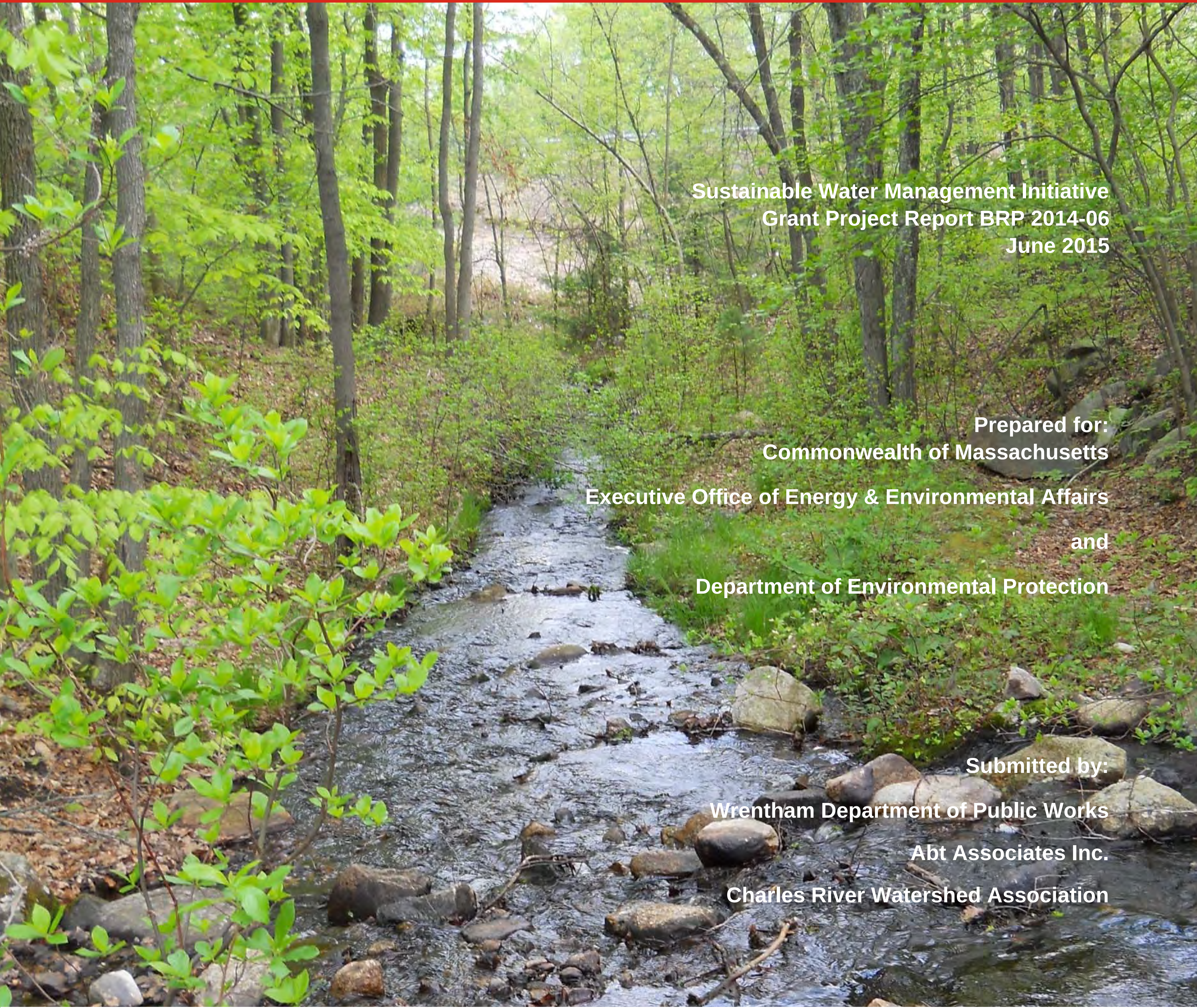
Enabling Permittees to Prepare Cost-Effective Strategies: Support to the Town of Wrentham and Reusable Tools

Sustainable Water Management Initiative



Sustainable Water Management Initiative
Grant Project Report BRP 2014-06
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Prepared for:
Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs
and
Department of Environmental Protection

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Executive Summary

The Commonwealth of Massachusetts (the Commonwealth) promulgated revisions to the Water Management Act (WMA) regulations, 310 CMR 36.00 (the Regulations) in November 2014 that seek to balance protecting the health of water bodies while meeting the needs of communities for water by implementing sustainable water management. The revisions include changes to the Massachusetts Department of Environmental Protection (MassDEP) process for reviewing and granting water withdrawal permits and actions required to minimize the existing impact of withdrawals and mitigate the impact of increases in withdrawals.

The Town of Wrentham (Wrentham) is located at the head of four watersheds – Blackstone, Taunton, Charles, and Ten Mile – and withdraws its water from the Charles and Taunton watersheds. MassDEP has categorized Wrentham's two source water subbasins as highly impacted by groundwater withdrawals; therefore under the Regulations, Wrentham will need to minimize the impact of its existing withdrawals to "the greatest extent feasible." In addition, MassDEP's baseline groundwater allocation for Wrentham is 1.08 million gallons per day (MGD).[1] This baseline volume is only 10 percent above recent Wrentham Water Division (WWD) withdrawals (0.98 MGD in 2010-2014); given projected development and population growth, Wrentham will likely be required to mitigate impacts of its withdrawal above baseline during the 20-year period of its permits. Wrentham's withdrawal permit in the Taunton basin is scheduled for renewal under the WMA in February 2016.[2]

The objective of this planning study was twofold: (1) to identify the least-cost combination of management actions that will meet both Wrentham's current and projected water needs and the Regulations' minimization and mitigation requirements; and (2) to develop two tools that WWD and other permittees may use to evaluate water conservation and stormwater management options. This report focuses on the first objective. The tools are covered in deliverables submitted separately to the Town of Wrentham and MassDEP.

In this study, we assess potential opportunities for implementing management actions that will help the Town meet its permit requirements in the two source subbasins. We review data obtained from MassDEP, WWD and other sources to identify implications of WMA regulatory changes on the Town's permit requirements, notably regarding the magnitude of impacts needing to be minimized or mitigated. We then identify potential actions that could help WWD meet those requirements. The assessment is informed by the use of EPA's Watershed Management Optimization Support Tool (WMOST) to screen and assess the relative cost-effectiveness of various management actions in the two subbasins. The assessment consists of three main parts and provides several insights for planning:

In the first part of the assessment, we consider requirements associated with **standard permit conditions**.

- Wrentham must meet the state standard of 65 residential gallons per capita per day (RGPCD). Wrentham's RGPCD has varied over time, and exceeded the threshold in 2014 with 69 RGPCD. Accordingly, Wrentham will need to implement measures to meet the state standards consistently

[1] This is Wrentham's system-wide baseline. In addition, the Town has individual watershed source baselines of 0.74 MGD in the Charles and 0.38 MGD in the Taunton.

[2] Permits in the Charles basin were renewed in 2010 and are scheduled for review in 2017, at which time the WMA requirements will apply.

by improving its water efficiency. Based on 2014 water use, Wrentham needs to reduce water use by an average of 0.04 MGD over the course of the year to meet the standard.

- A key focus area is nonessential outdoor water use. WWD's average summer withdrawals in 2010-2014 were more than 95 percent higher than winter demand. High outdoor summer use, which is primarily used for lawn watering and does not return to the groundwater, contributes to impacts during the summer low-flow period. The experiences of other Massachusetts towns demonstrate that significant reductions in outdoor water use can be achieved by relatively simple changes in outdoor watering practices and frequency. Reducing nonessential outdoor water use by 15 percent to 33 percent, such as may be accomplished by meeting or going beyond the Regulations standard conditions would not only help WWD meet the 65 RGPCD standard, but would also greatly reduce withdrawal impacts during the critical low streamflow period of June to September. We estimate that such changes would have saved 0.04 to 0.09 MGD in 2014, which is 4 to 10 percent of overall water withdrawals that year.

- Additional efficiency measures such as using water efficient residential and commercial fixtures and appliances can further reduce demand throughout the year and provide direct savings to residential and commercial customers.

- The measures above may be part of the RGPCD Compliance Plan that WWD needs to submit to MassDEP under its Charles withdrawal permit, based on exceeding the 65 RGPCD permit condition.

- Wrentham must also meet the state standard of 10 percent or less unaccounted for water. Unaccounted for water (UAW) averaged 17 percent in the last five years, and was 13 percent in 2014. WWD has improved its accounting of water uses to more accurately estimate UAW. Additional measures would include installing or upgrading meters in public buildings to determine actual water use, continuing the leak detection program, and promptly making any needed repairs. These measures may be part of the UAW compliance plan that WWD needs to submit to MassDEP under its Charles withdrawal permit.

- The Regulations include standard limits on nonessential outdoor water use that depend on the RGPCD performance discussed above. Under the Regulations, nonessential outdoor water use will be limited to 1-day/week watering (based on calendar or streamflow triggers) based on Wrentham's 69 RGPCD in 2014. This is more stringent than the permit requirements for the Charles subbasin of 2-day/week watering for RGPCD above 65 (which should already be in place in the summer of 2015 given the existing permit).

The second part of the assessment focuses on the requirements to **minimize existing impacts to "the greatest extent feasible."**

- The minimization requirements affect withdrawals system-wide given that the Charles source subbasin's August Net Groundwater Depletion (ANGD) is 57 percent.

- MassDEP specifies that minimization must be done "to the extent feasible" with the goal of improving streamflows.

- Measures to minimize existing impacts include reducing RGPCD and UAW to exceed the standard permit conditions described above.

- They also include and optimizing withdrawals among the two source subbasins.
- Other potential measures include increasing returns to the stream. The Town is already 100 percent on septic systems. Further increases in returns can be accomplished by managing Lake Pearl to allow timed releases of water when streamflows are below levels of concern (to be determined in discussion with MassDEP) and stormwater infiltration BMPs retrofits on existing development or implementing on-site infiltration in redevelopment projects.

The third part of the assessment focuses on the requirement to **mitigate impacts of withdrawals above baseline "commensurate with impact**."

- We estimated volumes of withdrawals that would need to be mitigated in the two source subbasins at 0.10 MGD in the Charles subbasin and 0.06 MGD in the Taunton subbasin, based on the difference between Wrentham's 2030 water needs forecast and baseline allocation. These mitigation volumes reflect estimated adjustments to account for the significant amount of water returning to the basins via septic systems.
- WWD may be able to avoid or delay having to meet the mitigation requirements by implementing additional water conservation measures to reduce RGPCD below the standard of 65 (e.g., water efficiency standards in new construction and retrofits), adopting more stringent limits on nonessential outdoor water use (e.g., 1-day/week watering vs. 2-day/week watering for 65 RGPCD).
- Similar to the minimization requirements above, timed water releases of water from Lake Pearl may help mitigate withdrawal impacts in the Charles subbasin.
- Meeting the mitigation requirements may also involve increasing the amount of water returning to the stream via stormwater infiltration (*e.g.*, via BMPs that will be implemented to control phosphorus pollution under the Small Municipal Separate Storm Sewer Systems (MS4) permit).
- Finally, the assessment suggests additional, more expensive, measures that may mitigate impacts, including developing alternate sources of water in the Blackstone basin.

Table of Contents

List of Exhibits

Abbreviations

ANGD	August net groundwater depletion
ASR	Public Water Supply Annual Statistical Report
BC	Biological category
BMP	Best management practice
CFR	Coldwater fish resource
GWC	Groundwater withdrawal category
MassDEP	Massachusetts Department of Environmental Protection
MG	Million gallons
MGD	Million gallons per day
MS4	Small Municipal Separate Storm Sewer Systems
RGPCD	Residential gallons per capita per day
SWMI	Sustainable Water Management Initiative
SYE	Sustainable Yield Estimator
UAW	Unaccounted for water
WMA	Water Management Act
WMOST	Watershed Management Optimization Support Tool
WWD	Wrentham Water Division

1 Introduction and Background

The Town of Wrentham (Wrentham), Abt Associates, and Charles River Watershed Association (the Project Team) are pleased to submit this report in satisfaction of a Sustainable Water Management Initiative (SWMI) Grant to identify cost-effective, sustainable strategies to meet human water needs of the Town of Wrentham.[3]

Despite 44 inches of precipitation in an average year, Massachusetts' rivers and streams have shown flow impacts from water withdrawals, impervious cover, and other factors (MassDEP, 2013). In November 2014, the Commonwealth of Massachusetts (the Commonwealth) finalized revisions to the Water Management Act (WMA) regulations, 310 CMR 36.00 (the Regulations) that seek to balance protecting the health of water bodies with communities' water needs by implementing sustainable water management.[4] The revisions include changes to the Massachusetts Department of Environmental Protection (MassDEP) process for reviewing and granting water withdrawal permits and actions required to minimize and mitigate the impact of withdrawals. In subbasins designated by MassDEP as net groundwater depleted in August,[5] permittees have to minimize "existing impacts to the greatest extent feasible." MassDEP also determined "baseline withdrawals" for permittees. Those requesting withdrawals above baseline have to mitigate the additional withdrawals "commensurate with impact." These changes affect planning decisions by cities and towns on how best to meet current and future water needs.

Wrentham residents get their water from two source subbasins that MassDEP has found to be highly impacted by existing groundwater withdrawals. As such, Wrentham will have to implement management practices to minimize the Town's existing impacts on streamflow "to the greatest extent feasible." In addition, projected development and economic growth in the next 20 years are expected to increase the town's water needs, which may exceed Wrentham's baseline withdrawals in the two source basins. If despite demand management, Wrentham exceeds the baseline withdrawals then the Town will need to implement mitigation actions.

The planning study portion of the project documented in this report sought to assess the implications of the regulatory requirements on the Town of Wrentham and to identify potential management actions that could help reduce, minimize, and mitigate impacts of water withdrawals while meeting the Town's current and future water needs. The remainder of the report is organized as follows.

- Section 2 describes the water demand and supply for Wrentham and for neighboring towns that overlap the source subbasins for Wrentham, summarizes relevant aspects of the Regulations and describes the data collection and assumptions for the study.

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3 The project also included the development of two tools: a stormwater credit calculator and a demand management calculator, submitted to MassDEP separately.

4 Water Management Act (MGL 21 G) Regulation (310 CMR 36.00). Available at http://www.mass.gov/eea/agencies/massdep/water/regulations/310-cmr-36-00-the-water-management-act-regulations.html

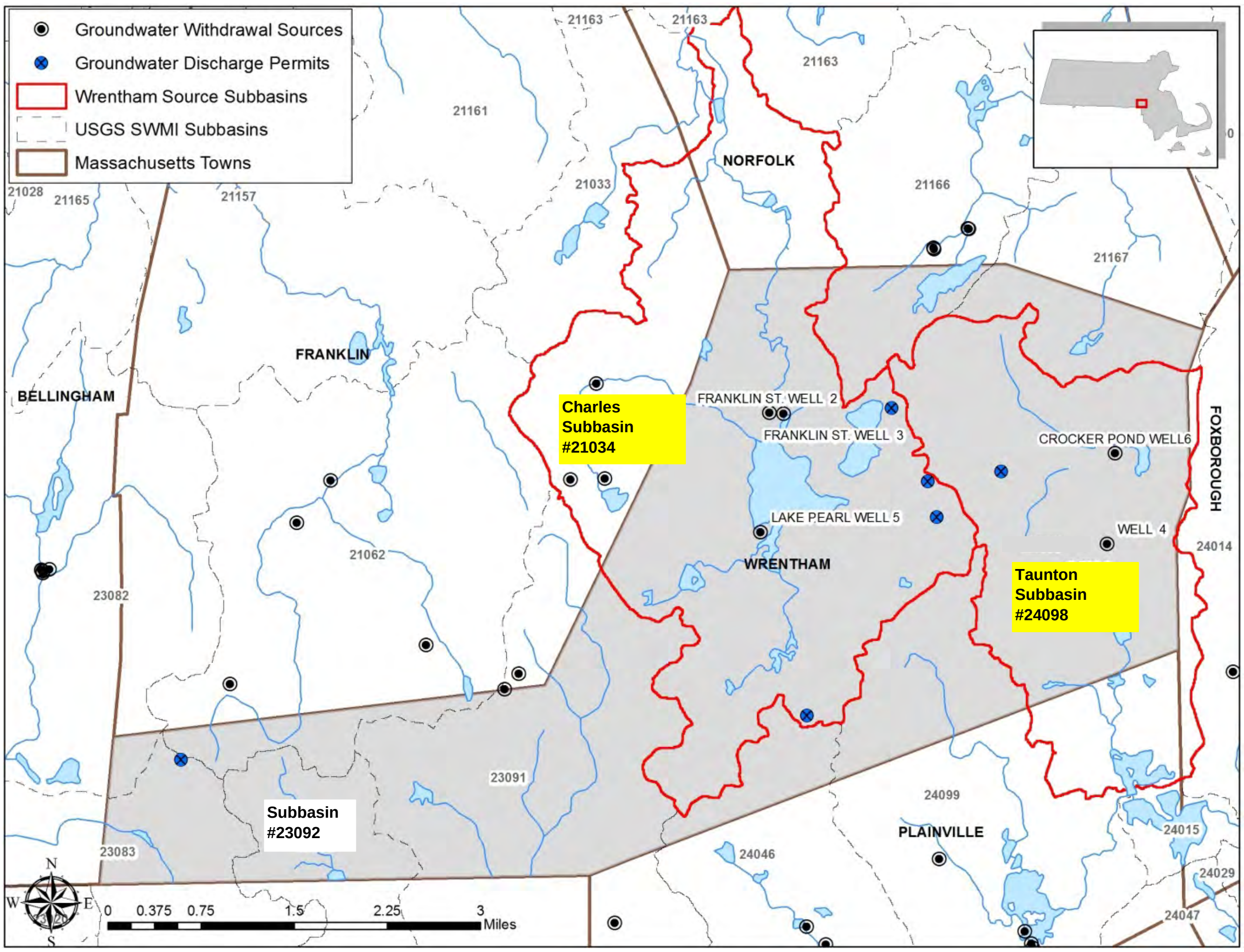
5 August net groundwater depletion (ANGD) is calculated as the unimpacted median monthly streamflow for August minus 2000-2004 groundwater withdrawals plus 2000-2004 groundwater returns (MassDEP, 2014b). Basins indicated as depleted have a ratio of August net groundwater depletion to unimpacted median flow that exceeds 25 percent.

