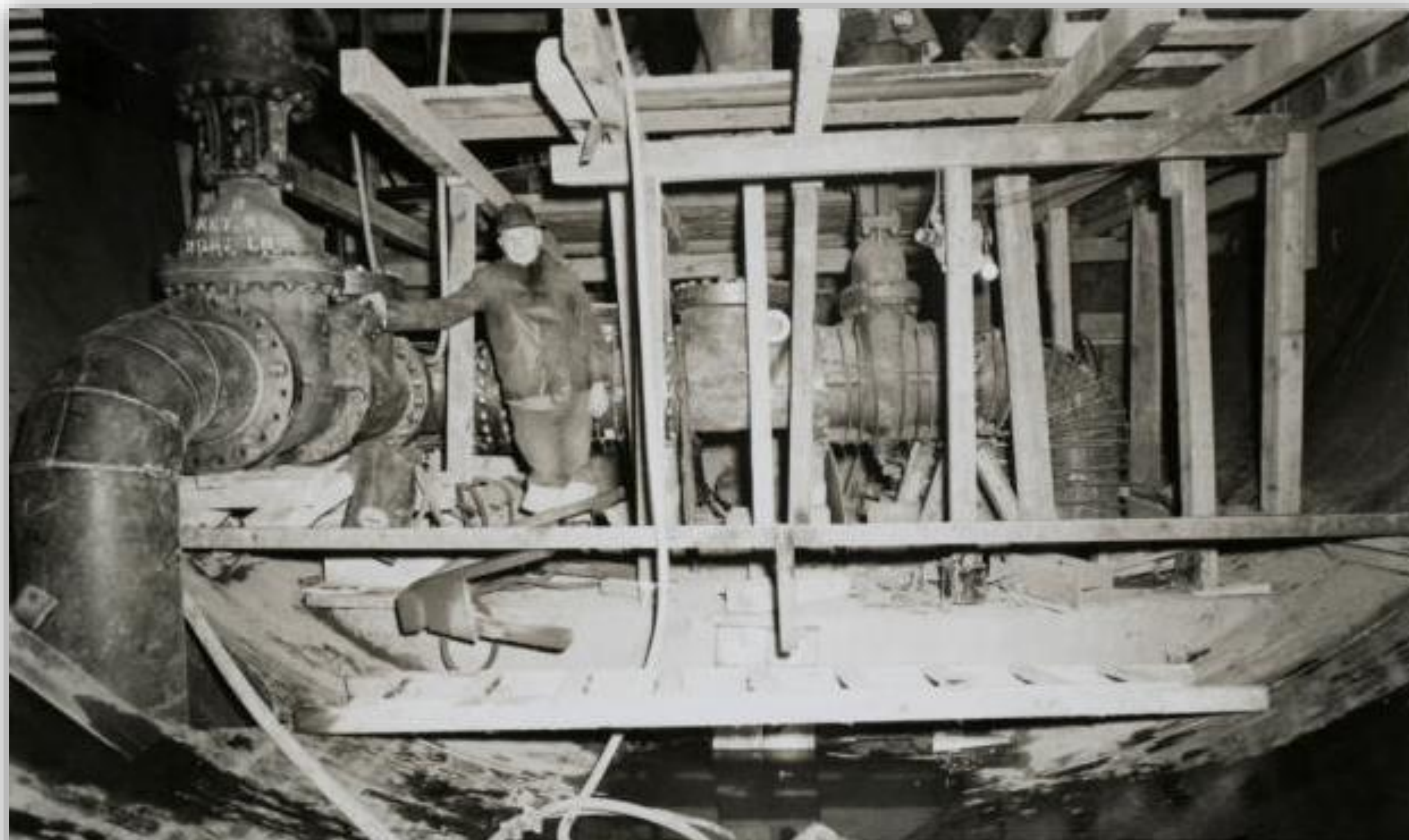


Location of Concern – Shaft 5 & 9 Pump Chambers



- Located at tunnel depth for the purpose of dewatering tunnels
- Access extremely difficult
- High pressure bronze pipes connect tunnel to dewatering pumps
- Smaller diameter piping from hydraulic valve actuators to surface

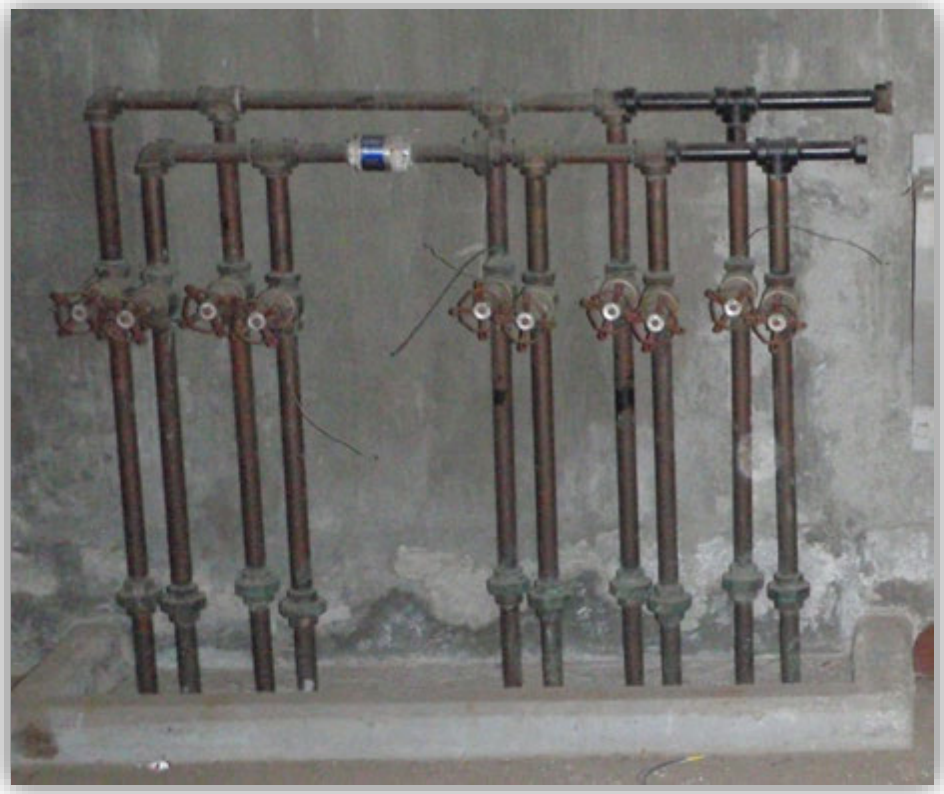
Shaft 9 Pump Chamber



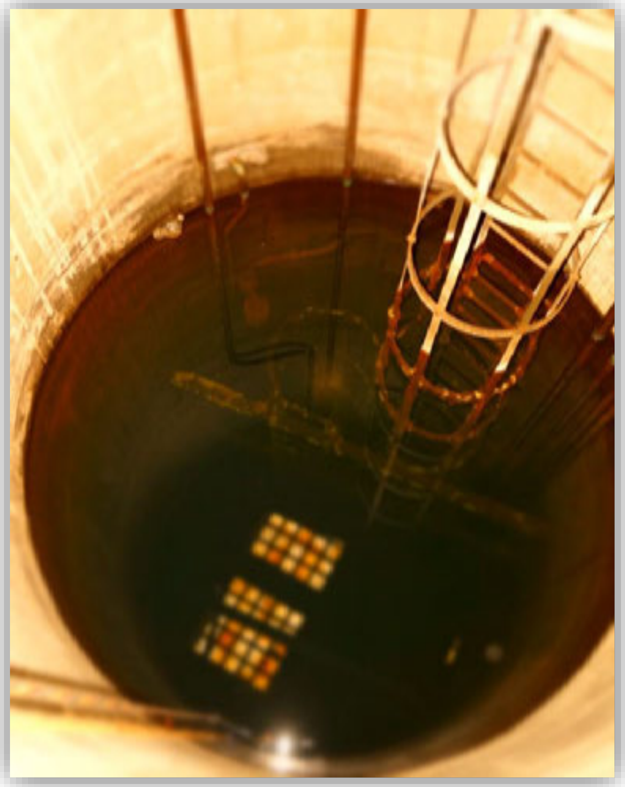
16" hydraulic valves and fittings - Looking N'ly from shaft -
Shaft #9 - City Tunnel Ext. - Contract 193 - 2/3/58 -
Photo Barbier -
193-181

Shaft 9 Pump Chamber

- Shaft 9 also has a hydraulically actuated tunnel isolation valve
- Access shaft and pump chamber have been submerged for decades

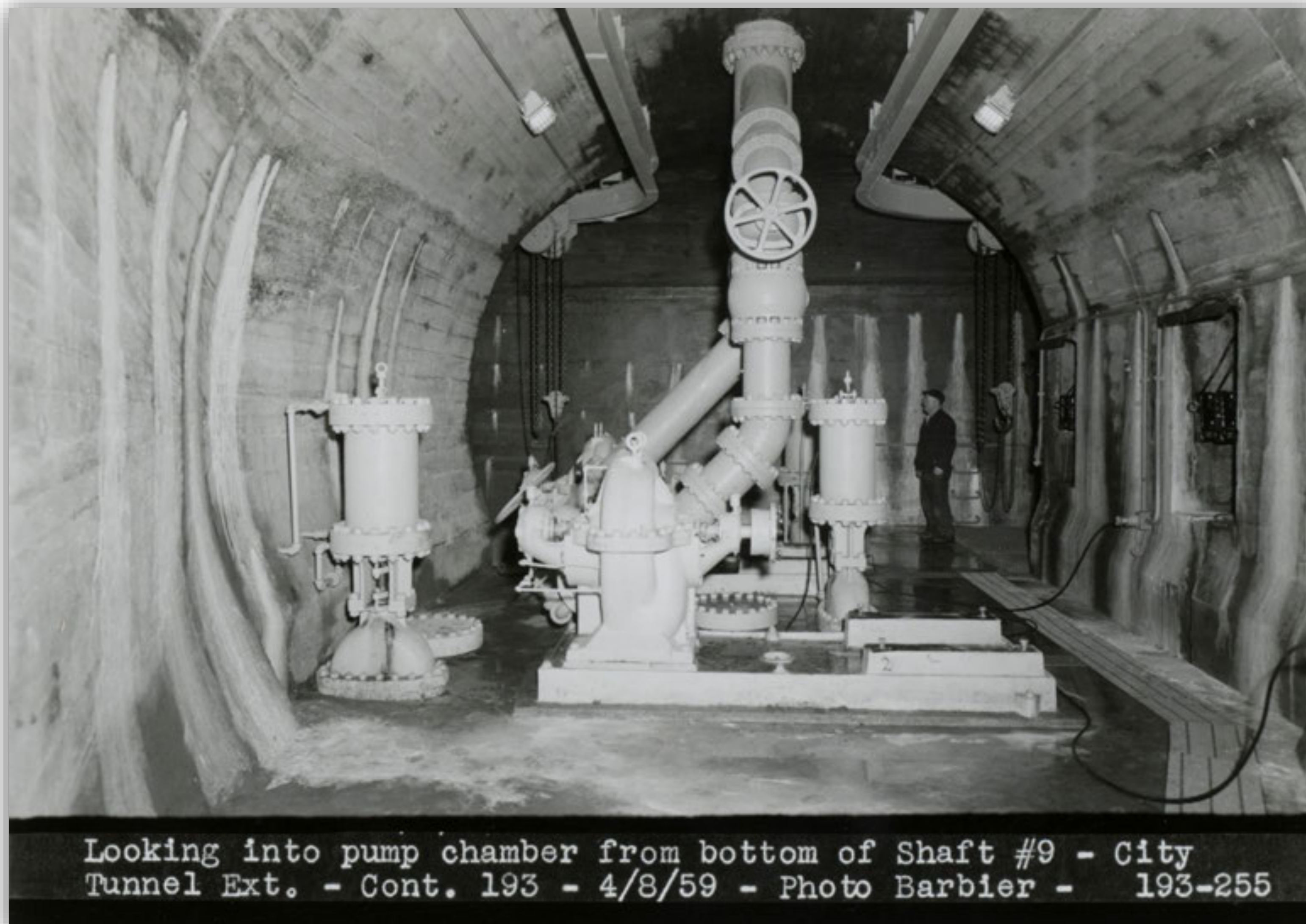


Valve control piping still present in both shaft buildings



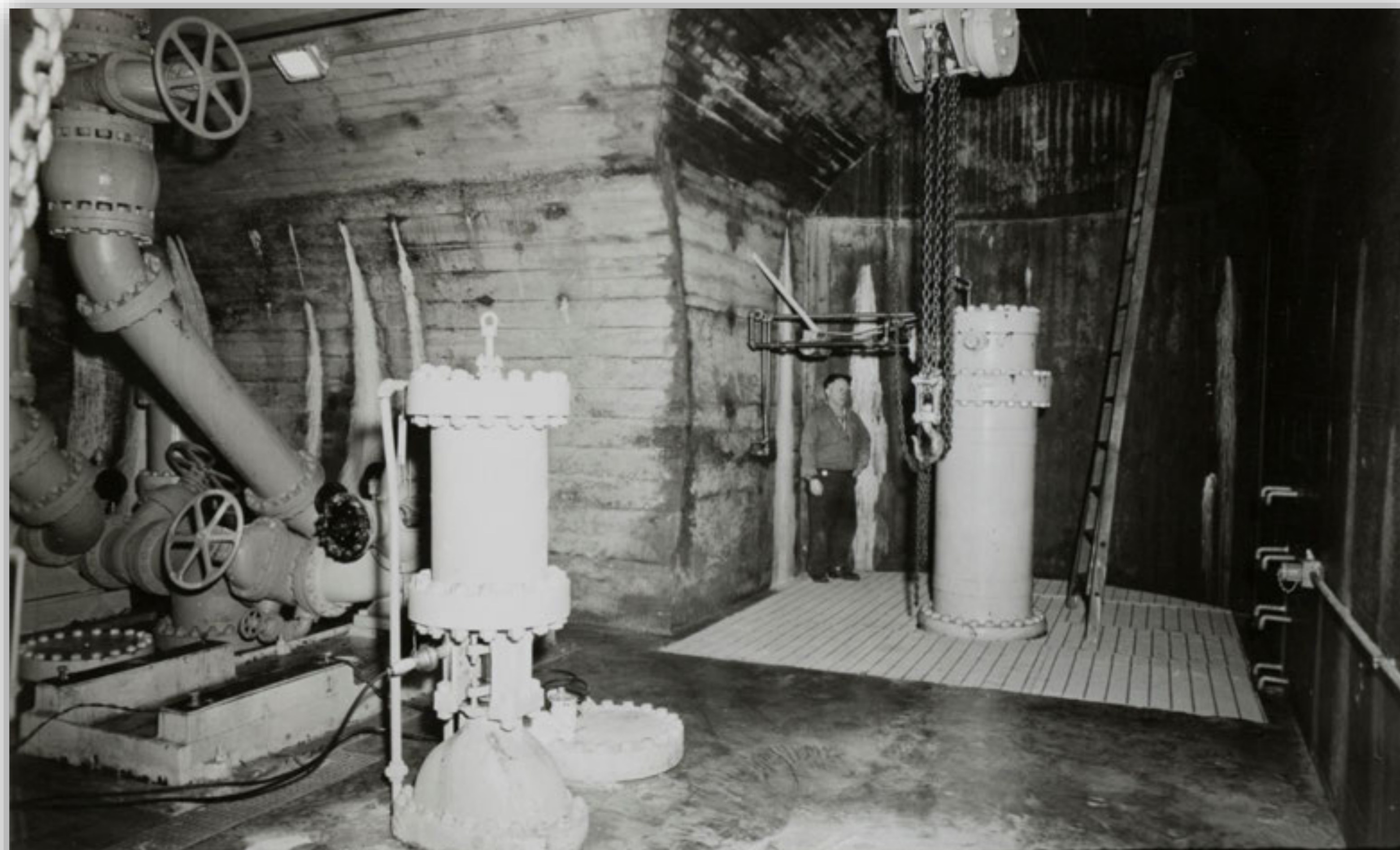
Shaft 9 access shaft is full of water

Shaft 9 Pump Chamber



Looking into pump chamber from bottom of Shaft #9 - City Tunnel Ext. - Cont. 193 - 4/8/59 - Photo Barbier - 193-255

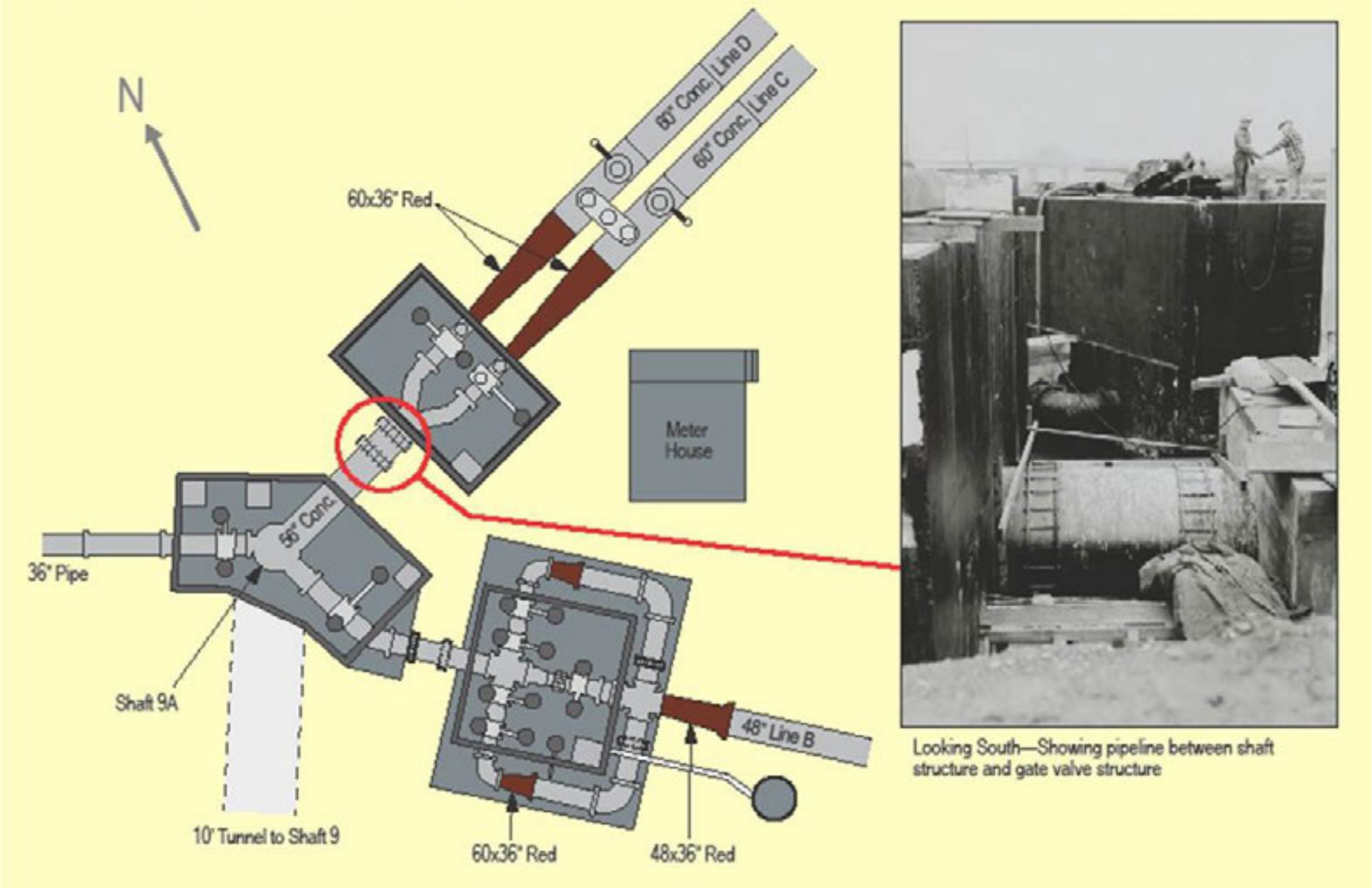
Shaft 9 Pump Chamber



Shaft #9 pump chamber - Cylinder at right operates 48" valve to Malden Tunnel - Left cylinder operates 16" dewatering line City Tunnel - Cont.193 - 4/9/59 - Photo Barbier - 193-257

