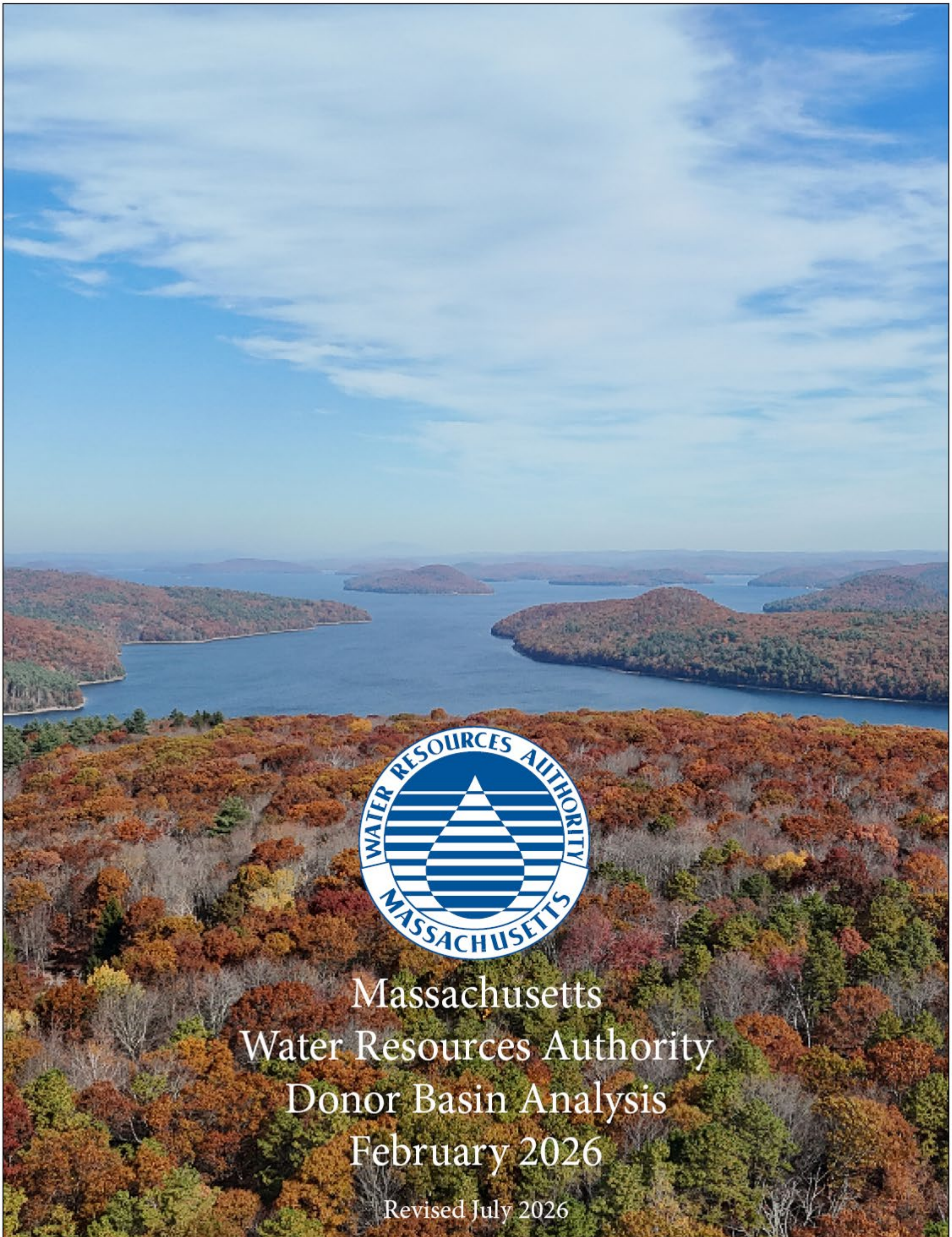

Massachusetts Water Resources Authority Donor Basin Analysis February 2026

Revised July 2026

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EXECUTIVE SUMMARY

The Massachusetts Water Resources Authority (MWRA) water supply system has the capacity to assist communities in addressing local water supply constraints by providing a highly reliable supply with comparatively low environmental impact. This donor basin analysis evaluates the system-wide effects of supplying an additional **20 million gallons per day (MGD)** on an average day and is intended to support multiple communities seeking admission to the MWRA system. The analysis is conducted at a comprehensive, system-wide scale to allow participating communities to focus their environmental review efforts on receiving-basin and local supply considerations.

MWRA's primary operational objective is to deliver a high-quality, adequate water supply while meeting all required minimum releases to the Swift, Nashua, and Ware Rivers. These objectives are consistently achieved through the substantial usable storage capacity of the Quabbin and Wachusett Reservoirs, MWRA's successful long term demand management programs, and through careful management of inflows and outflows, including demand withdrawals, planned releases, and overflows, under a wide range of hydrologic conditions. Seasonal operating patterns govern the proportional balance of releases and spills from each reservoir, while water quality considerations primarily drive transfers between reservoirs.

As of 2024, MWRA supplies an annual average demand of approximately **200 MGD** from a system with a safe yield of **300 MGD,** see Section 3 for additional information. The system's large multi-year storage capacity provides operational resilience under both dry and wet conditions and limits sensitivity to short-term demand variability. As a result, hourly, daily, or seasonal fluctuations in demand associated with the addition of new communities are operationally insignificant at the system scale.

Based on recent yield analyses and current demand conditions, MWRA can supply an additional 20 MGD on average without installation of additional facilities or changes to operating rules, see Section 3 for additional information. System performance was evaluated across a range of demand scenarios, including baseline demand (200 MGD), baseline plus new community demand (220 MGD), projected growth within the existing service area (260 MGD), and full utilization of system safe yield (300 MGD). Across all modeled scenarios, required minimum in-stream flows and downstream release obligations were met and exceeded, see Section 3 for additional information.

The analysis indicates that **expansion of service by an average of 20 MGD** would **result in minimal impacts** to reservoir elevations and storage volumes, aquatic base flow, and flood flows within the donor basin. Overall, the findings demonstrate that the MWRA system can accommodate the proposed additional average 20 MGD interbasin transfers while maintaining regulatory compliance, protecting aquatic resources, and preserving long-term system reliability.

SECTION 1 DONOR BASIN ANALYSIS OVERVIEW

Massachusetts Water Resources Authority (MWRA) has prepared this donor basin analysis to address applicable portions of the Scope for Water Suppliers Seeking Approval Under the Interbasin Transfer Act to join the MWRA's Water System developed by the Massachusetts Water Resources Commission (WRC). This donor basin analysis has been prepared to provide information needed to evaluate Criterion 5 - Reasonable Instream Flow, and Criterion 7 - Cumulative Impacts, of the WRC Interbasin Transfer Act (ITA) Performance Standards (2024). The ITA regulations describe seven criteria that the WRC must consider when deciding to approve or deny an Interbasin Transfer application that is not determined to be Insignificant. The Performance Standards are based on these criteria. Specific information required by the WRC to be included in an ITA application is outlined in 313 CMR 4.09(3) (2018). Individual communities requesting to join the MWRA water system will separately produce environmental review documentation describing their specific circumstances and respond to the receiving basin portions of the WRC review.

This donor basin analysis will be used to support multiple communities requesting admission to the MWRA water system and has been performed on a comprehensive scale to determine impacts from a cumulative flow of up to 20 MGD. This is designed to allow potential communities to focus their environmental review documents on the receiving basin impacts and local supply considerations.

1.1 Regulatory Background: Past Authorized Transfers and Withdrawals

MWRA was created in 1984 to assume operation of the drinking water system previously under the control of the Metropolitan District Commission (MDC). Chapter 488 of the Act of 1895, which established the MDC, and other preexisting acts of the Legislature granted MDC rights to waters from the Swift, Ware, and Nashua River basins. These statutes, which preceded the ITA, allow MWRA, as successor to MDC, to exercise the rights to use the waters of the Swift, Ware, and Nashua Rivers for water supply and to extend the water supply to additional cities and towns. Chapter 375 of the Acts of 1926 authorized the Metropolitan Water Supply Commission (a predecessor to the MWRA) "to divert into the Wachusett reservoir . . . the flood waters . . . of the Ware River . . . for the purpose of extending and increasing the water supply of the metropolitan water system, and of such cities and towns not members of the metropolitan water district as may hereafter require water from said system . . ." Chapter 321 of the Acts of 1927 also authorized the same commission to construct such tunnel, aqueduct and diversion dam structures as would create a storage reservoir in the Swift River valley (now the Quabbin Reservoir) "for the purpose of adding to, extending and further developing the additional sources of water supply of the metropolitan water system." The legislation provided further general authority to the commission to build such other future structures to become part of the metropolitan water system that in the commission's opinion "may be necessary for the additions, extensions and developments authorized by this act."

When the ITA became effective in 1984, the MDC water service area consisted of 44 communities, 42 of which were located outside the Chicopee and Nashua River Donor Basins, and MDC water service area demand was approximately 330 MGD. These existing transfers were authorized pursuant to the ITA regulations, which defined the "Present Rate of Interbasin Transfer" to be: "the hydraulic capacity of an interbasin transfer system which was authorized, constructed, and usable for water supply purposes without installation of additional facilities or change in any authority operating rule prior to the effective date of the Act."

Under the Water Management Act (WMA), MWRA is registered to withdraw a combined total of 312.82 MGD from the Nashua and Chicopee River Basins (186.7 MGD from the Chicopee River Basin and 126.12 MGD from the Nashua River Basin). Pursuant to the WMA, registered volumes are based on "Existing Withdrawals," which means the average volume of water withdrawn from a particular water source during the five years prior to January 1, 1986. MWRA withdrew an average of 312.82 MGD from the Nashua and Chicopee River Basins during the five years prior to January 1, 1986.

In addition to applicable requirements for ITA approvals, addition of new communities to the MWRA system is further regulated by Section 8(d) of Chapter 372 of the Acts of 1984 ("Enabling Act"), as well as MWRA Operating Policy #10 - Admission of New Communities to the Waterworks System. Since MWRA's creation, the WRC determined that a decision under the ITA was required for addition of the following communities to the system: Bedford, Stoughton, Wilmington, Reading, Ashland, Burlington, and the Lynnfield Center Water District (LCWD). Each interbasin transfer request was approved.[1]

Table 1-1 provides the recent history of communities admitted to the MWRA. In addition to providing the approved average day supply (MGD) within the table, actual use of these communities as well as the MWRA total system withdrawal are shown over time. This establishes a trend of expanding community access while the MWRA total system withdrawal has continued to increase in efficiency. Total MWRA withdrawal steadily decreased from 338 MGD in 1987 to 201.2 MGD in 2024.

[1] The WRC did not take jurisdiction under the ITA for Dedham/Westwood Water District (DWWD), as its predecessor was a named community under the Enabling Acts for the MDC and the MWRA.

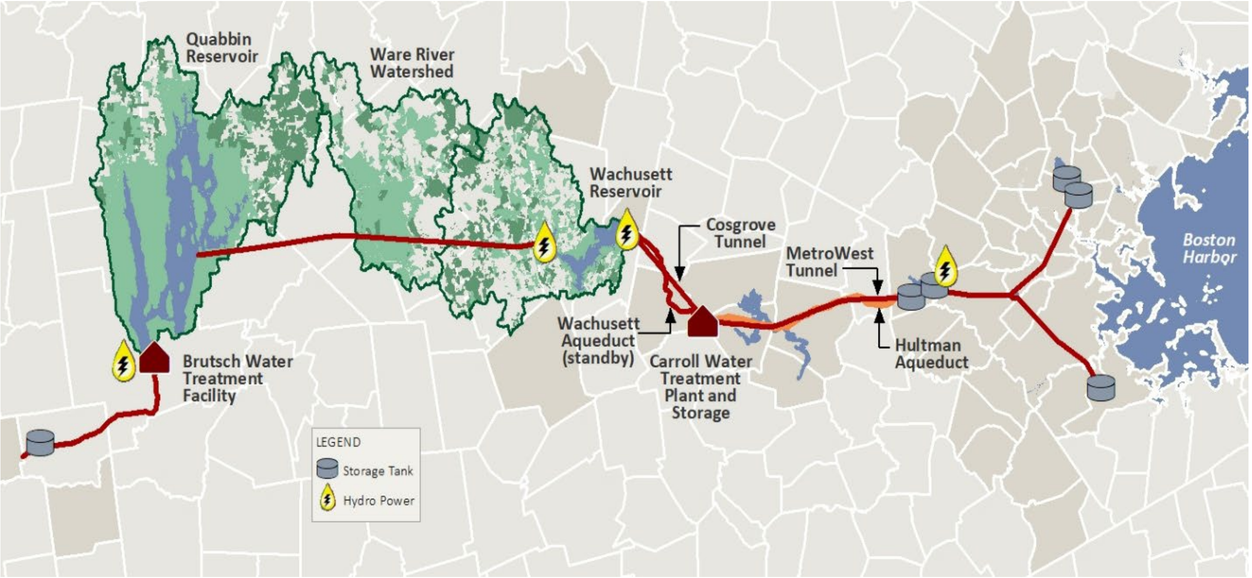
Table 1-1
Communities Admitted to the MWRA Subject to the Interbasin Act

Year	Community	MWRA Approved Average (MGD)*	WRC Approved Average (MGD)	MWRA Withdrawal (5-yr avg) at date of admission
1993	Bedford	1.51	1.75	271.4
2002	Stoughton	1.15	1.15	254.3
2005	Reading	2.10	2.27	237.4
2005	DWWD**	1.55	---	237.4
2009	Wilmington	1.23	1.70	218.1
2016	Hatchery***	7.00	---	204.3
2018	Ashland	0.09	1.49	202.8
2020	Burlington	3.50	3.50	200.4
2025	LCWD	0.28	0.28	201.1
*As documented in MWRA Water Supply Agreements (Contracts) with community.				
**DWWD not subject to ITA review.				
***Hatchery based on Memorandum of Agreement; subject to drought actions.				