- In Section 4, we use the information to assess implications of the regulatory requirements for the Town and screen potential management actions.
- In Section 5, we then highlight some of the key insight that can be drawn from this assessment to inform planning decisions.
- Three appendices provide additional details on items summarized in the main body of the report, including model descriptions, data, and references.

2 Town of Wrentham Water System

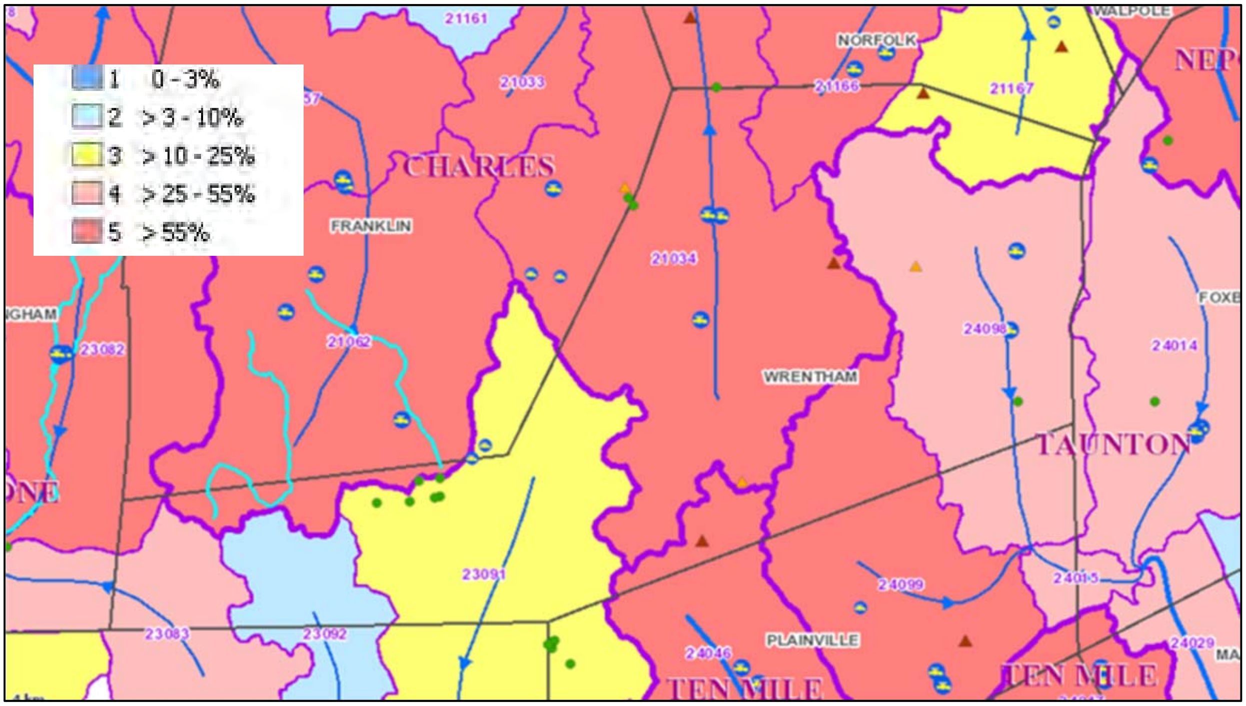
Wrentham is located at the headwaters of four watersheds: Blackstone, Taunton, Charles, and Ten Mile. Wrentham had a population of approximately 11,000 in 2010 (U.S. Census, 2010). The Wrentham Water Division (WWD) delivers drinking water to an estimated 9,873 residents, or approximately 90 percent of the population (WWD 2014). As shown in Exhibit 1, WWD withdraws water from five wells located in the Charles and Taunton basins, outlined in red on the map. Of the five wells, three are in the Charles basin (subbasin #21034 on the map), and the other two are in the Taunton basin (subbasin #24098). This study focuses primarily on these two source subbasins.

Exhibit 1: Town of Wrentham, MA, WMA subbasins, wells, and permitted withdrawals or discharges.



MassDEP has identified the Charles subbasin #21034 as highly impacted by groundwater withdrawals and assigned the subbasin groundwater withdrawal category (GWC) 5, the most altered category (MassDEP 2014a). MassDEP has identified the Taunton basin #24098 as significantly impacted, GWC 4. GWC is based on the amount of groundwater withdrawn relative to instream flow that would be present without the influence of withdrawals or impervious cover (*i.e.*, unaffected flow). August net groundwater depletion (ANGD) in the two source basins were 57 and 20 percent, for the Charles and Taunton subbasins respectively, indicating that August withdrawals rates exceed the amount of water returned to the aquifer. Further, both basins are categorized in biological category 5, indicative of “more than 65 percent decline in the range of riverine fish, loss in species, and marked decline in sensitive species or life stages.” (MassDEP, 2014a). These categories place the two subbasins in the upper range for existing impacts. Neither source subbasin is identified as a coldwater fish resource.

Exhibit 2: Town of Wrentham and WMA subbasins with their groundwater withdrawal categories (Source: MassDEP)



MassDEP determined the baseline withdrawals for the two basins at 0.74 MGD for the Charles subbasin (#21034) and 0.38 MGD for the Taunton subbasin (#24098), for a system-wide baseline[6] of 1.12 MGD. This baseline serves as the reference point from which increases in demand in each of the subbasins will be measured under the Regulations.

The Commonwealth forecasts that Wrentham’s water needs would range from 1.23 to 1.46 MGD by 2030, depending on whether Wrentham meets MassDEP’s performance standards of 65 RGPCD and 10 percent or less unaccounted for water (UAW). Exhibit 3 summarizes information according to the two source subbasins.

Total authorized withdrawals are 0.92 MGD in the WWD’s 2010 Charles permit and 0.61 MGD in the Town’s current Taunton permit, with a combined total for the Town not to exceed 1.08 MGD (MassDEP, 2010).[7] WWD withdrawals during 2010-2014 ranged from 0.94 to 1.04 MGD, system-wide, or an average of 0.98 MGD. Withdrawals from the Charles subbasin have been near or slightly above the

6 The baseline rate is based on the highest of the average of the 2003-2005 withdrawals or the 2005 withdrawal volume plus 5 percent.

7 We note that the total authorized system-wide withdrawals indicated in the permit (1.12 MGD) is less than the sum of authorized withdrawals for the two source subbasins (1.53 MGD), and also less than the quantity indicated on MassDEP’s WMA Permitting Tool (1.18 MGD) and on the permit renewal summary sheet (1.23 MGD).

subbasin baseline of 0.74 MGD (0.69–0.77 MGD), while withdrawals from the Taunton subbasin have been at about two thirds of the 0.38 MGD baseline (0.24–0.27 MGD).

Exhibit 3: Statistics of source water basins for Wrentham[a]

Basin	Charles (21034)	Taunton (24098)	System Totals
August Net Groundwater Depletion (%)	57	20	
Groundwater category (GWC)	5	4	
Biological category	5	5	
Coldwater fishery resource	No	No	
Baseline withdrawals (MGD)	0.74	0.38	1.12
Recent withdrawal 2010-2014 (MGD)	0.69-0.77	0.24-0.27	0.94-1.04
Total Authorized withdrawals (MGD)	0.92	0.61	1.23
Town's Water Needs Forecast (MGD)[b]			**1.23**

[a] Source: permit renewal summary sheet for the Taunton subbasin (MassDEP, undated).
[b] Based on 20-year water needs forecast +5% (65/10).

2.1 Wrentham Water Supply and Use

WWD has a total pumping capacity of 3.67 MGD and a total treatment capacity of 3.97 MGD. Approximately 93 miles of main distribution lines connect sources and customers. Appendix B provides additional details on the capacities of WWD's water supply assets.

As shown in Exhibit 4, WWD serves primarily residential customers (65 percent of total water use in 2010-2014), with commercial customers and municipal use (which includes hydrant flushing, street cleaning, etc.) representing the second and third most important shares of the total demand (8 percent and 7 percent, respectively). UAW represented about 17 percent of total water withdrawals.

Exhibit 4: WWD customer profile based on 2010-2014 average groundwater withdrawals and water sales (Source: WWD ASRs).

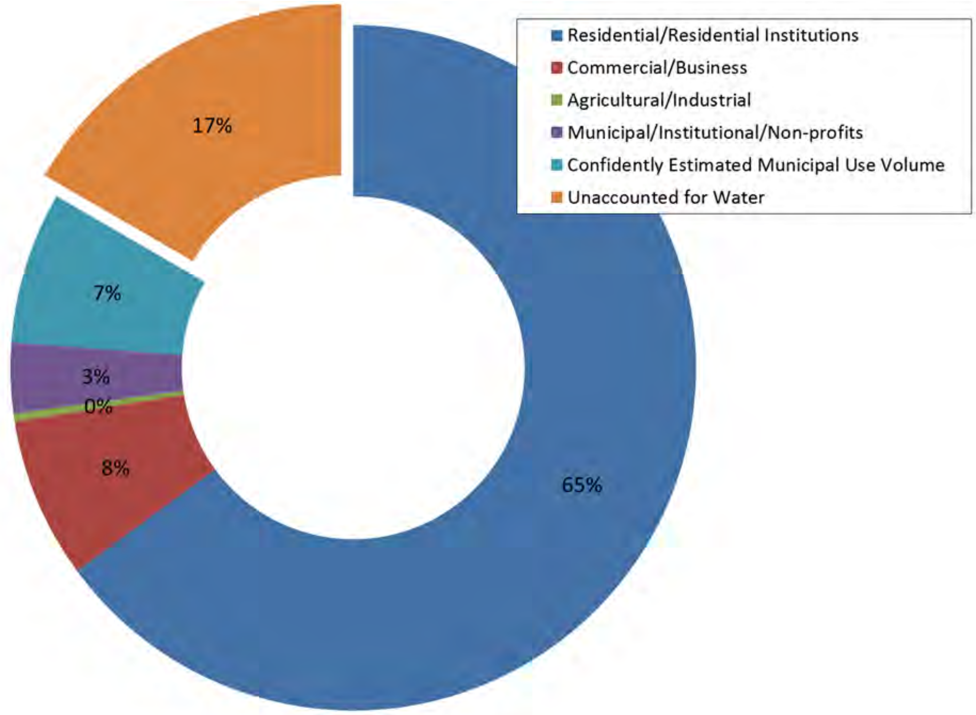


Exhibit 5 shows the change in residential water use per capita and UAW over time. While RGPCD has declined in recent years from an average of 75 RGPCD to 64 RGPCD, this trend was broken in 2014 with 69 RGPCD reported.[8] Except for one year during the period, UAW was consistently above 10 percent and as high as 22 percent in 2010.

The profile of average monthly withdrawals (Exhibit 6) shows a distinct increase in water use during the summer. Water use during the summer months is approximately double that during the winter months, or an additional 0.6 MGD.[9]

8 It is unclear in which use category WWD's sale of water to Norfolk Water Division in 2014 (0.428 MG) was reported in the 2014 ASR but even if reported under residential use, the volume of water sold is not large enough to account for the RGPCD increase observed in 2014 (source: WWD ASR, 2014).

9 We calculated winter demand as the average of demand for December through February and summer demand as the average of demand for June through September. We estimate indoor use as winter demand and outdoor use as the difference between winter and summer demand.

Exhibit 5: Profile of per capita water consumption and unaccounted for water over time (Source: WWD ASRs).

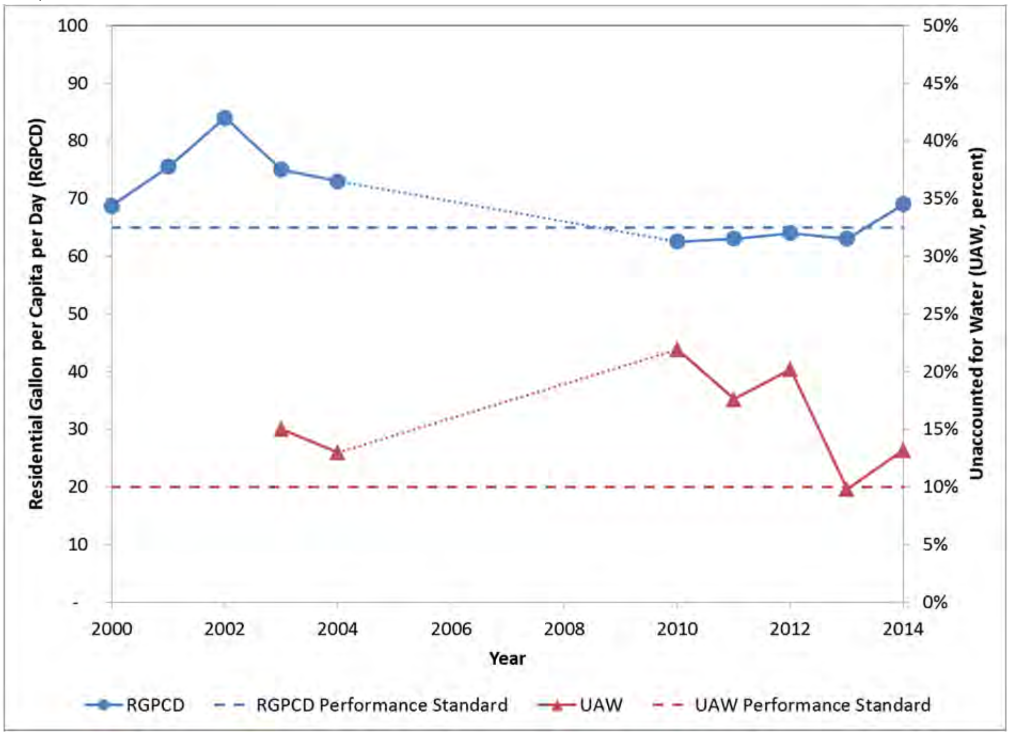
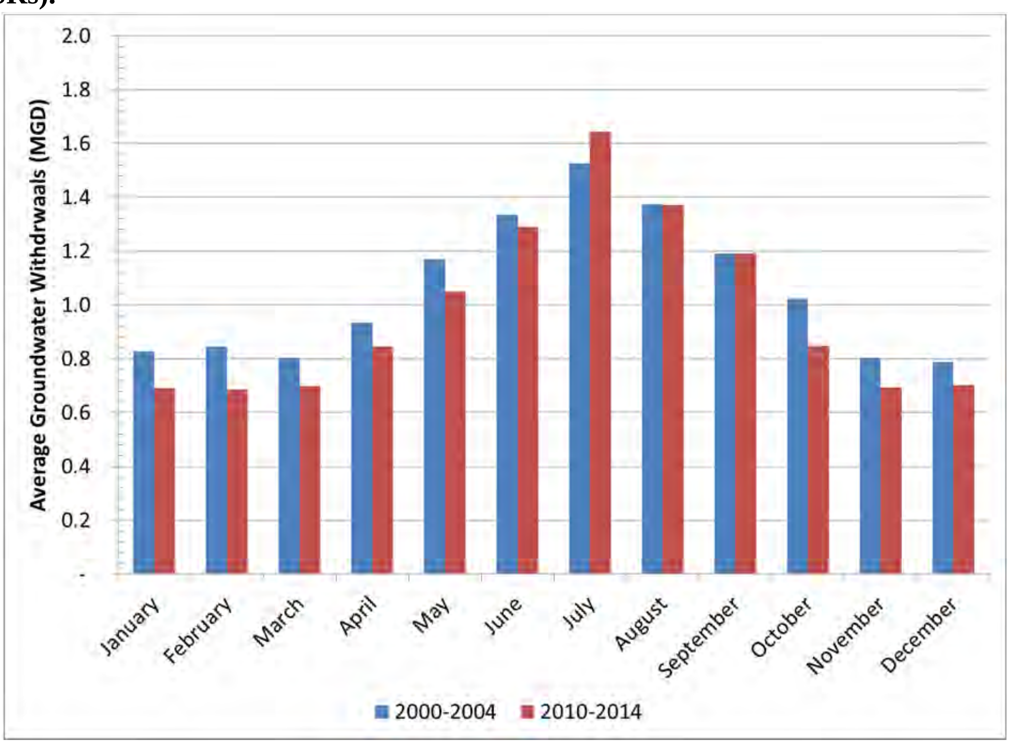


Exhibit 6: WWD average monthly withdrawals during 2000-2004 and 2010-2014 periods (Source: WWD ASRs).



Subbasins #21034 and #24098 respectively provide about 3/4 and 1/4 of the total water withdrawn by Wrentham. Exhibit 7 shows the monthly variability in the two subbasin sources of Wrentham water.

Exhibit 7: WWD average monthly groundwater pumping during 2010-2014				
	Average Pumping Volume (MGD)		% of Monthly Total	
Month	**Subbasin 21034**	**Subbasin 24098**	**Subbasin 21034**	**Subbasin 24098**
January	0.490	0.201	71%	29%
February	0.460	0.224	67%	33%
March	0.593	0.105	85%	15%
April	0.623	0.221	74%	26%
May	0.774	0.275	74%	26%
June	0.997	0.294	77%	23%
July	1.248	0.396	76%	24%
August	1.043	0.329	76%	24%
September	0.850	0.340	71%	29%
October	0.566	0.283	67%	33%
November	0.503	0.191	72%	28%
December	0.476	0.226	68%	32%
Total	**0.721**	**0.257**	**74%**	**26%**
Source: WWD ASRs				

2.2 Water Withdrawals and Returns for Source Subbasins

Exhibit 8 and Exhibit 9 provide high-level overviews of withdrawals and estimated returns in the two source subbasins (Charles #21034 and Taunton #24098), based on WMA data of average August values for 2000-2004.[10] The charts show other entities MassDEP's Water Management Act Permitting Tool (WMA Tool) reports as either withdrawing or discharging in the two source subbasins.