Location of Concern – Shaft 9A

- Couplings on pipeline located between tunnel shaft and isolation valves



Looking South—Showing pipeline between shaft structure and gate valve structure

Tunnel System Shut-down Impacts

Planned Shut Down – Service to the North

- Partially supplied communities use alternate supplies
- Gillis Pump Station / Spot Pond Pump Station
- Reconfigure Northern High piping
- Pump from Open Spot Pond Reservoir (BOIL ORDER) 1-2 months at average day demand; 1-3 weeks at high day demand
- Replenish from Low Service supply lines (WATER RESTRICTIONS)

Planned Shut Down – Service to the South

- Partially supplied communities use alternate supplies
- Chestnut Hill Emergency Pump Station
- Surface Mains to Blue Hills Tanks (PRESSURE SWINGS / BREAKS)
- Pump from Chestnut Hill Reservoir (BOIL ORDER)
- Replenish from Sudbury Aqueduct

Shut Down Sometimes Unplanned

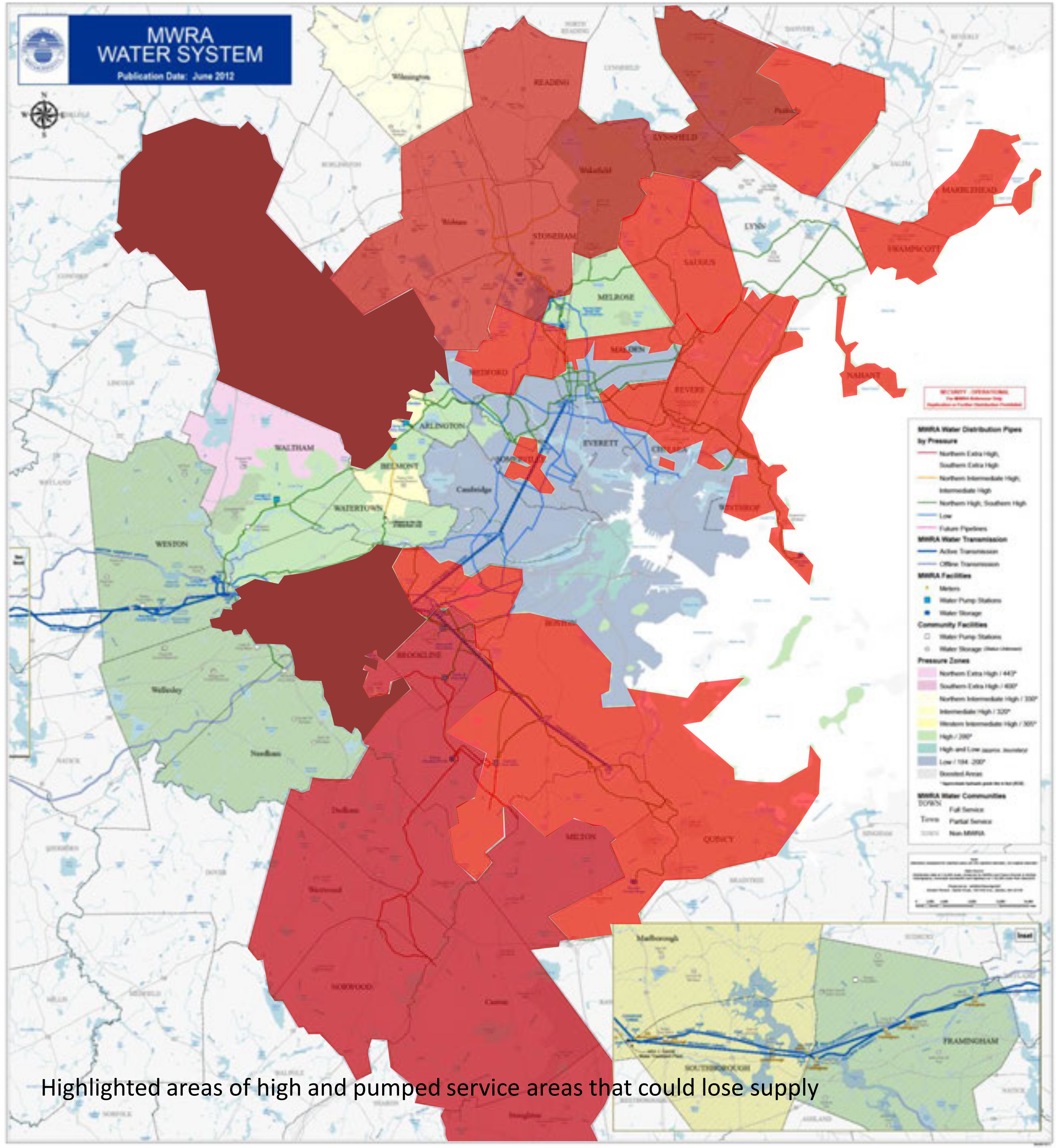
- Flooding/damage/public safety concerns
- May not have time to set up back up systems

Shut-down and Isolation Takes Time

- Extent of shut-down depends on failure
- Numerous shaft locations to isolate / multiple valves at some
- Some chambers require pumping
- Valve turn counts / time to close on the order of 45 minutes each

Wide-Spread Impact

- Sudden shut down of Metropolitan Tunnel system
- Loss of supply to high service areas
- Pumped Service Areas lose supply as tanks empty
- Whole system would be on boil order



Highlighted areas of high and pumped service areas that could lose supply

Economic Impact – Total Water Loss

- Daily Business Impact: $208 million
- Daily Residential Impact: $102 million

- Economic Impact for Total Water Loss - One Day:
  - $310 million

- Economic Impact for Total Water Loss - Three Days:
  - $930 million

Analysis based on guidelines in FEMA Benefit-Cost Analysis Version 4 standard

Service Restoration

- Activate back-up supplies
- Large areas of MWRA and community systems will need to be refilled SLOWLY to avoid breaking lines
- Flushing to remove air pockets could take days if not weeks
- Water Quality Samples to assure public

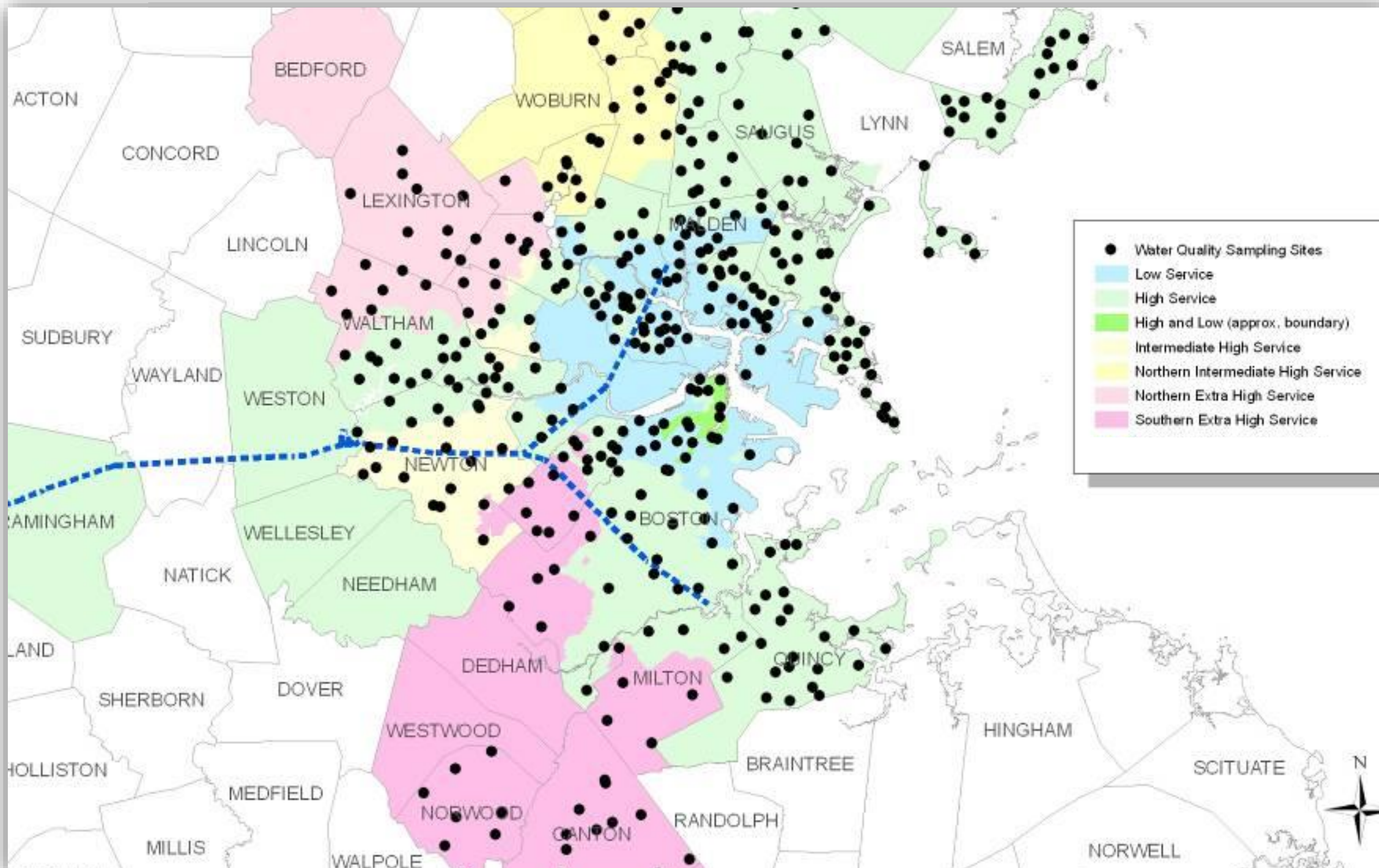
Economic Impact – Boil Order

- Daily Business Impact: $195 million
- Daily Residential Impact: $102 million

- Economic Impact for Boil Order – One Week:
    - $2.1 billion

Analysis based on guidelines in FEMA Benefit-Cost Analysis Version 4 standard

Water Quality Sample Locations



Break

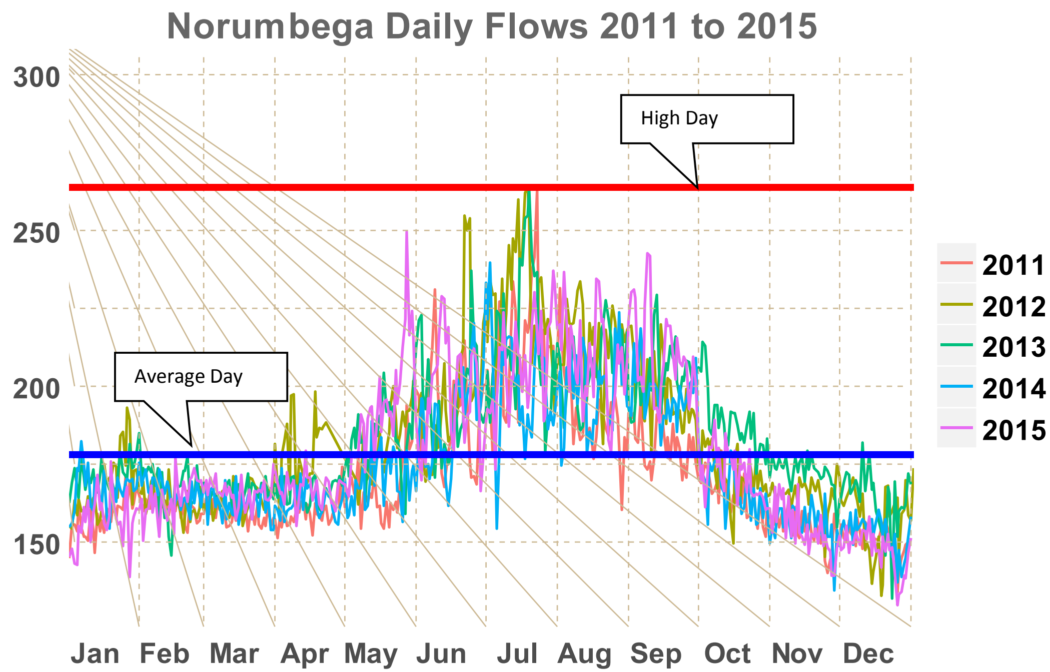
Strategic Goals for Redundancy Improvements

Water System Operating Goals

- Operating Goals:
  - Protection of Public Health
  - Providing Sanitation
  - Fire Protection

- Average day demand

- High day demand preferred
  - Longer shut downs possible



Strategic Goal for Redundancy Improvements

- Emergency-Only Capability
  - Utilize only if failure occurs
  - Does not allow planned maintenance
  - Decrease in level of service
  - Potential for damage to MWRA and community systems
- Planned Shut-Down Capability Preferred
  - Allows maintenance of system
  - Maintenance reduces risk of failure
  - Meet customer expectations for excellent quality water
  - Minor impact on normal service

National Guidance, Peer Organizations and Redundancy Planning at MWRA

National Guidelines and Standards for Redundancy

- Recommended Standards for Water Works ("10 States Standards"):
  - "Redundancy…should be incorporated into the design to eliminate single points of failure…"
- EPA Guidance 2011:
  - "Reduce outage risk through system redundancy/resiliency and repair capabilities…"

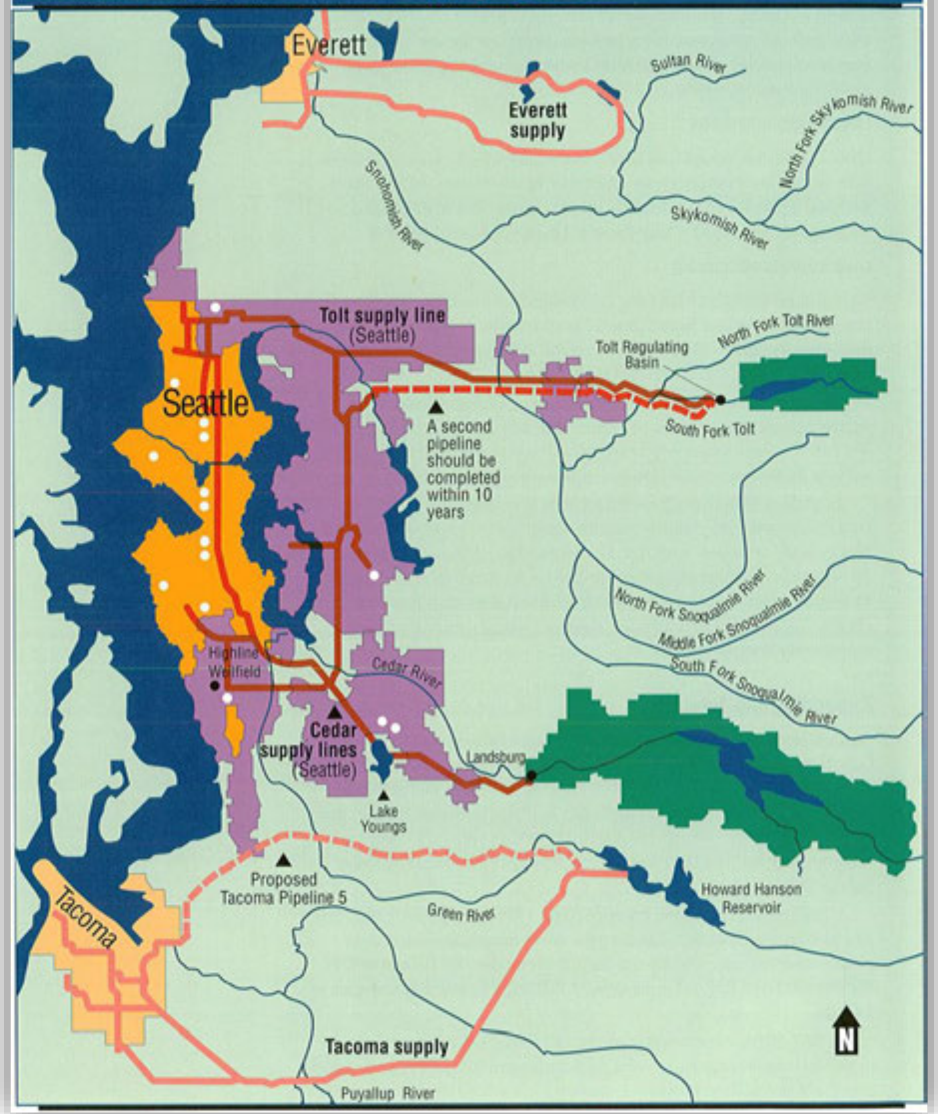
Example Peer Organization Redundancy Programs: San Francisco

- $4.8 billion Water Supply Improvement Program
- Major Transmission and Storage Projects
- Cross Bay Tunnel
- High Day Design Enables Maintenance of Either New or Old Tunnels

Example Peer Organization Redundancy Programs: Seattle

- Two ways to convey water to all parts of their system
- Two separate supply and transmission systems
- Opposite sides of the city
- Two different feed points
- Two separate tanks
- Looped Transmission System

Seattle's regional water supply system



Example Peer Organization Redundancy Programs: New York City

- Tunnel #3 - Designed for Full Redundancy to Tunnels 1 & 2
- Stage 1 and 2 Completed – 27 miles of 24' tunnel
- $4.7 billion through 2013

- $ 1 billion of Supply, Treatment, and Transmission projects will enable taking NYC's largest aqueduct and supply off line for a 2.5 mile Bypass Tunnel and Repairs

AMWA Survey of Redundant Water Sources and/or Treatment Systems - 2016

- 22 Systems Nationwide representing populations of 100K to 1.8 million
  - 8 designed for redundant max day /summer demand
  - 3 designed for most of summer peak
  - 7 designed for at least winter or average day
  - 3 systems can only handle less than an average day
  - 1 system with no redundancy
- MWRA in Lower 25%

Redundancy – It's Always Been a Goal for MWRA Water System

- Redundancy examples in our water system since 1800s:
  - Two basins of Chestnut Hill Reservoir
  - East and West Spot Pond Supply Mains
  - Hultman Aqueduct planned to have two barrels

Future Hultman Aqueduct connection at Shaft 4
(1940)

WASM 1 and 2 Pipe Yard
(1915)

Paired Pump Stations Provide Redundancy

Brattle Court Pump Station (1907)

Spring Street Pump Station (1958) redundancy to Brattle Court

Gillis Pump Station (1899)

Spot Pond Pump Station (2015) redundancy to Gillis Station

Other MWRA Redundancy Projects

- CVA pipeline redundancy
- Hultman interconnections / MetroWest tunnel
- Northern Intermediate High Pipe Loop

New valve chamber connecting MWWST and Hultman Aqueduct at Shaft 5 (2013)

Night work on 36-inch NIH pipeline in Woburn (2016)