SECTION 2 OVERVIEW OF THE WATER SUPPLY SYSTEM

The primary drinking water supply for Metro Boston and several communities in the Chicopee Valley is the Quabbin Reservoir. The Quabbin Reservoir has a multi-year storage capacity and well-protected watershed area. Water then flows eastward through a 25-mile-long deep rock Quabbin Aqueduct, passing first through Ware River watershed before releasing into the Wachusett Reservoir in the Nashua River basin. The Quabbin Aqueduct also includes an intake from the Ware River at the high point of the inverted siphon design, which allows for temporary reversal of flows through the tunnel to supplement Quabbin storage as required. After flowing the length of the Quabbin Aqueduct into the smaller Wachusett Reservoir, water then enters the Cosgrove Tunnel, travelling another 8 miles to the Carroll Water Treatment Plant in Marlborough, and then finally through a series of tunnels and pipelines to MWRA's member communities (see Figure 2-1 below).

Figure 2-1
Map of MWRA Water Supply System

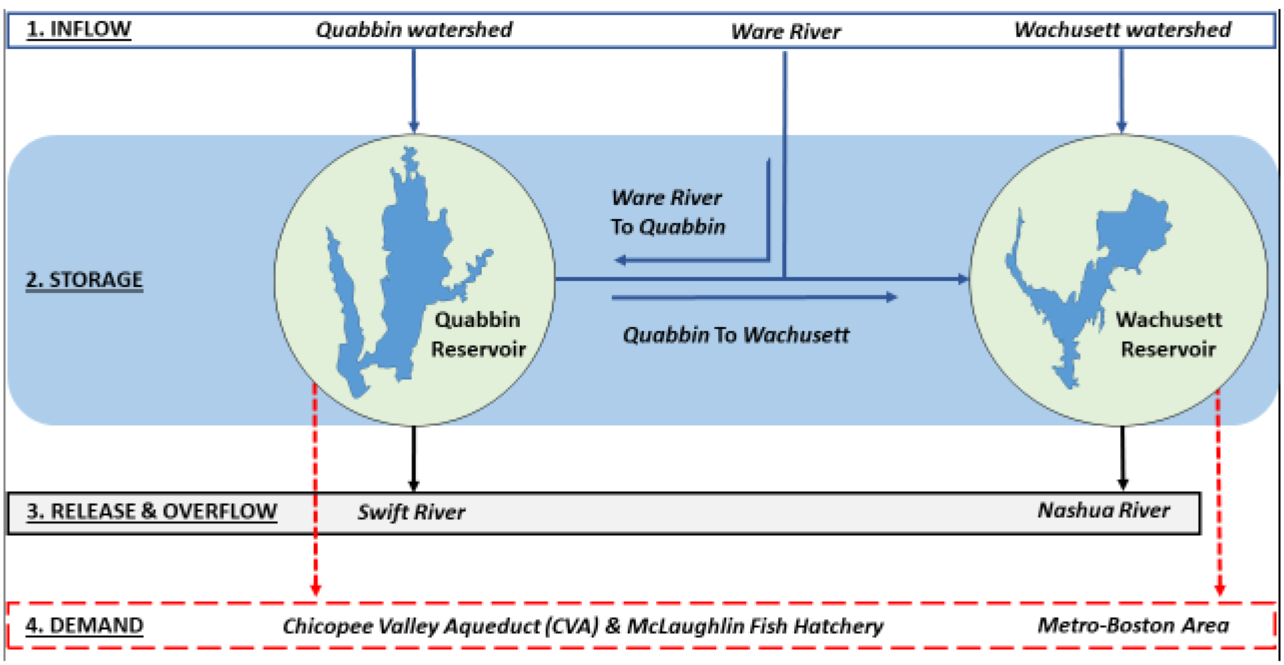


The MWRA water supply system's primary objective is to ensure a high-quality, adequate water supply while maintaining required minimum releases to the Swift, Nashua, and Ware Rivers. MWRA has consistently achieved these objectives thanks to the immense usable storage capacity across the Quabbin and Wachusett Reservoirs and careful management of the system by balancing inflows and outflows—demand withdrawals, planned releases, and overflows—under varying regional weather conditions, including seasonal droughts and floods.

The MWRA water supply system operates through four principal mechanisms: **Inflow**, **Storage**, **Release & Overflow**, and **Demand** (see Figure 2-2 below):

1. **Inflow**: Water enters the reservoirs via watershed inflows, river diversions, and interbasin transfers. The system's long-term inflow sources include the Quabbin watershed (53%), Wachusett watershed (34%), and the Ware River (13%) (MWRA, 2002).[2]
2. **Storage**: Water is stored primarily in the Quabbin and Wachusett Reservoirs. Transfers from Quabbin to Wachusett embody an integrated systems approach that balances water quality protection with quantity management.
3. **Release & Overflow**: Outflows consist of required and planned releases for seasonal drawdown/fill reservoir adjustments, overflows when reservoirs reach capacity, and water withdrawals to meet demand. Planned releases are designed to anticipate seasonal storage needs and facilitate reservoir maintenance.
4. **Demand**: After treatment, water is withdrawn based on customer needs and distributed through a network of deep rock tunnels and around 284 miles of distribution pipes to MWRA communities.

Figure 2-2
Supply System Schematic



[2] Watershed yields include data from 1948–2000.

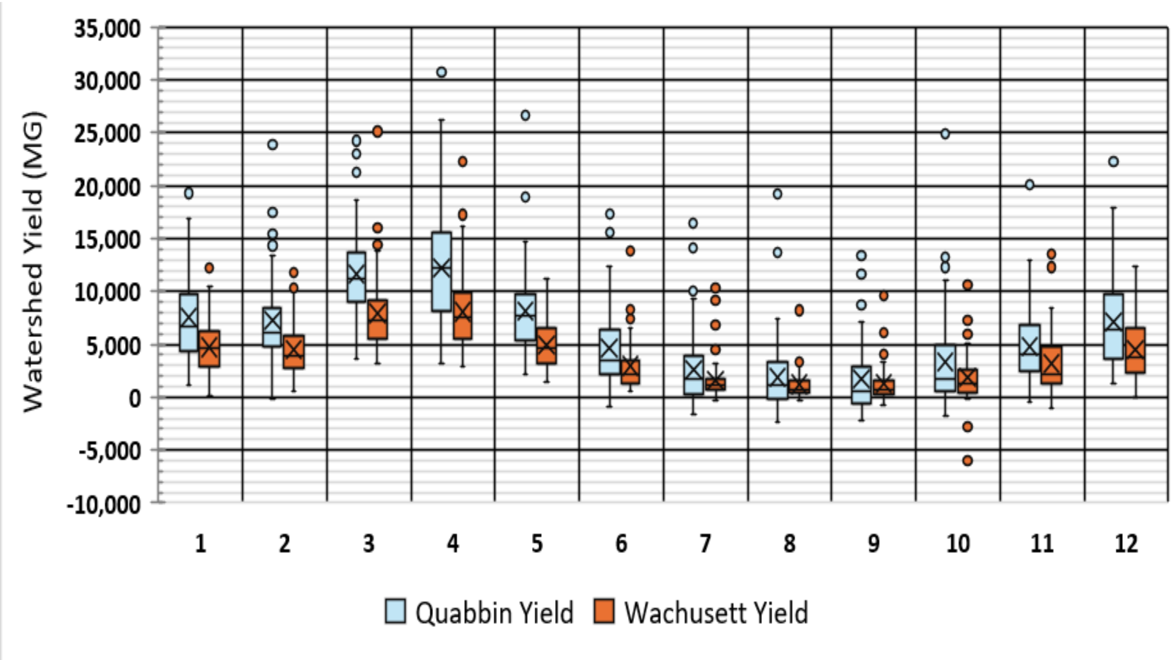
Inflow and storage are closely linked and are discussed together in Section 2.1, and the subsequent Section 2.2 describes the management of releases and overflows from the water supply system, including how multiple, sometimes competing objectives must be met by these releases. Before discussing the final principal mechanism of system demand, Section 3 defines several important limitations of the water supply and conveyance system, irrespective of final customer demand. These include constraints such as safe yield, hydraulic capacity of tunnels, watershed capacity to refill storage reservoirs, and the need to be able to respond to both flood risks and intense drought periods, including expected impacts of climate change. After these limits have been established, Section 4 provides an analysis of current and historical system withdrawal, including long-term trends, observed seasonal variability, and projected demand growth. Section 5 describes the process for evaluation of the MWRA water system under the various constraints and projected demands. Section 6 assesses the impacts of the proposed additional 20 MGD interbasin transfer.

2.1 Inflows & Storage

The reliability of the MWRA water system is supported by the large storage capacities of the Quabbin and Wachusett Reservoirs. The Quabbin Reservoir has a total capacity of 412 billion gallons, and the Wachusett Reservoir holds 65 billion gallons, providing a combined total capacity of 477 billion gallons. The MWRA's multi-year drought storage capacity significantly exceeds the definition of multi-year storage set by the Massachusetts Department of Environmental Protection (MassDEP) under the WMA regulations.

The immense size of the Quabbin-Wachusett watershed and reservoirs allow for the system to capture and retain watershed yields throughout the year while maintaining controlled release downstream when conditions demand. Yields vary throughout the year – especially during the spring melt. There are no strong trends noticed over time with inter-annual variability. The bar-and-whisker plot in Figure 2-3 demonstrates the monthly variability in the year 1948–2025. The box represents data within the 25th and 75th percentiles, upper and lower quantiles are found within the whiskers, which extend 1.5* the range of the box to set a boundary beyond where outliers are located. The tight box and overlay of mean (marked by X in the box) and median (vertical line) show the inter-annual variability is small.

Figure 2-3 Quabbin-Wachusett Watershed Monthly Yields (1948–2025)



For the MWRA, the authorized withdrawal is 312.82 MGD,[3] and required releases average at 28.4 MGD for Swift River and 1.7 MGD for Nashua River-—a total of 30.1 MGD[4], resulting in a total system demand plus releases of 343 MGD or approximately 125 billion gallons (BG) annually. The MWRA system provides 467 billion gallons of multi-year drought storage capacity or 3.74 years of drought storage—as calculated by the Water Management Regulation (310 Mass. Code Regs. §36.03, 2023). Because the MWRA has multi-year storage, the WMA allows the MWRA to have a system-specific drought plan based on its supply.[5]

2.1.1 Quabbin Watershed & Reservoir

The Quabbin Reservoir has a capacity of 412 billion gallons, a surface area of ~39 square miles (100 km²), and a watershed area of 187 square miles (485 km²). Approximately 57% of the watershed land is owned by the Massachusetts Department of Conservation and Recreation (MassDCR), and 75% protected from development impacts. Releases to the Swift River pass through the Winsor Dam, at the southernmost point of the Reservoir (see Figure 2-4).

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[3] The current actual 5-year average withdrawals is 200 MGD, over 110 MGD less that that authorized by the WMA and 130 MGD less that the withdrawal on the effective date of the Interbasin Transfer Act.

[4] Based on historical data (1948–2025) of required releases. Amount expected to have small variability year to year.

[5] See *MWRA Drought Response Plan*, 2025.

A substantial portion of the flow out of the reservoir is via the 13-foot diameter, 24.6-mile Quabbin Aqueduct that travels east to the Wachusett Reservoir. These transfers from the Quabbin Reservoir typically account for over half of the Wachusett Reservoir's average annual inflow. Demand by customer communities in the Chicopee Valley is met by supply from the Quabbin reservoir via the Chicopee Valley Aqueduct.

MWRA operates Quabbin Reservoir according to three main objectives:

1. Minimum releases: Required releases from the Quabbin Reservoir are defined by Chapter 321 of the Acts of 1927, which dictates a year-round minimum flow of 20 MGD with additional seasonal releases depending on flow of the Connecticut River, of which the Swift River is a tributary (see Section 2.2).
2. Water Quality: Quabbin water is improved by natural processes during the multi-year retention period and mixed with Wachusett water to maintain quality.
3. Water Quantity: Balance between retention and flood control is maintained through transfers and releases.

2.1.2 Wachusett Watershed & Reservoir

The Wachusett Reservoir has a capacity of 65 billion gallons, a surface area of around 6.5 square miles (17 km²), and a watershed area of 108 square miles (280 km²). MassDCR owns ~29% of the watershed, and 53% of the land is protected from development. In addition to inflow from the watershed, flow also enters the Wachusett Reservoir via the Quabbin tunnel outlet. During normal operation and after flowing the length of the reservoir, water enters the Cosgrove Aqueduct and travels a further 8 miles to the John J. Carroll Water Treatment Plant in Marlborough. After treatment, water moves further east via the Hultman Aqueduct and Metrowest Water Supply Tunnel before reaching users in MetroWest or Metro Boston.

MWRA operates the Wachusett Reservoir according to three main objectives:

1. Minimum releases: A minimum of 12 million gallons per week is released to the Nashua River, per Chapter 488 of the Acts of 1895 (see Section 2.2). Typical releases exceed this requirement.
2. Operate within elevation bands: Wachusett Reservoir elevation is maintained within a specific, relatively narrow range to balance available supply, prevent shoreline erosion, minimize downstream flooding, and improve water quality by submerging gull roosting areas.
3. Water quality: Quabbin water is mixed with Wachusett water to maintain quality. Transfers are most beneficial during reservoir stratification (May–October), where cooler Quabbin water forms an interflow, improving intake water quality. The benefits of this interflow on source water quality and treatment processes are detailed further in Section 2.2.1 below.

2.1.3 Ware River

The MWRA can supplement system yield by seasonally diverting water from the Ware River watershed to the Quabbin Reservoir. At current demand levels, this is typically only done when the reservoir is below "Normal Operations" based on the Drought Management Plan. Seasonal inflows from the Ware River typically flow by gravity for mixing and detention into the Quabbin Reservoir. When the system is within Normal Operating range, transfers are typically only made for flood prevention in the Ware River basin as well as annual facility exercise and training.