WWD and the Town of Franklin's Department of Public Works are the two primary permitted withdrawals in Charles subbasin #21034 (Exhibit 8). WWD gets approximately 65 to 85 percent of its water from this subbasin (~0.69-0.77 MGD) where approximately 50 percent of its customers are located. These customers discharge to septic systems; resulting in a net average return of 58 percent of the water withdrawn.[11] Franklin residents in the Charles subbasin are on septic systems and a portion of the water withdrawn by Franklin in the Charles subbasin is also returned. Camp Haiastan and the Franklin Country Club are the other withdrawal permit holders; they are included as "private" in the diagram.

10 The summary provided on the left of each chart was obtained from the WMA tool and may not match the sum of flows indicated in the more detailed breakout to the right of each chart, which came from SYE. For example, in subbasin 21034 (Exhibit 8), the WMA tool indicates total withdrawals of 1.413 MGD, but the sum of withdrawals in SYE is 1.152 MGD.

11 The returns are calculated by taking the total amount of water delivered to Wrentham residents, which was 0.98 MGD on average for 2010-2014 (of which 0.72 MGD was withdrawn from the Charles subbasin) and subtracting the amount consumed (15%), which provides the total amount returning (0.83 MGD). Since 50% of the Wrentham population lives within the Charles subbasin, we assume that the same share of total returns occur within the subbasin (0.42 MGD). This returned amount represents 58 percent of WWD withdrawals from this subbasin (0.42/0.72).

WWD and the Franklin Country Club are the two primary withdrawal permit holders in the Taunton subbasin #24098 (Exhibit 9). This subbasin meets the remaining 15 to 35 percent of WWD's water needs (~0.19-0.26 MGD) and customers are on septic system. The subbasin has approximately 29 percent of Wrentham's population, resulting in a net average return of 94 percent of the water withdrawn.[12]

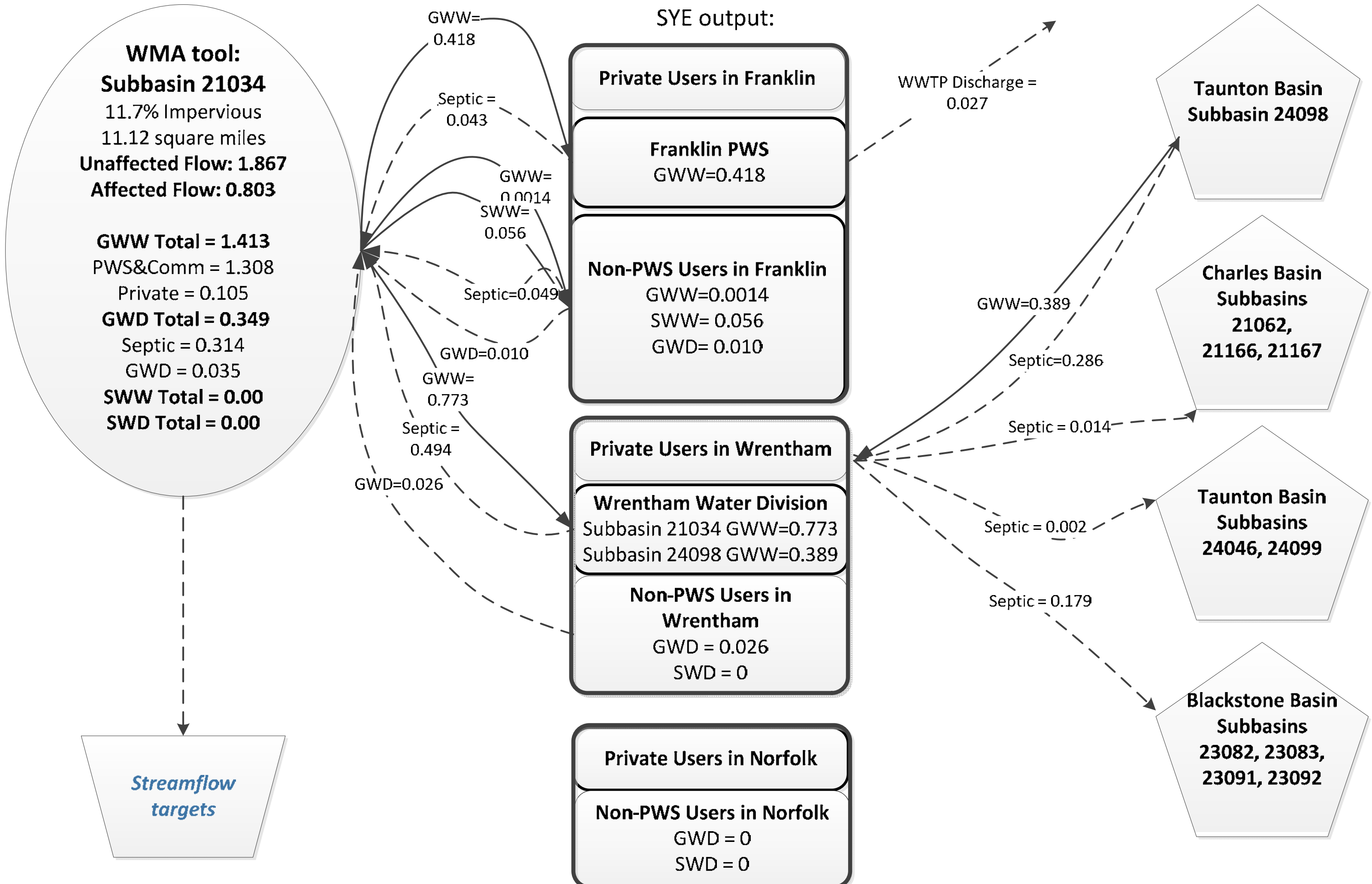
Surface withdrawals are small in both subbasins, relative to groundwater withdrawals. Permittees include Norfolk Cranberry Company and Franklin Country Club in the Charles basin and Morse Brothers Inc. in the Taunton basin. Private permitted groundwater and surface discharges are also relatively small. Groundwater dischargers include the Wrentham Village Outlets, Franklin Country Club and Adirondack Club in the Charles and Pond Nursing Home in Taunton; surface water dischargers are Buckley Mann and Anderson Greenwood Crosby, both in the Charles.

As shown in the map of Exhibit 1, Wrentham also intersects additional subbasins shown to the right of the two diagrams. In particular, about 18 percent of Wrentham's residents live in Blackstone subbasins (6 percent of the population lives in #23091; 10 percent in #23092). Septic discharges from these customers result in a net estimated return of 0.13 MGD in the two subbasins.[13] According to the WMA Tool, subbasin #23092 currently has no permitted withdrawal and is categorized as GWC 2, with a net groundwater depletion of -2.8 percent (*i.e.*, net recharge/surcharged). MassDEP categorized subbasin #23091 in GWC 3 and reports several private permittees. These subbasins could potentially serve as additional or alternate water sources, but as discussed later in the report, the amount of water that could be withdrawn is relatively limited.

[12] Calculated similarly as above, but using average withdrawals from the Taunton basin of 0.26 MGD and share of Wrentham population of 29 percent, i.e., 0.98 MGD x 29% x (1-15%) / 0.26 MGD = 94%.

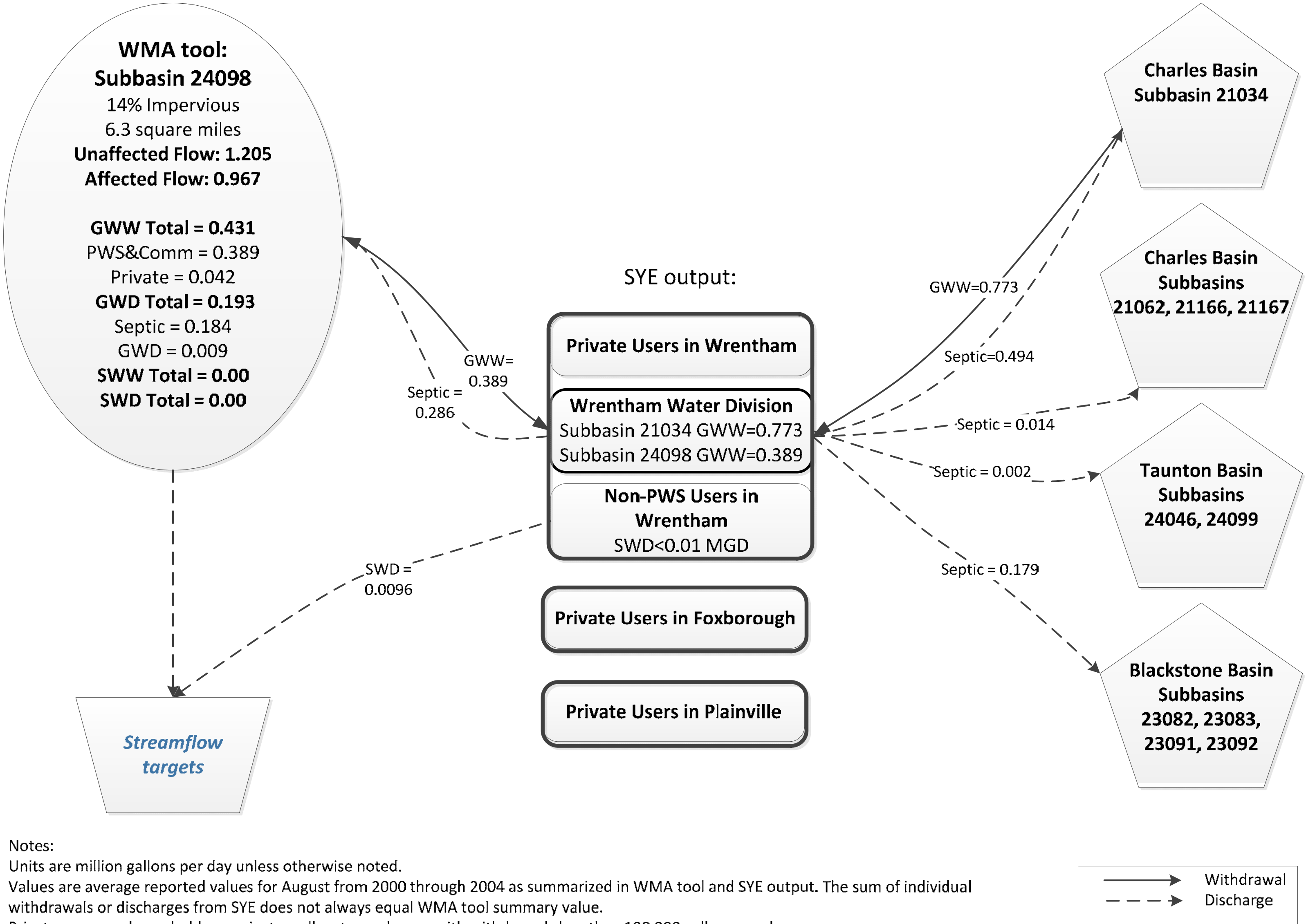
[13] 0.98 MGD x (1-15%) x 16% = 0.13 MGD

Exhibit 8: Overview of average August withdrawals and discharges 2000-2004 in Charles subbasin #21034



Notes:
Units are million gallons per day unless otherwise noted.
Values are average reported values for August from 2000 through 2004 as summarized in WMA tool and SYE output. The sum of individual withdrawals or discharges from SYE does not always equal WMA tool summary value.
Private users are households on private well water and users with withdrawals less than 100,000 gallons per day.
*Septic values were calculated based on MA Water Indicators report methodology.

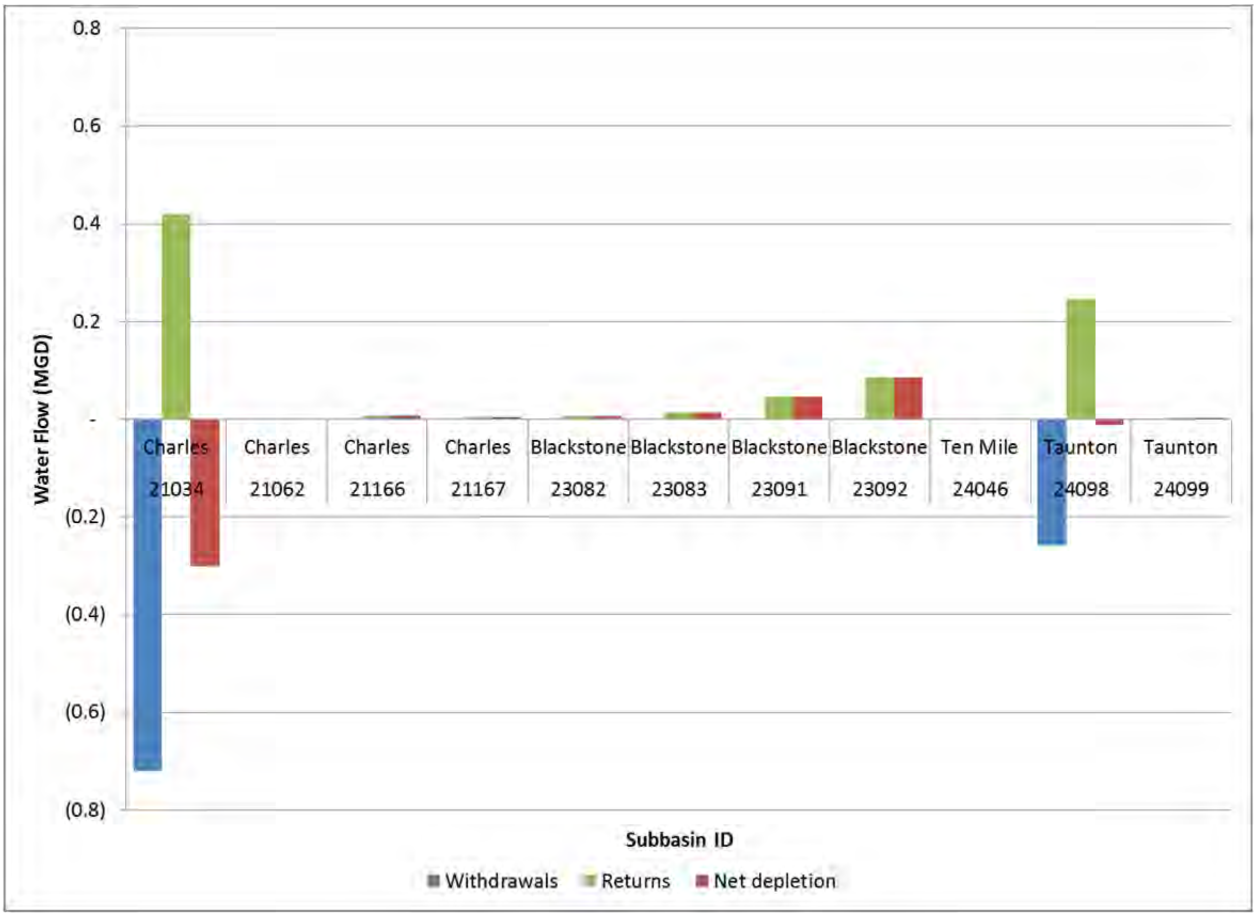
Exhibit 9: Overview of average August withdrawals and discharges 2000-2004 in Taunton subbasin #24098



Notes:
Units are million gallons per day unless otherwise noted.
Values are average reported values for August from 2000 through 2004 as summarized in WMA tool and SYE output. The sum of individual withdrawals or discharges from SYE does not always equal WMA tool summary value.
Private users are households on private well water and users with withdrawals less than 100,000 gallons per day.
*Septic values were calculated based on MA Water Indicators report methodology.

On an annual basis, most (estimated 85 percent) of the water withdrawn by WWD returns to groundwater either via septic systems or, for larger commercial facilities such as Wrentham Outlets, via permitted groundwater discharges. Since only two subbasins provide water for all customers, a net depletion occurs in subbasins #21034 and #24098 (Exhibit 10) while other subbasins intersected by the Town see a net recharge. As described in Section 3.3, septic system returns are used to adjust mitigation requirements for withdrawals above the baseline.

Exhibit 10: WWD withdrawals and estimated groundwater returns by subbasin based on average withdrawals in 2010-2014.



Note: Values estimated from volumes reported in WWD ASRs for years 2010 through 2014 and distribution of population across the subbasins (U.S. Census, 2010). Calculations assume 15 percent consumptive use and 100 percent of wastewater managed by septic systems. Values for each subbasin reflect only WWD withdrawals and estimated returns.

2.3 Permitting Timeline

Exhibit 11 summarizes MassDEP's most recent permitting timelines for the three major basins intersected by Wrentham. As noted in the table, permits in both the Charles and Blackstone basins were renewed before the Regulations and will be up for review in 2017. Permits in the Taunton basin were administratively extended through 2016, when they are due for renewal under the revised WMA requirements.

Exhibit 11: Permitting timelines for subbasins intersected by the Town of Wrentham					
Basin	**Subbasin(s)**	**Renewal**	**Basin Outreach Meeting by DEP**	**Permit Review or Renewal Date**	**Review/Renewal**
Charles[a]	21034[b] 21166 21167	February 2010	April 2016	February 2017	Review
Blackstone[a]	23082 23083 23091 23092	February 2009	April 2016	February 2017	Review
Taunton	24098[b] 24099	February 2015 with Interim Permit through 2016	April 2014	February 2016	Renewal

[a] Permits in the Charles and Blackstone basins were renewed before passage of the Permit Extension Act.
[b] Source subbasin for WWD

3 Assessment of Wrentham's Responsibilities under the WMA Regulations

The Regulations establish a framework for reviewing and issuing withdrawal permits to protect water bodies while meeting communities' needs for water. The framework applies to new permits, permit renewal requests and five-year permit reviews that MassDEP conducts on a rolling basis across all major planning basins within the Commonwealth. It specifies conditions that permittees must meet for existing and future withdrawal permits, depending on conditions in each subbasin and subject to cost feasibility. Below, we briefly summarize important aspects of the Regulations that affect WWD planning decisions. The description is based on the Regulations and Water Management Act Permit Guidance Document (MassDEP, 2014a).[14] We also note requirements currently incorporated into WWD's Charles permit, which may differ from those under the Regulations.