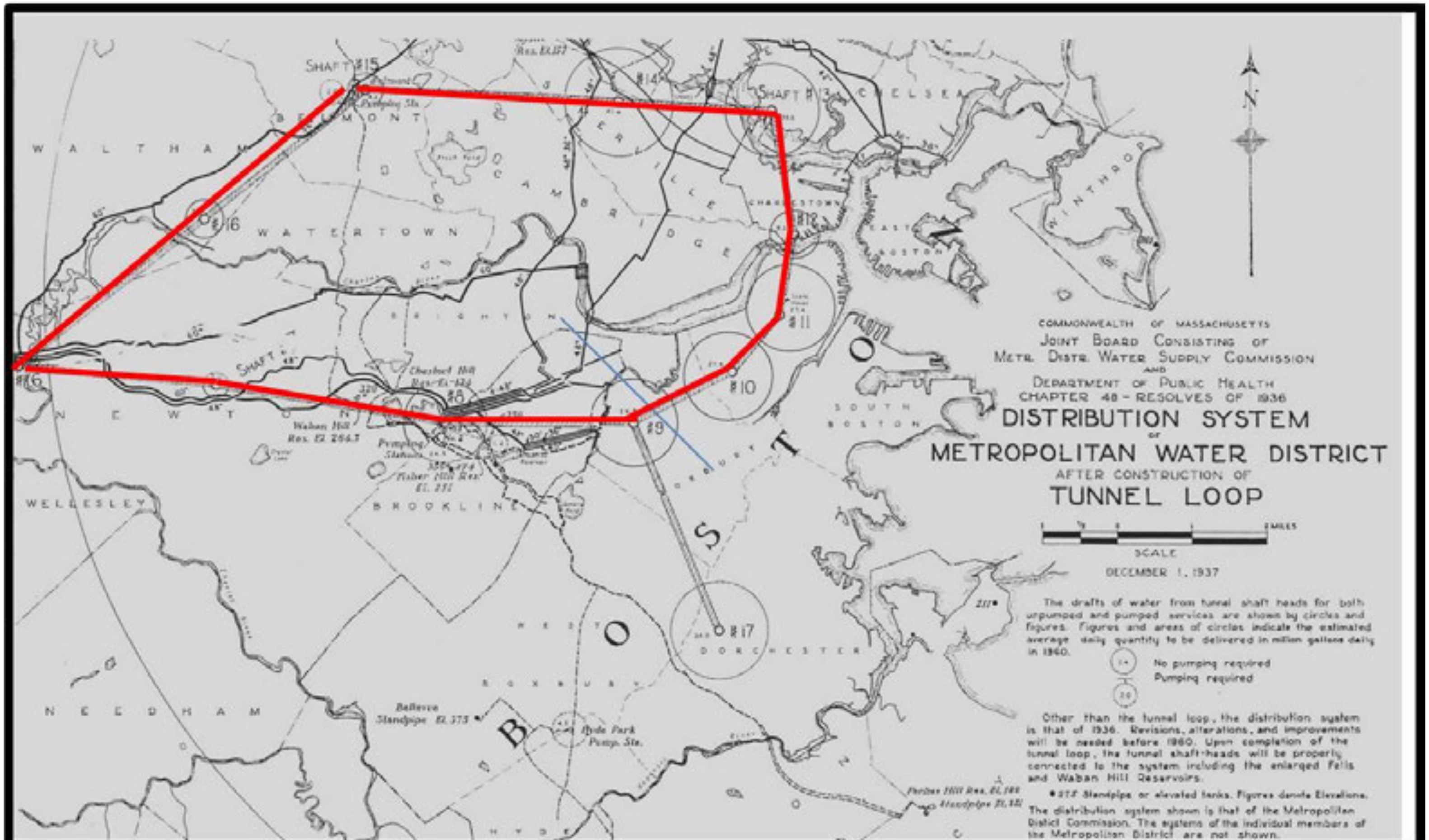
Other MWRA Redundancy Projects

- Southern Extra High Pipe Loop to provide redundant supply to Boston, Norwood, Canton, Stoughton, and Dedham/Westwood

- Wachusett Aqueduct Pump Station to Provide Redundancy to Cosgrove Tunnel between Wachusett Reservoir and Carroll Treatment Plant

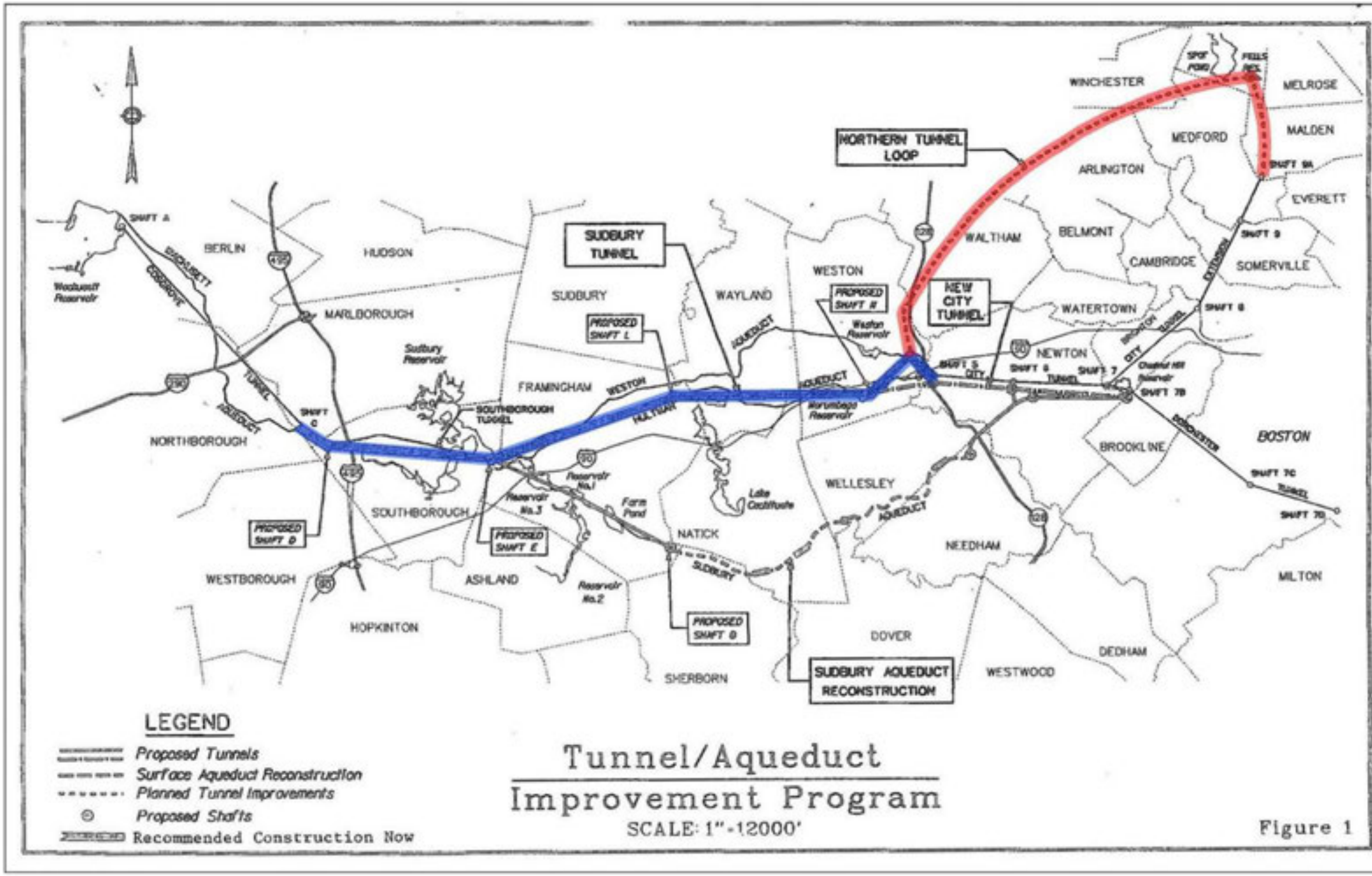
Wachusett Aqueduct Pump Station

Original 1936 Tunnel Loop Plan



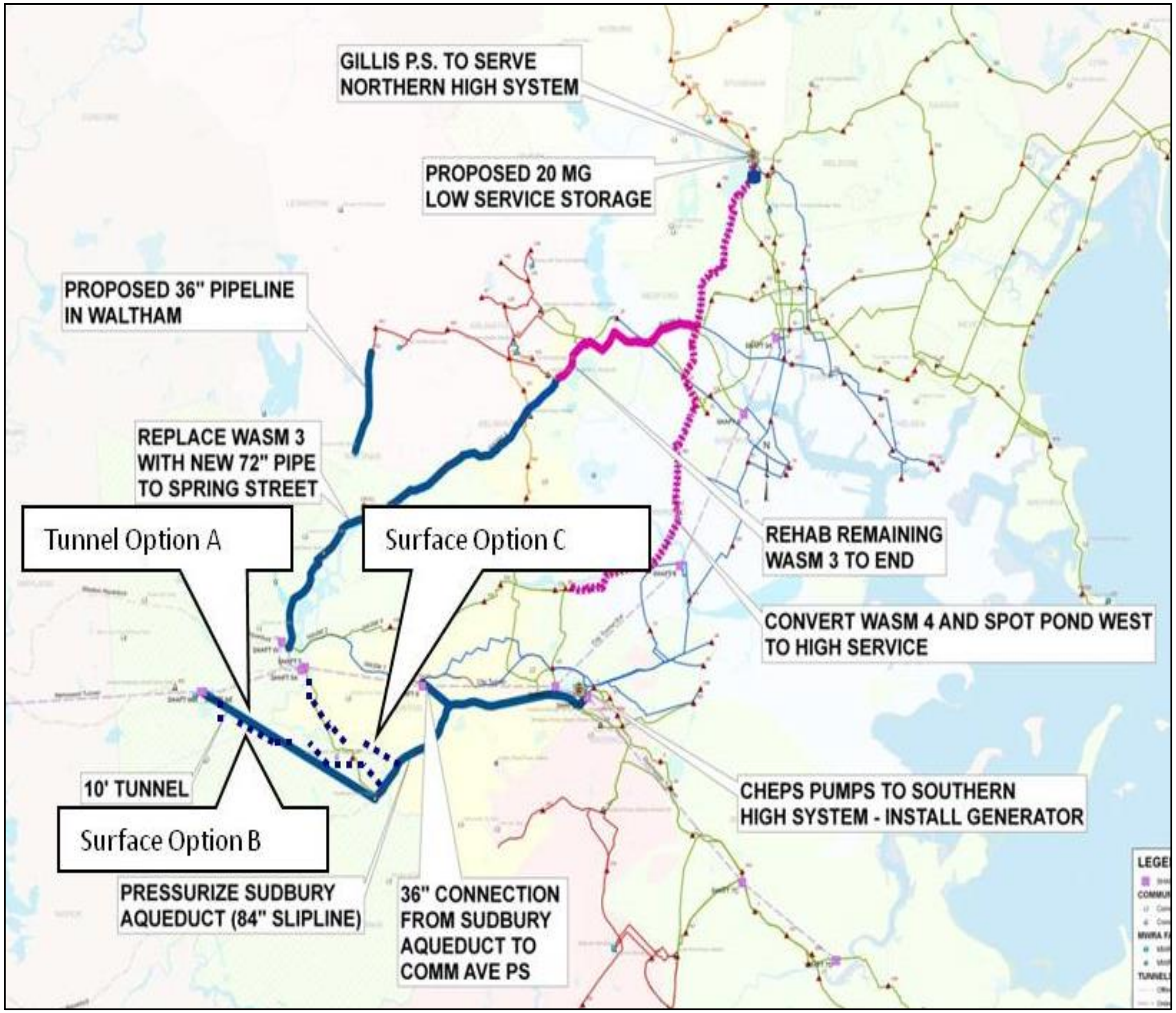
Previous Redundancy Evaluations (continued)

- 1990 Plan – MetroWest Tunnel followed by Northern Tunnel Loop



Previous Redundancy Evaluations (continued)

- 2011 Plan – Surface piping with Northern and Southern Components

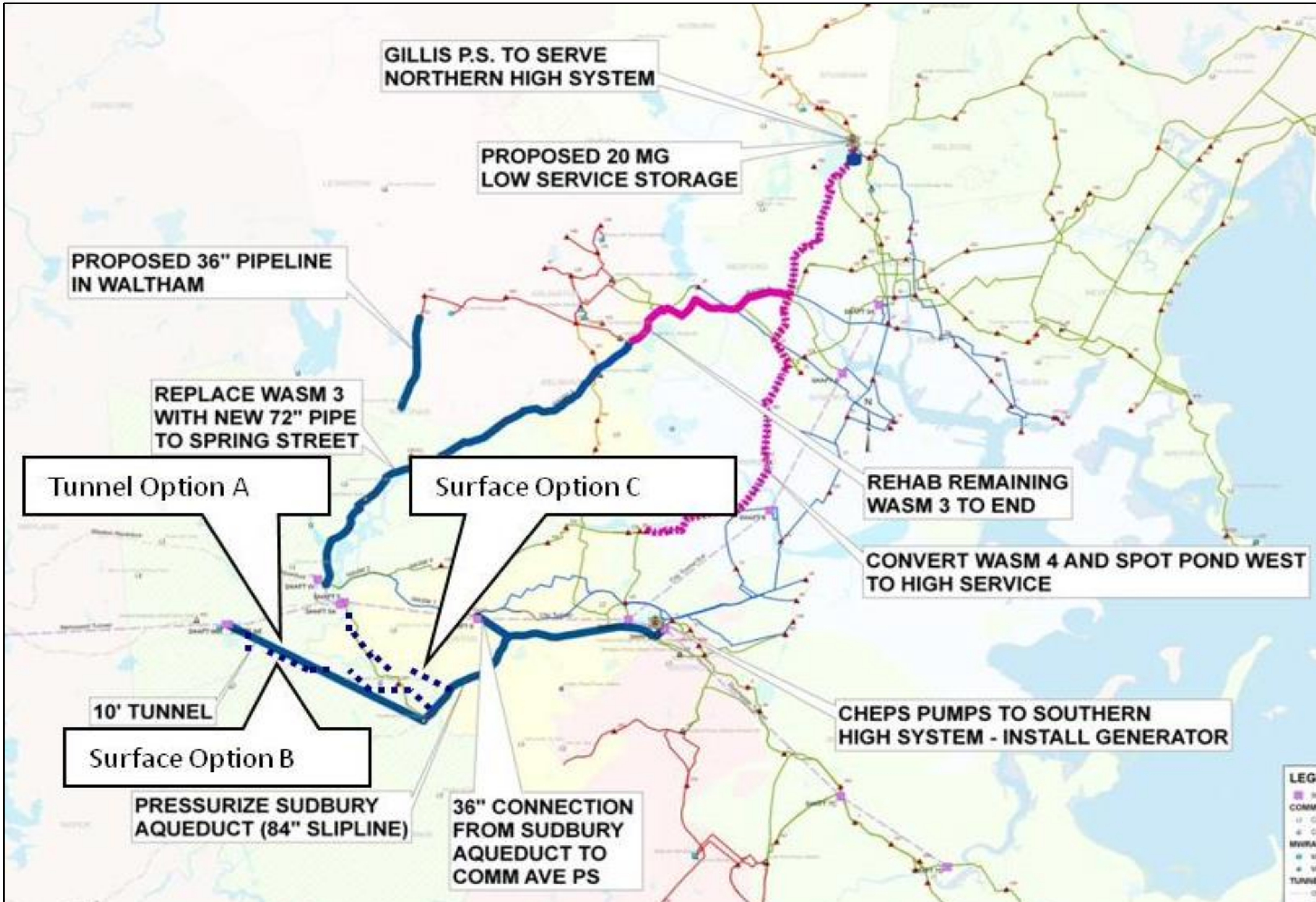


Difficulties Carrying Out 2011 Plan

2011 Redundancy Plan

- 14 alternatives evaluated
- 2011 Proposed Redundancy Plan included
  - 7 miles of 72-inch pipeline construction to the north
  - 4 miles of 84-inch steel pipe slip-lining Sudbury Aqueduct to Chestnut Hill area
  - 4 miles of tunnel or large diameter surface pipe from Norumbega or Shaft 5 area to the Sudbury Aqueduct

2011 Plan – Surface piping with Northern and Southern Components



Impacts of Surface Pipeline

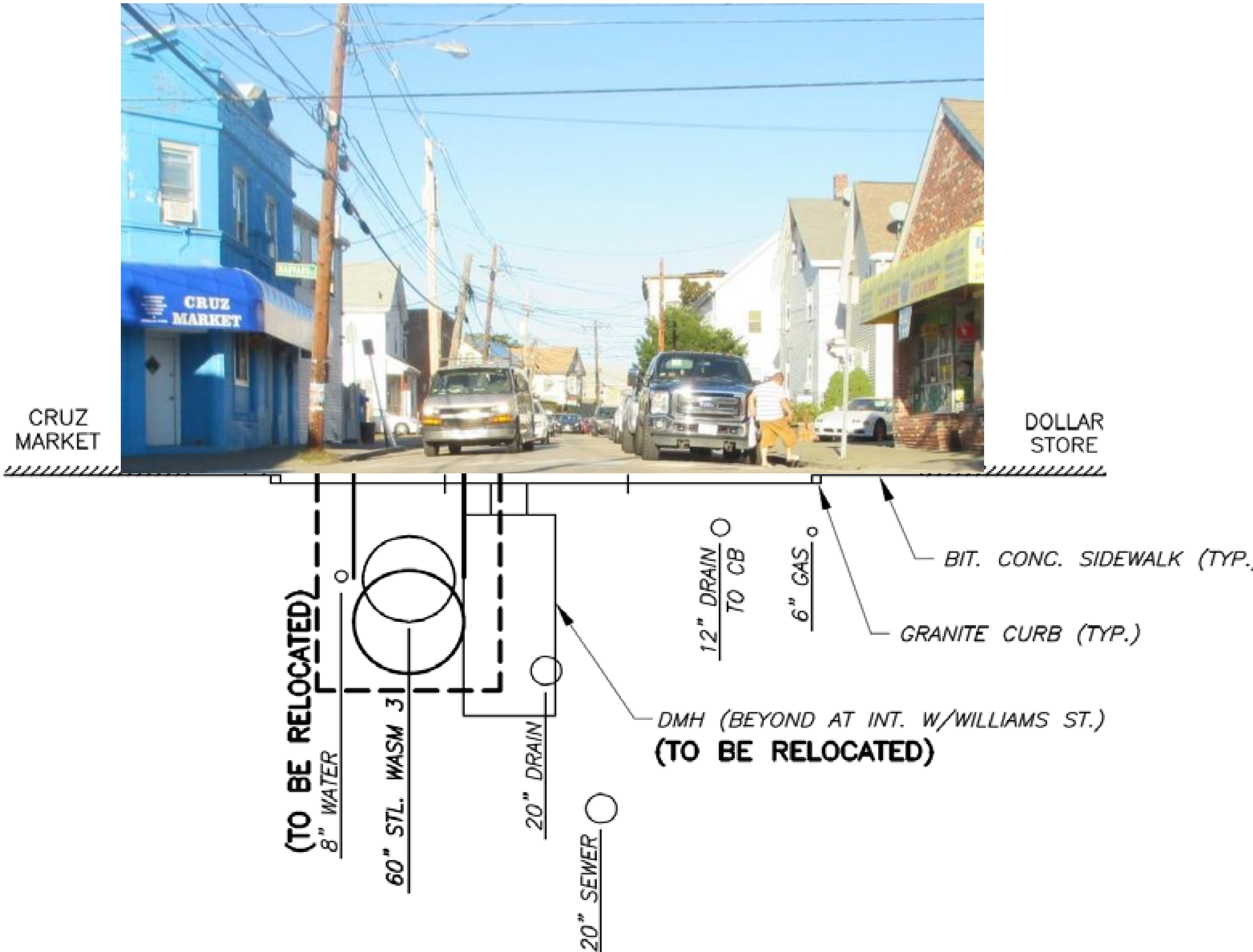
- Traffic
  - Street Closures & Detours
  - Congested City Streets/Gridlock
- Business Disruption
  - Access Disruption
  - Loss of Business
- Permitting & Approval
  - Multiple Environmental and Agency Permits
  - Street Opening Approvals & Fees
- Community Disruption
  - Noise
  - Dust
  - Detours
  - Long Period of Impacts Over Large Areas
  - Mitigation