Table 2-1 Ware River Diversion Conditions[6]

Time Period	*Diversion allowance, if river flow:*
Jan 1st to Jun 1st	> 85 MGD
Jun 1st to Jun 15th	> 85 MGD with prior DEP notice
Jun 15th to Oct 15th	No diversion allowed
Oct 15th to November 30th	> 85 MGD with prior DEP notice
Nov 30th to December 31st	> 85 MGD

These guidelines ensure that water transfers are conducted responsibly, balancing the needs of the MWRA water system with environmental considerations. Typical operations limit diversions when the Quabbin Reservoir is within its normal operating elevation band and prioritize reducing the risk of transferring invasive species.

2.2 Releases & Spills

Releases are operationally managed to create capacity and sustain downstream conditions. Spills occur during seasonal refill, when inflows exceed storage and transfer capacity.

Releases from the Quabbin and Wachusett Reservoirs are required by the legislation and permits that have allowed MWRA and its predecessor agencies to use the waters from the Swift, Nashua River, and Ware River basins. The MWRA ensures all minimum releases are met, year-round, according to legislation and permits. MWRA also manages releases and spills to maintain a balance between the two main reservoirs that minimizes downstream flood risk while also ensuring that the best possible quality water reaches treatment plants.

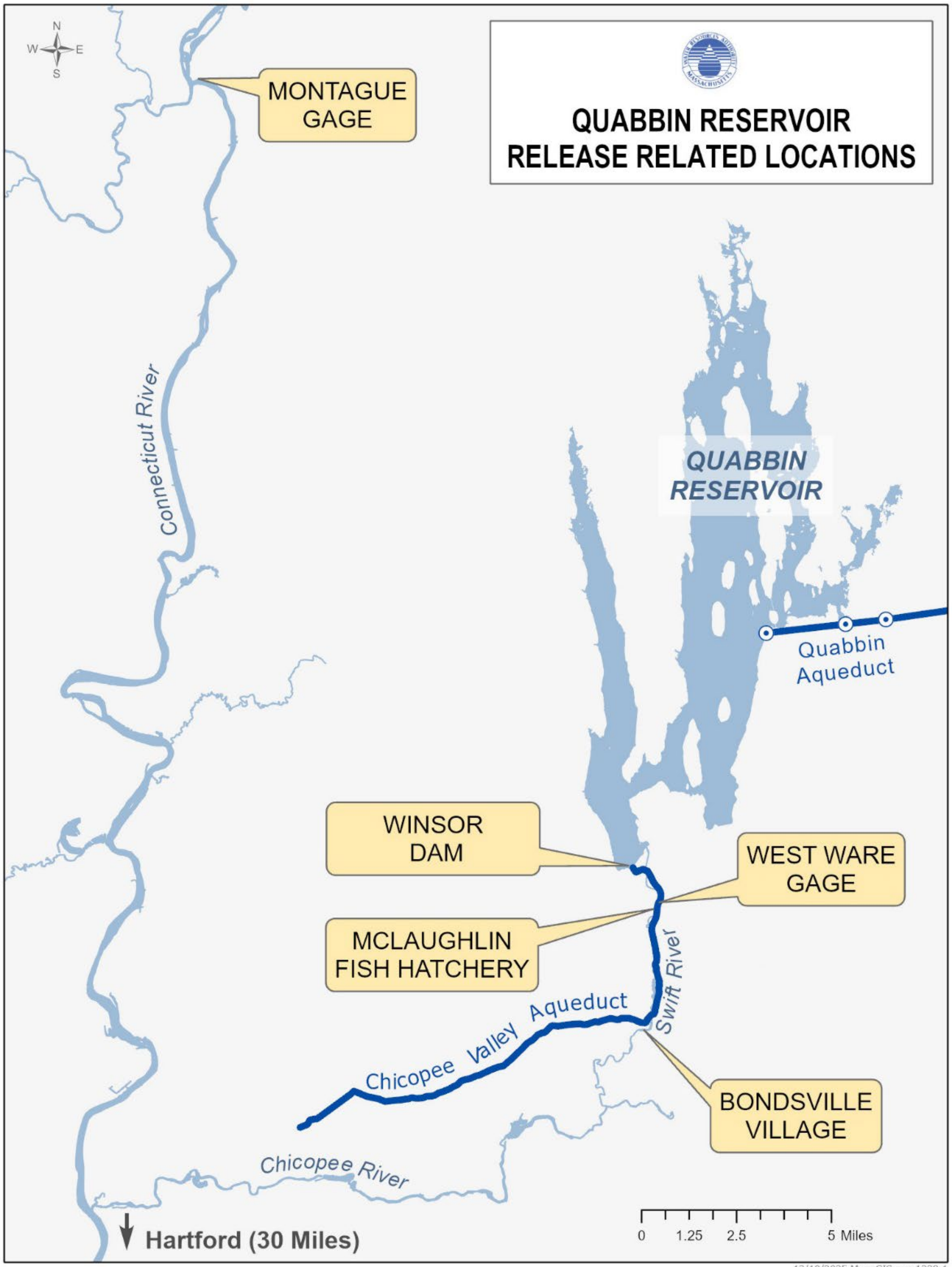
Required releases from the Quabbin Reservoir are defined by Chapter 321 of the Acts of 1927, which dictates a year-round minimum flow of 20 MGD at Bondsville approximately 4 miles downstream of the Winsor Dam, as well as 1929 War Department permits which can require additional seasonal releases depending on flow of the Connecticut River, of which the Swift River is a tributary (see Figure 2-4). The historical average (1948–2025) as well as the 10-year average (2016–2025) of the Swift River Releases is around 28.4 MGD). The required releases defined in legislation and permits are listed in Table 2-2 below.

[6] Per Ware River Act, 1926.

Table 2-2
Downstream Required Releases — Swift River

Required Minimum Release	Elevated Release - Seasonally (Jun 1st to Nov 30th)	
20 MGD	*Based on Montague Gage – Daily Flow (cfs)*	
	* Greater than 4900 cfs	20 MGD
	Between 4650 and 4900 cfs	45 MGD
	Less than 4650 cfs	71 MGD
*Note: *Required Minimum Release takes precedent.*		

Figure 2-4
Quabbin Reservoir Release Related Location



Releases to the Swift River include 6 MGD of water provided to the McLaughlin State Trout Hatchery delivered via a 4,400-foot pipeline and returned to the river below the West Ware gage. This provides clear cold water to the hatchery by gravity, generating hydroelectrical energy and avoiding the energy demand for pumping by the hatchery. The Memorandum of Agreement (MOA) governing this supply indicates that the McLaughlin State Fish Hatchery flow is subject to reduction and cutoff during drought conditions in efforts to conserve water supply.

Releases from the Wachusett Reservoir are a minimum of 12 MG per week to the Nashua River, as required by Chapter 488 of the Acts of 1895. However, when Wachusett watershed yield is sufficient to maintain reservoir elevations within the normal operating range, additional transfers are made from the Quabbin Reservoir for water quality purposes. Consequently, additional transfers lead to additional releases to the Nashua River thus maintaining the reservoir within its operating band and reducing risk of uncontrolled spills.

2.2.1 Wachusett Water Quality—Impacts of Quabbin-Wachusett Transfers

Water quality in the Wachusett Reservoir benefits from transfers of water from the Quabbin Reservoir, which is generally of higher quality due to extended retention time and greater degree of watershed protection. Quabbin-Wachusett transfers reduce concentration of reactive organic matter through dilution, which is considered a precursor to lowering disinfection byproducts. Transfer rates are typically between 100 and 300 MGD.

Reservoir modeling and field testing indicate these transfers to be most beneficial between May and October, when the reservoir stratifies and develops a distinct thermocline or thermal layer. During this period, cold Quabbin water forms an interflow from the aqueduct's discharge point to the Cosgrove Intake. Sustained transfer rates of approximately 220 to 310 MGD are generally necessary to establish and sustain this desired interflow regime.

Additional transfers may occur from October to when the reservoir surface freezes—typically January or February—to submerge shallow areas of the reservoir and assist with bird management.

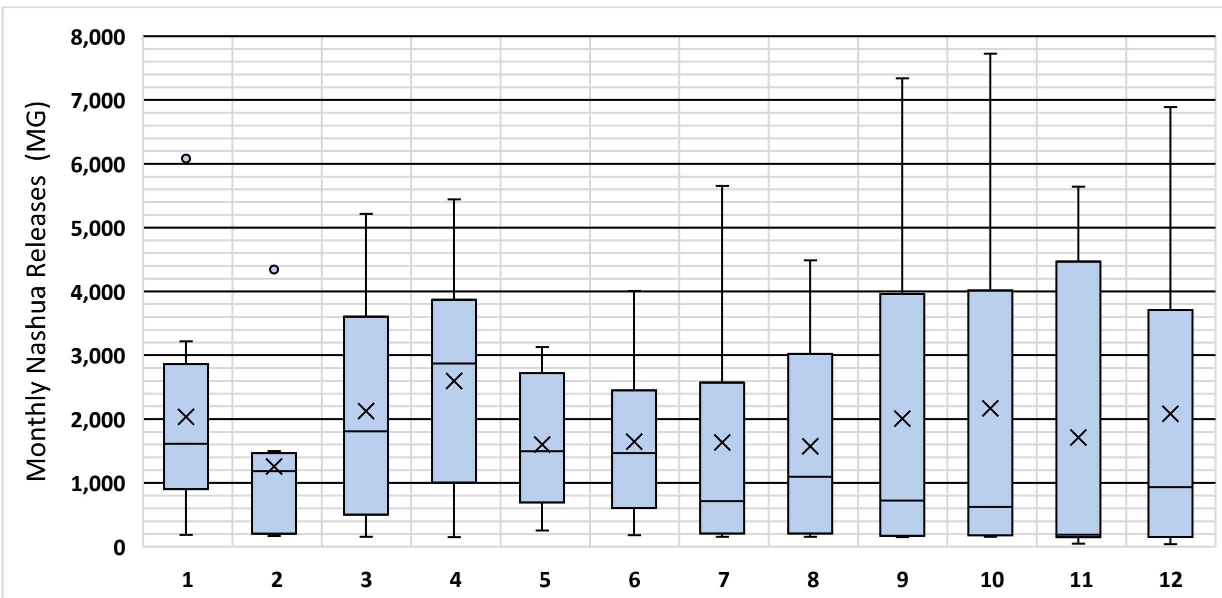
Following the reduction of demand since the peak of the early 1980s, Quabbin-Wachusett transfers are increasingly conducted for water quality optimization rather than to meet demand. When the Wachusett watershed yields are sufficient to maintain reservoir elevations within normal operating range, water quality governed transfers from the Quabbin must be offset with increased Wachusett releases and spills to the Nashua River to maintain adequate operational freeboard and mitigate downstream flood risks.

2.2.2 Patterns of Outflow (Releases & Spills) Operations

The MWRA daily operations—past and future—ensure all minimum releases are met according to legislation and permits. Quabbin Reservoir releases to the Swift River occur year-round and are increased during summer dry periods in response to downstream gage requirements, as informed by Connecticut River gage (see Table 2-2 above). Quabbin Reservoir spills primarily occur during reservoir seasonal fill, with a majority observed in the first five months of the calendar year when inflows exceed available storage and transfer capacity.

Wachusett Reservoir releases to the Nashua River are also required year-round; but during wet periods additional releases are made to make room for Quabbin transfers being made for water quality purposes. Minimum release is maintained via fountain (or other releases in winter due to freezing). Between 2015–2024, Wachusett releases average roughly 200 MG per month—substantially exceeding the minimum release requirement of ~50 MG per month (12 MG/week), as seen in Figure 2-5. Additional releases are considered whenever the Wachusett Reservoir is above the MWRA's seasonal operating band. Figure 2-5 indicates that additional releases can occur on almost any month, but more typically necessary in March and April due to snow melt (as indicated by the median release).

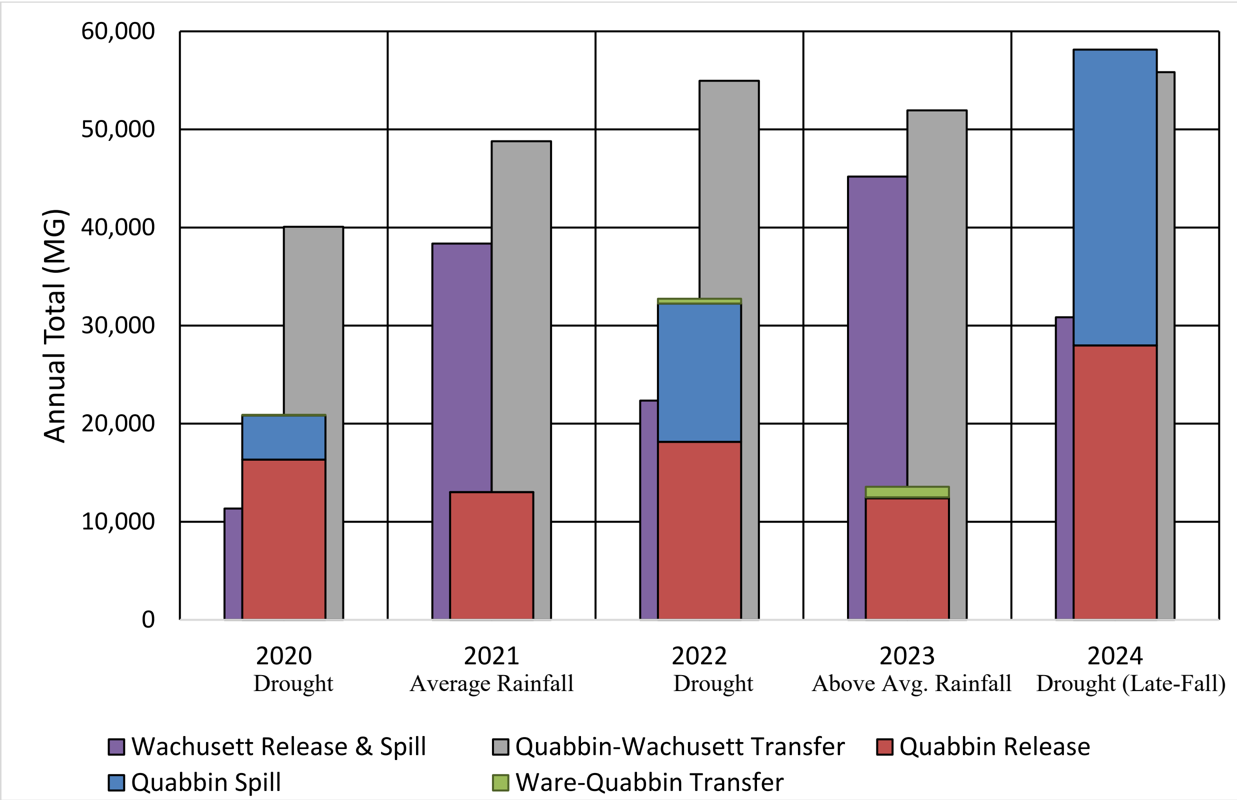
Figure 2-5 Nashua Releases—Monthly Sum (MG)



Due to its substantial multi-year storage capacity of its reservoirs, the MWRA system responds slowly to hydrological conditions. Therefore, the proportional balance of Quabbin and Wachusett Reservoir releases and spills is driven by seasonal dynamics and operational objectives of maintaining quantity and quality water within the MWRA system. Multi-year droughts show the resiliency of the system by dampening the drought impacts to allow recovery to occur over an extended period. Maximum releases are impacted by the Quabbin-Wachusett interflow operations, not by increased demand as will be further demonstrated in Section 6.