The assessment consists of three main parts:

1. Standard conditions (discussed in Section 3.1 below);
2. Minimization requirements (discussed in Section 3.2); and
3. Mitigation requirements (discussed in Section 3.3).

3.1 Standard Conditions

3.1.1 WMA Requirements

All permittees must meet permit "standard conditions" 1-8 in the Regulations. These standard conditions include performance requirements for residential per capita water use, percent UAW, limits on non-essential outdoor water use, and minimum water conservation best management practices (BMPs) that follow Massachusetts' Water Conservation Standards (EEA and WRC, 2012), such as leak detection and repair, among others.

Exhibit 12 lists the practices and standard conditions applicable to Public Water Suppliers (from Tables 5a-1 through 5a-4 in MassDEP, 2014a).

Exhibit 12: Standard Permit Conditions for Public Water Suppliers
Performance Standards
Performance Standard for Residential Gallons Per Capita Per Day Water Use (RGPCD) • The RGPCD performance standard for PWS permittees is 65 gallons*. • If the permittee fails to document compliance within two full calendar years, then it must implement either an Individual RGPCD Compliance Plan of its own creation designed to bring the system into compliance within three additional years, or adopt the Department's RGPCD Functional Equivalence Plan (FEP) that includes BMPs. – An Individual RGPCD Compliance Plan must, at a minimum, include at least one of the following: ▪ Program that provides water savings devices at cost; ▪ Program that provides rebates or other incentives for purchase of low water use appliances; and/or ▪ Adopt and enforce an ordinance, bylaw, or regulation requiring moisture sensors or similar

[14] The guidance is available at http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/wmaguide14.doc.

Exhibit 12: Standard Permit Conditions for Public Water Suppliers

climate technology on automatic irrigation systems.

  - The Department's RGPCD FEP requires:
    - Permittee be in compliance with conditions of their permit including the limits on nonessential outdoor water use;
    - Adopt all three items from the Individual RGPCD Compliance Plan above;
    - Use of increasing block rates or a seasonal water rate structure; and
    - Implement bi-monthly or quarterly billing.
- A permittee that has been unable to meet the standard within five years must implement the Department's RGPCD FEP.

*PWS permittees on the Cape and Islands and other season communities are not required to meet the RGPCD standard because of seasonal population shifts that make calculating an accurate value difficult.

Performance Standard for Unaccounted-for-Water (UAW)

- The UAW performance standard for all PWS permittees is 10% of total water withdrawal.
- If the permittee fails to document compliance within two full calendar years, then they must implement either an Individual UAW Compliance Plan of their own creation designed to bring the system into compliance within three additional years, or they may adopt the Department's UAW FEP that includes BMPs.
  - The Department's UAW FEP requires:
    - Permittee must complete a water audit and leak detection survey of the entire system within one year;
    - Within one year of conducting the audit/survey, make sufficient repairs to reduce leaks by 75% (by water volume) of all leaks detected in the survey;
    - If UAW remains above 10%, repeat above steps;
  - Repair, replace, and calibrate meters as follows: Large Meters (2" or greater) within one year, medium Meters (1" - 2") within two years, and small meters (<1") within three years;
  - Implement bi-monthly or quarterly billing within three years; and
  - Within one year of filing the UAW FEP, implement water pricing that is sufficient to pay the full cost of operating the system including: repairs resulting from any leak detection survey(s); meter repair, replacement and calibration; employee and equipment costs; and ongoing maintenance and capital costs.
- A permittee that has been unable to meet the 10% UAW performance standard within 5 years must implement the Department's UAW FEP.

Hardship Provision for Performance Standards

Both RGPCD and UAW FEP Plans include a hardship provision that allows a permittee to present an analysis of the cost effectiveness of conservation measures included in the Department's plans and to present alternatives. The analysis must consider environmental impacts and alternatives must produce equal or greater environmental benefits.

Limits on Nonessential Outdoor Water Use

Standard Outdoor Water Use Restrictions	Calendar Option		Streamflow Option	
	All Season	When 7-day low flow trigger occurs	When flow is below ABF	When 7-day low flow trigger occurs
Standard Outdoor Water Use Restrictions in subbasins with ANGD < 25%				
Below 65 RGPCD	7 days, no 9 am to 5 pm	1 day, no 9 am to 5 pm	7 days, no 9 am to 5 pm	1 day, no 9 am to 5 pm
Above 65 RGPCD	2 days, no 9 am to 5 pm		2 days, no 9 am to 5 pm	

Exhibit 12: Standard Permit Conditions for Public Water Suppliers				
Standard Outdoor Water Use Restrictions in subbasins with ANGD > 25% (for minimization planning)				
Below 65 RGPCD	2 days, no 9 am to 5 pm	1 day, no 9 am to 5 pm	2 days, no 9 am to 5 pm	1 day, no 9 am to 5 pm
Above 65 RGPCD	1 day, no 9 am to 5 pm		1 day, no 9 am to 5 pm	

Water Conservation

System Water Audits and Leak Detection

- Conduct a full leak detection survey at least every three years in accordance with American Water Works Association (AWWA) standards. More frequent detection is required for those not meeting the 10% UAW Standard.
- Full leak detection survey whenever unaccounted for water increases by 5% or more over the percentage reported on the Annual Statistical Report (ASR) for the prior calendar year. Submit a report detailing the leak detection survey, dates of leak repairs, and estimated water savings.
- Have repair reports available for inspection by the Department.
- A schedule shall be established for repairing leaks based on guidance provided by the Department.

Metering

- Ensure that the system is 100% metered.
- Calibrate all source and finished master water meters at least annually.
- Properly size service lines and meters for all water users. Meters must meet AWWA calibration and accuracy standards.
- Ongoing program to inspect service meters : a) for accuracy; b) for the need to repair or replace; and c) to check for tampering to identify and correct illegal connections.

Pricing

- Establish a water revenue structure that covers the full cost of the PWS including operations, maintenance, capital improvements, water conservation activities, and indirect costs (such as environmental impacts and watershed protection). Evaluate revenues every three to five years and adjust rates as needed.
- Decreasing block rates are not allowed by M.G.L. Chapter 40, Section 39L. Increasing block rates are strongly recommended.

Residential and Public Sector Conservation

- Meet the standards of the Federal Energy Policy Act, 1992 and the Massachusetts Plumbing Code.
- Meter or estimate water used by contractors using fire hydrants for pipe flushing and construction.
- Municipal buildings
- Submit a report of municipally owned public buildings retrofitted with water saving devices
- Submit a schedule for retrofitting remaining buildings within two years or as agreed upon with the Department
- Water Districts and Water Companies must demonstrate “Best Effort” to work with the Town and complete retrofits.
- Municipally owned public buildings scheduled for rehab or demolition may be exempted from this condition.

Industrial and Commercial Water Conservation

- Review the use records for industrial, commercial and institutional water users and develop an inventory of the largest water users.
- Develop and implement an outreach program designed to inform and (where appropriate) work with industrial, commercial and institutional water users on ways to reduce water use.
- Upon request by the Department, submit a report on conservation results.

Lawn and Landscape

- Permittees must have a water use restriction bylaw, ordinance or regulation providing authority to implement and enforce required restrictions on outdoor water use.

Exhibit 12: Standard Permit Conditions for Public Water Suppliers
Education and Outreach • Develop and implement a Water Conservation Education Plan to educate customers on ways to conserve water. Permit lists the outreach techniques included in the WRC Conservation Standards.
Permittees must be in compliance with these measures on or before a date specified in the permit.

3.1.2 Implications for Wrentham

WWD currently meets only some of the standard conditions. As summarized in Exhibit 13, Wrentham's per capita water consumption was 69 RGPCD in 2014, which is higher than the 65 RGPCD standard and marked an increase relative to 2010-2013 when the town was slightly below the threshold. WWD's estimated UAW was 13 percent in 2014, which was lower than the average of 17 percent over the period of 2010-2014, but still higher than the 10 percent UAW standard.

Because the Town exceeded the 65-RGPCD standard in 2014, the Charles permit limits town residents to 2-day/week watering in 2015 outside the hours of 9 am and 5 pm. This restriction applies town-wide. Under the Regulations, the Taunton permit will allow nonessential outdoor watering 1-day/week or 2-day/week watering (or a watering limit triggered by streamflows), depending on whether the Town is above or below the 65-RGPCD in 2015.

Exhibit 13: Standard permit conditions and WWD's status

Condition[a]	WWD Status[b]
Performance standards	
65 residential gallons per capita per day (RGPCD)	In 2014: 69 RGPCD Average 2010-2014: 64 RGPCD
10 percent UAW	In 2014: 13% Average 2010-2014: 17%
Limits on nonessential outdoor water use	Required per Charles permit, based on calendar year or streamflow triggers. As of 2015: If based on calendar, schedule is 2 days a week watering only due to greater than 65 RGPCD performance in 2014
Water conservation requirements	
System water audits and leak detection	WWD program meets the requirements (audits and leak detection completed every 2 years) As noted in Exhibit 12, failure to meet the UAW standard requires adoption of a Compliance Plan now; failure to meet the standard within 5 years will require WWD to adopt MassDEP's Functional Equivalency Plan.
Metering	WWD program meets the requirements (full metering)
Pricing	WWD program meets the requirements; Will need to increase capital set-aside
Residential and public sector conservation[c]	No specific program
Industrial and commercial water conservation[c]	No specific program

Exhibit 13: Standard permit conditions and WWD's status	
Condition[a]	**WWD Status[b]**
Lawn and landscape[c]	No specific program
Education and outreach[c]	Some education and outreach through information leaflets

[a] Conditions as described in *Water Management Act Permit Guidance Document*, MassDEP 2014a
[b] Unless otherwise noted, WWD status based on WWD's 2010-2014 Annual Statistical Report to MassDEP
[c] Information from WWD staff (personal communication, 2015)

The Town will need to implement measures to meet the conditions above,[15] irrespective of any other requirements associated with minimization or mitigation. Wrentham is also required to develop an UAW Compliance Plan now for submission to MassDEP because it has not met the 10 percent or less UAW standard pursuant to its Charles River watershed withdrawal permit.[16] If WWD fails to meet that performance standard within 5 years, it will have to implement MassDEP's Functional Equivalence Plan in Exhibit 12.

Similarly, since the Town did not meet the 65-RGPCD standard in 2014, Wrentham is also required to submit an individual RGPCD Compliance Plan to MassDEP or adopt MassDEP's FEP.[16,17]

Exhibit 14 estimates the effects of meeting the three performance standard on total withdrawals, based on WWD withdrawals for 2014. As shown in the table, reductions that may be achieved by reducing outdoor watering (0.04 to 0.09 MGD, depending on assumed compliance) are equal to or exceed those associated with simply meeting the 65-RGPCD threshold (0.04 MGD). Assuming that residential customers are responsible for the higher water use in the summer, reducing consumption from outdoor watering should be sufficient to meet the RGPCD standard. Any reduction associated with other water efficiency measures such as indoor fixtures would be additional.

Exhibit 14: Estimated reduction in withdrawals resulting from achieving MassDEP performance standards, based on 2014 data

Item	WWD system performance in 2014[a]	Performance standard	Estimated reduction based on 2014 withdrawals (MGD)	Reduction as % of 2014 withdrawals (0.96 MGD)
RGPCD	69	65	0.04	4%
UAW	13%	10%	0.03	3%

15 Note that the 65 RGPCD was required to be met by the end of 2011 under the Charles permit. The Town will need to implement an individual compliance plan or the State plan, with measures that may include a water efficiency program, an irrigation ordinance/bylaw, block rates, bi-monthly or quarterly billing, etc.

16 See Appendix A in Charles permit for conditions applicable to failure to meet the RGPCD and UAW performance standards.

17 The FEP requires: compliance with limits on nonessential outdoor water use; a program that provides water savings devices at cost; program that provides rebates or other incentives for purchase of low water use appliances; ordinance, bylaw or regulation requiring moisture sensors or similar climate technology on automatic irrigation systems; increasing block rates or seasonal water rate structure; and bi-monthly or quarterly billing.

Exhibit 14: Estimated reduction in withdrawals resulting from achieving MassDEP performance standards, based on 2014 data				
Item	**WWD system performance in 2014[a]**	**Performance standard**	**Estimated reduction based on 2014 withdrawals (MGD)**	**Reduction as % of 2014 withdrawals (0.96 MGD)**
Limits on nonessential outdoor water use		2-day watering (15% reduction)[b]	0.04	4%
		1-day watering (33% reduction)[b]	0.09	10%
TOTAL[c]			**0.07 - 0.16**	**7% - 17%**

[a] Source: WWD 2014 ASR
[b] MassDEP does not establish a numeric performance standard for outdoor watering. We assumed reductions in outdoor water use (calculated as the difference between average water use in summer months vs. winter months) to be 15% when moving from 7-day/week watering to 2-day/week watering, and 33% when moving from 7-day/week watering to 1-day/week watering. Monthly outdoor water use in 2014 was estimated as 44.3 MG - 19.2 MG = 25.1 MG.
[c] The total represents the range of reductions that may be accomplished depending on the assumed limit on outdoor watering (1-day or 2-day/week), and whether the reductions in residential consumption are inclusive, or additional to, reductions in outdoor water use.

We note that the above reductions represent a significant share (7-17 percent) of recent withdrawals. Meeting the standard conditions will therefore provide significant flexibility to Wrentham in meeting future demand and preventing or delaying exceedance of its baseline allocation of 1.08 MGD. For example, using the values above and adjusting the 2014 withdrawals of 0.96 MGD to reflect achievement of 10 percent UAW and the reductions expected with a 1-day/week watering schedule provides an adjusted withdrawal of 0.79 MGD, leaving 0.33 MGD relative to the baseline allocation for additional growth. This flexibility may be particularly important to avoid or delay needing to implement mitigation measures required for withdrawals above baseline (see Section 3.3).

Exhibit 15: Estimated reduction in withdrawals due to achieving performance standards		
Item	**Estimated reduction based on 2014 withdrawals (MGD)**	**Percent of Baseline**
Baseline	1.08	100%
2014 withdrawals	0.96	89%
Minus adjustment for UAW and outdoor watering performance improvements	0.12	
Adjusted withdrawals	0.84	78%
Remaining withdrawals before reaching baseline	**0.24**	**22%**

Further, the reductions estimated above represent achievable targets for Wrentham, as demonstrated by the experience of other Massachusetts towns. For example, the Town of Franklin reduced its outdoor water use by 34 percent after adopting a 1-day/week outdoor water use restriction by-law and outdoor water use in Franklin is now approximately 13 percent of the total water use (Town of Franklin, 2014), as compared to approximately 24 percent in Wrentham during the period of 2010-2014.[18] (Town of Franklin, 2014). Scituate saw reductions in outdoor water use of approximately 23 percent with a similar measure (cited in Town of Franklin, 2014).

3.1.3 Potential Management Actions and Costs

Wrentham has been implementing a meter modernization program. This program will help WWD obtain more accurate estimates of UAW – *e.g.*, by providing a better estimate of municipal water use – while possibly enabling monthly billing, which in turn can be an effective water conservation measure by providing timely feedback to customers, particularly on their summertime water use.

Another measure related to UAW would be a full UAW audit followed by completion of repairs and upgrades. This audit is required under the MassDEP's FEP (see Exhibit 12), along with billing and water pricing adjustments to cover costs of ongoing maintenance and repairs.

Additional possible measures to improve water efficiency include various demand management strategies focused on outdoor watering, such as drip irrigation or sensors. In addition to implementation and enforcement of watering restrictions, other measures may involve educating water customers through mail or other outreach, implementing seasonal or block rates to send price signals targeted at outdoor use, revising monthly bills to provide information to understand water consumption (*e.g.*, show consumption history, compare performance to neighbors or other benchmarks), and providing incentives for water efficiency equipment focused on outdoor watering such as rain barrels or moisture sensors for sprinkler irrigation systems.

Demand management measures to reduce indoor water use include a combination of outreach and rebates or other incentive to increase adoption of water efficient equipment (*e.g.*, faucets, shower heads, toilets, washing machines, and dishwashers for residential customers; high efficiency nozzles for rinsing and cleaning equipment for commercial customers). Exhibit 16 summarizes the annual water savings expected from selected water efficiency measures, based on the *Water Efficiency Cost Benefit Calculation Tool* (Abt Associates, 2015). The calculations reflect Wrentham-specific data on the number of residential and commercial water supply connections, population, baseline average water use, peaking factor, water supply and treatment costs, and breakout of water use by customer class, indoor/outdoor water use, and fixture. For the purpose of these calculations, we assumed that WWD would provide a rebate equal to 25 percent of the cost per unit and that 25 percent of residential or commercial customers would upgrade their equipment or fixtures for more water efficient fixtures.

As shown in Exhibit 16, several measures have expected annual water savings, either individually or in combination with other measures, that exceed the 0.04 MGD estimated to be needed to reduce Wrentham's residential water use from 69 RGPCD to 65 RGPCD (see Exhibit 14). For example, retrofitting 784 ultra-low flush toilets would save an estimated 0.03 MGD at a program cost of $42,922 (based on a 25 percent rebate on the purchase cost); retrofitting the same number of showerheads would save less than 0.01 MGD, at a cost of $3,608. The measures with the largest water savings potential seem to be those related to outdoor irrigation (*e.g.*, 0.05 MGD for soil moisture-based irrigation controller system). The last column in the table provides the "net cost" to WWD, accounting for the avoided

18 Outdoor water use is approximately 84.8 MG per year, based on the difference between water withdrawals during June-September and average water use during the winter months. This is approximately 24 percent of the total water use in 2010-2014 of 357 MG.

marginal production costs (*i.e.*, electricity and chemicals) and forgone water sales. Note that forgone water sales represent most of the net cost to WWD ($5,400/MG, based on the 2014 average water rates).