Newton Street - Waltham

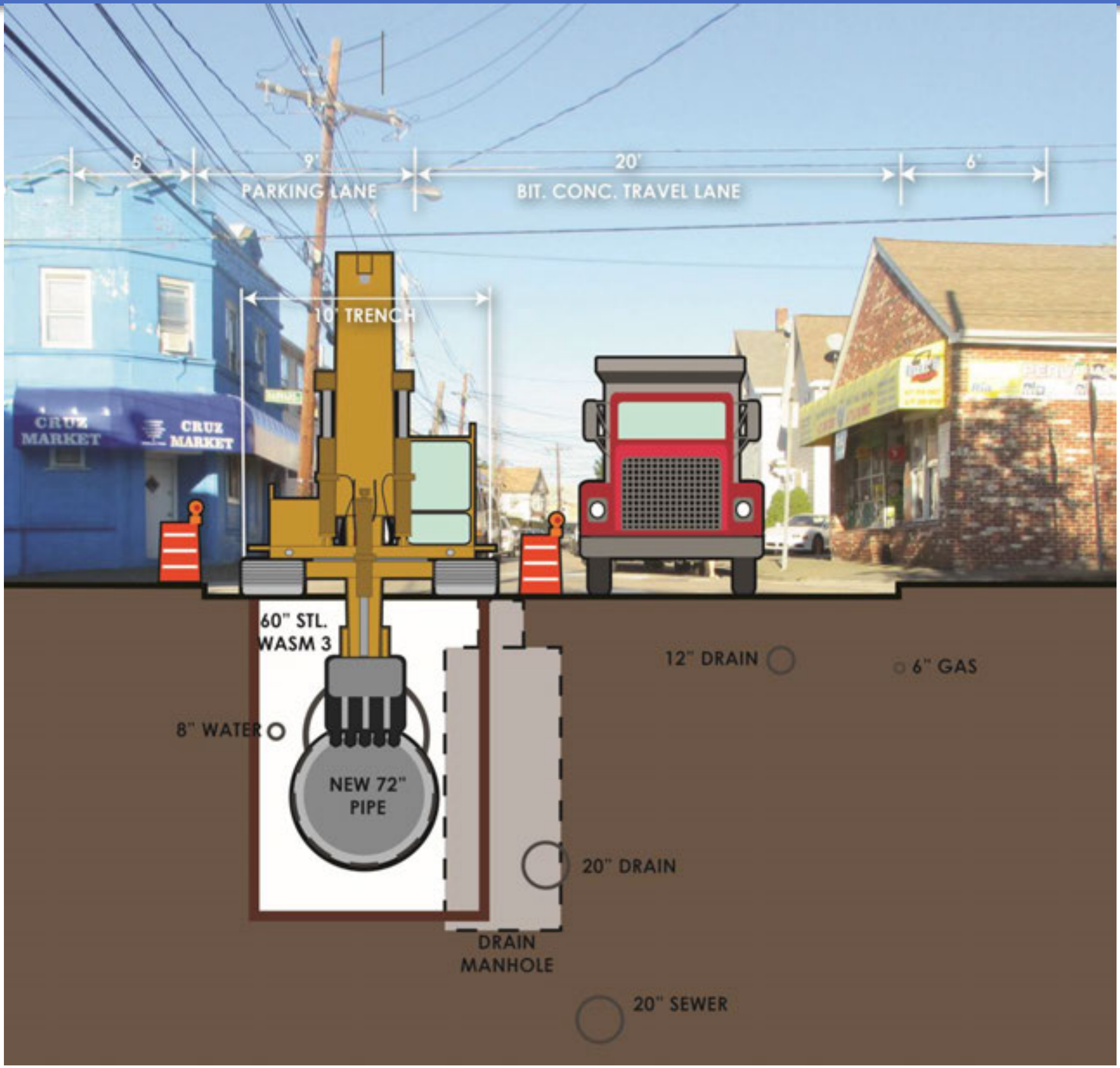
Main Street (Route 20) Waltham

Trapelo Road at Pleasant Street - Belmont

Felton Street - Waltham



Felton Street - Waltham



Construction of 72-inch Spot Pond Pipeline

56-Inch Concrete Pipe – South Boston CSO Project

Other Utilities Have Constructed Tunnels to Avoid Surface Pipe Construction Impacts

- Washington Suburban Sanitary District
  - 5.3 mile tunnel was constructed in 2015 to avoid construction impacts of a surface pipe
- East Bay Municipal Utility District (MUD)
  - 4 mile tunnel to avoid construction impacts to neighborhoods
- Metropolitan Water District of Southern California
  - 9 mile Tunnel in San Bernardino to avoid construction impacts and seismic concerns

Evaluation of Alternatives

Re-evaluation of Alternatives

- Due to the major impacts of miles of large pipe construction, additional tunnel alternatives were evaluated

- Previous and new alternatives were evaluated including pipelines, pumping and tunnels

  - 13 alternatives to the north
  - 14 alternatives to the south

Six Categories of Alternatives

North

- No new pipes - Push northern system to its limits
- Replace WASM 3 with larger pipe or construct new pipe and/or add pump station
- Construct tunnel to north

South

- New tunnel or pipeline from Norumbega or Shaft 5 area to Chestnut Hill and upgrade Chestnut Hill Emergency Pump Station
- New pipe to southern surface mains with or without new Pump Station
- Tunnel to Dorchester Tunnel Shaft 7C

Baseline Components For All Alternatives

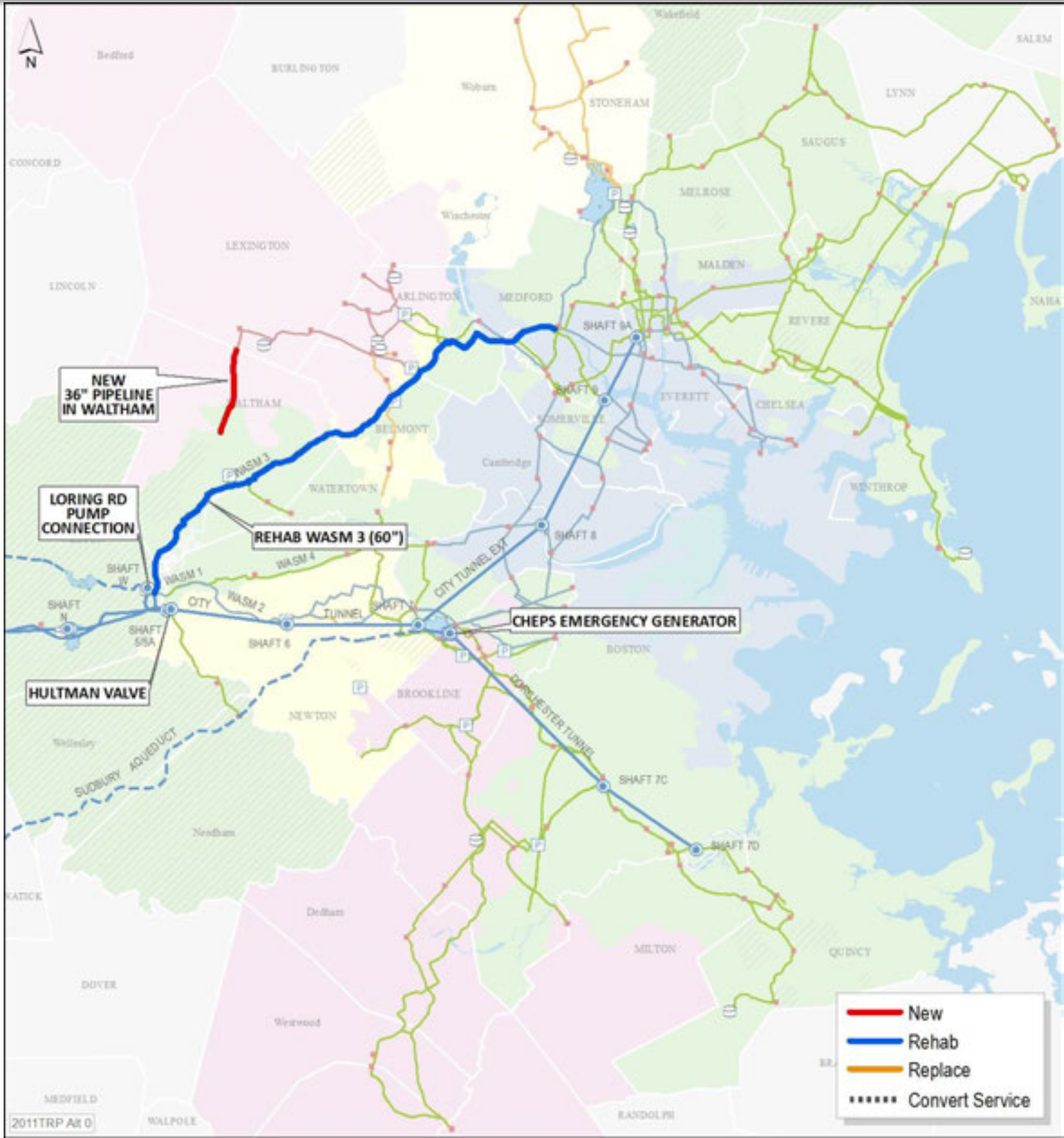
Baseline Construction:

- Rehabilitate WASM 3
- CHEPS Emergency Generator
- New Loring Road pump connection
- New Hultman valve
- New 36” Waltham pipeline

Cost to Complete:

$145M

(Midpoint of Construction)

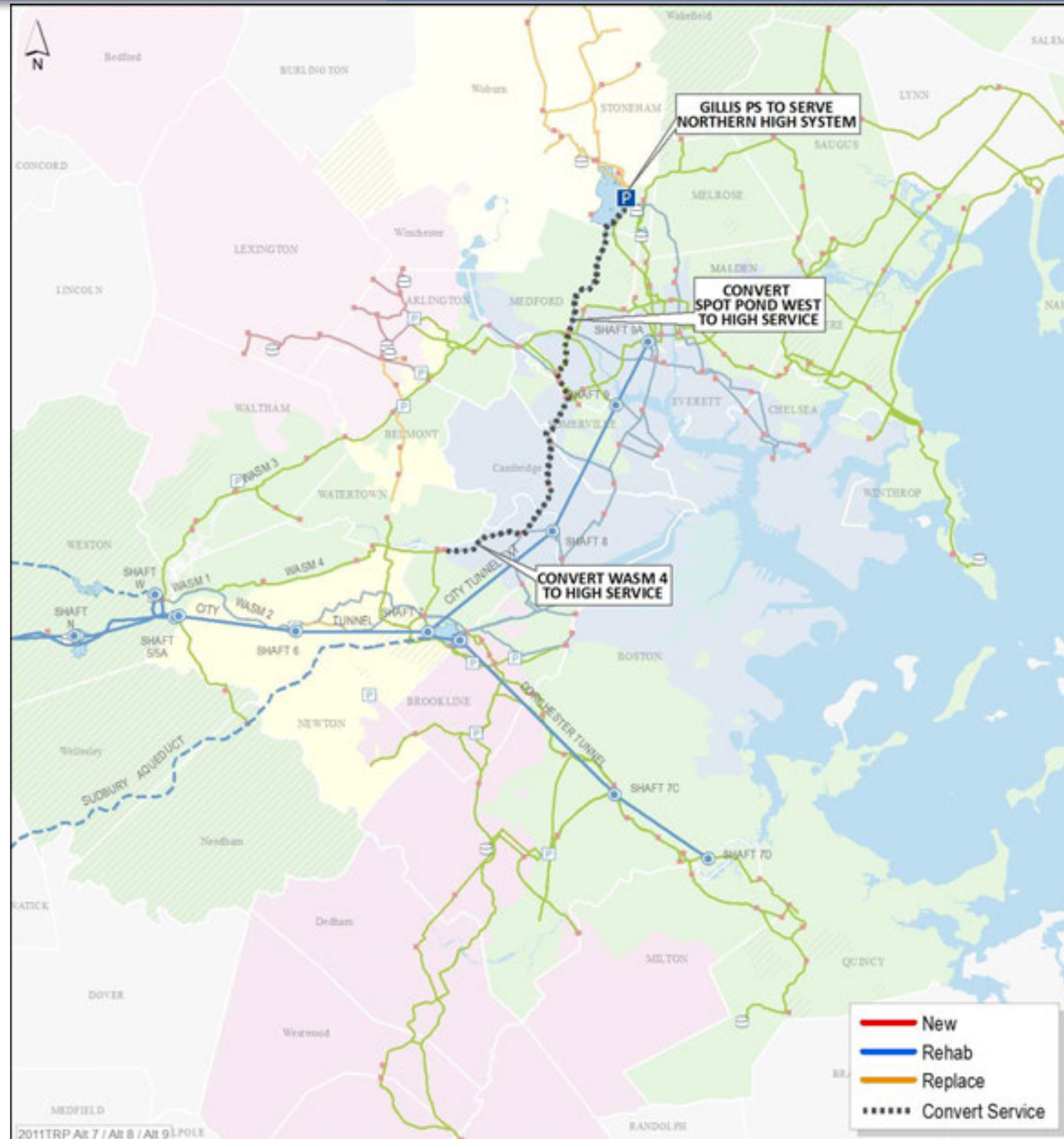


Northern Component – Category 1 (one alternative) Push Existing System to Its Limits

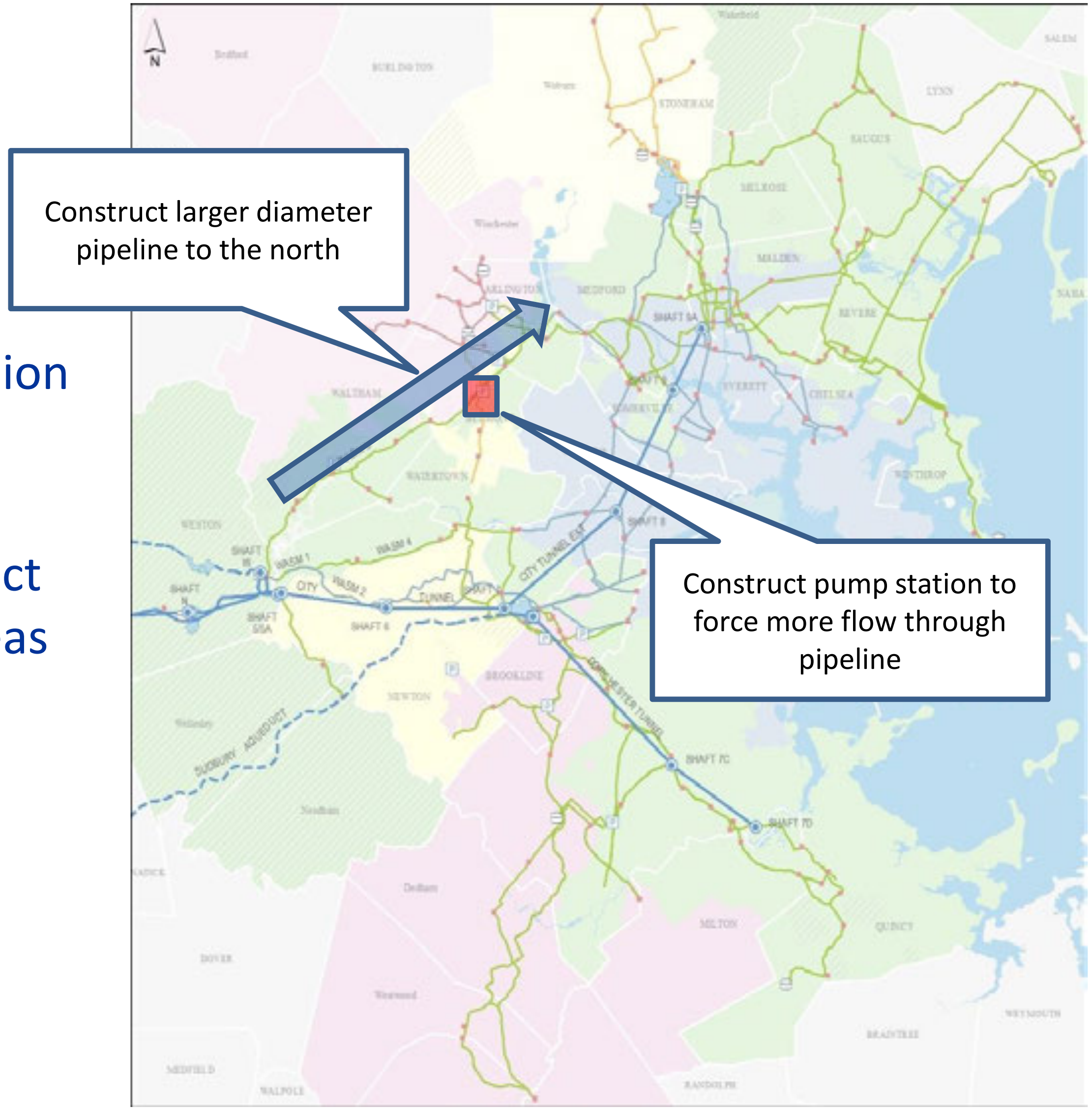
Convert part of WASM 4 and entire West Spot Pond pipeline to high service

- Cost: $10 million (one alternative)
- Cannot supply summer season demands
- Not reliable for planned maintenance shut down of tunnel system
- Could be used as contingency plan for emergency use while long term solution is being implemented
- Potential pipe replacement

Cost is midpoint of construction. Does not include WASM 3 baseline work



Northern Component – Category 2
Increase Capacity to North (Larger Pipe and/or Pump Station)



- Cost: $138 million - $473 million (six alternatives)
- Large diameter pipelines are extremely difficult to construct through congested urban areas
- Pump station could cause potential pressure surges in distribution system

Cost is midpoint of construction. Does not include WASM 3 baseline work

Northern Component – Category 2
Increase Capacity to North (Larger Pipe or Pump Station)

Alt 2N

Alt 3N

Alt 4N *

Alt 5N

Alt 6N

Alt 7N

Northern Component – Category 3
Increase Capacity to North (Tunnel)

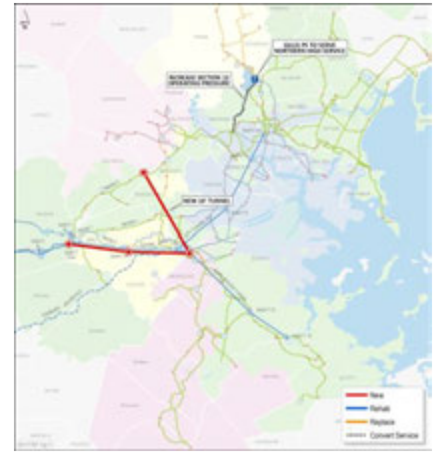
- Cost: $472 million - $1,292 million (six alternatives)
- Construction impacts would be limited to shaft construction sites and pipe connections
- Would provide redundancy to WASM 3 pipeline
- Meets redundancy goals under all demands
- Allows year round maintenance of tunnel system (in combination with a southern solution)

Cost is midpoint of construction. Does not include WASM 3 baseline work

Northern Component – Category 3
Increase Capacity to North (Tunnel)