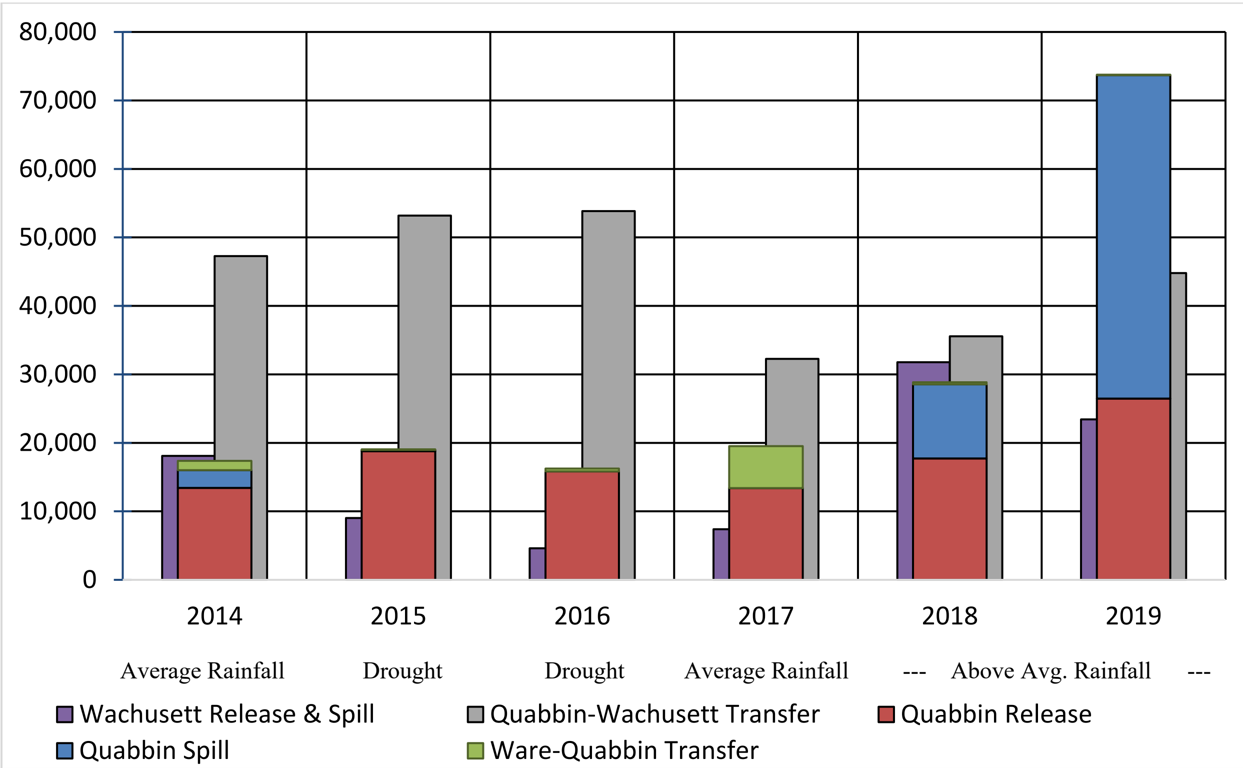
Figure 2-6 illustrates typical operational pattern for the MWRA reservoir system under alternating years of drought and non-drought conditions. Central stacked bars (red, blue, and green) represent Quabbin flows; the left-side column (purple) represents combined Wachusett releases and spills, and the right-side column (grey) represents Quabbin-Wachusett transfers. Quabbin releases and spills are stacked to express a combined total of water outflow into the Swift River.

Figure 2-6
MWRA Reservoir Transfers, Releases, and Spills (2020–2024)



During drought years of 2020, 2022, and 2024, Quabbin spills are still observed during early calendar year, reflecting seasonal hydrologic inputs and the system's multi-year storage response (see Figure 2-6). During reservoir recovery, post-drought conditions, Quabbin Reservoir releases are dampened slightly and spills minimized. In contrast, the Wachusett Reservoir generally inverts this pattern, releases and spills increase during non-drought or recovery years as local watershed inflows increase, and water quality governed transfers from Quabbin are maintained. As reservoirs replenish through average or above average precipitation conditions, water is routed through the supply system via Quabbin-Wachusett transfers to maintain high quality of water at the Cosgrove Intake.

Figure 2-7
MWRA Reservoir Transfers, Releases, and Spills (2014–2019)



Several observations are noteworthy from Figure 2-7, illustrating MWRA reservoir outflows during a multi-year drought (2014–2019). The minimum annual Wachusett Releases & Spills during this period—4,620 MG in 2016—is approximately 7.5 times greater than the required minimum release to the Nashua River (624 MG per year). The significance of 2016 represents the peak drought conditions of the 2015–2017 multi-year drought. Over the past 20 years, Quabbin-Wachusett transfers have averaged around 46,000 MG annually. Following the multi-year drought of 2015–2017, transfers were intentionally reduced to prioritize reservoir refill resulting in Quabbin spills once storage capacity was full. Increased Ware-Quabbin transfers in 2017 reflect targeted efforts to accelerate Quabbin Reservoir recovery and are typically limited to drought response actions due to water quality considerations.

SECTION 3 DONOR BASIN SUPPLY CAPACITY

MWRA employs a proactive, management-based approach to water supply planning, where strategic interventions guide operations toward long-term goals and reduce reliance on costly reactive measures. The water supply system has a great advantage in its very large capacity relative to typical demand, but the final capacity to meet this demand can be limited by physical limitation of conveyance infrastructure and the need to ensure reliable, high-quality supply into the future. Standard Operational Procedures and planning strategies have been established to ensure a reliable, high-quality water supply during drought events.

Currently, MWRA is withdrawing an annual average of around 200 MGD (as of 2024) from a watershed and reservoir system with a safe yield of 300 MGD.

3.1 Safe Yield

Traditionally, water engineers have assessed a water supply system's capacity using a measure known as safe yield—the maximum constant average annual demand that the system can reliably supply during a critical drought period. In addition to safe yield, MWRA has adopted a nuanced approach to measuring capacity. This approach evaluates yield, the impacts on the reservoirs themselves, and the effects on customers as system demand increases.

The safe yield of the Wachusett-Ware-Quabbin system has been designated as 300 million gallons per day since the design of the Wachusett Aqueduct in 1895 (Massachusetts State Board of Health, 1895). Subsequent studies in 1922, 1950, and several in the 1980's and 90's have affirmed 300 MGD as a conservative estimate of system safe yield (Massachusetts State Department of Public Health and Metropolitan District Commission, 1922; Coffin, in Boyce et al., 1950; Wallace, Floyd, Associates, Inc., 1986; Vogel and Hellstrom, 1988; Joyce et al., 1994). The demand of the existing MWRA service area continues to be substantially below the system safe yield, thereby allowing MWRA to serve additional communities without affecting MWRA's ability to stay well within safe yield of the watershed system and its WMA registrations of 312.8 MGD.

In 2010, the MWRA in conjunction with the National Center for Atmospheric Research (NCAR) and the Stockholm Water Institute investigated the probable impact of a changing climate on safe yield. The results indicated that due to its large multi-year storage, the MWRA was poised to leverage a wetter Northeastern Climate (suggested by most climate models at the time) into a modest increase of about 8% in its safe yield. Similar to demand projections (see Section 4), MWRA is using a conservative approach to safe yield projections by not considering the likely future increase in safe yield in these analyses as outlined in the next section.

3.1.1 Climate Change Impacts Safe Yield

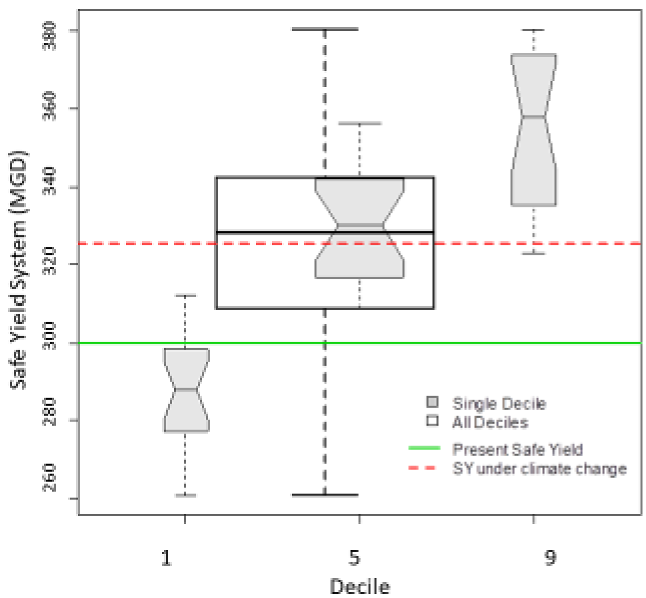
The approach used to assess the potential impacts of climate change on safe yield, detailed in a 2011 Water Research Foundation report (Yates and Miller), applies results from multiple General Circulation Models (GCMs) to develop regional probability distributions for temperature and precipitation changes. Unlike earlier studies that relied on single-point estimates from a specific climate model and greenhouse gas scenario, 21 different GCMs were used to define a plausible range of future temperature and precipitation changes, calculated from 20-year means around the year 2060. This method then uses statistical techniques to generate climate ensembles at the 10th percentile, median, and 90th percentile (1st, 5th, and 9th deciles).

The results indicate a projected increase in safe yield to 324 MGD, an estimated 8% increase over the historical 300 MGD figure under a moderate emissions scenario. This analysis incorporated geographically refined rainfall projections, using localized rainfall data adjusted for climate projections at weekly time steps, rather than relying solely on generalized regional data at monthly intervals. For the Northeast region, these models range from -0.1mm to 1.0mm of additional precipitation per day, and from roughly 1°–4° C. A probability density for the mean outputs for all models was created, and those at the extremes of these distributions were given less weight. The values reported in the K-NN decile box & whisker plots within Figure 3-1 are projected from these GCMs.

Figure 3-1 illustrates the expected increase in safe yield under climate change scenarios. The first column (1st decile) represents the 10th percentile of projections, the second column (5th decile) reflects the median estimate, and the third column (9th decile) represents the 90th percentile. The red line indicates the weighted average of the three modeled deciles, representing the projected safe yield increase due to climate change. The green line marks the current safe yield of 300 MGD. In more than 90% of the simulations, safe yield increased, though a small number of cases projected potential decreases. These findings were reinforced with a similar application of the K-NN method applied by research at UMass Amherst, which examined a broader range of climate scenarios with similar results (Brown et al., 2012). In this case, the projections of temperature and precipitation from 39 climate projections (emissions scenario A1B) from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model data set, runs were used to estimate future reliability probabilistically (Carvalho et al., 2022). Both studies utilized the MWRA system safe yield of 300 MGD for the modeled climate change scenarios; therefore, underutilizing all available increased yield potential.

The conclusion of climate change research for New England suggests an ongoing trend of increased precipitation and greater seasonal variability, with more frequent shifts between intense wet and dry periods (Yates and Miller, 2011; Brown et al., 2012). The reliability of snowmelt as a seasonal water source is expected to diminish as winter seasons shorten and temperatures rise. The shift from snowmelt-driven (nival) to rainfall-driven (pluvial) hydrology will result in increased reliance on direct precipitation rather than stored snowpack. The projected increase in safe yield is largely attributed to the Quabbin Reservoir's multi-year storage capacity. The reservoir's watershed captures and retains the increased precipitation and inflows from more intense storms, making additional water available for use during dry periods. MWRA will continue to comply with all Safe Drinking Water Regulations and does not foresee a reduction in volumes of drinking water produced to maintain compliance with these regulations.

Figure 3-1
Potential Increase in Safe Yield with Climate Change



3.2 Out-Of-Basin Conveyance Infrastructure

In total, the MWRA transmission system consists of over 100 miles of active tunnels and aqueducts as well as over 40 miles of stand-by/emergency aqueducts that transport water by gravity to points of distribution within the MWRA service area.

The Quabbin Tunnel is 24 miles long, extending from Shaft 12 at the Quabbin Reservoir intake in the Chicopee River Basin to the Wachusett Reservoir in the Nashua River Basin. Quabbin flow transferred via the Quabbin Aqueduct enters the upper end of Wachusett Reservoir and constitutes more than half of the average annual inflow to Wachusett Reservoir. The Quabbin Tunnel can also transfer water from the Ware River watershed to Quabbin Reservoir via the Ware River Intake at Shaft 8 in Barre.

The other principal conveyance structure that is actively used to transport MWRA water out of the donor basins is the Cosgrove Aqueduct, which conveys water from Wachusett Reservoir in the Nashua River Basin to the John J. Carroll Water Treatment Plant (JJCWTP) in Marlborough in the Sudbury-Assabet-Concord (SUASCO) River Basin. The Wachusett Aqueduct serves as back-up to the Cosgrove Aqueduct and similarly conveys flow from Wachusett Reservoir to the JJCWTP. After treatment, water is sent eastward through the MetroWest Water Supply Tunnel or Hultman Aqueduct.