Exhibit 16: Estimated water savings from selected water efficiency measures via rebate program covering 25 percent of purchase cost

Water Efficiency Measure	Unit Capital Cost[a]	Assumed Number of Units Installed[b]	Program Total Upfront Cost[c]	Total Average Water Savings (MGD)	Annualized net cost per water saving ($/MG)[d]
Residential customers (assume 25 percent uptake)					
Soil moisture-based irrigation controller system	$799	784	$156,545	0.05	$14,284
Weather-based irrigation controller system	$703	784	$137,890	0.03	$17,318
Turf replacement (Xeriscape)	$1,421	784	$278,500	0.03	$28,750
Residential survey (untargeted indoor)	$53	784	$10,290	0.02	$6,776
Graywater system	$1,186	784	$232,460	0.02	$46,790
High efficiency washing machine	$670	784	$131,289	0.03	$19,607
Hot water recirculation on demand -Existing home	$819	784	$160,589	0.01	$52,498
Showerhead	$18	784	$3,608	0.00	$7,500
Faucet aerator	$3	784	$515	0.00	$6,239
Leak detection tablet	$15	784	$2,915	0.01	$6,315
Ultra low flush toilet	$219	784	$42,922	0.03	$9,755
High efficiency toilet	$332	784	$65,092	0.03	$11,929
Dual flush toilet	$484	784	$94,956	0.02	$17,979
Commercial/institutional customers (assume 25 percent uptake)					
Food service appliance – Pre-rinse valve	$258	30	$1,937	0.01	$5,705
Food service appliance – Connectionless steamer	$290	30	$2,176	0.01	$5,757
Dishware sensing gate	$1,326	10	$3,316	0.01	$6,525
Low flow pre-wash spray head	$221	30	$1,658	0.00	$6,116
Once-through A/C condenser	$1,810	30	$13,574	0.04	$6,011
Faucet aerator	$11	40	$111	0.00	$5,436
Ultra low flush toilet	$303	40	$3,033	0.00	$11,885

[a] Average cost per unit (*i.e.*, total cost per fixture)
[b] Number of units retrofitted, based on 25 percent of eligible connections participating in the program.
[c] Upfront costs are calculated from the perspective of WWD and are based on the assumed rebate (25 percent of the cost per unit times the number of units installed)
[d] Annualized net cost per water saving reflects the avoided water production cost and forgone water sales. Forgone water sales account for the majority of the annualized net costs to the utility based on WWD water rates of $5,400/MG in 2014.
Source: Water Efficiency Cost Benefit Calculation Tool, based on Wrentham-specific consumption data (Abt Associates, 2015).

These potential water savings need to be further investigated to refine the estimate of potential savings and program costs. For example, a closer review of the approximate age of equipment and fixtures currently in use would help determine the relative water savings that may be accomplished, as well as the number of fixtures that may be eligible for retrofits. Residential or commercial water audits (which may be combined with energy efficiency audits to identify additional saving opportunities) may help provide the needed information and identify the best, most targeted opportunities for cost-effective water saving measures. As shown in Exhibit 16, residential surveys would provide estimated savings of 0.02 MGD if conducted at a quarter of residential customers.

3.2 Minimize Existing Impacts

3.2.1 WMA Requirements

The Regulations require minimization in subbasins defined as having August net groundwater depletion (ANGD) of 25 percent or more, based on MWI data. Management actions may include additional conservation measures beyond the standard permit conditions discussed in Section 3.1, minimizing depletion during the summer through optimization of existing or alternative source, [19] water releases from impoundments, and returns such as stormwater recharge and wastewater discharges that would result in improvements to the quantity and timing of streamflow.[20]

3.2.2 Implications for Wrentham

Of the two groundwater sources for Wrentham, the Charles subbasin (#21034) has ANGD of 57 percent and therefore additional actions to minimize existing impacts. The permit for the Charles subbasin was renewed in 2010 and is scheduled for review in 2016. MassDEP will require system-wide minimization of existing impacts during this review.

The Taunton subbasin (#24098) has an ANGD of 20 percent and therefore minimization is not triggered by the issuance of this permit.

Accordingly, we assessed potential for minimizing existing impacts “to the greatest extent feasible” system-wide and in the Charles subbasin (#21034). We discuss this assessment below.

3.2.3 Potential Management Actions and Costs

One approach for minimizing impacts in the Charles subbasin would be to increase withdrawals in the Taunton basin. However, this increase could push the Taunton subbasin above 25 percent ANGD. Data from the WMA Tool indicates that increasing withdrawals in the Taunton subbasin by approximately 0.06 MGD would result in ANGD greater than 25 percent.[21] This still might be a feasible alternative depending on operational constraints and cost.

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19 When seeking to optimize use of sources, MassDEP sets a series of considerations for prioritizing withdrawals from relatively less impacted subbasins.

20 MassDEP guidance specifies that the priority for evaluating returns should be first on returns to the same subbasin, then to the same major basin, and finally to another major basin.

21 The WMA Tool reports net withdrawals (withdrawals minus returns) of 0.238 MGD, relative to unaffected flow of 1.205 MGD (20 percent ANGD). Net withdrawals of 0.301 MGD corresponds to 25 percent ANGD for this subbasin, or an increase of 0.063 MGD based on the WMA Tool data.

To evaluate other possible options, we used the U.S. Environmental Protection Agency's Watershed Management Optimization Support Tool (WMOST). WMOST is a public-domain software application designed to aid decision making in integrated water resources management. The model combines a water balance model with an optimization framework to screen various management actions within a watershed context, looking at the concurrent impacts of the actions on water quantity and instream flows. The model considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for the cost and performance of each practice. Appendix A provides more details on the model application to this study.

MassDEP does not define "maximum extent feasible." Accordingly, we developed a range of scenarios that look at streamflows equivalent to volumetric impacts at various levels. The first level (Level 1 scenario) is based on reducing impacts such that the subbasin improves by one GWC category (*i.e.*, from the current GWC 5 to GWC4). The second level (Level 2 scenario) is based on reducing impacts such that the subbasin improves by two GWC categories (*i.e.*, from GWC 5 to GWC 3). Because WMOST's objective must be specified in terms of achieving a minimum streamflow, we estimated the approximate equivalent amount of water which would be added to the stream by reducing impacts to the levels suggested by the change in GWC categories. Exhibit 17 summarizes this calculation.

We note that this calculation is based on the GWC definitions, which relate the amount of withdrawals to unaffected streamflows and do not account for the share of those withdrawals returning to the stream via septic flows. This is an environmentally conservative metric for expressing impacts, particularly for Wrentham where 100 percent of wastewater goes to septic systems. WMOST accounts for these returns internally through the model's internal water balance when calculating instream flows. The estimated septic return for Wrentham in the Charles subbasin is 0.42 MGD (see Section 2.2), which is greater than the estimated reduction calculated for the Level 1 scenario (0.39 MGD).

Exhibit 17: Minimization objectives for Charles subbasin #21034[1]

Calculation Step	Level 1 GWC 5-GWC 4	Level 2 GWC 5-GWC 3
Estimated unaffected streamflow (MGD)[2]	1.863	1.863
Maximum % withdrawals for target category	55%	25%
Maximum withdrawals for groundwater category (MGD)	1.025	0.466
Total withdrawals reported in WMA Tool (MGD)	1.413	1.413
Needed reduction to meet target category (MGD)	0.388	0.947
Corresponding increase in streamflow (cfs)	**0.601**	**1.466**

[1] We also estimated streamflows corresponding to the change needed to reduce AGND to below 25 percent but this streamflow target was generally less than that estimated for the Level 2 target and therefore provided little additional insight.
[2] SYE estimates streamflow in subbasins without stream gage data based on a subbasin that has similar characteristics and has gage data. SYE estimates "unaffected flow" which represents natural streamflow without human withdrawals or discharges. SYE also estimates "affected flow" by adding and subtracting withdrawals and discharges from the unaffected flow based on MassDEP data.
1 cfs = 0.646 MGD

Another minimization approach, evaluated separately, involves using Lake Pearl as surface water storage. We evaluated this approach "offline" from the WMOST model discussed above because although WMOST allows specification of a surface water reservoir, this reservoir cannot be disconnected in WMOST from sources used to meet water demand without custom model modifications that were not possible within the project schedule. So while the calculations are based on WMOST outputs, they are done separately from the model. We discuss this minimization approach first in Section 3.2.3.1, followed by the WMOST-based analysis of other possible management actions.

3.2.3.1 Water Releases from Lake Pearl

As mentioned above, a relatively low-cost approach that seems promising for minimizing impacts is the use of Lake Pearl as surface storage to allow timed release of water during the summer months when streamflows are at their lowest. MassDEP guidance specifically discusses releases from "surface water supply impoundments and measures that could return water to the subbasin or basin to improve flow" as acceptable components of a minimization plan (MassDEP, 2014a; page 22).

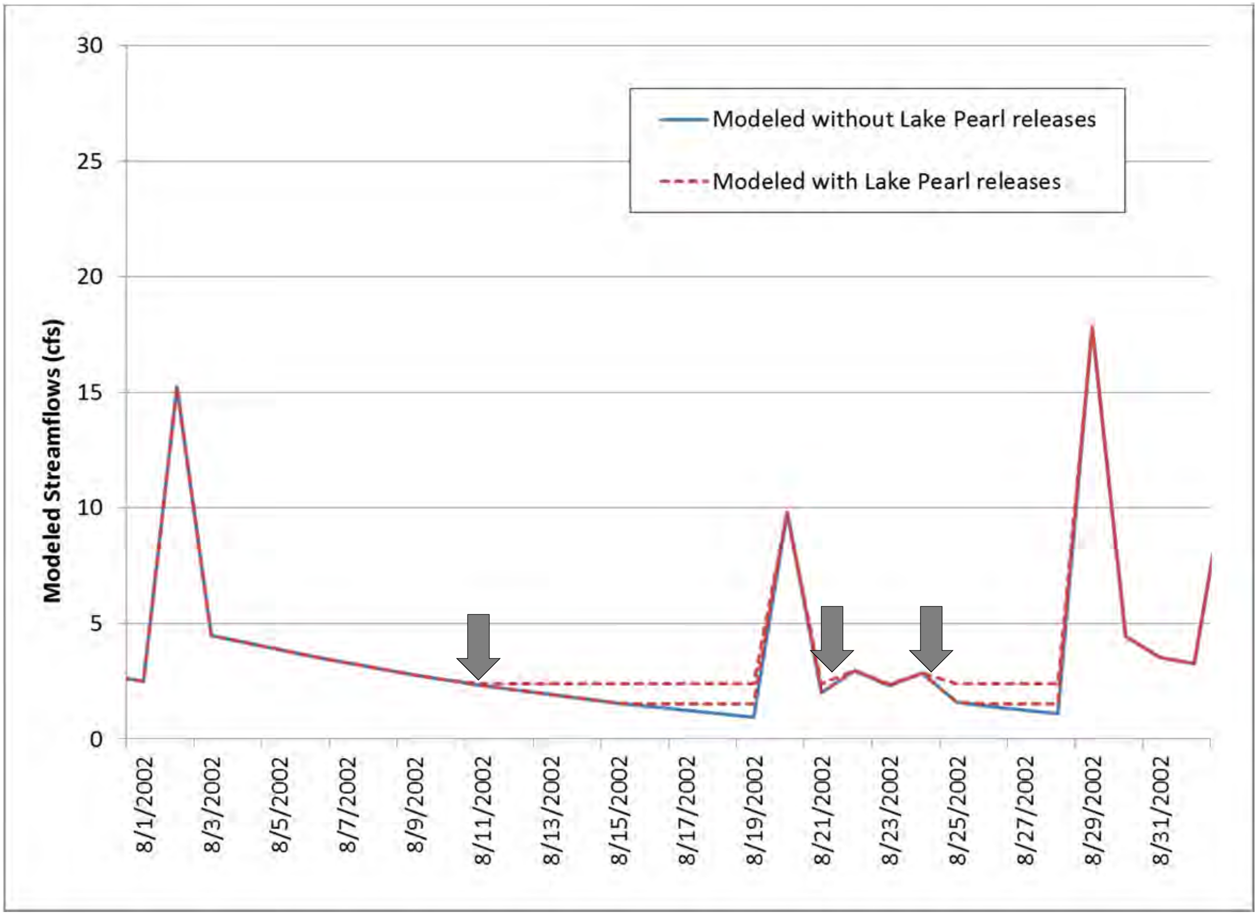
The WMOST model simulations indicate that July-September streamflows were below the Level 1 and Level 2 values discussed above during 7 days and 19 days of the 5-year modeling period, respectively.[22] We estimated the volumes of water necessary to "make up" these low streamflows at 3.3 MG and 20.4 MG, respectively. These volumes are a fraction of the estimated capacity of Lake Pearl (352 MG, based on a rough calculation in GIS, assuming a simple geometry). The maximum rate for water releases (0.9 MGD and 2.2 MGD) occur in mid-August. Accordingly, managing Lake Pearl to release water on days when streamflows are low, could provide additional, low-cost, flexibility to WWD and environmental benefits.

Given the high cost of alternatives identified in WMOST in the next section (Section 3.2.3.2), use of Lake Pearl seems a practical, low-cost approach for minimizing existing impacts when combined with demand management and water efficiency measures outlined earlier for meeting standard permit conditions (Section 3.1).

A more detailed evaluation is needed to confirm that this use of Lake Pearl would be consistent with other uses (*e.g.*, recreation) and would not negatively affect neighboring property owners, as well as to determine the management rules. WWD should also confirm with MassDEP that the measure is available even if Lake Pearl is not a "surface water supply impoundment" specifically discussed in the guidance.

[22] As discussed in Appendix A, the modeling period reflects weather conditions observed in 2000-2004 (corresponding to the modeled streamflows), but with withdrawals adjusted to overall levels reported in 2010-2014.

Exhibit 18: Estimated effects of timed water releases from Lake Pearl on WMOST modeled streamflows. The two dashed lines represent alternative streamflow thresholds for releases (1.519 cfs (lower line) and 2.386 cfs (higher line)); the arrows highlight the timing of releases for the higher streamflow threshold.



3.2.3.2 Other Potential Approaches: WMOST Screening Results

We also screened several other potential approaches to meet the demand while minimizing streamflow impacts.

As described in Appendix A, we ran WMOST to reflect existing conditions and system constraints in 2010-2014 (*i.e.*, available infrastructure, demand) with the objective of meeting the specified streamflows calculated above. We let the model select among several potential actions, including:[23]

- Residential demand management through consumer rate increase and water efficiency program;
- Surface water pumping;
- Interbasin transfer (*i.e.*, water sources from outside the source subbasin);

[23] We also enabled the following management options in WMOST: water/wastewater treatment plants (costs are instead included as part of groundwater/surface water pumping), water reuse facility, and nonpotable water distribution system.

- Aquifer storage and recovery; and
- Stormwater BMP retrofits.

We varied the menu of management actions available in different runs to assess how the feasibility of an action that may otherwise be consistently selected affects costs of meeting the minimization objective, and to identify possible alternative approaches. Overall, the lowest cost approach was obtained by letting the model select among the broadest set of possible management actions. From the full menu of management actions, the model typically selected demand management first, and then met the remaining water demand by adding surface water pumping, aquifer storage and recovery, stormwater BMP retrofits, and other measures. Since demand management is a pre-requisite to minimization (and mitigation), we performed most of the model runs by turning off this option to see what other approaches the model would then select to get a "worst case" estimate. We also conducted several model runs where we limited other options available to meet the system constraints to see the effects on the types of measures selected and the resulting costs. For example, when we limited the availability of surface water pumping, the model either went outside the basin to find the next most cost-effective way to meet demand and the streamflow target or increased implementation of other measures such as aquifer storage and recovery, depending on the relative costs and performance of the remaining management actions present in the model.

Exhibit 19 summarizes results of the model runs and indicates the magnitude of costs associated with various minimization strategies for the two impact levels. Under the best scenario where all options are available to meet the first impact level (Level 1), estimated impacts on system costs are approximately $75,000 per year, which is equivalent to a 42 percent increase relative to WWD's O&M costs in 2014.[24] For the Level 2 threshold, the costs increase by approximately $283,000, or 160 percent of WWD's existing costs. These values are annualized costs and reflect significant upfront capital investments ($380,000 to $1 million) in surface water pumping and treatment and aquifer storage and recovery facilities. Shift from groundwater to surface water reduces operating cost for groundwater pumping, reflected in the negative incremental cost shown for this management action in the table.

Exhibit 19: Potential minimization actions for Charles subbasin (#21034)

Management Action	Level 1: Streamflow 1.521 cfs Existing Water Demand: 0.67 MGD		Level 2: Streamflow 2.386 cfs Existing Water Demand: 0.67 MGD	
	Implementation Quantity (MGD)	Incremental Annualized Operating Cost	Implementation Quantity (MGD)	Incremental Annualized Operating Cost
Surface water pumping	0.83	$76,048	1.04	$229,908
Aquifer storage and recovery	Not selected	Not selected	0.10	$58,226
Groundwater pumping		-$1,340		-$4,758
Total		**$74,708**		**$283,376**

The results of the model are reliable and accurate to the extent that the input data are reliable and accurate (cost and effectiveness of practices, runoff/recharge and groundwater recession coefficient). In addition,

[24] O&M costs calculated as total expenditures on electricity, natural gas, and chemicals.

we made several assumptions about the technical feasibility of the management actions. These factors are important to keep in mind when considering the results and conclusions.