Alt 8N *

Alt 9N



Alt 10N

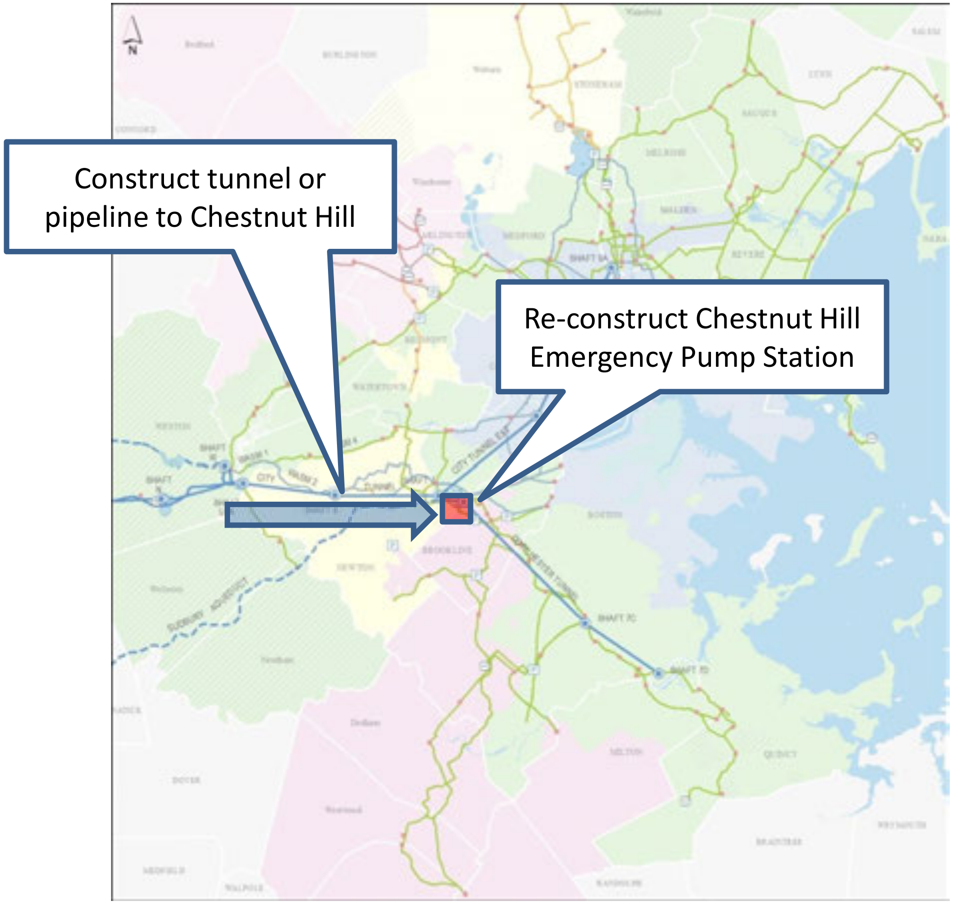
Alt 11N

Alt 12N

Alt 13N

Southern Component – Category 1
Increase Capacity to Chestnut Hill (tunnel or pipeline)

- Cost: $293 million - $629 million (nine alternatives)
- Large diameter pipelines are extremely difficult to construct through congested urban areas
- Pump station would cause higher pressures and potential surges in distribution system



Cost is midpoint of construction. Does not include WASM 3 baseline work

Southern Component – Category 1
Increase Capacity to Chestnut Hill (tunnel or pipeline)

Alt 5S

Alt 6S

Alt 7S

Alt 9S

Alt 11S

Alt 12S

Southern Component – Category 1 (continued)
Increase Capacity to Chestnut Hill (tunnel or pipeline)

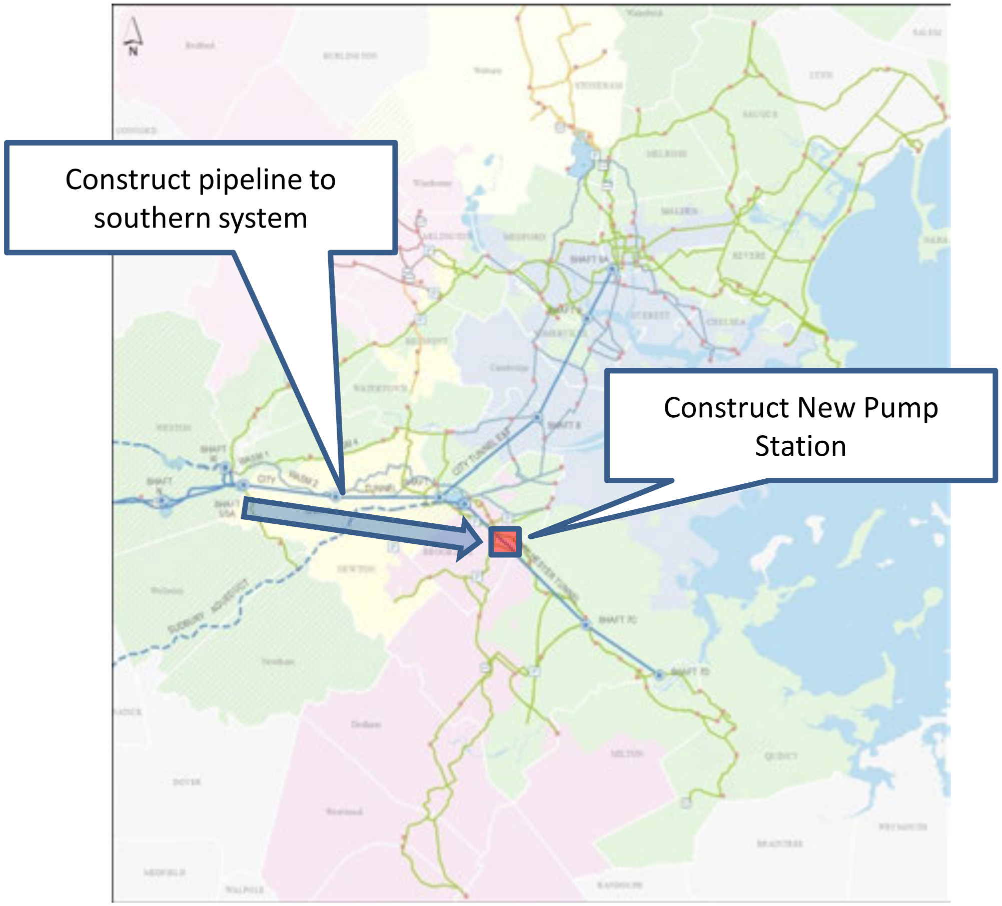
Alt 14S

Alt 15S *

Alt 16S

Southern Component – Category 2
Increase Capacity to South (pipeline with or without pump station)

- Cost: $363 million - $390 million (two alternatives)
- Large diameter pipelines are extremely difficult to construct through congested urban areas
- Pump station would cause potential damaging pressure surges in distribution system



Cost is midpoint of construction. Does not include WASM 3 baseline work

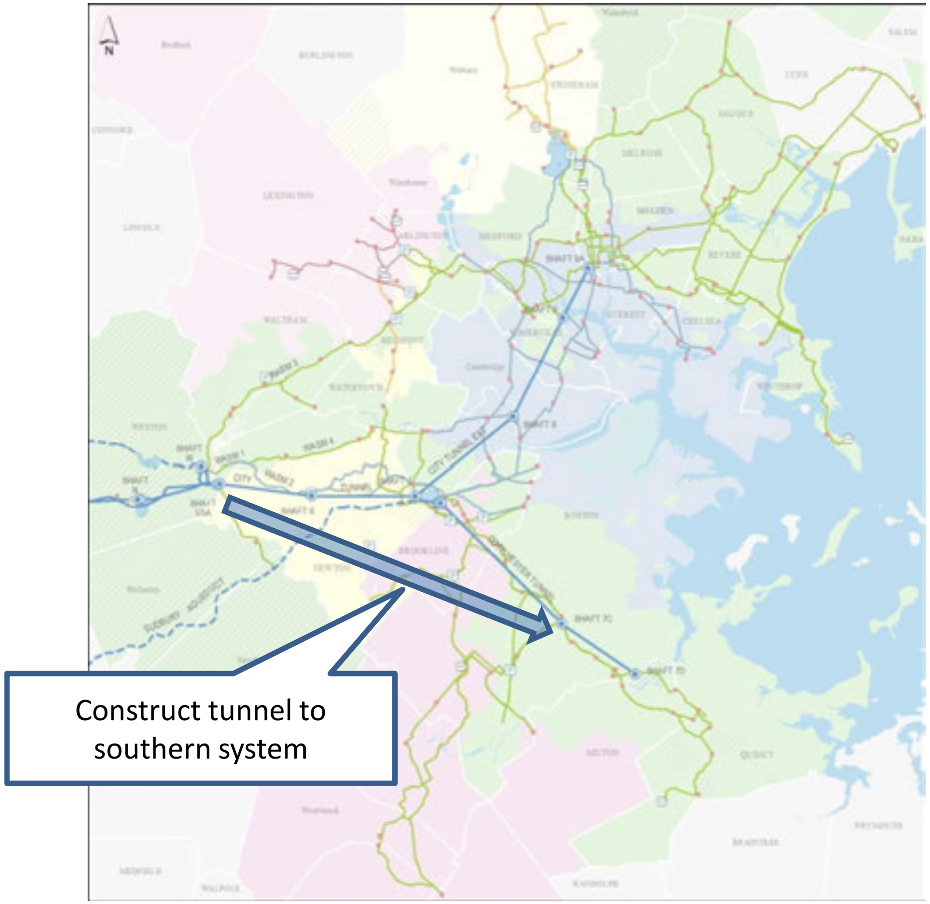
Southern Component – Category 2
Increase Capacity to South (pipeline or pump station)

Alt 8S *

Alt 10S

Southern Component – Category 3
Increase Capacity to South (Tunnel)

- Cost: $716 million - $1,034 million (three alternatives)
- Construction impacts would be limited to shaft construction sites and pipe connections
- Meets redundancy goals under all demands
- Allows year round maintenance of tunnel system (in combination with a northern solution)

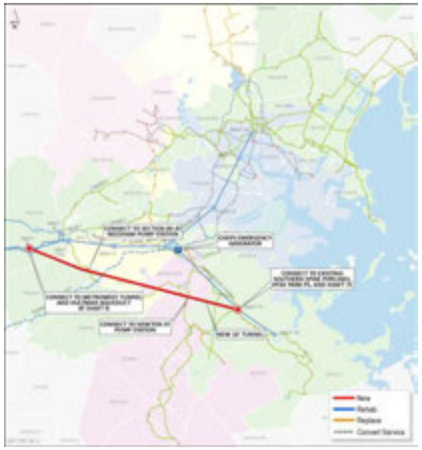


Cost is midpoint of construction. Does not include WASM 3 baseline work

Southern Component – Category 3
Increase Capacity to South (Tunnel)

[Alt 17S]

[Alt 18S] *



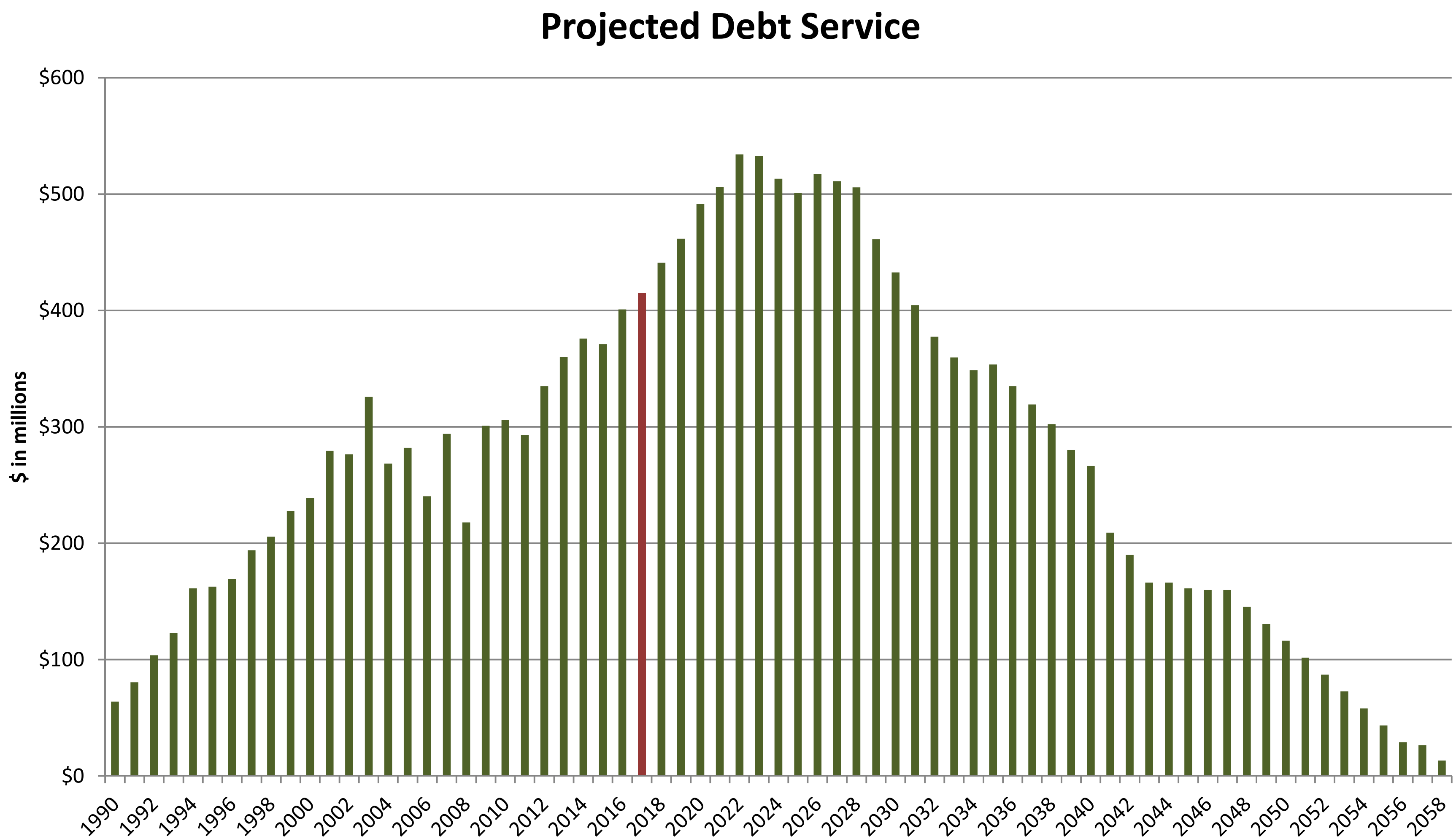
[Alt 19S]

Financial Considerations

Financial Considerations

- Preserve Sustainable and Predictable Rates at Water Utility level
- Ensure Adequate Capital is Available When Necessary
- Minimize Cost of Borrowing

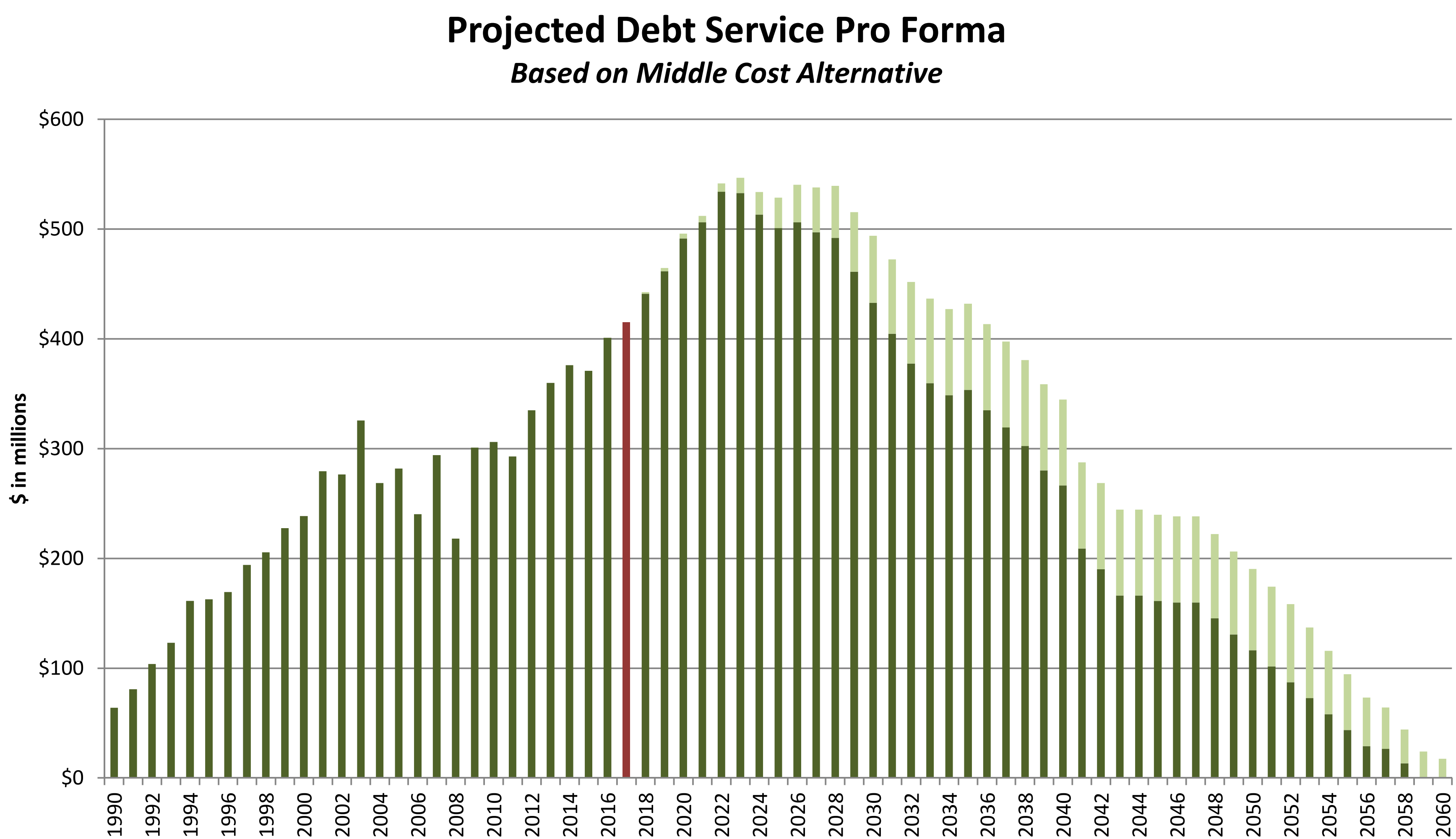
Debt Service Profile



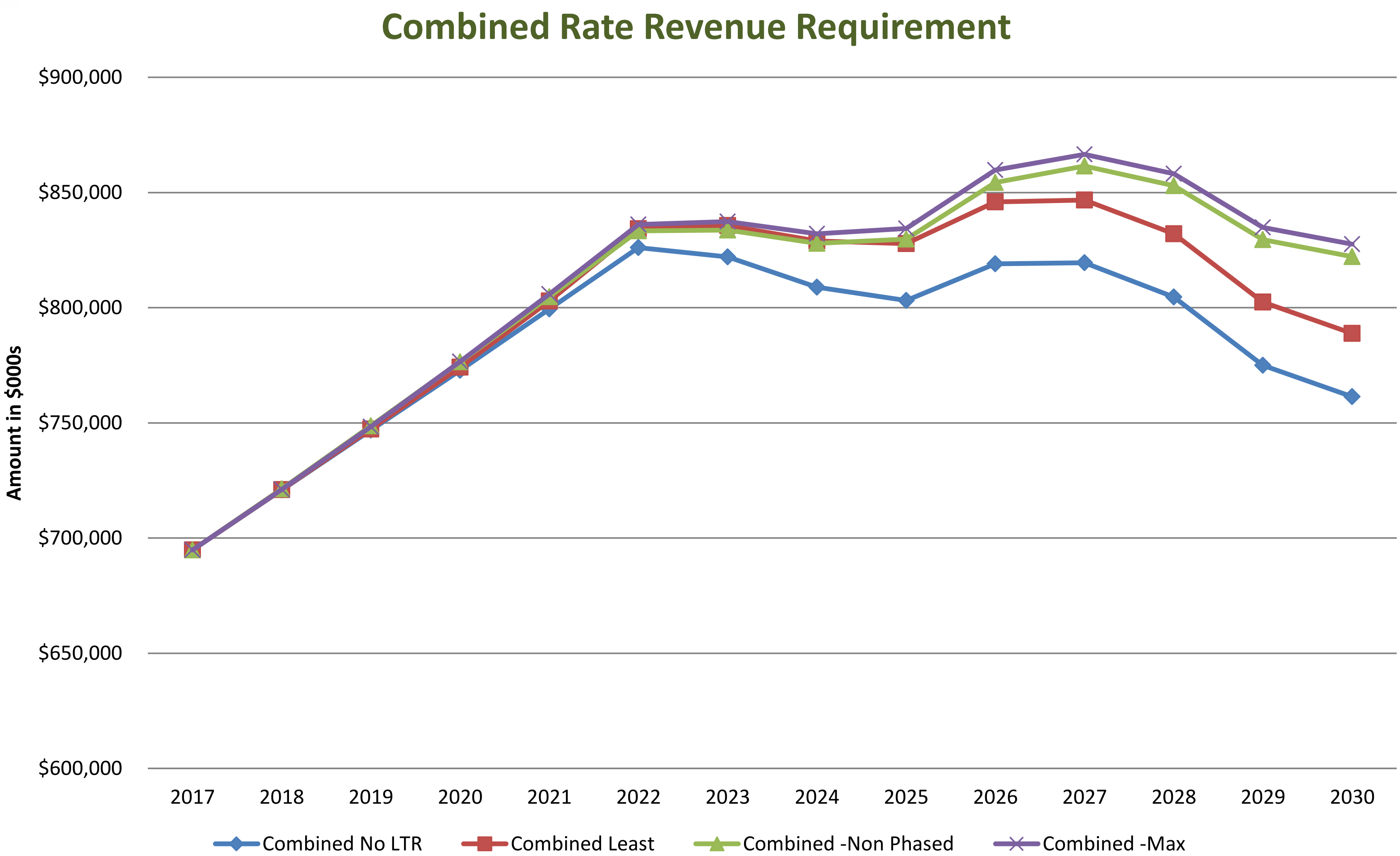
Four Alternatives Modeled

1. CIP without Long –Term Redundancy Project
2. Lowest Cost Alternative - $729M *midpoint of construction*
3. Middle Cost Alternative - $1.47B *midpoint of construction*
4. Highest Cost Alternative -$2.3B *midpoint of construction*