Table 3-1 provides an overview and information on capacity of the MWRA aqueducts and tunnels that transport flow from the Chicopee and Nashua River donor basins to downstream points of distribution.

Table 3-1

MWRA Interbasin Transfer System

Aqueduct/Tunnel	Transfer	Year Built	Capacity (MGD)	Length (miles)	Status
Quabbin Aqueduct	Quabbin Res. & Ware River (Chicopee River Basin) to Wachusett Res. (Nashua River Basin)	1939	610*	24.6	Active
Chicopee Valley Aqueduct	Downstream Chicopee River Basin communities; Connecticut River Basin	1949	16.5	14.8	Active
Cosgrove Aqueduct (under normal operating conditions)	Wachusett Res. (Nashua River Basin) to JJCWTP (SUASCO River Basin)	1967	450	8	Active
Wachusett Aqueduct (back-up to Cosgrove for redundancy)	Wachusett Res. (Nashua River Basin) to JJCWTP (SUASCO River Basin) or Sudbury Reservoir (SUASCO River Basin)	1897	240-250	12	Stand-by
MetroWest Water Supply Tunnel (MWWST) (Provides redundancy to Hultman)[7]	JJCWTP and points downstream in MWRA service area.	2003	342	17.6	Active
Hultman Aqueduct (provides redundancy to MWWST)[9]		1939	291	17	Active
City Tunnel, City Tunnel Ext., Dorchester Tunnel		1950 1963 1976	300 200 200	5.4 7.0 6.4	Active Active Active
* While Quabbin tunnel has a flow capacity of 610 MGD under certain conditions, flow is restricted at its outlet (the Oakdale turbine and bypass valve) to 300 MGD.					

[7] On July 8, 1991, the Water Resources Commission unanimously passed a motion to accept a staff recommendation to exempt the Sudbury Tunnel Project (now called the Metro West Tunnel) from the provisions of the Interbasin Transfer Act, based on 313 CMR 4.02(j), provided that the combined transfer through the Hultman Aqueduct and the Metro West Tunnel did not exceed the capacity of the Hultman Aqueduct of 300 MGD.

3.3 Flood Control

MWRA operations, under current demand, typically mitigate flooding and dam overflow at the Quabbin Reservoir by maintaining the lower spillway elevation at a maximum of 528 elevation to allow a 2-foot additional storage before activation of the spillway's full length. In March 2010, a series of substantial rain events caused spillage of approximately 2 billion gallons per day. Spills like these create the risk of aggravating downstream flooding and can cause dam safety concerns in extreme flood events.

After significant rain events, the Wachusett Reservoir watershed can produce a level of inflow that exceeds available storage in the reservoir and causes spillage. For example, a rain event on April 14, 2007 caused reservoir elevation to rise 2.2 feet (about 3 billion gallons) in a 40-hour period, which resulted in a rate of spillage of approximately 800 MGD. Since then, additions of a new crest gate and the use of advanced modeling of potential inflows have helped MWRA to avoid excessive releases by proactively releasing water ahead of a storm. Lower reservoir maximum levels—to provide a safety void—benefit flood control by providing a cushion to absorb severe storms. The MWRA typically releases additional water in anticipation of major storm events.

3.4 Drought Response

Drought planning has shaped the operations and long-term management strategies for the MWRA. Drought is characterized by prolonged periods of abnormally dry conditions resulting from precipitation deficits and increased evapotranspiration due to heat stress. Recent years have seen the emergence of "flash droughts," which are periods of rapid drought intensification driven by high temperatures, reduced precipitation, strong winds, and accelerated evapotranspiration. These events can develop within weeks and may occur either at the onset of drought or during an ongoing dry period. While flash droughts add complexity to water resource management, especially to systems with limited storage capacity, the MWRA system's substantial multi-year storage capacity provides extended lead time to monitor conditions and implement operational and demand management responses.

Historically, droughts affecting the MWRA system have developed over extended periods exerting cumulative impacts on regional water supplies. The 1961–1969 drought remains the most severe on record, during which 37 communities declared water emergencies, and the Quabbin Reservoir dropped to 45% of capacity in May of 1967. Water use during this period peaked at 278 MGD, during what subsequent analysis estimated to be 1-in-400-year occurrence (Nechamen, 1983, as cited in Water Supply Citizens Advisory Committee, 1985; Pederson, 2016; Pederson et al., 2013). As a result, this severe drought event defines model parameters, along with safe yield, for long-term planning purposes.

A second major period of water stress occurred in the late 1980s, driven by below-normal precipitation and declining watershed yield over four years along with water use exceeding the system's safe yield. This led to localized water emergencies and the prompting formalization of MWRA drought management framework.

More recently, the 2015–2016 drought provided a relevant test of the system under multi-year dry conditions. Total rainfall in 2016 was approximately 37 inches, comparable to cumulative precipitation deficits experienced during the 1960s statewide drought. Streamflow and groundwater levels hit record lows, with 15 gages and 41 wells recording all-time low levels in September 2016. Despite these conditions, system storage and operational flexibility allowed MWRA to manage the event without approaching the severity of historic system impacts.

Together, these drought periods demonstrate how the MWRA's multi-year storage, operational planning, and demand management strategies allow the system to absorb both gradual and rapidly intensifying drought conditions while fulfilling all operational objectives.

3.4.1 MWRA Drought Response Plan

The MWRA Drought Response Plan is founded on the principle of trigger planning, a project management technique designed to identify and prepare for potential risks or issues that may arise during a project. This approach involves developing a list of potential triggers—specific events or conditions that could signal a problem—and outlining corresponding response actions to address them. The MWRA's official drought declaration criteria rely on a critical key measurement to activate drought plan triggers—the elevation of the Quabbin Reservoir. This indicator serves as an effective and straightforward gauge, as it integrates many elements of typical drought indices, such as weather conditions, streamflow, soil moisture, evaporation, and reservoir yield into the single easily understood and communicated measure.

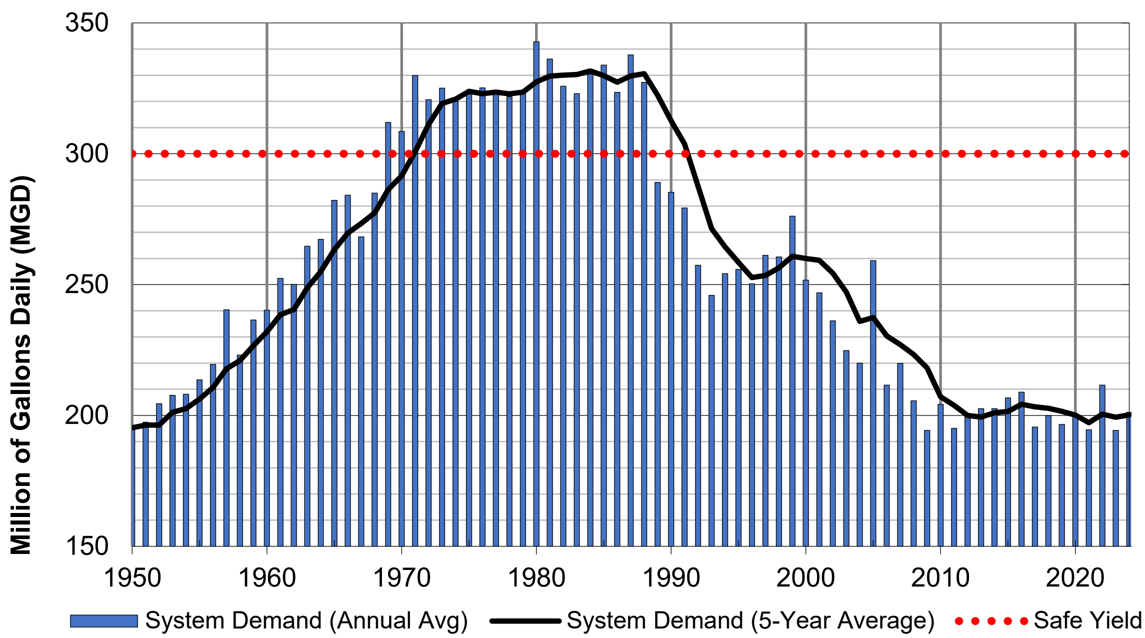
MWRA models the performance of the system under drought conditions based on Quabbin Reservoir elevation (see Section 5). This approach accounts for the dampening effect of the system's large storage volume. The state drought plan and drought task force may recommend the declaration of drought conditions even when MWRA reservoir levels remain above "Normal" levels, as other indices—such as precipitation, streamflow, and groundwater—may reflect severe conditions for systems with less storage. The resilience of MWRA's water supply buffers against immediate impacts, continuous monitoring of all drought conditions in MWRA's approach and response plan is crucial to avoid missing the transition into a prolonged drought.

The MWRA Drought Response Plan defines drought conditions and triggers response actions based on Quabbin Reservoir elevation, recognizing seasonal variations in reservoir levels due to normal fill and drawdown cycles. The plan establishes seasonally adjusted elevation triggers that dictate appropriate response measures to ensure continued reliable water supply. Progression of response measures escalate in stringency from voluntary to mandatory as drought severity increases. Response measures are actions, policies, and programs that influence the consumption behavior of the system. Drought management relies heavily on the ability to understand and influence demand on the system. As described in Section 5, the degree of drought actions is a key evaluation parameter for donor basin evaluation.

SECTION 4 MWRA SYSTEM WITHDRAWAL

The MWRA water system serves approximately 2.7 million users in Metropolitan Boston, Metro-West and the Chicopee Valley in Western Massachusetts. System water demand increased steadily during the 1960's, 70's and 80's. In 1986, rather than pursuing options for increasing supply, MWRA's Board of Directors opted to pursue a range of demand management and supply protection strategies. 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 increase conservation and efficiency throughout the MWRA service area while preserving local sources. MWRA's aggressive water conservation efforts, including local leak detection and repair programs, yielded significant gains early on, with a 20 percent drop in the first five years. Current system withdrawal rates have dropped to levels last seen in the 1950's (see Figure 4-1). New plumbing codes, more efficient appliances, shifts from water-intensive manufacturing to less intensive commercial users, improved system management and metering all contributed to lower demand. Significant water and sewer rate increases also played a part in focusing attention on water use efficiency and thus reducing water use in member communities.

Figure 4-1
MWRA System Withdrawal[8] — Annual & 5-yr Averages



[8] MWRA often distinguishes between "demand," or potable water delivered to customer communities, and "withdrawals," meaning customer demand plus additional uses such as Worcester's rights to the Quinapoxet sub-basin of the Wachusett watershed or supply to the McLaughlin Fish Hatchery downstream of the Windsor Dam. For this analysis, "demand" and "withdrawal" are used interchangeably and refer to all uses supplied by MWRA from the Quabbin and Wachusett watersheds.

4.1 Fully vs Partially Supplied Communities

The MWRA water system serves two primary categories of communities: fully supplied and partially supplied. Fully supplied communities receive all their water directly from MWRA. This group of 22 core MWRA water and sewer communities also includes the three Chicopee Valley Aqueduct (CVA) communities and seven additional metropolitan communities served by the MWRA water system but not the sewer system. Together, these 35 fully supplied communities have maintained an average annual demand of approximately 167 MGD over the past decade (2015–2024).

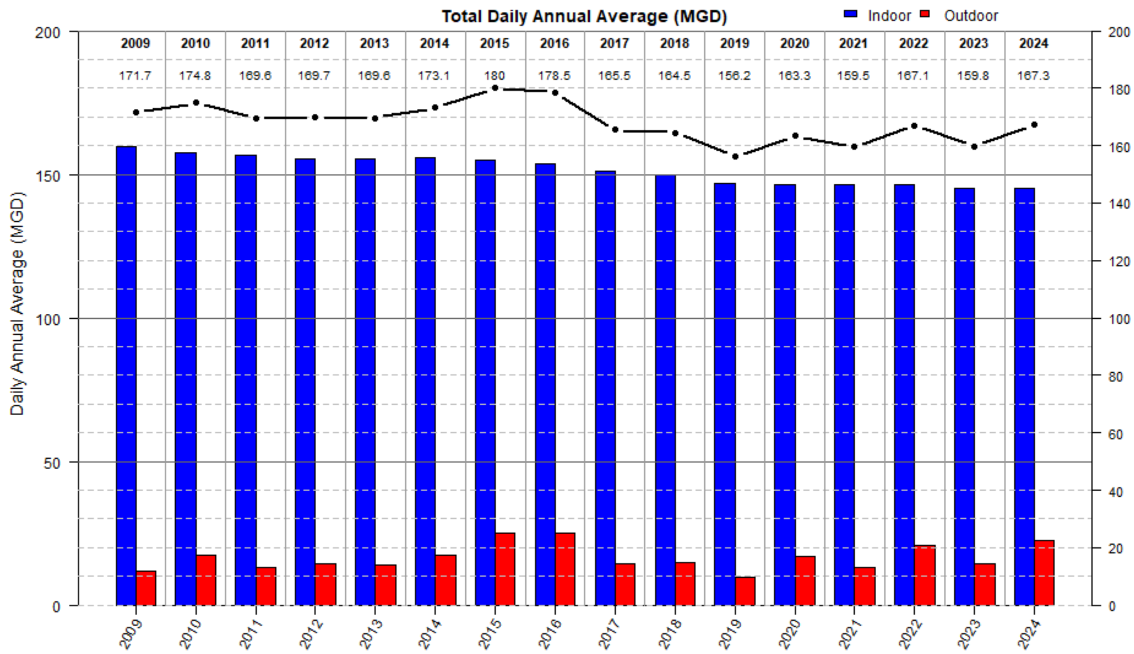
Partially supplied communities—currently 15 in total—supplement their local water sources with MWRA supply to varying degrees. Between 2015 and 2024, an average of 14.8 MGD of demand in these communities was met by MWRA, while 73.8 MGD were supplied by their local sources. Excluding the three communities that take water only during emergencies—Leominster, Worcester, and Cambridge—MWRA provided an average of 12.54 MGD to these partial communities, while the remaining local sources supplied 43.5 MGD.