3.3 Mitigate Withdrawal Requests above Baseline

3.3.1 WMA Requirements

The Regulations require mitigation of any increases in withdrawals above baseline, *commensurate with impact*. Further, increases that cause a change in the biological or groundwater category are assigned a Tier 3 permitting designation.[25] The Regulations allow for the presumed impact to streamflow to be reduced by eligible wastewater adjustments. Impacts must be addressed in a mitigation plan that estimates the volume of mitigation, identifies feasible options, and includes a timeline for implementing the mitigation options. In general, mitigation must be completed before withdrawals above baseline occur.

3.3.2 Implications for Wrentham

WWD's baseline withdrawal rate is 0.38 MGD in the Taunton subbasin and 0.74 MGD in the Charles subbasin and a total of 1.08 MGD system-wide (MassDEP, 2015). Whether the WMA mitigation requirements will apply to Wrentham – and the extent of any mitigation – depends on the withdrawal volume requested during permit renewal to meet the Town's projected waster demand.

Exhibit 20 summarizes Massachusetts Department of Conservation and Recreation (DCR) 20-year water needs forecast for Wrentham. The 2030 forecast is in the range of 1.23 to 1.46 MGD, depending on the assumptions. The lower end of this range assumes that WWD meets the standard permit conditions of 65 RGPCD and 10 percent UAW.

Exhibit 20: WWD water needs forecast through 2030

Year	Based on 65/10	Based on Current WWD Trends
2020	1.05	1.25
2025	1.11	1.32
2030	1.17	1.39
Buffer	0.06	0.07
2030 Volume + Buffer	**1.23**	**1.46**

Estimates include a 5 percent buffer to accommodate uncertainty in growth projections.
Source: MassDEP, Permit Renewal Summary Sheet – Taunton River Basin (undated)

WWD currently does not have alternate projections of its water needs, but WWD staff noted the town's rapid growth and significant planned or permitted commercial and residential development, including construction of over 800 residential units. WWD staff also noted potential needs to accommodate episodic requests to supply water to other permittees such as Norfolk Water Division which purchased 0.43 MGD of water from WWD in 2014.

[25] Tier 3 designation prompts additional review and sets a higher bar for demonstrating that no alternative source can be used that would be less environmental harmful than the option proposed.

For the purpose of this assessment, we assumed that Wrentham will seek to renew its permit for the full volume currently authorized in the Taunton subbasin (#24098), which is 0.61 MGD. This is 0.23 MGD above WWD's baseline withdrawal in this subbasin of 0.38 MGD.[26] Under these assumptions, WWD will have to prepare a mitigation plan for the Taunton subbasin (but will not have to implement that plan fully until it exceeds its baseline). Currently, under its Charles permit, WWD is required to conduct an offset feasibility study if it exceeds its baseline of 0.74 MGD in that subbasin. Exceedance of the baseline in a subsequent year triggers the requirement to implement the measures in the study. For the purpose of this study, we assumed a scenario where the Town would seek to withdraw up to its existing authorization in the Charles subbasin (#21034) of 0.92 MGD.

The volume above baseline to be mitigated is reduced by eligible wastewater adjustments (reflecting wastewater returns) as well as additional demand management actions. Wrentham currently discharges all wastewater via septic systems. Therefore Wrentham's two source subbasins benefit from significant wastewater adjustments, and withdrawals above baseline that return to groundwater via septic systems will reduce the volumes that must be mitigated. Exhibit 21 shows the calculation for the two subbasins, based on the assumed withdrawals and estimated septic returns. For the purpose of this calculation, we distributed septic returns in proportion to the fraction of Wrentham's population living in the various subbasins.[27] Note that the Regulations allow full adjustment for returns within the source basin, and adjustment of 50 percent for returns outside the source basin (after accounting for 15 percent consumptive loss).[28]

Exhibit 21: Adjusted Mitigation Requirements

Calculation Step		Taunton Subbasin (#24098)	Charles Subbasin (#21034)
a. Baseline withdrawals (MGD)		0.38	0.74
b. Requested withdrawal (MGD)		0.61	0.92
c. Initial mitigation volume (MGD) [b-a]		0.23	0.18
Adjustments	d. Initial mitigation volume *minus* 15% lost to consumptive use, potentially available for recharge (MGD) [0.85 × c]	0.20	0.15
	e. Estimated fraction of water used within basin (based on % of total town population)	29.7% (29.5% in #24098 and 0.2% in #24099)	51.9% (50.5% in #21034; 1.0% in #21166; and 0.4% in #21167)
	f. 100% of estimated volume	0.06	0.08

26 Note that a request greater than 0.61 MGD in the Taunton subbasin would change the GWC category for this subbasin, prompting designation as Tier 3. The amount of indirect mitigation credit necessary also increases for Tier 3. See Guidance at 39.

27 Note that this is an approximation of actual returns; a more accurate calculation would account for the water distribution network.

28 According to MassDEP guidance, the adjustments are for returns within the same *basin*, *i.e.*, the returns need not be in the same *subbasin*. Further, the adjustments are made for each individual basin, resulting in potential double-counting of the returns in cases where the permittee is withdrawing water from two different basins and where the sum of the withdrawals exceeds the system-wide totals.

Exhibit 21: Adjusted Mitigation Requirements			
Calculation Step		Taunton Subbasin (#24098)	Charles Subbasin (#21034)
	returned within source basin via septic [d × e]		
	g. 50% of estimated volume returned outside source basin via septic [50% × (1-e) × d]	0.07	0.04
h. Remaining volume to be mitigated (MGD) [c-(f+g)]		**0.10**	**0.06**

The mitigation plan must be submitted as part of the permit application. Implementation of the mitigation plan does not need to occur immediately (*i.e.*, at the time the permit is renewed), but actions must be in place *before* the town exceeds its baseline. Thus, the actions described in the mitigation plan must be implemented at the start of the first 5-year permit review cycle during which Wrentham's demand is projected to exceed the baseline.

MassDEP Guidance specifies that the Regulations should be met first by implementing all feasible options for demand management. If mitigation is still required after all demand management options have been exhausted, then direct mitigation, or direct gallon-for-gallon creditable actions, should be prioritized, with consideration given first to direct mitigation in the same subbasin or upstream of the withdrawal. Finally, if demand management and other direct mitigation actions are exhausted or are not economically feasible, then indirect measures with a defined credit system may be considered.

As previously discussed in Section 3.1, approaches to manage and reduce overall water demand, and to reduce unnecessary outdoor water use in particular, may enable the Town to reduce residential demand below the 65-RGPCD threshold. This would enable Wrentham to avoid or delay exceeding its baseline allocation and resulting mitigation measures.

3.3.3 Potential Management Actions and Costs

3.3.3.1 Water Releases from Lake Pearl

One approach for mitigating withdrawals above the baseline involves releasing water from Lake Pearl to maintain minimum streamflows, similar to the approach described in Section 3.2.3.1 to minimize existing impacts. We used the same methodology described in Section 3.2.3.1 to estimate the frequency of Lake Pearl releases needed to offset the impacts of the larger withdrawals.

These calculations indicate releases over 10 to 23 days, depending on the assumed streamflow threshold (as compared to 7 and 19 days for the minimization scenario). Corresponding volumes of water released range from 8.2 to 30.9 MG (as compared to 3.3 to 20.4 MG), at maximum daily rates of 0.9 to 2.2 MGD.

While more significant than for the minimization scenario discussed in Section 3.2.3.1, these releases are still relatively small when compared to the total estimated volume of Lake Pearl (352 MG).

As noted in Section 3.2.3.1, a more detailed evaluation is needed to confirm that this use of Lake Pearl would be consistent with other uses (*e.g.*, recreation) and would not negatively affect neighboring property owners, as well as to determine the management rules. Following MassDEP guidance, consultation with the appropriate state agencies will be needed if WWD would like to include surface water releases as part of its mitigation plan (MassDEP, 2014a; page 37).

3.3.3.2 Other Potential Approaches: WMOST Screening Results

We used the same model described for Section 3.2.3 (WMOST) to screen additional potential management actions that could mitigate impacts projected given an increase in withdrawals above baseline. We specified the modeling scenarios to meet the flow targets estimated for the minimization scenarios, but with the increased withdrawals. The model accounts for septic returns occurring within the subbasin implicitly by performing a water balance that accounts for withdrawals, demand, consumptive losses, septic returns and other components of the natural and human system. However, the model does not account for returns occurring outside the subbasin. Accordingly, we adjusted the flow targets to reflect the returns occurring outside the subbasin, for which Wrentham would receive an adjustment under the Regulations.

We did the analysis for each source subbasin individually, using as demand input the total withdrawals. We note that this analysis overstates the demand since the system-wide water needs forecast is actually less than the sum for the two individual source subbasins.

Given MassDEP guidance on management action priorities, we did not evaluate indirect credit actions such as land conservation, habitat restoration, or stormwater by-laws in the model. Exhibit 22 and Exhibit 23 provide the WMOST results for the Charles and the Taunton source subbasins, respectively. Appendix A provides details on model runs.

Exhibit 22: Potential mitigation actions for Charles subbasin (#21034) – Forecast water demand (0.92 MGD)

Management Action	Level 1: Streamflow 1.464 cfs		Level 2: Streamflow 2.329 cfs	
	Implementation Quantity (MGD)	Incremental Annualized Cost	Implementation Quantity (MGD)	Incremental Annualized Cost
Surface water pumping	1.12	$122,246	1.43	$309,323
Groundwater pumping		-$2,256		-$6,385
Total		**$119,989**		**$302,938**

Exhibit 23: Potential mitigation actions for Taunton subbasin (#24098) – Streamflow 1.364 cfs; Forecast Water Demand: 0.61 MGD

Management Action	Implementation Quantity (MGD)	Incremental Annualized Cost
Surface water pumping	0.96	$110,903
Groundwater pumping		-$2,168
Interbasin transfer	No change[1]	No change[1]
Aquifer storage and recovery	0.06	$39,683
Total		**$148,418**

[1] The model selects interbasin transfer (at full 0.15 MGD potential) to meet water demand even when no streamflow target is specified.

The model suggests additional measures to mitigate impacts, if still needed after implementing the demand management approaches discussed in Section 3.1, minimization measures discussed in Section 3.2, and low-cost releases of water from Lake Pearl.

We note that when interbasin transfer was enabled, the model runs relied on this measure to meet the system constraints, suggesting that alternate water sources could be used to mitigate impacts in the two subbasins. WWD's two existing source subbasins, #21034 and #24098, are headwater subbasins with significant human use and are highly constrained systems in terms of water quantity. Although WWD customers use septic systems and thereby return most of the water to the groundwater, higher impacts occur during the summer months of high outdoor use. Additional loss of water occurs because of customers living outside the two subbasins, thereby exporting water. Developing a new source in subbasins #23091 or #23092 could help to re-balance the water budget by "localizing" water use. These subbasins have septic returns that are currently roughly equal to or exceed withdrawals, and have no significant permitted withdrawals. However, the Town would need to further investigate potential well yields in these subbasins and confer with MassDEP as to whether withdrawals there would change the subbasins' biological or groundwater withdrawal categories. Our preliminary calculations suggest that additional withdrawals may be limited to about 0.15 MGD before triggering a change in GWC category. Accordingly, we assumed a limit of 0.15 MGD on interbasin transfers allowed in the WMOST model runs.

While available in the model, stormwater infiltration BMPs were typically not selected in any of the model runs. This is due to the small additional recharge gained from implementing the BMPs in the two source watersheds and the relatively high costs of the BMPs. For example, a review of WMOST inputs indicates that broad implementation of 0.6" stormwater infiltration trenches on all existing high density residential and commercial-industrial-transportation development on "till and fine grain deposit" soils in subbasin #24098 would result in incremental recharge of 0.006 and 0.046 MGD, respectively, at annualized costs of $9,060 and $70,093. This is both more limited in terms of potential recharge and more expensive (about $1.5 million per MGD) than some of the other management actions available in the model (*e.g.*, surface water pumping, aquifer storage and recovery, interbasin transfer). To the extent that such stormwater BMPs need to be implemented for other reasons, such as to meet MS4 permit requirements and reduce phosphorus loadings, they may still be an attractive way of getting direct mitigation credits under the Regulations, reducing the need to implement other measures.

4 Insight from the Assessment

4.1 Insight on Cost-Effective Strategies to Meet WMA Requirements

4.1.1 Demand reduction

The assessment in Section 3 highlights opportunities to manage and reduce water consumption. These activities will need to be prioritized, both because they are required to meet the standard permit conditions, and because they will help the Town minimize its existing impacts and delay the need to mitigate any increase in withdrawals above baseline in either the Taunton or Charles watersheds (or total system-wide baseline).

The analysis presented in Section 3.1 shows that significant reductions can be achieved by outdoor watering reductions similar to those that have been achieved in other towns (e.g., Franklin achieved savings of approximately 34 percent in outdoor water use following passage of a 1-day/week outdoor water use restriction bylaw; Town of Franklin, 2014). These reductions would be sufficient to meet – and likely improve upon – the 65-RGPCD performance standard in the Town's withdrawal permits.

Using the demand calculator developed under this Grant and WWD data on the number of connections and distribution of demand among user category, we calculated the potential costs and water savings from a range of demand management options that have been empirically demonstrated as effective in reducing water consumption. These options, which include a variety of measures such as residential or commercial audits, retrofits of irrigation equipment (*e.g.*, weather-based irrigation controllers, evapotranspiration controller) and appliances or fixtures (*e.g.*, water efficient washing machines and toilets), are estimated to provide sufficient water savings to meet the 65-RGPCD performance standard.

This tool can be used to identify, develop and refine a strategy for meeting the standard conditions; the tool can also help identify additional measures to exceed these standard conditions as part of the Town's mitigation plan.

Placing limits on nonessential outdoor water use through a 1-day/week or 2-day/week limit, should also provide significant savings during critical summer months when streamflows are the lowest.

4.1.2 Minimization

Based on current withdrawals and MassDEP information, a minimization plan will be needed when MassDEP reviews and modifies the Charles subbasin (#21034) permit in 2016 to include conditions in the new Regulations, and that mitigation plans may be needed in both the Taunton (#24098) and Charles (#21034), depending on the requested withdrawals volume in the Taunton and whether the Town exceeds the baseline in the Charles.

Key measures to minimize existing impacts include:

- Enhanced demand management that goes beyond the standard permit conditions. For example, these measures may include town-wide watering restrictions of 1-day/week (instead of the 2-day/week currently allowed under the Charles permit given RGPCD greater than 65).

- Optimizing pumping between the two source subbasins to minimize impacts in the Charles while ensuring that impacts in the Taunton subbasin do not change the GWC for that subbasin.

- Managing water levels and outflows from Lake Pearl to release water when needed to maintain streamflows downstream. This management action would be effective and low cost. As discussed in Section 3.2.3.1, however, more information is needed to more fully evaluate the potential of this action, considering other potential users who may be affected (*e.g.*, recreational users, residents), and to outline management rules (minimum and maximum levels, release triggers, etc.) If further review confirms that this is a viable option, WWD will need to provide MassDEP with an evaluation that includes: "a) an analysis of the [e]ffect that releases will have on the firm yield of the supply impoundment, b) how any identified change to firm yield will affect the permittee's ability to meet the projected 20-year demands used to prepare the permit application, c) any [e]ffect to the permittee's ability to meet anticipated peak seasonal or peak day demands, and d) whether there are sources within the current PWS-system with capacity that could be used to meet projected demand."[29] (MassDEP, 2014a)

4.1.3 Mitigation

We calculated volumes to be mitigated for both basins in the event that WWD exceeds its baseline withdrawals. We estimated mitigation volumes at 0.10 MGD in the Taunton subbasin and 0.06 MGD in the Charles subbasin, including adjustments for septic returns. Implementing stringent water efficiency and demand management measures will delay the need to implement more expensive mitigation actions.

MassDEP places priorities on demand management first, followed by direct measures that are volumetrically quantifiable. Direct measures include:

- Managing water levels and outflows from Lake Pearl (in the Charles subbasin). WWD should discuss with MassDEP the process for determining the credits from surface water releases.

- Stormwater infiltration BMPs that will also be needed under the new MS4 requirements to control phosphorus loadings. Stormwater BMPs, while not the most cost-efficient option when considering WMA requirements alone, are eligible for direct mitigation credit for redevelopment projects. WWD should inventory the practices and determine how much credit they may provide. This project provides a separate tool (Stormwater Calculator) that can be used to estimate the potential volumetric credits.

If additional measures are necessary, the WMOST model suggests some management actions that may be taken to meet demand while also ensuring streamflows that are sustainable and protective of biological conditions. For example, the assessment highlights potential advantages to diversifying water sources with withdrawals in the Blackstone basin. The Town would need to further investigate potential well yields in these subbasins and confer with MassDEP as to whether withdrawals there would change the subbasins' biological or groundwater withdrawal categories. Our preliminary calculations suggest that additional withdrawals may be limited to about 0.15 MGD before triggering a change in GWC category.

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29 Lake Pearl is not a supply impoundment. Accordingly, discussion of the "effects that releases will have on the firm yield of the *supply impoundment*" would not apply to this management action. We assume, however, that this does not imply that releases from Lake Pearl would not be accepted by MassDEP as a minimization measure. WWD needs to confirm this understanding with MassDEP.

4.2 Insight on Data and Planning Process

We note four areas for reducing planning uncertainty:

- Refine or confirm data: This planning study relied on input data from published reports, previous WMOST case studies, and rough estimates. While we used the best information available to us within the scope and schedule of the project, additional data would be needed to verify some of the analysis assumptions. For example, the model assumes that all water pumped by the wells comes from groundwater. However, given Lake Pearl well's proximity to the similarly named surface waterbody, it is conceivable that at least part of the flow from this well is coming from the Lake via induced infiltration. We did not have sufficient information to include this assessment as part of our evaluation. Similarly, we estimated returns based on the relative distribution of Wrentham's population among the subbasins. A more accurate calculation would also consider the water distribution network.