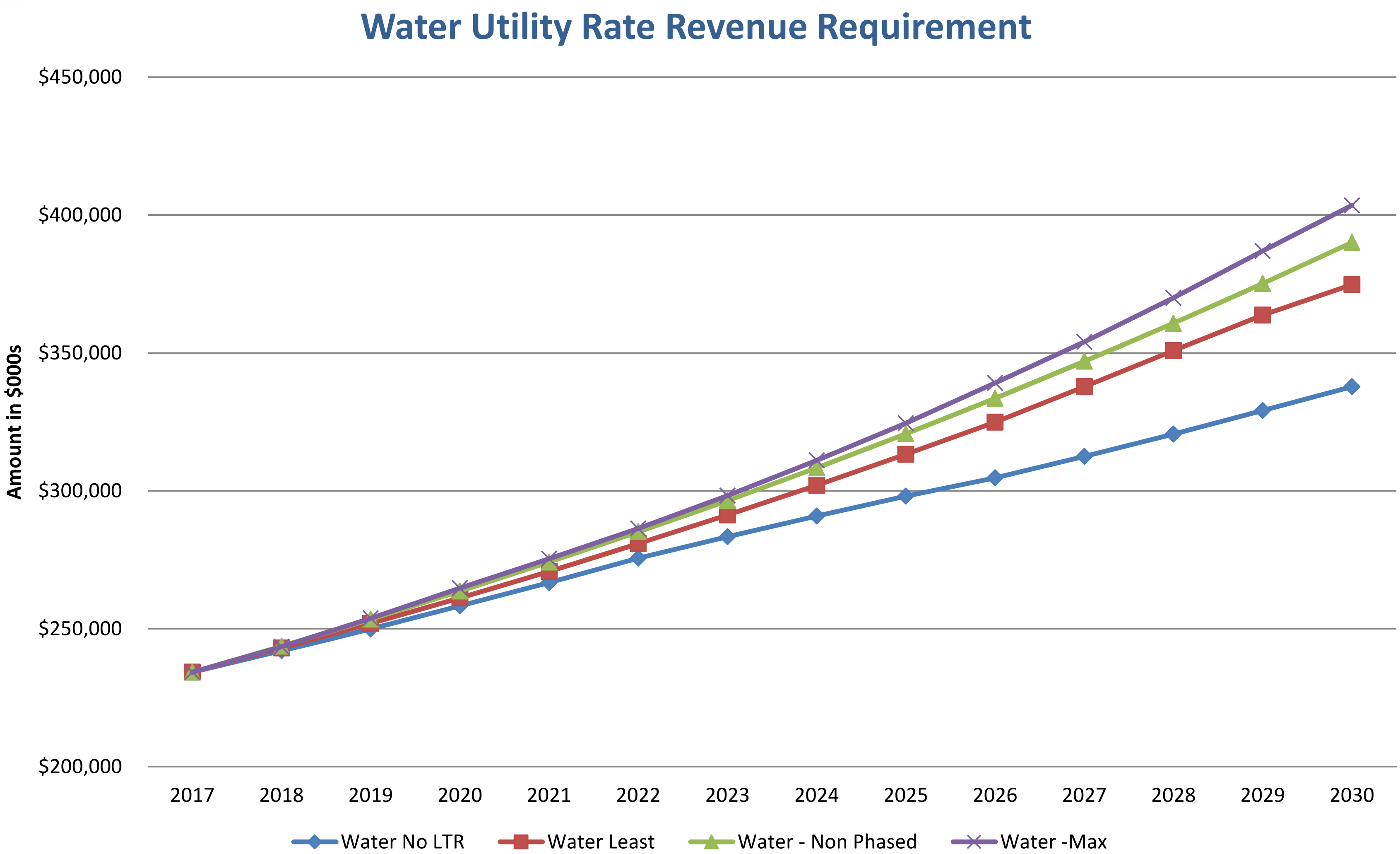
Debt Service Pro Forma



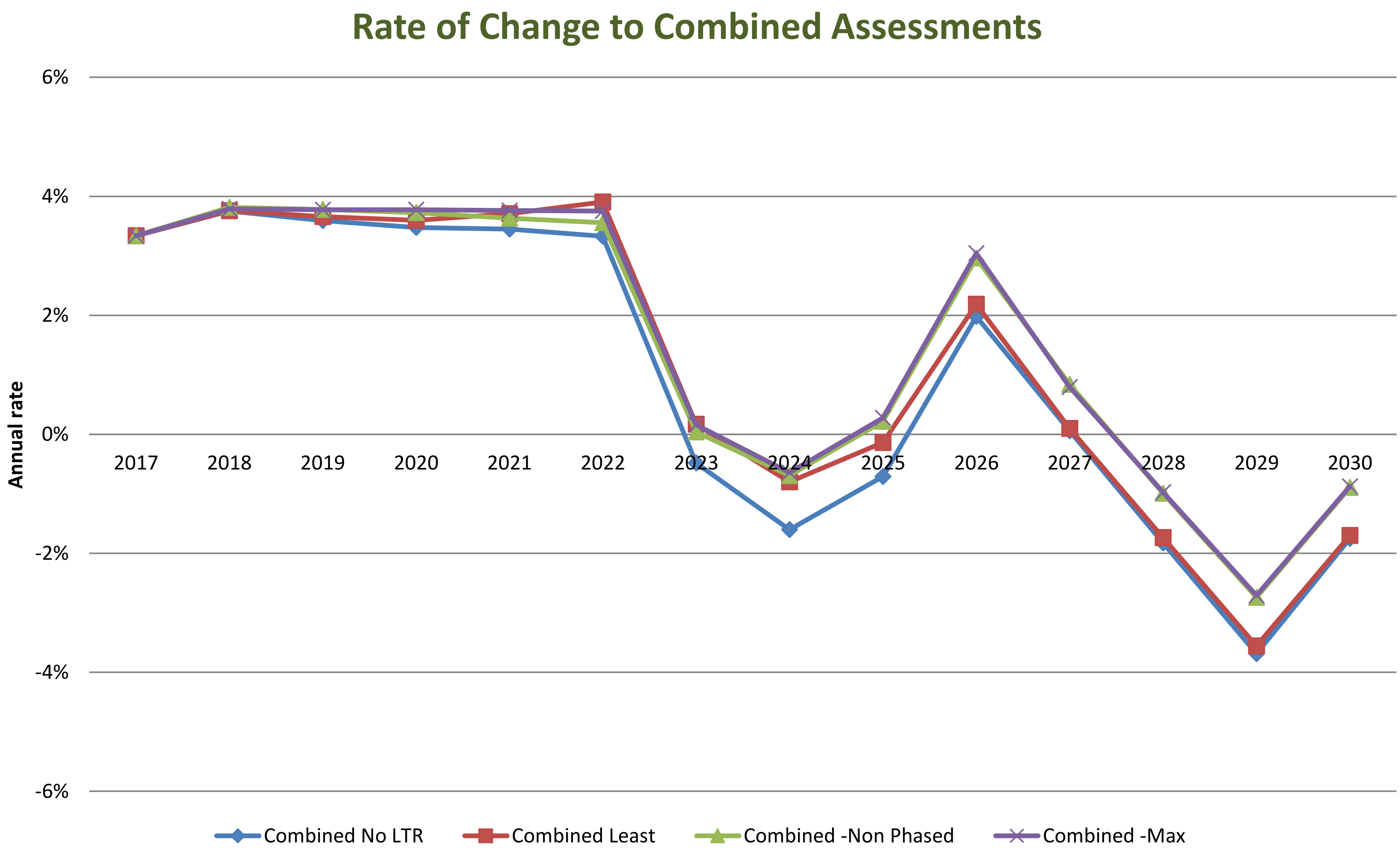
Combined Assessments



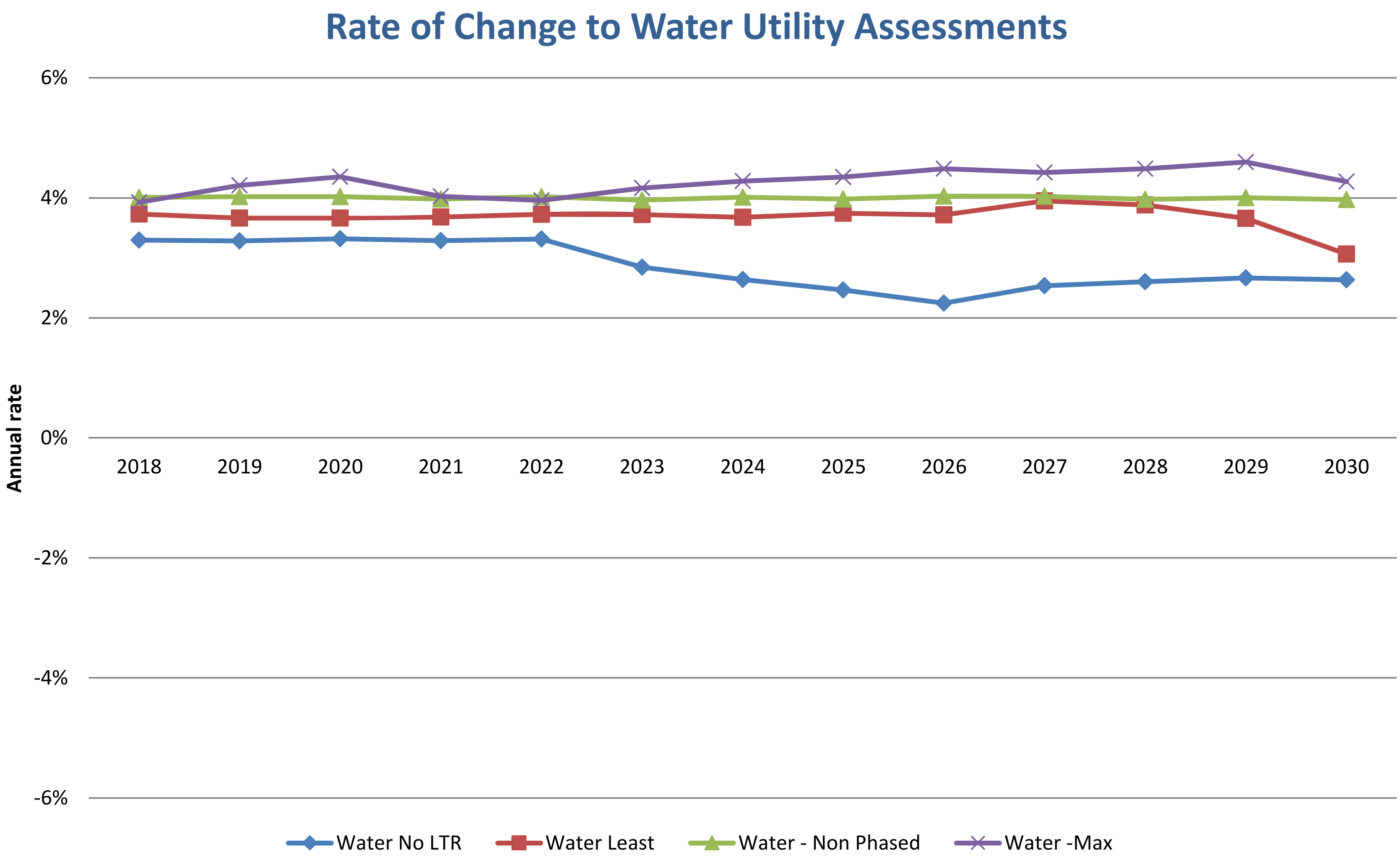
Water Utility Assessments



Combined Rate Projections



Water Utility Projections



Staff Preferred Alternative

Staff Recommendation – Interim Measures

- Take action now to reduce risk of failure/improve ability to respond:

– Tunnel-shaft pipeline improvements	$ 7.5 million
– Chestnut Hill Pump Station improvements	
• Emergency power	$ 10.9 million
• Investigate feasibility of pump output controls	$ 22.5 million
– WASM 3 rehabilitation	$104.6 million
– Commonwealth Avenue pump station low service suction capability	$ 8.0 million
– Increase PRV capacity WASM 3 and WASM 4	$ 8.7 million
– PRVs for East/West Spot Pond Supply Main community connections	$ 1.3 million
Total	$ 163.5 million

Strategic Goal for Long-Term Redundancy

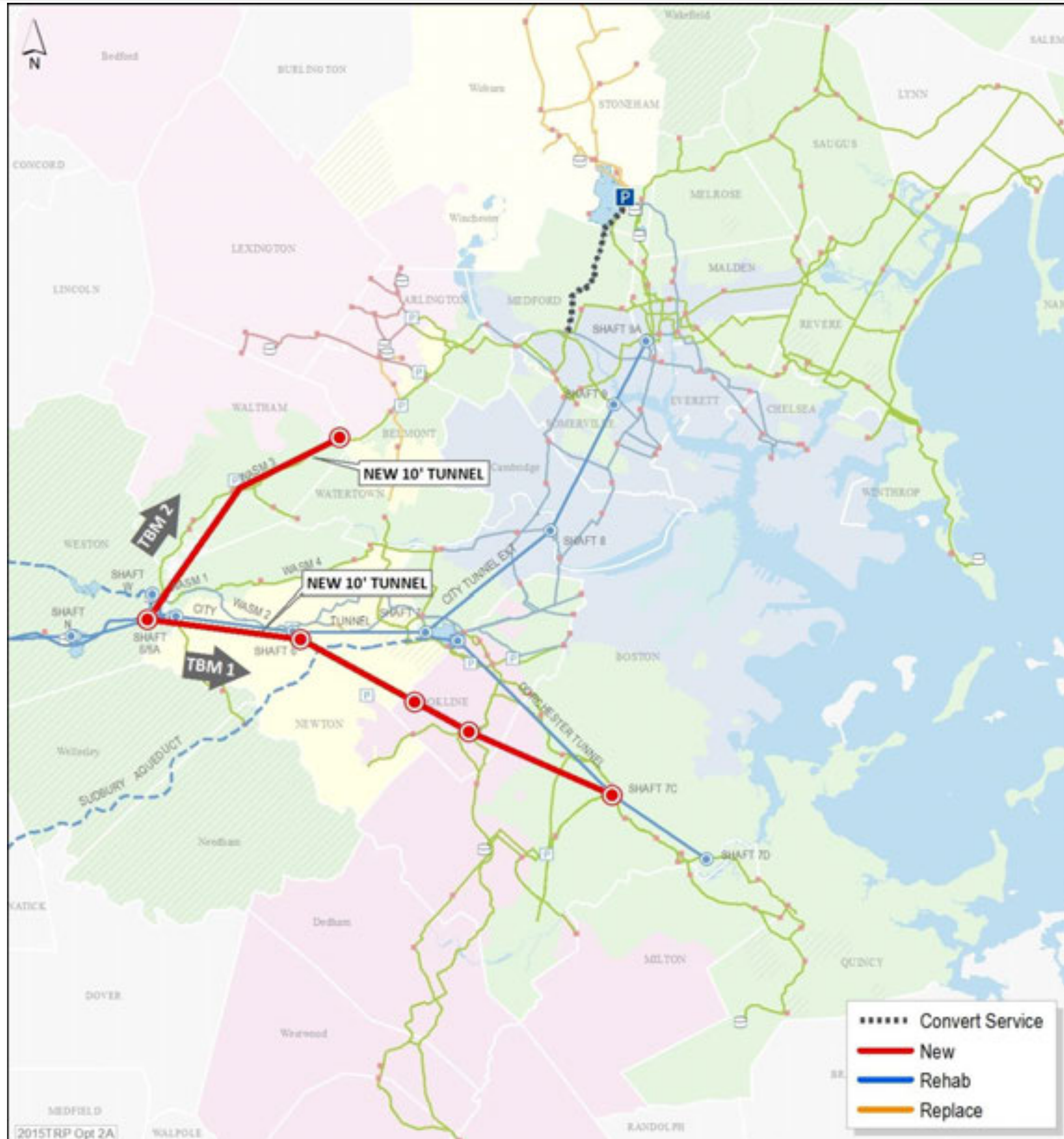
- Emergency and Planned Shut-Down Capability Preferred
  - Allows maintenance of system
  - Maintenance reduces risk of failure
  - Meet customer expectations for excellent quality water
  - Minor impact on normal service

Findings of Alternatives Analysis

- Need additional capacity to supply water to both the north and south
- Chestnut Hill Emergency Pump Station cannot reliably supply enough water to the south with the Dorchester Tunnel shut down
- Long distance large diameter surface pipelines in urban areas present significant implementation challenges

Preferred Alternative for Long-Term Redundancy

- **Two Tunnel Option Preferred**
- Time to Complete: 17 - 23 years
- Tunnels begin in the Mass Pike/Route 128 vicinity
- Northern Tunnel 4.5 miles, connects to mid-point of WASM 3 in Waltham/Belmont area.
- Southern Tunnel 9.5 miles, connects to Shaft 7C and southern surface mains



Preferred Alternative for Long-Term Redundancy

Meets Many Objectives:

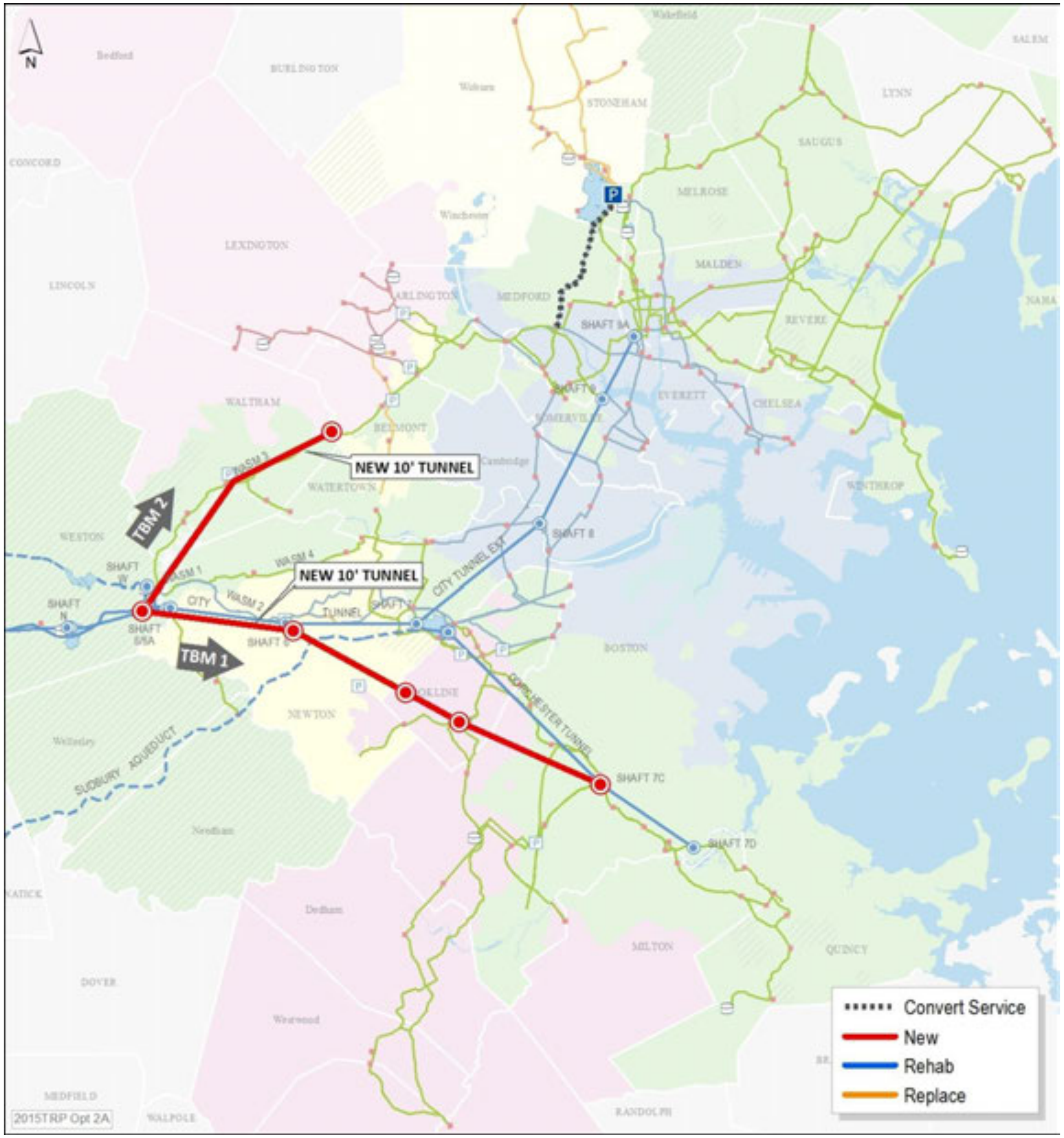
- No boil order
- Flow and pressure for normal service and fire protection
- Ability to perform maintenance
- Additional benefit: Ability to meet high day demand. No seasonal restrictions.

Preferred Alternative for Long-Term Redundancy

- Midpoint of Construction Cost: $1,470 -$1,700 million

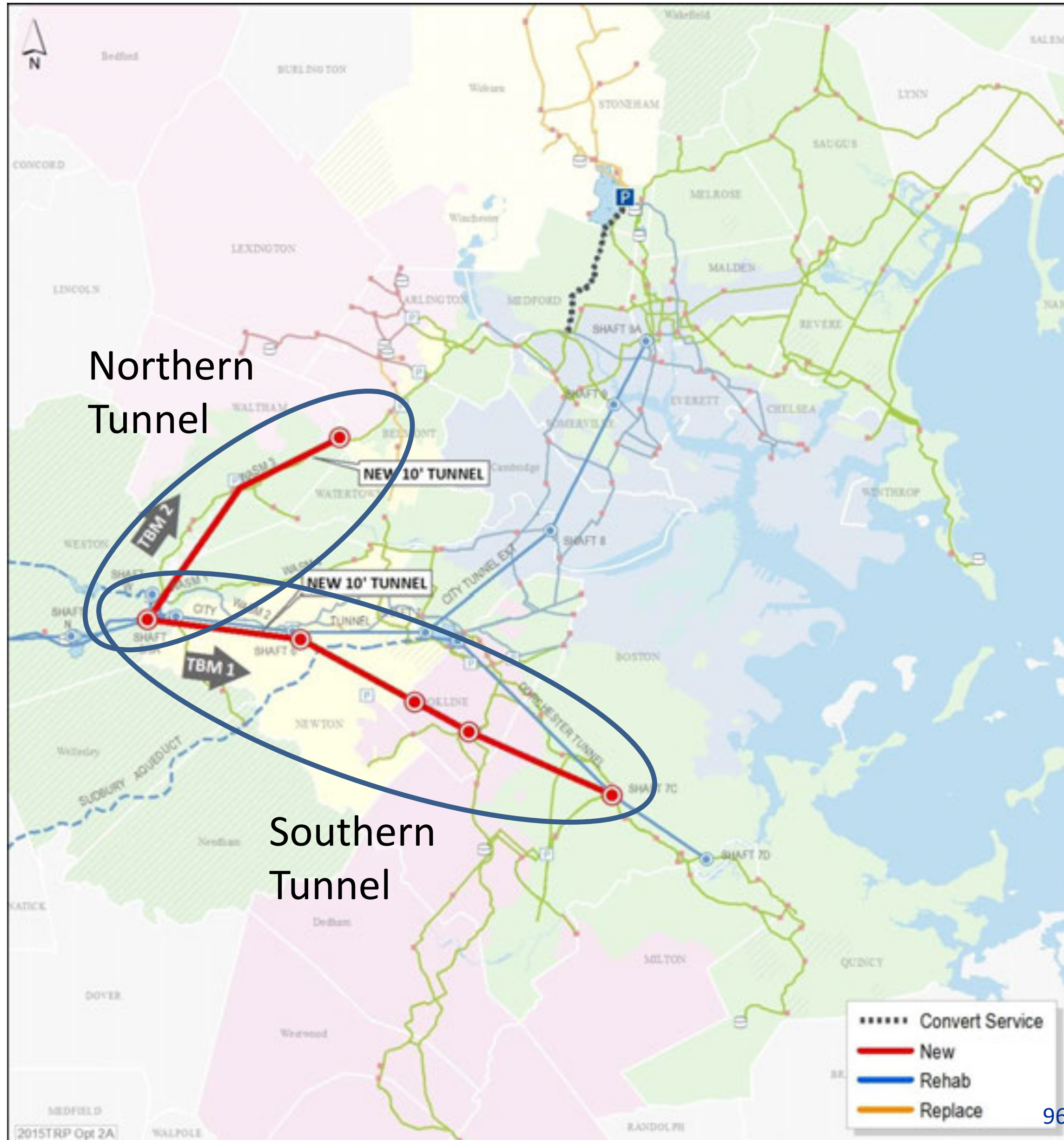
- Costs include:
  - 30% contingency factor
  - 4% annual escalation

- Cost does not include baseline / interim improvement costs.



Construction in Phases Still Provides Benefit

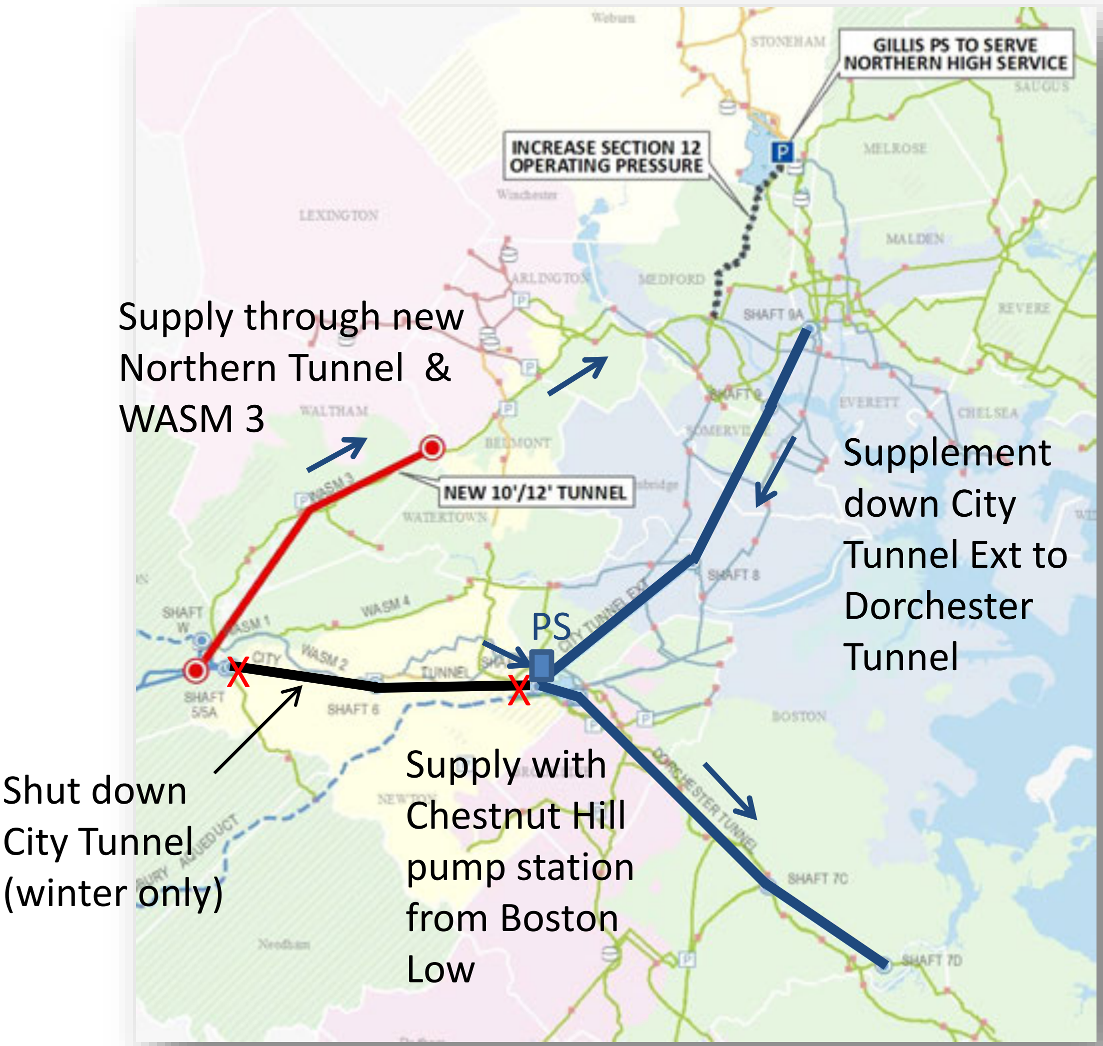
- Could be built in phases
- Northern Tunnel
  - Redundancy for City Tunnel Extension
  - Could shut City Tunnel during periods of low demand and still feed south
- Southern Tunnel
  - Redundancy for Dorchester Tunnel
  - Eliminates reliance on the CHEPS



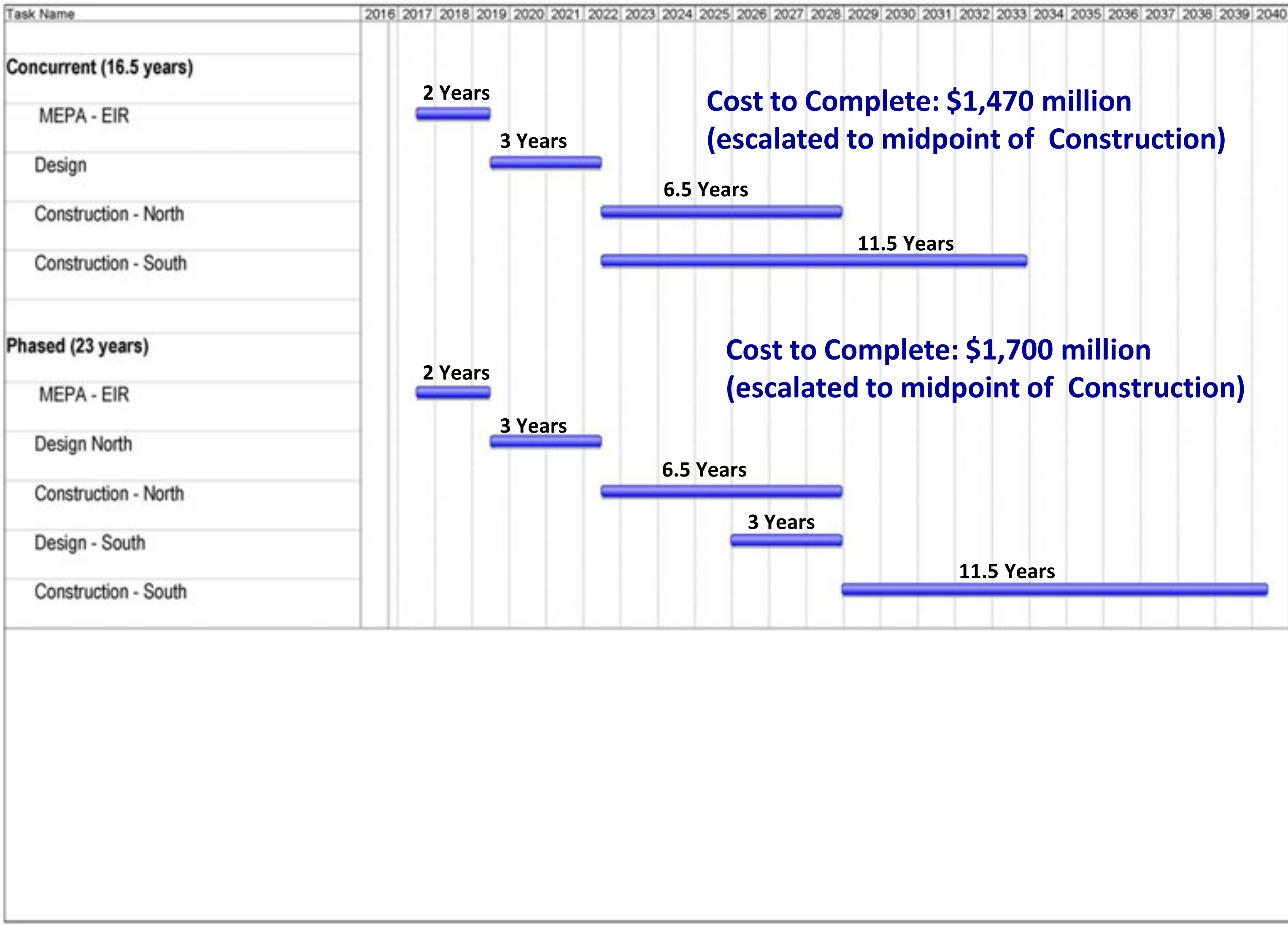
Phased Construction of Preferred Alternative

- If a phased approach is a goal, staff would recommend that the Northern Tunnel be constructed first

- With Northern Tunnel in place
  - test valves at Shaft 7
  - potentially address Shaft 5, Shaft 9 or Shaft 9A concerns



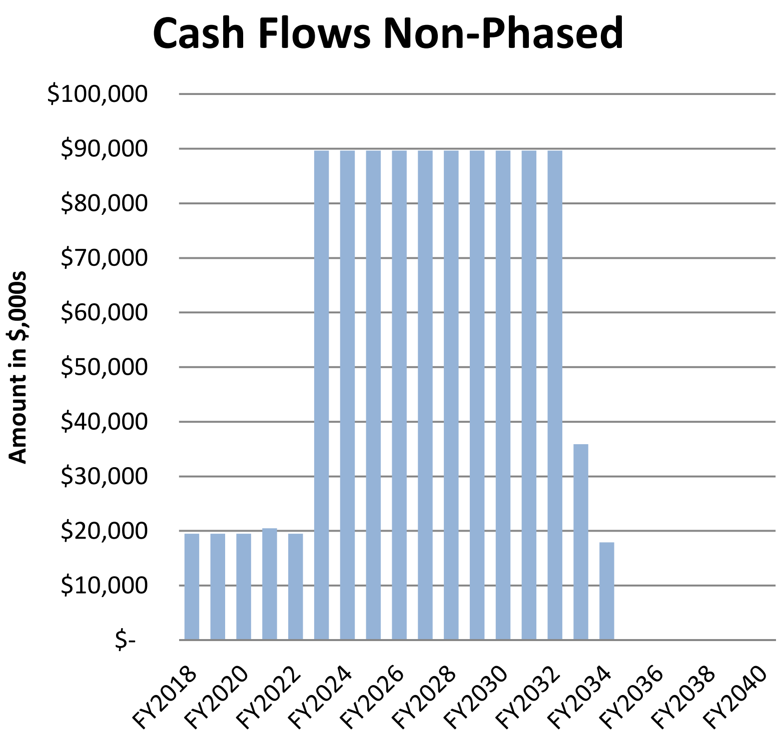
Possible Schedule for Preferred Alternative



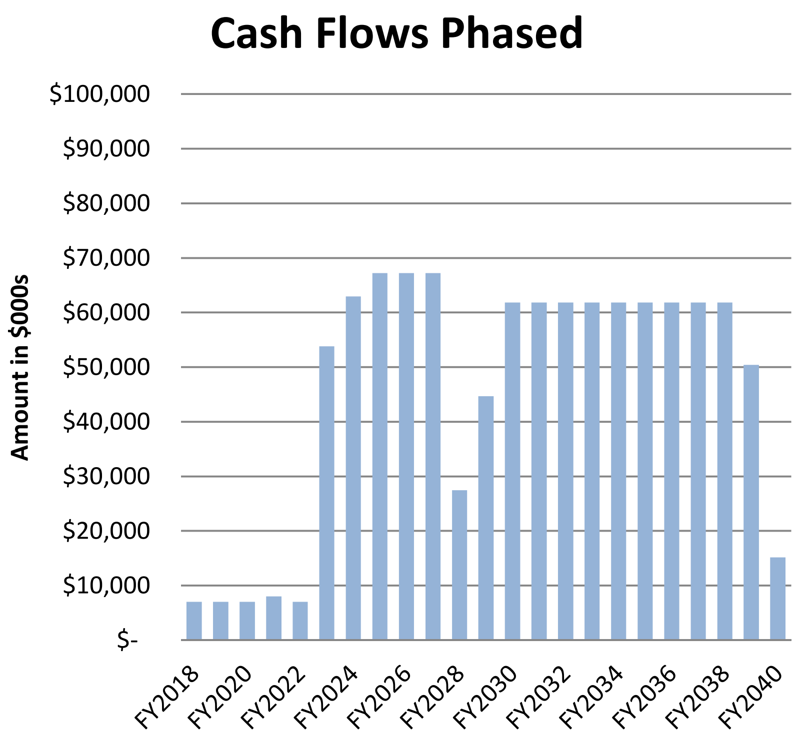
2 Preferred Alternatives Modeled

Description	Duration	Cost Mid-point of Construction
Non Phased	17yrs	$1.47B
Phased	23yrs	$1.70B

Cash Flows



Cash Flows Non-Phased
Amount in $,000s
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
FY2018
FY2020
FY2022
FY2024
FY2026
FY2028
FY2030
FY2032
FY2034
FY2036
FY2038
FY2040