4.2 Seasonality

Many of these partially supplied systems are relatively small and therefore more sensitive to annual variations in precipitation and temperature. Shorter dry periods that would have little impact on the Quabbin, Wachusett, or Ware River systems can produce localized shortages, prompting additional use of MWRA supplies. The MWRA drought model accounts for both seasonal dynamics and interannual variability, anticipating increased supplemental demand during dry conditions—see Section 5 for details. Seasonal (outdoor) demand within fully supplied communities varies from 10 to 26 MGD (7–14% of total demand) depending on hydrological conditions (see Figure 4-2). MWRA's analysis is based on daily data from the fully supplied communities, which account for 90% of total demand, with similar assumed seasonal demand for partially supplied communities. Given the low seasonal demand relative to annual totals, this range is considered appropriate for projections. Historical experience during the 1960s and more recent droughts indicates that demand from emergency connection communities, including Cambridge and Worcester, increase as local supplies became stressed.

As part of the MWRA efforts to understand and respond to changing conditions due to climate change, the MWRA staff continue to analyze factors of seasonal use—with the assumption of dry conditions impacting outdoor consumption. With consideration of current climate reports, the demand projections presented below do not make any specific allowance for climate change increases in residential or commercial uses, beyond those already accounted for in our modeling—see Section 5 for details. MWRA staff will continue to monitor this dynamic and revise projections as new climate information is made available. Because seasonal demand represents only a small fraction of MWRA's total demand, averaging about 8 percent, climate change related increases in this demand would be negligible for the long-term projections seen below. However, the MWRA does address possible climate change impacts on partial users with an emergency contingency—see Section 5 for details.

Figure 4-2
Fully Supplied Communities' Annual Indoor and Outdoor Demand



4.3 Projecting System Demand in 2050

A reliable estimate of drinking water demand in 2050 provides an essential benchmark for long-term planning and investment. MWRA's demand projections incorporate expected population and employment growth across its service area, multiplied by appropriate water use intensity factors that reflect historical trends, regulatory standards, and expected future efficiencies (Massachusetts Department of Transportation, 2023; UMass Donahue Institute, 2024).[9,10]

4.3.1 Methodology & Results

In the forthcoming 2026 update to MWRA's Master Plan, there are four scenarios for residential demand increases evaluated by MWRA for 2050 that span from excessively conservative to expected realistic efficiency (see Table 4-1). The most conservative scenario utilizes the state 65 gallons per capita per day performance standard used in statewide forecasts, which is significantly higher than the current use by MWRA customers. An additional three scenarios incorporate more realistic variables—community demand variability and increasing system efficiency. MWRA applied Residential Gallons per Capita per Day (RGPCD) values derived from Annual Statistic Reports (ASR) from MassDEP. Data within individual member communities utilizes data from 2017–2024 in order to capture RGPCD values using 2020 census data for accuracy. These values

[9] Projections are an MAPC supplement to projections published by the UMass Donahue Institute.

[10] Provided upon special request to update Somerville projections.

are generally lower than the 65 gallons per capita per day performance standard used in earlier forecasts, reflecting the higher efficiency typical of MWRA communities.

Two scenarios were considered—one with an expected efficiency improvement of 10% for new population growth with a consistent base current demand, and another with the same plus an additional 5% expected efficiency within the base system demand. These scenarios assume that future residents will continue to use slightly less water per capita than existing users, exerting additional downward pressure on residential demand growth. This assumption is supported by the 10-year and 20-year average of continuous efficiency within the MWRA system, MassDEP statewide reporting, and national trends (LeVangie and Chen, 2025; Mayer, 2026). Future population growth is expected to concentrate within denser, transit-accessible areas, and Massachusetts has passed legislation to support and encourage this type of growth (760 Mass. Code Regs. §72.03, 2025). The projection scenarios also assume that community system leakage will remain the same, if not improve over time, due to the extensive technical and financial assistance programs advocated and supported by the MWRA on-call leak detection, pipeline rehabilitation, education opportunities, etc. For these reasons, the MWRA believes the scenarios presented below are more realistic outcomes than would be projected by simply applying 65 gallons per day to all expected population growth.

Residential growth within MWRA's existing service area (excluding emergency-only connections to Worcester, Leominster, and Cambridge) is projected at 323,963 people (+12.6%) between 2020 and 2050. Applying the WRC standard of 65 RGPCD would result in an estimated 21.1 MGD increase in residential demand. When more recent community-specific RGPCD values are applied, this projection drops to 15.4 MGD, and if 10% efficiency improvement is assumed for future development, the increase further declines to 13.8 MGD.

Commercial growth projections are incorporated using a single non-residential water use intensity factor based on the WRC forecasting methodology, which assumes future growth to have the same water use efficiency as now. Commercial growth across the same area is projected at 192,153 jobs (10.8%) by 2050. Using the WRC forecasting method, this translates to an estimated 6.5 MGD increase in non-residential demand, or about 31.5 gallons per employee, substantially below the 45 gallons per additional employee assumption used in prior MWRA 2018 Master Plan forecasts. Assuming new development is 10% more efficient than current use yields an increase of 5.9 MGD.

Finally, the forecast includes a contingency for partially supplied communities that may rely more heavily—either in the short-term or long-term—on MWRA water due to local constraints such as stressed watersheds, limited/decreasing yield, or emerging contaminants. A partial-user contingency of 18.5 MGD—representing 25% of the local-source demand in partially supplied communities[11]—is added to account for potential increased reliance on MWRA sources. The 18.5 MGD contingency provides a supplementary buffer of potential additional demand year-to-year based on the average local water supply use of partial communities —including emergency only

[11] Average consumption from local sources of all partial communities between 2015–2024; with physical limitations on transmission to Lynn and Worcester considered.

connections for Cambridge and Worcester. Leominster is not included within this calculation as infrastructure is not in place to provide emergency services. This 25% of total volume of average local supply use contingency could potentially accommodate 50% of all partial community demand for half the year.

Table 4-1
2050 Projected Demand – Total MWRA System Withdrawal

		Conservative State Std 65 GPPD for Growth	*Individual Community Trends (2017-2024 Avg)*	*Forecast with Expected Efficiency in Growth*	
				Static Base Demand	*More Efficient Base Demand*
Base System Demand		201.1	201.1	201.1	192.1
2050 Estimate	Residential Growth	21.1	15.4	13.8	13.8
	Commercial Growth	6.5	6.5	5.9	5.9
	Partial User Contingency	18.5	18.5	18.5	18.5
Projected Total System Withdrawal		**247.2**	**241.5**	**239.3**	**230.3**

Based on these assumptions, total system withdrawals are projected to potentially increase from 201 MGD today to between 230 and 250 MGD in 2050, compared to the system's safe yield of 300 MGD (Table 4-1). For the purpose of this analysis, MWRA selected the year 2050 projection of total demand to be **240 MGD**. This is an appropriately conservative value considering ongoing efficiency trends and the characteristics of MWRA's service area.

SECTION 5 WATER SYSTEM PERFORMANCE & EVALUATION

MWRA's system modeling integrates inflows, operational outflows, physical and regulatory constraints, and demand characteristics of the regional water supply system described in Sections 2 through 4. Together, these models can evaluate the reservoir system's resiliency, or its ability to withstand, respond to, and recover from prolonged hydrologic stress while maintaining reliable water supply performance over time.

The system evaluation that follows provides data needed to assess the donor basin water system's reliability and performance for demands ranging from the base demand of 200 MGD to 220 MGD, 240 MGD or 260 MGD arising out of 20 MGD of potential new community demands and 40 MGD of increased demand within the existing service area from population and employment growth and a contingency for increases in use by current partial user communities.

5.1 MWRA Modelling Framework

The aim of MWRA's modelling framework is to simulate system performance across a wide range of hydrologic and demand scenarios, providing a time-based assessment of vulnerability and resilience. The modeling framework is comprehensive, incorporating parameters that capture operational constraints and external stressors, including:

- Conditions of local water sources serving MWRA communities and adjacent systems.
- Planned or proposed projects and events with the potential to affect supply or demand.
- Watershed conditions and operational procedures within the MWRA reservoir system.
- Applicable laws, regulations, and interagency agreements.
- Climate variability, precipitation patterns, and streamflow conditions.
- Public expectations and behavior related to water resource management, conservation, and use.

MWRA evaluates long-term system performance using a set of planning metrics developed through a study completed in collaboration with the Water Supply Citizens Advisory Committee (WSCAC), Massachusetts Audubon Society, and U.S. Army Corps of Engineers (Joyce et al., 1994). This study established the analytical foundation for the reservoir elevation-based triggers that continue to underpin the MWRA Drought Plan. Trigger planning links reservoir storage conditions, rates of reservoir drawdown and recovery, and projected demands to a forward-looking decision framework. Rather than reacting to shortages, the approach emphasizes early detection and proactive management in order to maintain system reliability.

5.1.1 Modeling Approach and Assumptions

MWRA uses a system dynamics model developed in the STELLA® modeling environment (Stella Research Software Package, Version 5.0) to evaluate the impacts of varying demand levels on the trigger-planning performance measures described above (Karpack, 1992). The modeling approach uses system dynamics to represent the reservoir system as an interconnected set of storage, inflow, withdrawal, releases, and operational feedback relationships that evolve over time. STELLA, a system dynamics modeling platform developed by ISee systems, is used to simulate historical hydrological conditions and operational assumptions to evaluate potential drought impacts on reservoir levels and system resilience. Model performance is evaluated using the historical hydrologic record from 1948 through 2024, which includes the drought of record from the 1960s. This period provides a robust basis for assessing system response under severe and sustained drought conditions. These results assume MWRA's current operating procedures for the Ware River - limited diversions only during below "Normal Operations" - remain unchanged.

For any given scenario of annual average demand (MGD), the model assumes regular seasonal variability. This provides a month-to-month average of daily demand based on a 16-year average (2009–2024). The drought model adds additional demand to the seasonal variability with expected incremental increases during dry conditions—influenced by previous months reservoir yield.

Once the Quabbin Reservoir triggers drought conditions, the model includes additional demand referred to as "pop-up demand." This is the extra drought-induced demand for partially supplied and emergency communities. It is modeled as —10 MGD at Below Normal, 15 MGD at Drought Warning, 20 MGD at Drought Emergency Stage 1, 25 MGD at Drought Emergency Stage 2, and 35 MGD at Drought Emergency Stage 3.

The model also implements incremental decrease in overall demand with the introduction of conservation action goals based on a percentage of the 5-year average annual demand. There is a progression of conservation action goals into lower drought trigger stage—0% at Below Normal, 5% at Drought Warning, 10% at Drought Emergency Stage 1, 15% at Drought Emergency Stage 2, and 30% at Drought Emergency Stage 3—illustrates the escalation of expected response actions.[12] These conservation action goal percentages represent realistic and adaptable targets for both MWRA operations and the public.

5.2 Maximum Pool Descent

Maximum Pool Descent is used to assess the Quabbin Reservoir's maximum drawdown under modeled conditions and to evaluate whether system performance thresholds are approached or exceeded. Drought triggers are established at specific Quabbin Reservoir elevations which, together with drought conservation measures, form the basis of the MWRA Drought Plan.[13] Modeling reservoir elevation change is a focus of demonstrating system capability under various conditions.

Maximum Pool Descent is defined as the maximum deviation of the Quabbin Reservoir water surface elevation below a specified target pool level at a given system demand. The Trigger

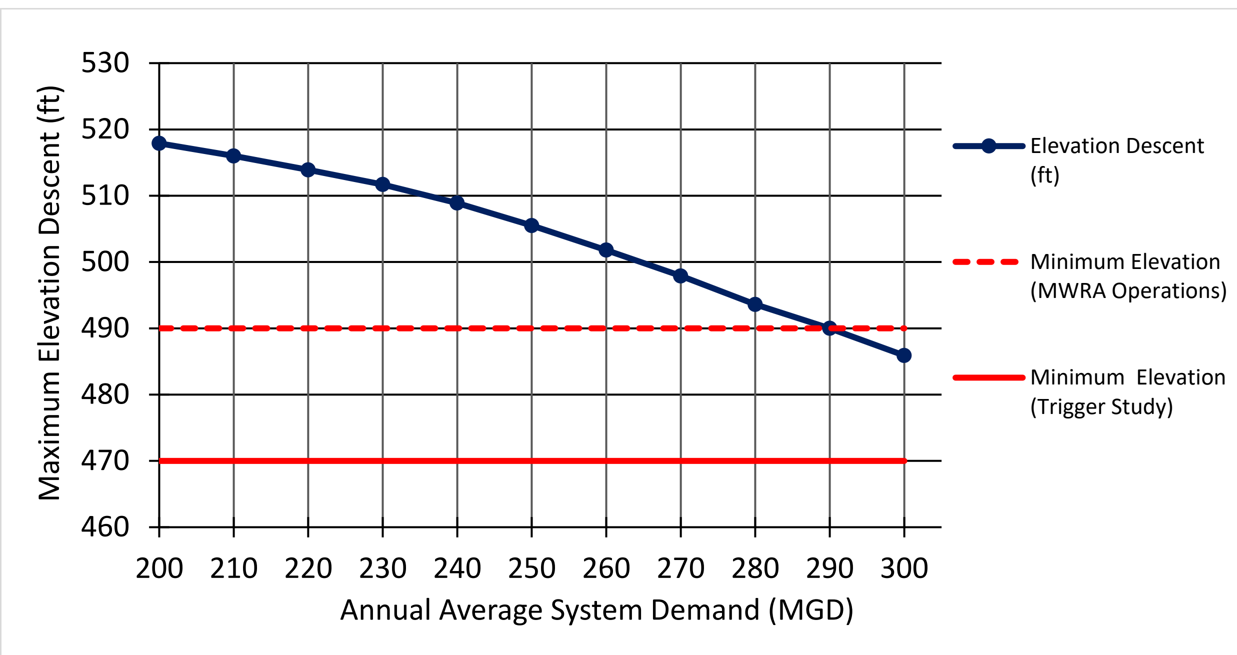
[12] See *MWRA Drought Response Plan*, 2025.

[13] See *MWRA Drought Response Plan*, 2025.