- Agree on quantitative minimization target and timeline: As described in Section 3.2, WWD will need to minimize existing impacts in the Charles. The Regulations require minimization *to the greatest extent feasible, i.e.*, does not provide numeric or quantitative metrics; however, the goal is "improvement." WWD should discuss with MassDEP the level of measure implementation needed to demonstrate acceptable and sufficient minimization of existing impacts to meet the regulatory requirements.

- Agree on quantitative mitigation target and timeline: Mitigation reflects anticipated future water needs and mitigating the impacts of additional withdrawals, after accounting for returns. The actual volume to be mitigated will depend on requested withdrawals. They also depend on the calculation of returns. We followed the MassDEP guidance to estimate the adjustments to mitigation targets for the two subbasins individually.

- Clarify the availability of impoundment releases for minimization and mitigation credits: As noted in footnote 29 on page 33, Lake Pearl is not a supply impoundment. We assume that this does not limit its applicability as a minimization measure as allowed in the MassDEP guidance, but WWD should confirm this understanding with MassDEP. Additionally, the MassDEP guidance addresses the use of surface water releases for mitigation, noting that credits for such releases will need to be determined on a case-by-case basis and consultation with appropriate state agencies will be required when including the measure as part of a mitigation plan. WWD should discuss the process involved in such consultation with MassDEP.

- Refine understanding of available measures: The assessment provides some suggested measures that seem cost effective, based on our understanding of the measure feasibility and costs. More detailed information could change the recommendations. The minimization and mitigation plans should be "living documents" informed by insight WWD gains from further evaluations and initial implementation of management actions (*e.g.*, participation in water efficiency program and impacts on water use). Note that the mitigation plans need to be implemented before the Town's withdrawals exceed its baseline, which could be several years away given demand management measures. Consequently, there may be opportunities to investigate and refine understanding of the mitigation measures before they would need to be in place.

- Stormwater retrofit feasibility study: Conduct a feasibility study for available land appropriate for stormwater retrofit (i.e., inventory of municipal parcels and cooperative land owners and assessment of which of those parcels are feasible for retrofit). The study should consider potential co-benefits of stormwater management including meeting requirements under the MS4 permit. Based on the results of the study, WWD could update estimates of minimization or mitigation credits.

- Returns from Lake Pearl: As discussed in Sections 3.2.3.1 and 3.3.3.1, releasing water from Lake Pearl during low streamflow periods may be a cost-effective way to minimize or mitigate withdrawal impacts in the Charles subbasin. Further evaluation is needed to confirm the feasibility of this approach given recreational users and property owners, and to define operational rules.

- Aquifer storage and recovery: Although WMOST recommended aquifer storage and recovery in some scenarios, we recommend consultation with MassDEP to determine the feasibility of this measure. Aquifer storage and recovery provides the ability to store water during seasons of relatively high availability and low demand and utilize it during the summer season when availability is low and demand high. The practice is common in western states and valuable insights may be gained from their experience. Although aquifer storage and recovery is practiced in the Western and Southeast U.S, we did not find any aquifer storage and recovery wells or feasibility studies for aquifer storage and recovery in the Northeast except for one instance in New Hampshire.[30] Given unknown acceptability and potentially higher costs due to lack of regional experience, this option is less favorable at least in the near term.

- Surface water pumping: This was another option consistently selected by WMOST as a way to minimize the impacts on streamflows. Accordingly, WWD may want to explore the practicality and regulatory acceptability of surface water pumping to supplement and change the timing of groundwater withdrawals. WMOST scenarios could be re-run to include either refined costs for pumping and treating surface water or to exclude surface pumping if deemed impractical (as was done for a subset of model runs).

30 (http://water.usgs.gov/ogw/artificial_recharge.html, http://water.epa.gov/type/groundwater/uic/aquiferrecharge.cfm#inventory).

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Appendix A WMOST Modeling

We used WMOST in this planning study to screen among water management options to meet WWD customer demand while complying with requirements of the Regulations. WMOST is a public-domain software application designed to aid decision making in integrated water resources management (U.S. EPA, 2013). WMOST is intended to serve as an efficient and user-friendly tool for water resources managers and planners to screen a wide-range of strategies and management practices for cost-effectiveness and environmental sustainability in meeting watershed or jurisdiction management goals. WMOST identifies the least-cost combination of management practices to meet the user specified management goals.

A.1 General Modeling Approach

The general approach for the modeling study involved populating WMOST with data characterizing the watershed system, human water system, and management costs and effects, for each of the two target subbasins (Charles #21034 and Taunton #24098). Appendix B provides the data catalog for each subbasin detailing the values used to populate the model. The watershed system representation (runoff and recharge in response to precipitation) used in WMOST was obtained from an HSPF model developed by USGS for the New England region (USGS, 2010).

We first ran validation scenarios using data for the period of 2000 through 2004 without streamflow targets or management practices that would modify historic operations. We used these results to compare WMOST streamflow estimates to streamflow derived from the Massachusetts Sustainable Yield Estimator (SYE) data, adjusting the groundwater recession coefficient as needed to match the SYE data as closely as possible. As shown in Exhibit 24 and Exhibit 25, the validation scenarios show generally good agreements between WMOST and the SYE estimates used by MassDEP to establish the WMA requirements. Nash-Sutcliffe Efficiency (NSE) values[31] for monthly streamflows in July-September are 0.70 and 0.68 for the Charles and Taunton subbasins, respectively, which we deem acceptable for a screening-level model such as WMOST.[32]

31 NSE values are used to indicate the fit between modeled discharges and observed data (in this case observed data are streamflows estimated in the SYE tool).

32 While SYE estimates show more "flashy" flows than HSPF-based WMOST, the models estimate similar low flow conditions during the July to September periods. Since neither HSPF nor SYE were directly calibrated for the target subbasin, it is unclear which would represent streamflow more accurately.

Exhibit 24: WMOST vs. SYE Streamflows for 2000-20004 in Charles subbasin #21034

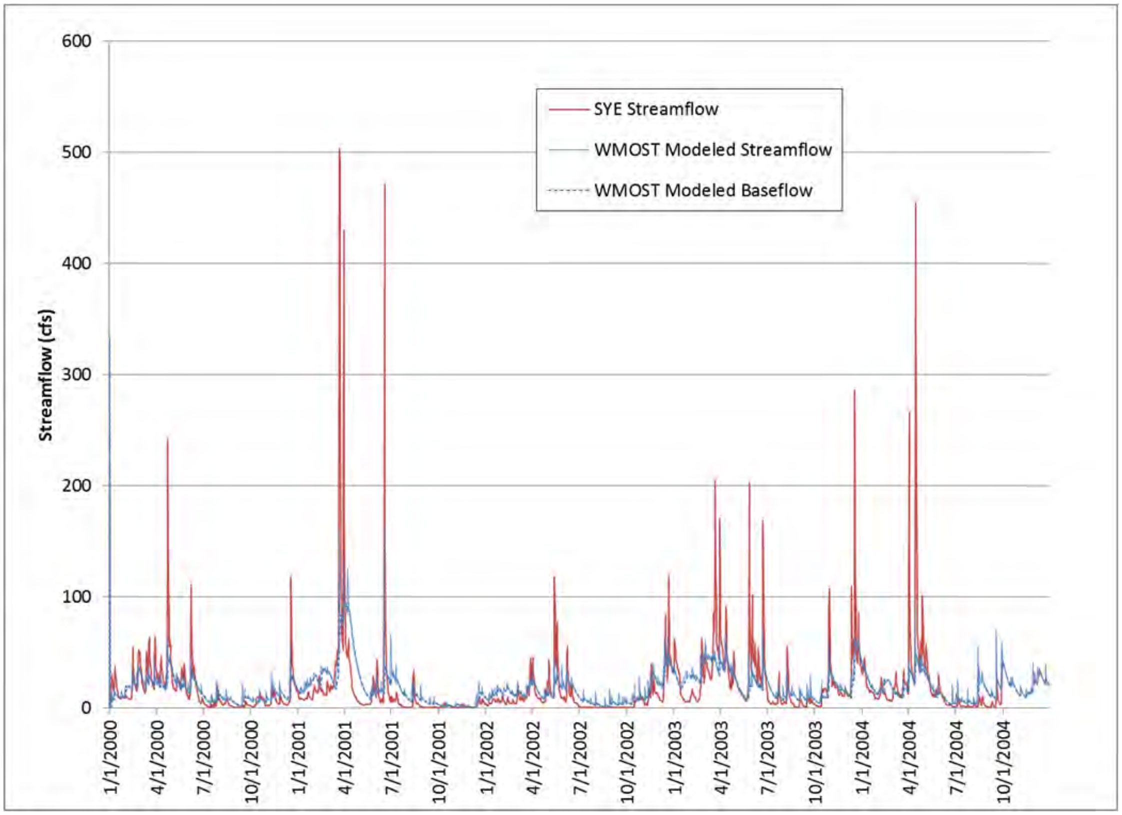
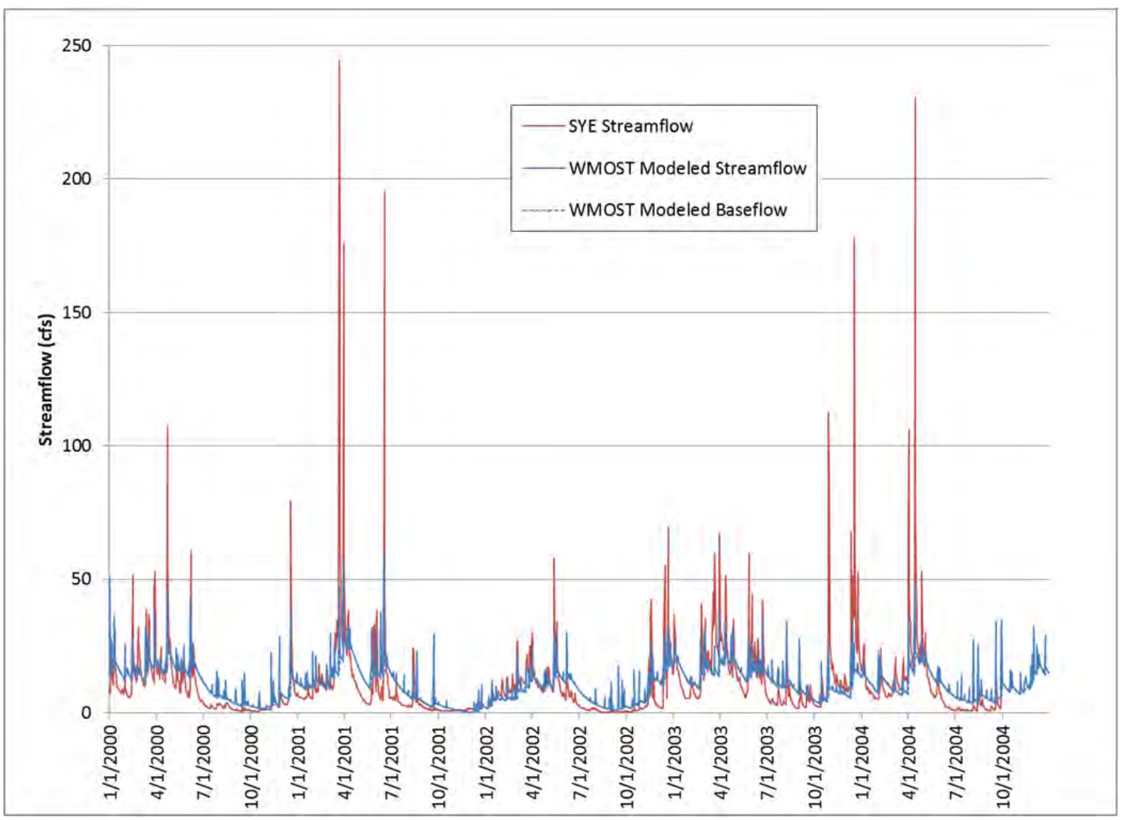


Exhibit 25: WMOST vs. SYE Streamflows for 2000-20004 in Taunton subbasin #24098



The validation scenarios are based on the period MassDEP used to determine the Regulations' subbasin groundwater categories. Therefore, we used streamflows from the validation scenario to calculate the minimization and mitigation streamflow targets for the planning scenarios.

We ran two planning scenarios: one for minimizing existing impacts considering current demand (2010-2014) and one for mitigating potential increases in withdrawals to meet 20-year projected demand. To determine the incremental cost of the management actions selected to meet the Regulations, we ran one scenario where we did not set streamflow targets to estimate the cost of "no regulations", that is, what would be the most cost-effective strategy for WWD to meet its customers' water demand under business-as-usual in absence of regulations.

We ran these scenarios for each of the two target subbasins. WMOST models one watershed or subbasin at a time (i.e., one receiving stream). However, since WWD's human system (demand, infrastructure) is distributed across the two target subbasins, decisions in one subbasin may affect conditions in the other subbasin. We accounted for the interaction between the subbasins when specifying the scenario parameters (e.g., making sure there is no double counting across the subbasins of the withdrawals, demand and returns), and when compiling insights gained from the individual models.

The tool considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for both the cost and performance of each practice. For this study, we considered the practices listed in Exhibit 26 to be available for some or all model runs.

Exhibit 26: Management actions modeled in WMOST

Practice	Effect
Stormwater management	Increase area of land use type treated by specified management practice to reduce runoff and increase recharge. Practices considered include: infiltration trench, detention basins and bioretention at the 0.6'', 1'' and 2'' design depths
Surface water storage capacity	Store spring flows in Lake Pearl for release during low-flow periods, propose to accomplish by using stop logs at the outlet weir to manage the water levels (subbasin 21034 only)
Surface water pumping capacity	Add pumping capacity to reduce quantity and/or timing of demand from other sources
Groundwater pumping capacity	Add pumping capacity to reduce quantity and/or timing of demand from other sources
Change in quantity of surface versus groundwater pumping	Change in pumping time series for surface and groundwater sources to change the timing of withdrawal impact on water source(s) to alleviate low-flows
Potable water treatment capacity	Increase maximum treatment capacity to meet potable human demand
Leak repair in potable distribution system	Decrease the percentage of leaks to reduce demand for water quantity
Water reuse facility capacity	Add advanced treatment to wastewater treatment facility to produce water for nonpotable demand and/or aquifer storage and recovery
Nonpotable distribution system	Add secondary distribution system to reduce demand for potable water

Exhibit 26: Management actions modeled in WMOST	
Practice	**Effect**
Aquifer storage and recovery facility capacity	Add aquifer storage and recovery facility to recharge groundwater supply especially during high flows
Demand management by price increase	Increase customer price of water to reduce demand
Direct demand management	Reduction in demand from rebates, education and other customer programs
Interbasin transfer – potable water	Increase capacity to transport water from other subbasins to reduce demand for subbasin sources, in this case, new well field in subbasin 23091. Note that the cost of this practice includes an estimated cost for developing new wells and building a new water treatment facility.

We did not consider land conservation for this application of WMOST (although this management action is available in the model) because preserving existing forest and other undeveloped land is an indirect measure and will be considered by MassDEP only once direct measures have been exhausted or proven cost prohibitive.

The remainder of this Appendix provides more details on model setup for the scenarios and summarizes results across the scenarios and subbasins.

A.2 Scenario Descriptions

We configured scenarios to simultaneously meet two management goals at least cost: 1) provide WWD customers' water demand and 2) achieve quantitative, minimum in-streamflow targets based on GWCs delineated in the Regulations. Using these management goals, we ran two planning scenarios.

First, we specified *minimization* scenarios for subbasins 21034 to estimate the cost of minimizing existing impacts considering existing demand (i.e., 2010-2014 average demand). DEP's determination that subbasin 21034 has greater than 25 percent net depleted in August (i.e., net groundwater withdrawals and returns) requires that permittees minimize the impact of their withdrawals. WWD and other permittees will need to minimize their existing impacts independent of demand growth and potential additional withdrawal requests (see Section 3.2).

Second, we specified *mitigation* scenarios for each of the three subbasins to estimate the cost of meeting the projected 20-year demand and offsetting the impact of withdrawals above WWD's baseline. The Regulations require that the impact of any new requests about "baseline withdrawals" be offset or mitigated (see Section 3.3).

Exhibit 27 summarizes the model setups for the two main planning scenarios. Input data consistent across scenarios include 2000-2004 hydrology (i.e., daily time series of runoff and recharge in response to precipitation), 1999 land use delineation, and non-WWD withdrawals and discharges. During this time period, hydrologic conditions included a 1 in 3 dry year in 2001 followed by a 1 in 20 dry year in 2002.[33]

[33] Calculated using data from Boston precipitation station from 1961 to 2005 and the methodology presented at: http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx

The scenarios differ primarily in the assumed demand (existing or Water Needs Forecast) and target flow (level 1 or level 2). Because existing demand data for 2010-2014 corresponds to potentially different weather conditions than in 2000-2004, we constructed a synthetic daily withdrawal time series for 2010-2014 for use in the model by scaling up daily withdrawals for 2000-2004 to match the increase in actual withdrawals between 2000-2004 and 2010-2014. The resulting synthetic demand time series follows the *pattern* of demand observed in 2000-2004, but at the level of 2010-2014. We used a similar approach to develop the time series of withdrawals for the demand forecast by scaling up the daily withdrawals in 2000-2004 by the expected change in total withdrawals.