Cash Flows Phased
Amount in $000s
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
FY2018
FY2020
FY2022
FY2024
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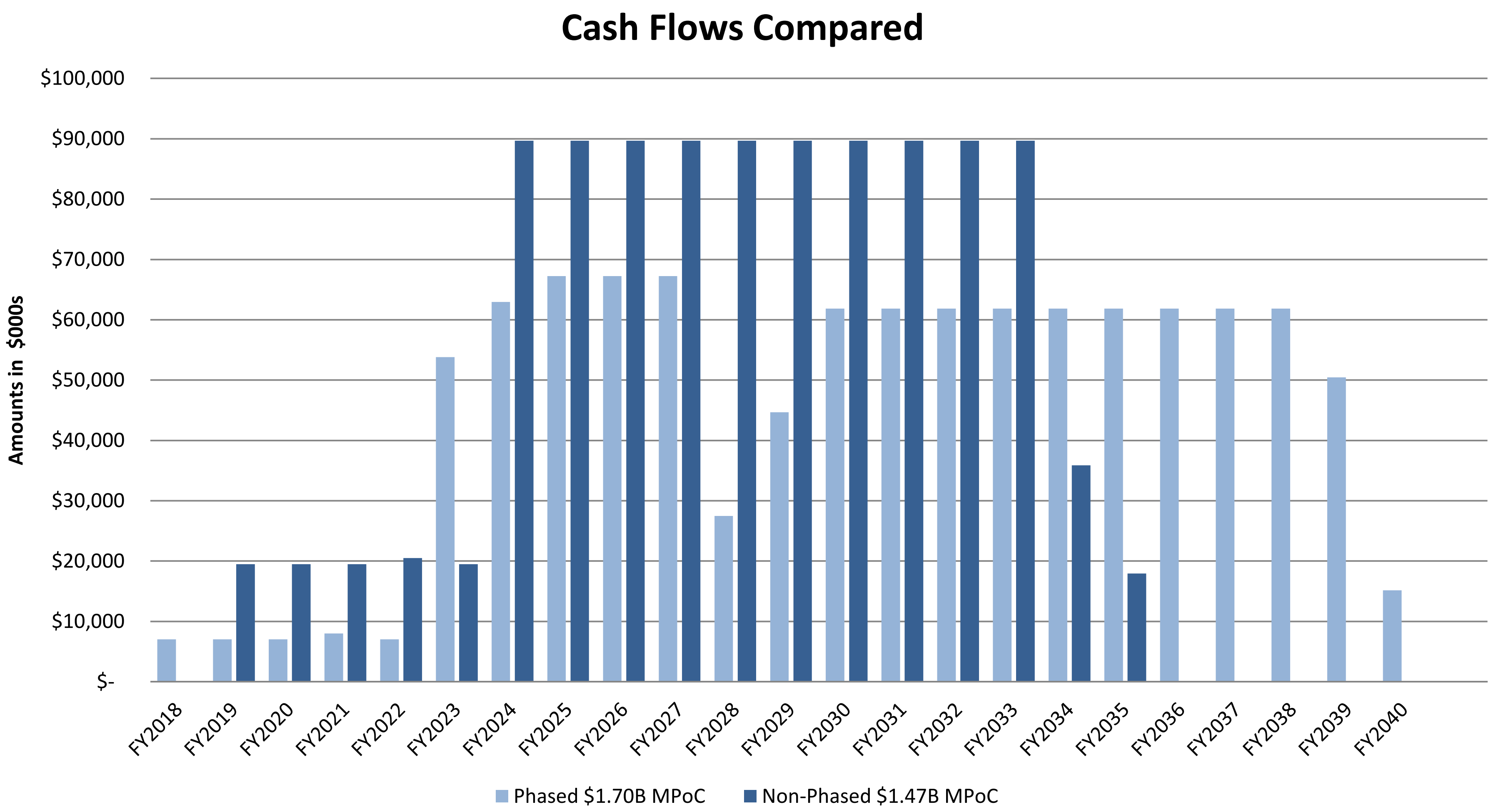
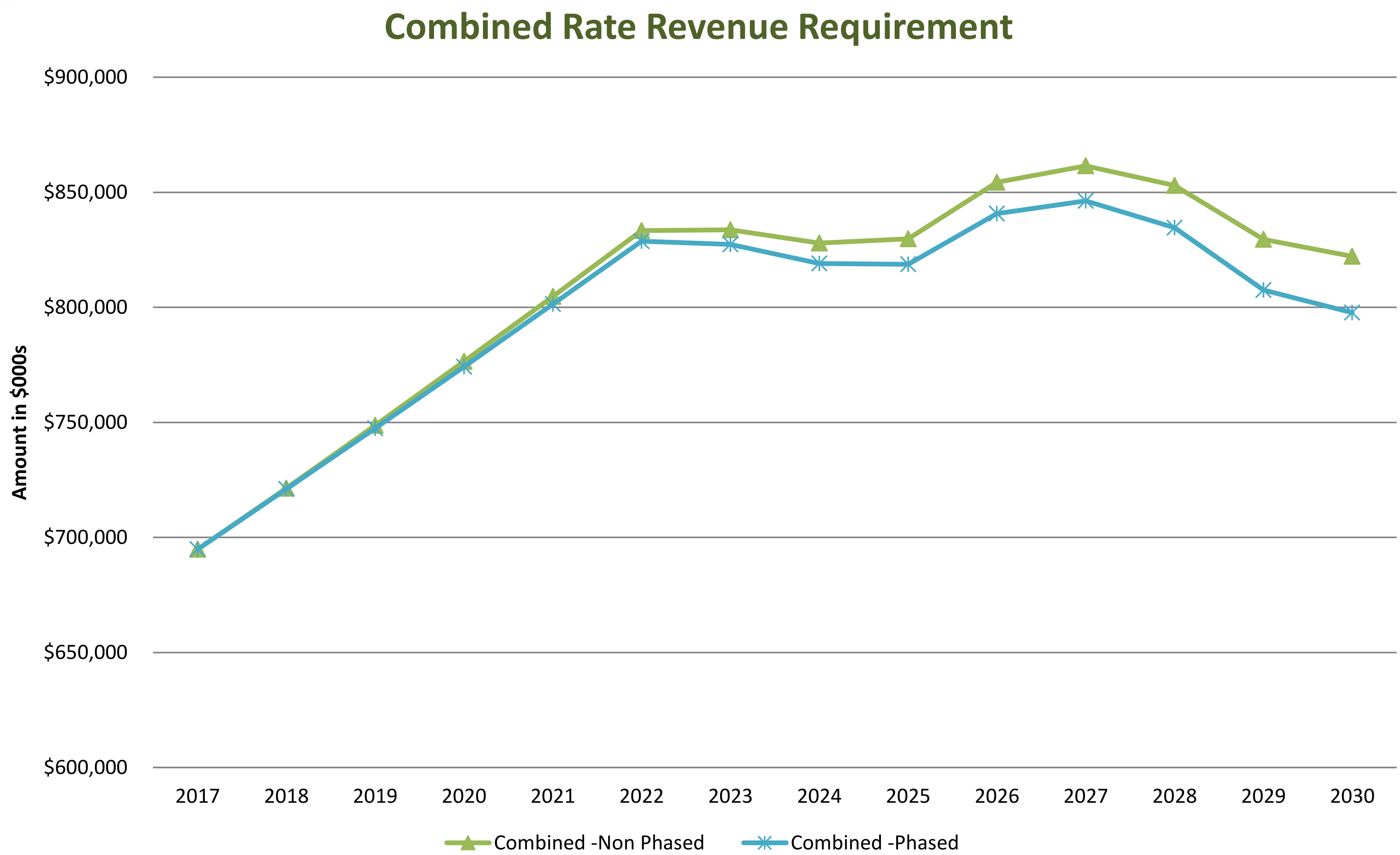
FY2032
FY2034
FY2036
FY2038
FY2040

Cash Flows

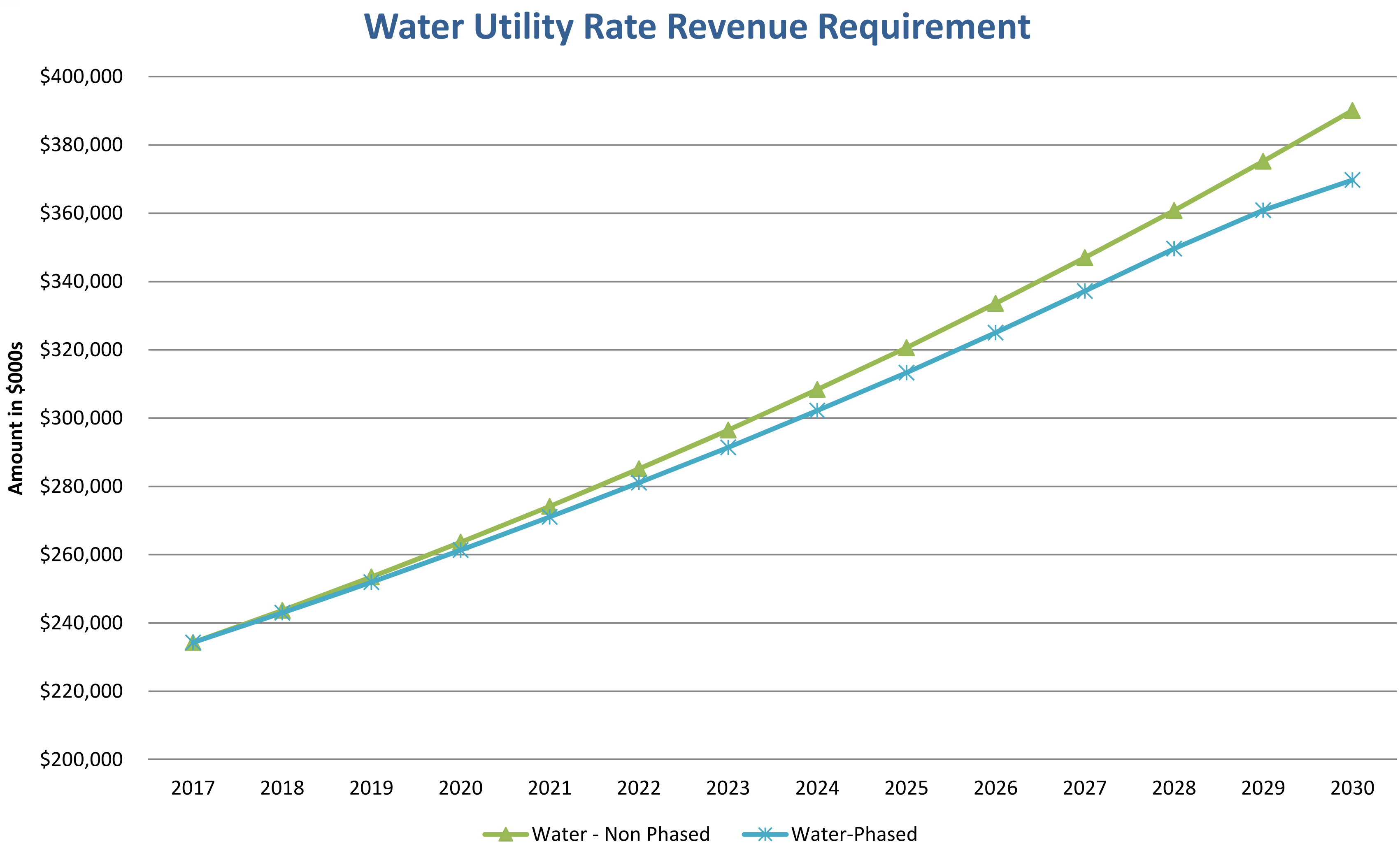


Cash Flows Compared
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
Amounts in $000s
FY2018
FY2019
FY2020
FY2021
FY2022
FY2023
FY2024
FY2025
FY2026
FY2027
FY2028
FY2029
FY2030
FY2031
FY2032
FY2033
FY2034
FY2035
FY2036
FY2037
FY2038
FY2039
FY2040
Phased $1.70B MPoC
Non-Phased $1.47B MPoC

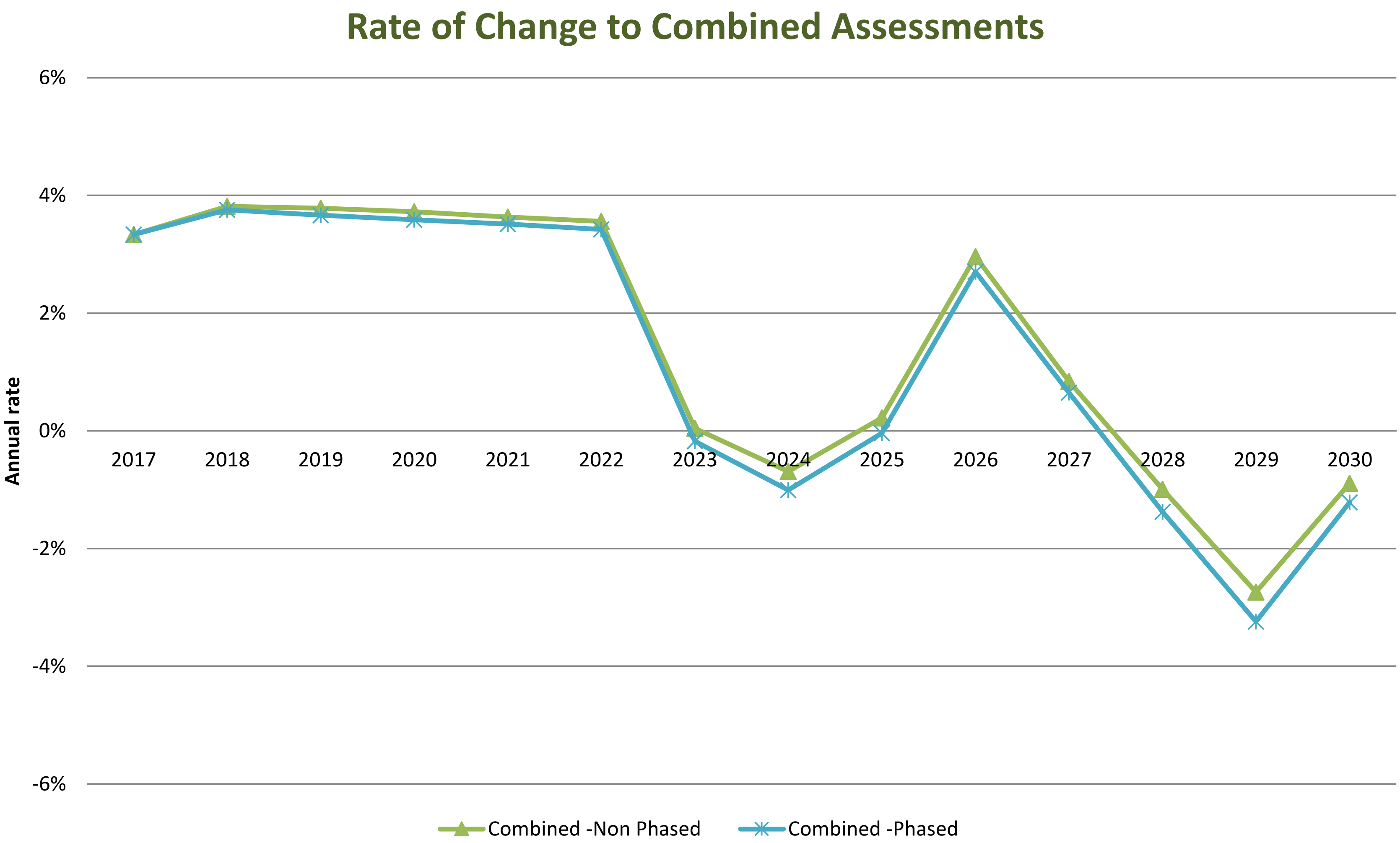
Combined Assessments



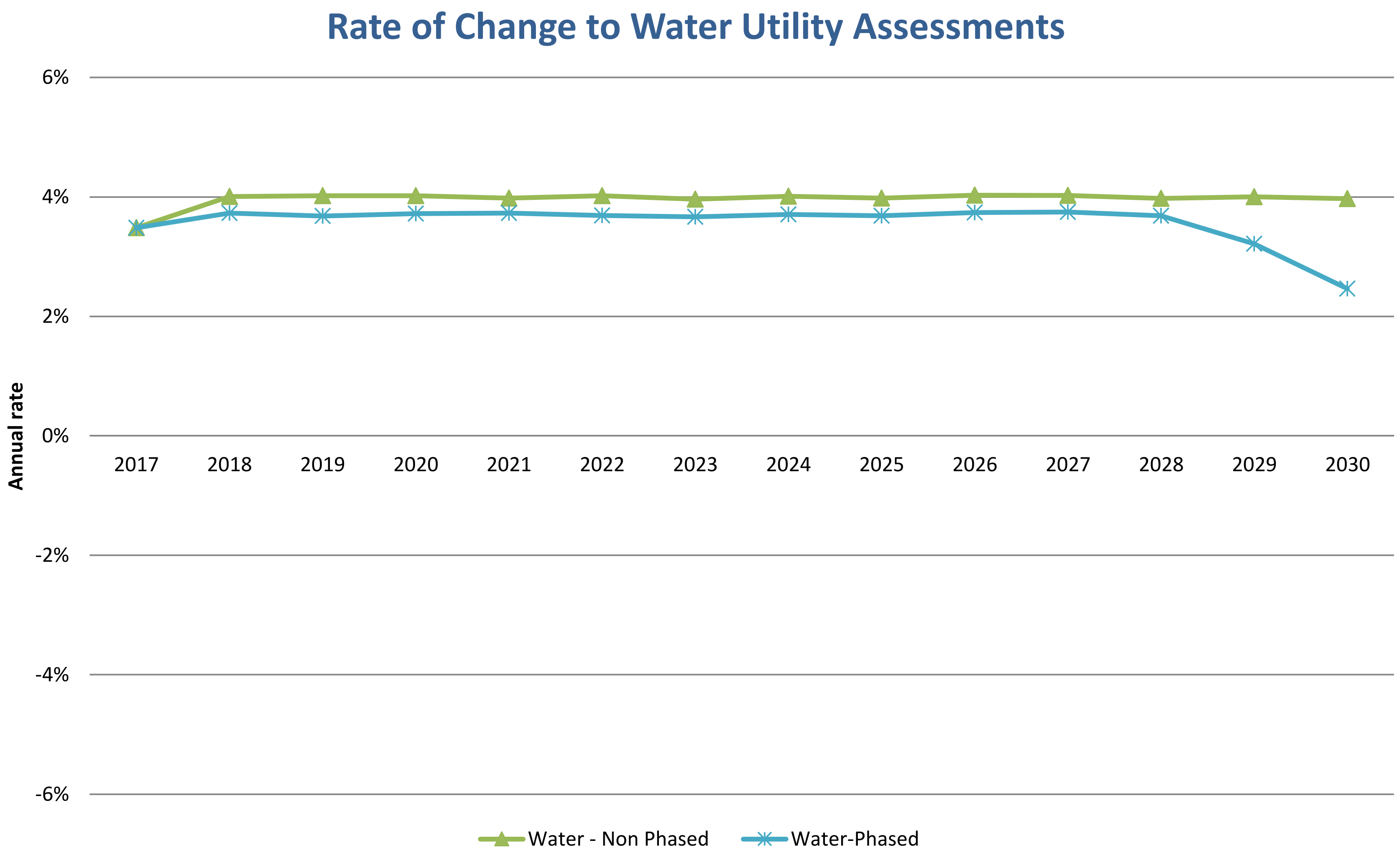
Water Utility Assessments



Combined Rate Projections



Water Utility Rate Projections



Meeting Summary

- Redundancy for Metropolitan Tunnel system is necessary for maintenance and emergency response
- If we do nothing, failure will eventually occur
- Extensive alternatives were identified and evaluated
- Long distance large diameter pipeline alternatives present significant implementation challenges
- Operational reliability problems were identified with Chestnut Hill Pump Station and other proposed pump stations

- Preferred tunnel alternatives meet service objectives and goals
  - Allows planned maintenance of 60+ year old infrastructure that are beyond their useful life
  - Allows emergency response at normal level of service
  - Constructible