Planning Study recommended limiting maximum pool descent to elevation 470 feet, below which Quabbin Reservoir no longer functions as a single, hydraulically connected unit (Joyce et al., 1994). Maintaining reservoir elevations above this threshold is therefore a key performance objective. To be conservative, the MWRA has adopted a minimum elevation of 490 ft, or 38% reservoir volume, with a focus on water quality rather than just the ability to deliver adequate quantity of water. This minimum elevation is represented by the Drought Emergency: Stage 2 level at 38%. Model results are shown across the range of withdrawal scenarios—from 200 MGD to 300 MGD, at 10 MGD intervals (see Figure 5-1 and Table 5-1 below). As demand rises from the base demand of 200 MGD to 220 MGD, during a drought as severe as the 1960's, the maximum reservoir descent would drop several feet from 518 to 514. At 240 MGD it would drop to 509 feet, and at 260 MGD to 502 feet.

The addition of 20 MGD of additional demand would not adversely affect this performance measure at current demand levels or at those conservatively expected in 2050. The maximum reservoir descent during various droughts at different demand levels can be seen clearly in Figure 5-1. It is not until demands are over 290 MGD that the Quabbin Reservoir drops to an elevation of 490 feet under all modeled scenarios. Under drought conditions comparable to the 1960s drought of record and a system demand of 300 MGD, modeled reservoir levels decline to approximately elevation 485 feet—still above the system minimum of 470 feet, at which point reservoir performance would be compromised.

Figure 5-1
Quabbin Reservoir—Maximum Pool Descent with System Demand



5.3 Reservoir Resiliency

Resiliency is defined as the ratio of drawdown months to recovery (fill months) within drought stages, while severity is defined as the total number of consecutive months spent below the target pool elevation of 490 feet. Together, these measures characterize the duration and pacing of system response within and between drought stages. They are used to determine the lead time available for drought conservation and operational actions to take effect.

Resiliency is inherently complex, as recovery continues to follow seasonal drawdown and fill patterns. This measure focuses on the degree to which reservoir elevations diverge from and recover toward monthly drought trigger elevations. Model results indicate that the most challenging recovery occurred during the 1960's drought of record, which exhibited an approximate 2:3 recovery ratio—meaning for every 2 months of drawdown months required 3 months of recovery. By comparison, the droughts of the 1980's and 2015–2016 exhibited recovery ratios of approximately 2:1 and 3:2, respectively. These recovery rates are dependent on the post-drought precipitation conditions, operational strategies, drought management actions, and public behavior shifts. Modeling of reservoir resiliency at demands ranging from 200 to 260 MGD indicates no adverse impacts with recovery ratios ranging from 2:1 within "Below Normal" to 1:2 within "Drought Warning". There is no ideal resiliency ratio—the measurement serves as an expected timeline for conservation actions to be implemented.

5.4 Drought Severity

Drought Severity, defined as the total number of consecutive months spent below the target pool elevation of 490 feet, is used as a long-term planning metric to evaluate the impacts of increased system withdrawal rates (see Table 5-1 below). This minimum elevation of 490 ft focuses on water quality rather than just the ability to deliver adequate quantity of water; and demarcated by Drought Emergency: Stage 2 level at 38%. Table 5-1 illustrates the maximum elevation descent expected along with the modeled amount of months within each drought stage based on the historical conditions and various system demands from 200 MGD to 300 MGD.

The current withdrawal at 200 MGD provides a lead time window of 12 months between drought stages. A STELLA model run at 250 MGD produced a 6-month rate drop from Below Normal to Drought Warning. During a significant drought, the MWRA system would be expected to see transition of drought stages from Normal to Below Normal in the fall season and then transition from Below Normal to Drought Warning in the late-Spring to Summer when reservoirs fail to hit seasonal fill expectations.

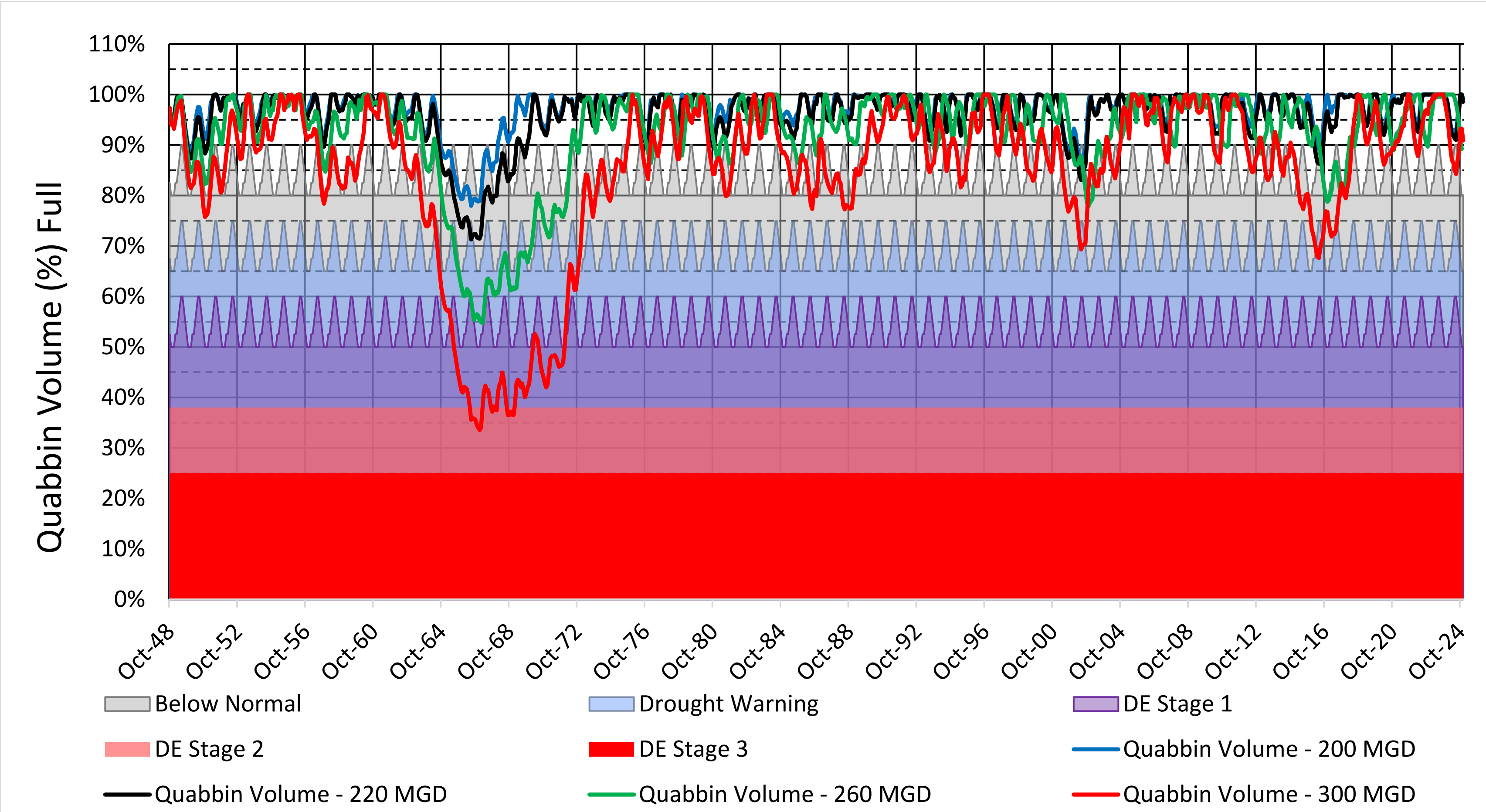
MWRA's reservoir system was designed with substantial storage capacity to buffer seasonal variability and multi-year droughts. The purpose of this multi-year storage capacity is to provide operational flexibility, allowing the system to draw upon reserves during dry periods and recover during subsequent refill seasons. It is not until an average withdrawal of 260 MGD that the system experiences a dip into Drought Emergency: Stage 1 in a drought as severe as the 1960's. Brief and infrequent entry into Drought Emergency: Stage 1 should be understood as an expected and acceptable outcome of a system that is both efficiently sized and actively managed. These brief periods provide appropriate lead time for conservation response measures to take effect and allow reservoir levels to stabilize. The modeling results indicate that, under current and moderately increased demand scenarios, the system may enter Drought Emergency: Stage 1 for limited periods but recovers without progressing to more severe stages between the levels of 260–270 MGD (see Table 5-1 and Figure 5-2 below).

A 20 MGD increase from the current demand of 200 MGD to 220 MGD adds just one month in Drought Warning stage during a drought as severe as the 1960's. A 20 MGD increase from 240 to 260 MGD increases the number of months in Drought Warning from 2 percent to 5 percent and adds 5 months of Drought Emergency Stage 1, all during that severe drought. Like Figure 5-1, Table 5-2 demonstrates that as demand rises from the base demand of 200 MGD to 220 MGD, the maximum reservoir descent would drop several feet from 518 to 514. At 240 MGD it would drop to 509 feet, and at 260 MGD to 502 feet. As shown in Figure 5-2, in droughts that are less severe than the 1960's, the reservoir would rarely dip into Below Normal and never as low as Drought Warning. These changes are all within acceptable levels of system performance.

Table 5-1
MWRA 2025 Drought Plan—Drought Severity

Drought Severity Overview – Based on Annual Average Demand (MGD)												
Annual Average of Demand (MGD)	**MWRA Drought Stage**										Maximum Reservoir Descent	
	Below Normal		**Drought Warning**		**Drought Emergency**							
					Stage 1		**Stage 2**		**Stage 3**		Elevation (ft)	Volume (%)
200	24	3%	--	--	--	--	--	--	--		517.9	78.0%
210	32	4%	--	--	--	--	--	--	--		516.0	74.7%
220	42	5%	1	1%	--	--	--	--	--		513.9	71.2%
230	49	5%	8	1%	--	--	--	--	--		511.7	67.2%
240	54	6%	17	2%	--	--	--	--	--		508.9	63.2%
250	66	7%	44	5%	--	--	--	--	--		505.5	58.2%
260	73	8%	50	5%	5	1%	--	--	--		501.8	53.0%
270	67	7%	60	7%	19	2%	--	--	--		497.9	47.7%
280	91	10%	43	5%	46	5%	--	--	--		493.6	40.5%
290	155	17%	22	2%	71	8%	--	--	--		490.0	38.0%
300	226	25%	18	2%	71	8%	17	2%	--		485.9	32.0%
Historic Data	113	12%	69	8%	25	3%	--	--	--		495.5	
Note: Data represented is 914 Months between October 1948–December 2024. Model condition limits Ware River Transfers to below "Normal Operations."												

Figure 5-2
Modeled Quabbin Reservoir Volume (%) System Demand



Critical Quabbin Elevations with associated volume and volume percentage as well as designation on chart above.

- 530 ‘ 412,240 BG 100% Reservoir Full
- 490 ‘ 156,651 BG 38% Drought Emergency 2 Designated MWRA Operational Minimum
- 475 ‘ 103,060 BG 25% Drought Emergency 3

5.5 Donor Basin System Performance Conclusions

Taken as a whole, these system performance measures demonstrate that the MWRA water system in the donor basin would operate reliably and effectively to meet demands up to and including 260 MGD. Even with 20 MGD of potential system expansion and up to 40 MGD of conservatively estimated growth within the existing service area with a contingency for additional needs by partial users, the system reliably meets all of its performance measures, essentially using only the upper stages of MWRA's drought planning stages, even in a drought as severe as the multi-year drought of the 1960's.

Under the total projected system demand of approximately 260 MGD, model results indicate brief and infrequent entry into Drought Emergency: Stage 1 (see Table 5-1 and Figure 5-2). This stage would trigger conservation response measures to increase system efficiency and reduce demand, including mandatory restrictions and bans on nonessential outdoor use.

In a more immediate assessment of the additional 20 MGD to current withdrawal demand, the system has a small chance to drop into drought warning (see Table 5-1). This would trigger increased conservation outreach, and voluntary cutbacks to large users and non-essential municipal use.[14] As the next section demonstrates, the system is able to meet these increased demands while maintaining appropriate minimum downstream releases and without adversely affecting natural system attributes of the reservoirs and downstream river reaches.

[14] See *MWRA Drought Response Plan*, 2025.

SECTION 6 IMPACTS OF ADDITIONAL 20 MGD INTERBASIN TRANSFER

The analysis that follows evaluates whether the proposed interbasin transfer expansion of 20 MGD produces effects outside the water system operational conditions already demonstrated to be sustainable. Within the modeled demand range, variations in any new community's demand — whether over a 24-hour period, day-to-day, or between seasonal conditions —do not significantly impact reservoir operations or interbasin transfer performance.

Based on current system yield data and existing demand conditions, no changes to MWRA infrastructure or operating rules are required to supply an additional 20 MGD. Under system demands of 200 MGD (baseline), plus projected growth through 2050, partial-user supply contingency, and a potential additional 20 MGD, minimum in-stream flows and discharges required by the 1927 Acts of Massachusetts (ch. 321), the 1895 Acts of Massachusetts (ch. 488), and the 1929 War Department permit are met (U.S. War Department, 1929). Table 6-1 below summarizes demand projections.

The Quabbin Reservoir is expected to be filled more often due to higher yield potentials. Natural variability in Quabbin Reservoir elevation will be driven by climate and not by the additional 20 MGD demand. The range of elevation variation within a given year will not change with the addition of 20 MGD demand. The Wachusett Reservoir elevation will remain stable following the seasonal operation band. The slighter higher demand will reduce the need for higher releases to maintain the operation band. This will reduce higher flow releases during wet periods, and reduce the risk of downstream flooding events.

Table 6-1

Summary of Demand Projections

Total MWRA System Withdrawal	MGD
Base total system demand	201.1
Projected Growth 2050	21.9
Partially supplied contingency	18.5
Proposed Expansion	20.0
TOTAL WITHDRAWAL – Projected 2050 with Expansion	**261.5**

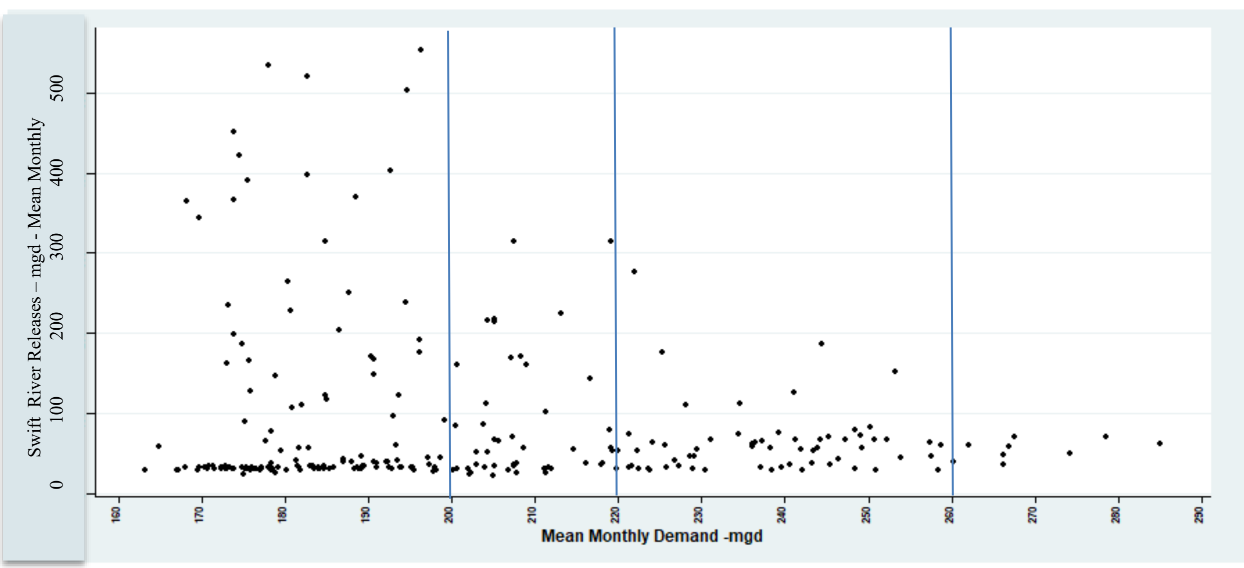
6.1 Potential Impacts on Downstream Releases—Quabbin

Swift River flows vary according to a combination of operational practices, War Department permit requirements, spillway operations, and prevailing climatic conditions. This behavior will persist, with or without the supply of an additional 20 MGD to new communities.

As illustrated in Figure 6-1 below, the relationship between monthly MWRA system demands between historical ranges of 160 to 300 MGD and discharges to the Swift River is quite weak, with a correlation coefficient of -0.17. However, a faint pattern is still observable: as system demand increases within this range, the frequency of large releases and spill events exceeding 100 MGD declines. This commonsense trend reflects an increased storage retention and proportional balancing between Quabbin and Wachusett reservoirs.

With demand between 220–260 MGD, monthly releases are frequently moderated within a range of 70–100 MGD, rather than as infrequent high magnitude discharge events. This pattern is consistent with operational objectives to contain spills through storage management, reduce downstream flood risks, and water quality-driven transfers to the Wachusett Reservoir while continuing to meet all downstream release requirements.

Figure 6-1
Quabbin Reservoir Monthly Releases

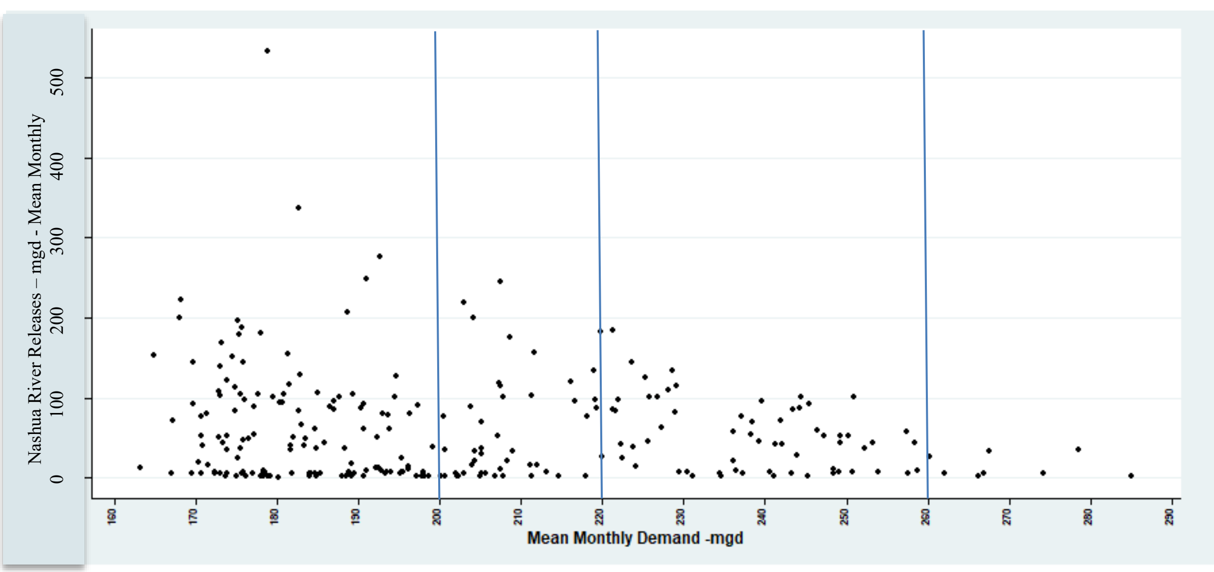


6.2 Potential Impacts on Downstream Releases—Wachusett

Controlled releases from Wachusett Reservoir are governed primarily by statutorily required minimum releases and established operational practices to support and optimize water supply and water quality objectives along with MWRA environmental initiatives. All modeling summarized in this analysis assumes full compliance with mandated releases, which are met or exceeded under all evaluated demands, up to and including 300 MGD.

Figure 6-2 below plots monthly MWRA system demand (MGD) against discharges to the Nashua River and also exhibits a relatively weak relationship with a correlation coefficient of -0.16. However, a similar faint pattern observed at Quabbin Reservoir in Figure 6-1 above is apparent: as demand increases within the historical observed data range, the frequency of large releases and spill events exceeding 100 MGD declines. This reflects an increase in retention and operational balance between reservoirs. Three blue lines indicate the demands of interest (200, 220, and 260). This trend moderates monthly releases to manageable levels between 70–100 MGD.

Figure 6-2
Wachusett Reservoir Monthly Releases



6.3 Environmental Impacts of Additional 20 MGD

The downstream release patterns described in Section 6.1 provide a stable downstream regime under which environmental conditions are evaluated. Given the relatively small magnitude of the proposed interbasin transfer to the overall reservoir capacity, and the fact that typical/minimum discharges are governed by regulatory requirements, the proposed expansion is not expected to result in measurable changes to reservoir conditions, downstream hydrology, or any adjacent wetlands and associated flora and fauna.

Providing water to potential new communities at a cumulative total of 20 MGD does not affect the minimum flows that MWRA must discharge to the Swift River, and existing instream flows are maintained. As previously concluded by WRC for prior interbasin transfer approvals at higher initial baseline flows (see Table 1-1), impacts to the Aquatic Base Flow, 95% flow duration, and flood flows will be minimal at this scale of expansion. The proposed system expansion of 20 MGD would have no effect on anadromous fisheries, sea-run brook and brown trout, smelt and American shad. There are numerous downstream barriers to fish passage on the Swift and Chicopee Rivers, and the Swift River is not a component of the Connecticut River Anadromous Fish Restoration Program.

Independent of system expansion, MWRA has implemented operational and infrastructure measures that enhance downstream flow and habitat conditions for the Swift River, including:

- Implementation, in the early 1990s, of continuous 24-hour discharges from Quabbin Reservoir into the Swift River all year round, in response to fishery concerns. In prior decades, MWRA met its year-round 20 MGD minimum release requirement through releases 5-7 hours a day.
- Revision of MWRA operations to more slowly ramp up the higher volume discharges made in the summer months, in response to a request of the Division of Fisheries and Wildlife.
- Established coordination with the hatchery on water quality issues.
- Developed operating procedures to reduce the impacts of warm water spills, by increasing the cold-water release through the powerhouse diluting and cooling the spills, and adding stop logs to reduce the quantity of the warm water releases when flood control considerations would allow.
- Collaboration between MWRA and Department of Fish and Game and Division of Fisheries and Wildlife construction of a pipeline to the McLaughlin Fish Hatchery to convey 6 MGD to the Hatchery to provide a consistent and reliable supply of cold water to the Hatchery. This enhances fishery operations and in effect, results in an increased flow to the Swift River, as the Hatchery will replace its existing river withdrawals with MWRA water. MWRA provides this water to the Hatchery free of charge.

6.3.1 Downstream Flow & Dams

There are no Areas of Critical Environmental Concern (ACECs) mapped downstream of Quabbin Reservoir or the Ware River intake. The Central Nashua River Valley ACEC is located downstream of the Wachusett Reservoir, but will not be affected by this transfer as current operating procedures and required discharges to the river will not change. There are no designated wild and scenic rivers downstream of MWRA's water sources. As discussed in Section 6.1 and Section 6.2, downstream flows will see minimum to no impacts from the additional 20 MGD, with all required releases met and exceeded.

There are no hydropower projects on the Swift River downstream of Winsor Dam. On the Chicopee River, downstream of the Swift River, there is the Red Bridge Dam, the Ludlow Dam, Indian Orchard Dam, Chicopee Falls Dam and Dwight Dam. These Chicopee River hydropower projects are affected by flows from a much greater drainage area than just the Swift above Winsor Dam. From the Winsor Dam to the Swift River's confluence with the Ware River, the Swift River is 9.8 miles long and drains an additional 30 square miles. Downstream of the Ware and Swift Rivers' confluence, the Ware River becomes confluent with the Quabog River. In turn, the main stem of the Chicopee is formed by the union of the Ware River and the Quabog River. The Chicopee River has a total drainage area of 727 square miles. The recent 6 MGD increase in the Swift River below the Hatchery translates to approximately 9 cfs increase in flow. This is small in comparison to the design flow for the downstream hydropower projects on the Chicopee. Past investigations by MWRA indicated that the design flows of the Chicopee River hydroelectric facilities ranged from approximately 250 cfs to approximately 900 cfs. These projects would be unaffected by the proposed withdrawals detailed in this analysis.

6.3.2 Downstream Flow & Fisheries & Common Loon Habitat

Importantly, the moderated discharge patterns described above are consistent with flow regimes that support habitat stability for aquatic species. Normandeau Associates examined the effect of flow on fisheries habitat in 1997 through the development of a relationship between instream flow and an index of habitat availability called Weighted Usable Area (WUA) (Normandeau Associates, 1997). WUA versus flow relationships were generated for target organisms (the brown trout, brook trout, and rainbow trout) and target life stages, and were developed over a range of spatial scales to a generalized relationship for the whole river.

The conclusions of Normandeau's study were that the existing minimum flow standards were adequate to protect the Swift River trout fishery, and that flows lower than 75-90 cfs may provide somewhat better conditions for adult and juvenile brook trout, based on the observation that substantial, large, deep pools exist throughout the Swift River which would serve as habitat refuge for adult trout. The Normandeau study stated that facing higher discharges, juvenile brook trout could be expected to concentrate in low velocity areas along stream margins, which in the Swift River typically possess abundant quantities of overhanging and instream cover. WUA for juvenile brook trout appears to decline with increasing discharge.

The Massachusetts Department of Conservation and Recreation (DCR) has a Common Loon monitoring program for both Quabbin and Wachusett Reservoir. The program deploys floating rafts to serve as loon nests during the mating season, which occurs between April 1st and August 1st. In 2024, 21 rafts were deployed with 11 successful nesting uses. Annual DCR Common Loon Reports are available upon request from DCR. The Quabbin Reservoir has an expected seasonal pattern. The fluctuation in Quabbin Reservoir month to month is based on an annual average, volume change of +/-2.5% or elevation change of +/-1 ft[15]. The variability increases to around +4.0% (2.2 ft) in the spring melt and -3.5% (2.1 ft) during intense drought periods. In the last decade, the average and median volume change month-to-month between the dates of April 1st to August 1st is around -1.0%. The drought of 2015-2016 produced outlier in 2017 with a Quabbin Reservoir volume change of -8.3% (elevation change 4.5 ft) in the 5-month period. This seasonal outlier remains well within the month-to-month volume change of 2.5%. The additional 20 MGD will have minimal impact on the Quabbin Reservoir fluctuation pattern. Variability in the start and end elevations may shift year to year, as we have already seen in 2017, but the rate of change (elevation and volume) will not be greatly impacted.

6.4 Conclusion—Donor Basin Analysis

Based on recent yield analyses and current demand conditions, MWRA can supply an additional 20 MGD on average without installation of additional facilities or changes to operating rules. Across all modeled scenarios, required minimum in-stream flows and downstream release obligations were met and exceeded. An average 20 MGD service expansion would result in minimal impacts to aquatic base flow, 95% flow duration, and flood flows within the donor basin. Overall, findings demonstrate that the MWRA system can accommodate the proposed additional interbasin transfers while maintaining regulatory compliance, protecting aquatic resources, and preserving long-term system reliability.

This analysis evaluated individual components of the MWRA water supply system to understand system performance under varying operational and demand conditions. Effective system operation depends on the coordinated function of the watershed, reservoirs, conveyance infrastructure, and operating rules as an integrated whole. The protected watershed provides the foundation for water quality entering the system, while reservoir operations and regulatory controls govern how that resource is stored, released and protected over time.

MWRA manages and operates the Quabbin and Wachusett Reservoir system in coordination with the Massachusetts Department of Conservation and Recreation to maintain watershed stability, protect source water quality, and support long-term system resiliency. The operational patterns described in Sections 5 and 6, including release behavior and compliance with downstream flow requirement, reflect this integrated management approach and contribute to stable environmental conditions both within the reservoir and downstream.

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[15] Volume to Elevation Ratio is rough estimate due to varying volumes at different elevation depths.

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