Exhibit 27: Summary of modeling scenarios

Data/Assumption	Minimization	Mitigation
Applicable subbasins	#21034	#21034 and #24098
WWD demand	Actual pumping in 2010-2014, adjusted to meet 10% UAW standard condition	Water needs forecast for 2030
Non-WWD Withdrawals and Discharges	2000-2004 SYE/WMA Tool water use and discharge flows	Same as minimization
Customer price for water	2014 rate with maximum annual increase of 2 percent for 20 years[34]	Same as minimization
Management actions[1]	All available Or selected practices	All available Or selected practices
Management costs	2014 non-O&M costs plus minimization actions selected by the model	2014 non-O&M costs plus mitigation actions selected by the model
Streamflow target (see Section 3.2.3 for methodology to determine targets)[2]	Flow corresponding to reducing impacts to GWC 4 Flow corresponding to reducing impacts to GWC 3	Same as minimization, with adjustment for septic returns outside of modeled subbasin

1) See list of available practices in Exhibit 26.
2) We also estimated flows corresponding to the change needed to reduce AGND to below 25% but this flow target was generally less than that needed to reduce impacts go GWC 3 and therefore provided little additional insight.

We ran multiple minimization scenarios varying the quantitative streamflow restoration targets. For minimization Level 1, we calculated the additional amount of withdrawals that need to be offset and would return to the stream to meet the definition of GWC 4. The calculated improvement in streamflow is added to the August WMOST estimated baseline streamflow from a model run without any management action. We also calculated a higher minimum flow corresponding to changes needed to meet GWC 3. The mitigation scenarios assume maintenance of these same flows under forecast demand conditions.

[34] Note that the two percent annual increase in rates represents the maximum increase in rates attributable to actions to meet the Regulations. It does not represent additional increases needed to cover other changes in costs.

Exhibit 28: Calculation of GWC 4 and GWC 3 August relative streamflow targets, based on WMA tool data and baseline results using adjusted actual withdrawals for 2010-2014

	21034	**24098**
Unimpacted August Flow (MGD)	1.863	1.202
Minimum In-Stream Flow (MGD)[1]	0.857	0.904
Calculation of Target for Achieving GWC 4 (55% maximum groundwater withdrawal)		
Maximum Withdrawal (MGD)	1.025	
Average of Total Withdrawals 2000-2004 (MGD)	1.413	
Reduction in Total Impact Required (MGD)	0.388	
Estimated increase in in-stream flow above modeled baseline (cfs)	*1.521*	GWC4 already met
Calculation of Target for Achieving GWC 3 (25% maximum groundwater withdrawal)		
Maximum Withdrawal (MGD)	0.466	0.301
Average of Total Withdrawals 2000-2004 (MGD)	1.413	0.431
Reduction in Total Impact Required (MGD)	0.947	0.131
Estimated target increase in in-stream flow above modeled baseline (cfs)	*2.386*	*1.519*
Calculation of Target for Achieving ANGD 25% maximum		
Total withdrawal (MGD)	1.413	
Total return (MGD)	0.349	
Net depletion	1.064	ANGD 25% already met
Net depletion at 25%	0.466	
Reduction in Net Impact Required (MGD)[b]	0.598	
Estimated target increase in in-stream flow above modeled baseline (cfs)	*2.369*	

a) WWD share of impact was calculated as the ratio of WWD net withdrawal (WWD withdrawals minus return) to total basin net withdrawal (total withdrawal minus total returns)
b) Reflects percent of demand returning to septic.
Note that the target streamflow applies to the median of August streamflow. WMOST allows the user to specify *minimum* streamflow rather than the median. Setting the target based on minimum flow is more environmentally conservative and results in higher median flows.

Other key assumptions for the planning scenarios are summarized below. The data catalogs in Appendix B provide more details.

- <u>Planning horizon and financing</u>. We assume a 20-year planning period based on the WMA water withdrawal permit cycle. We use an interest rate of 3 percent for financing the capital cost of infrastructure. New capital cost investments in the model are therefore amortized over 20 years at a rate of 3 percent.

- <u>Replacement costs</u>. There is (at least) 25 years remaining lifetime on existing structures and therefore we assume no replacement costs within the simulation period.

- <u>Land use</u>. Regulations do not require accounting for projected changes in land use (which will affect runoff and recharge rates); therefore, we used 1999 land use to define the subbasins, the year of available data closest to the 2000-2004 baseline period.

- Climate. We run scenarios using runoff and recharge coefficients that reflect precipitation patterns in 2000 to 2004 time period. Hydrologic conditions included a 1 in 3 dry year in 2001 followed by a 1 in 20 dry year in 2002.[35]
- Demand and Pumping Time Series. We scaled 2000-2004 daily pumping time series to the current, 2010-2014, and projected 2030 demand to create the demand time series for the minimization and mitigation scenarios, respectively. We scaled the 2000-2004 time series rather than using 2010-2014 pumping data directly in order to keep consistency between human use to weather patterns (e.g., high withdrawal during hot days and weeks).
- UAW. We assume a starting UAW of 10 percent in both the minimization and mitigation scenarios since this is a standard permit condition.
- Stormwater Management. WMOST provides modified runoff and recharge rate time series that reflects the implementation of stormwater BMPs. The model considers implementation of infiltration basins, swales and detention basins at the 0.6-inch, 1-inch and 2-inch design depths. We determined the maximum area available for stormwater retrofit of existing development within the Town of Wrentham for each type of land use and soil combination that existed in 1999, the closest year of available land use data to 2000-2004 baseline period.

A.3 Minimization of Existing Impacts

As described above, we specified *minimization* scenarios for subbasin #21034 to estimate the cost of minimizing existing impacts considering existing demand (i.e., 2010-2014). This section summarizes WMOST results for the minimization scenarios. Costs are estimated *annual operating* costs for WWD, *i.e.*, they do not include bond payments on previous capital investments.[36] New capital costs (i.e., new, one-time investments) are annualized over the 20-year planning period.

In each subbasin, the model meets the water demand using resources available within the subbasin and importing water from the Blackstone basin if needed and allowed as part of the management actions in the particular model run. Overall, the costs, revenues and management practices reflect actions that would be completed during the next 20 years and the operations strategy for WWD in 2034.

A.3.1 Primary Minimization Run

Exhibit 29 summarizes results of the minimization run for Subbasin #21034 and the two flow targets. The table lists those management actions selected under any of the model runs discussed in this Appendix.

[35] Calculated using data from Boston precipitation station from 1961 to 2005 and the methodology presented at: http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx

[36] For this planning study, we estimated current operating costs as the average annual operating cost divided by volume of water sales. Future refinement to the planning analysis can include the use of more detailed data from WWD to determine the fixed portion of operating costs (e.g., salaries) and the variable portion of operating costs (e.g., electricity use, treatment chemicals).

Exhibit 29: WMOST Minimization Results for Charles Subbasin #21034						
Management Actions	**No Streamflow Target Existing Demand 2010-2014 (0.67 MGD)**		**Level 1 Streamflow Target (1.521 cfs) Existing Demand 2010-2014 (0.67 MGD)**		**Level 2 Streamflow Target (2.386 cfs) Existing Demand 2010-2014 (0.67 MGD)**	
	Quantity	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
Surface water pumping	0.00	$0	0.83	$76,075	1.04	$229,908
Groundwater pumping		$177,322		$175,982		$172,564
Interbasin transfer	Not available	Not available	Not available	Not available	Not available	Not available
Aquifer storage and recovery	0.00	$0	0.00	$0	0.10	$58,226
Total annualized costs		$177,322		$252,057		$460,698
Total incremental annualized costs				**$74,735**		**$283,376**

Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.

As may be expected, the model implements additional practices to meet higher minimum streamflows (Level 2), which results in correspondingly greater minimization costs.

A.3.2 Additional Minimization Runs

Uncertainty in the primary minimization run includes the extent of minimization requirements and whether some of the management actions may be feasible. We performed additional minimization runs for subbasin #21034 to evaluate potential changes in management strategy when varying assumptions.

We ran the same scenarios as above, but limited the set of management actions available. When we removed surface water pumping as a possible approach in the model, WMOST increased use of aquifer storage and recovery to meet the water demand and streamflow target. Exhibit 30 summarizes these results for the Level 1 streamflow target. As shown in the table, taking out surface water pumping as management option increases the annualized costs to $178,755, as compared to annualized costs of $74,735 when this option is available (see Exhibit 29).

Taking out both surface water pumping and aquifer storage and recovery results in unfeasible solution, suggesting that the remaining measures (*i.e.*, stormwater BMPs) do not provide sufficient recharge to meet the system constraints.

Exhibit 30: WMOST Minimization Results for Charles Subbasin #21034 with Limited Set of Management Actions		
Management Actions	**Level 1 Streamflow Target (1.521 cfs) Existing Demand 2010-2014 (0.67 MGD)**	
	Quantity	**Cost**
Surface water pumping	Not available	Not available
Groundwater pumping	0.00	$161,651
Interbasin transfer	Not available	Not available
Aquifer storage and recovery	0.31	$172,909

Exhibit 30: WMOST Minimization Results for Charles Subbasin #21034 with Limited Set of Management Actions		
Management Actions	**Level 1 Streamflow Target (1.521 cfs) Existing Demand 2010-2014 (0.67 MGD)**	
	Quantity	**Cost**
Total annualized costs		$336,705
Total incremental annualized costs		**$159,383**
Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.		

A.4 Mitigation of Withdrawal Request above Baseline

For the mitigation scenarios, we evaluate additional action to offset withdrawals above WWD baseline (1.08 MGD system-wide; 0.74 MGD in the Charles subbasin and 0.38 MGD in the Taunton subbasin) to meet demand projected through 2030. For the purposes of this study, we set demand in the Charles subbasin to 0.92 MGD and demand in the Taunton subbasin to 0.61 MGD. Note that the sum of the two subbasins (1.53 MGD) is greater than the total system-wide forecast of 1.23 MGD. The expectation is WWD would manage withdrawals in the two subbasins so as to meet the individual *and* system-wide limits.

To preserve the improved flows achieved under the minimization scenario, we maintain the target flows specified for that scenario, but with adjustments for returns occurring outside the subbasins.

A.4.1 Primary Mitigation Run

The primary runs include the mitigation scenario for each of the two target subbasins, allowing all management actions to be selected. Exhibit 31 and Exhibit 32 present the results for the two subbasins.

The model selects a combination of measures to meet the demand in Subbasin #24098 while maintaining minimum streamflows. Specifically, the model uses interbasin transfer to the greatest extent possible (0.15 MGD) throughout the year and supplements this measure with surface water withdrawals for some days of the year; a fraction of the surface water withdrawals are redirected to an aquifer storage and recovery facility to maintain groundwater volumes. This combination of measures reflects the constrained resources available within the subbasin, as well as the relatively high cost and small opportunities for groundwater recharge using stormwater BMP retrofits.[37]

[37] A review of WMOST inputs indicates that broad implementation of 0.6” stormwater infiltration trenches on all existing high density residential and commercial-industrial-transportation development on “till and fine grain deposit” soils in subbasin #24098 would result in incremental recharge of 0.006 and 0.046 MGD, respectively, at annualized costs of $9,060 and $70,093. This is both more limited in terms of potential recharge and more expensive (about $1.5 million per MGD) than some of the other management actions available in the model (*e.g.*, surface water pumping, aquifer storage and recovery, interbasin transfer).

Exhibit 31: WMOST Mitigation Results for Charles Subbasin #21034 – Forecast Water Demand						
Management Actions	**No Flow Target**		**Level 1 Streamflow Target**		**Level 2 Streamflow Target**	
	Quantity	**Cost**	**Quantity**	**Cost**	**Quantity**	**Cost**
Surface water pumping	0.00	$0	1.12	$122,246	1.43	$309,323
Groundwater pumping		$244,193		$241,937		$237,808
Interbasin transfer	Not available	Not available	Not available	Not available	Not available	Not available
Aquifer storage and recovery	0.00	$0	0.00	$0	0.00	$0
Total annualized costs		$244,193		$364,183		$547,131
Total incremental annualized costs				**$119,990**		**$302,938**
Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.						

Exhibit 32: WMOST Mitigation Results for Taunton Subbasin #24098 – Forecast Water Demand				
Management Actions	**No Flow Target**		**Minimum Streamflow Target**	
	Quantity	**Cost**	**Quantity**	**Cost**
Surface water pumping	0.19	$32,563	0.96	$143,371
Groundwater pumping		$122,173		$120,007
Interbasin transfer	0.15	$97,446	0.15	$97,446
Aquifer storage and recovery	0.00	$0	0.06	$39,683
Total annualized costs		$254,513		$400,508
			Total incremental annualized costs	**$145,995**
Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.				

A.4.2 Additional Mitigation Runs

In additional runs, we evaluated the impacts of limiting the set of management actions available.

Exhibit 33 shows the results of limiting the set of options available in Subbasin #21034 to remove surface water pumping, an option otherwise consistently selected by WMOST. When we take this option off the menu, the model uses aquifer storage and recovery instead to meet the system constraints.

Exhibit 34 shows the results of two additional mitigation runs in Subbasin #24098 to evaluate the impacts of limiting the options available to concurrently meet water demand and minimum streamflows. In the first run, we did not allow for surface water withdrawals, while in the second run we did not allow the model to use water resources outside the subbasin. The model did not select stormwater BMPs as part of the solution mix in either runs; instead the model basically relied on aquifer storage and recovery to a greater extent than in the scenario where all measures are available. In fact, concurrently disabling surface water withdrawals, aquifer storage and recovery, and interbasin transfer results in an unfeasible solution, *i.e.*, the remaining management actions are not sufficient to meet both the water demand and minimum streamflows. For instance, we performed an additional model run where we set artificially low costs for stormwater BMPs (at $1/acre). While the model then selected stormwater BMPs as part of its solution, it still needed to bring in additional surface water pumping and interbasin transfer to meet the system constraints (but did not use aquifer storage and recovery).

Exhibit 33: WMOST Mitigation Results for Charles Subbasin #21034, with Limited Set of Management Actions

Management Actions	Level 1 Streamflow Target Forecast Demand 2030	
	Quantity	Cost
Surface water pumping	Not available	Not available
Groundwater pumping		$244,193
Interbasin transfer	Not available	Not available
Aquifer storage and recovery	0.56	$312,379
Total annualized costs		$556,573
Incremental annualized costs		**$312,380**

Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.

Exhibit 34: WMOST Mitigation Results for Taunton Subbasin #24098, with Limited Set of Management Actions

	Flow Target Forecast Demand 2030		Flow Target Forecast Demand 2030	
Management Actions	**Quantity**	**Quantity**	**Quantity**	**Cost**
Surface water pumping	Not available	Not available	0.84	$135,961
Groundwater pumping	0.00	$122,825	0.00	$159,221
Interbasin transfer	0.15	$97,446	Not available	Not available
Aquifer storage and recovery	0.45	$271,650	0.26	$170,959
Total annualized costs		$491,921		$466,141
Incremental annualized costs		**$237,408**		**$211,628**

Note: Costs are rounded to the nearest thousand dollars. Capacity for new infrastructure is the maximum capacity in millions of gallons per day (MGD) and not the average daily use.

Appendix B Input Data

B.1 Data Collection and Assumptions

In general, WMOST requires four categories of input data: watershed system, human water system, management costs, and effects of management practices on the watershed and/or human system. Because the quality of the input data affects the reliability and accuracy of modeling results, a significant portion of the study focused on acquiring location-specific data and translating available data and expected WMA requirements for WWD into appropriate modeling inputs and parameters.

Key data sources used for the study include:

- WWD operational data on water sources, users, pumping rates, etc.,
- WMA Tool (MassDEP 2014a), which provides data for each of the subbasins, including estimated unimpacted August median streamflow, groundwater pumping rates, wastewater discharge rates, impervious cover percentage, and area in square miles,
- "Massachusetts Water Indicators" (WMI) report and associated data (USGS 2013), which provides seasonal estimates for private well users and septic return flows,
- Massachusetts Sustainable-Yield Estimator (MA SYE) (USGS 2010), which provides estimated streamflows for ungauged stream locations based on correlations between reference stream gauges and ungauged sites and 2000-2004 water withdrawals and discharges as well as an output of water withdrawal and discharge time series,
- HSPF model of the Sudbury River (USGS 2010), which provides simulated runoff and recharge time series based on historical precipitation data in the vicinity of the target subbasins, and
- MassGIS for geospatial data on land use, surficial geology and protected land areas.

Data processing to prepare WMOST inputs ranged from simply converting units or calculating demand time series for various user types (e.g., residential, commercial, etc. based on total pumping and percent user type) to extracting data from the HSPF simulation model using standard WMOST routines. Appendix B describes the input data, their original source, and any processing, transformations, and assumptions.

B.2 Data Catalog

Input Data	Units	21034	24098	Notes
Land Use				
Number of land uses/HRUs	Numerical value	21	14	Based on delineation in Charles or Taunton HSPF watershed simulation model
Stormwater Management Sets	Numerical value	9	9	Infiltration basin, bioretention area, and dry pond at 3 depths: 0.6", 1.0", 2.0". USGS Charles or Taunton HSPF Model Output modified using SUSTAIN
Existing land use for each HRU	Acres	Varies by HRU, see model interface		Intersection of MassGIS 1999 Land use and Surficial Geology layers, crosswalked to HSPF HRU categories. For land conservation maximum areas, all land that has been conserved are removed.
Minimum area for each HRU		Same as existing		
Maximum area for each HRU		Same as existing		
Capital cost to conserve land use/HRU	$/acre	$115,000		Realtor listings for vacant land in Wrentham
O&M cost to conserve land use/HRU	$/acre/year	$1,150		1% of capital cost
Stormwater Management				
Capital cost	$/acre	Varies based on stormwater BMP type and size		Based on data in TetraTech (2010) Stormwater BMP Performance Analysis report
O&M cost	$/acre/year	5% of capital costs		Default value
Runoff and Recharge				
Recharge rates for each unmanaged HRU	in/day	See model interface for time series or summary table of average annual values in report Appendix		Based on delineation in Sudbury-Assabet HSPF watershed simulation model
Runoff rates for each unmanaged HRU				
Recharge rates for each stormwater managed HRU				HSPF watershed simulation outputs modified with SUSTAIN
Runoff rates for each stormwater managed HRU				
Water Demand				
Number of water user types	Numerical value	5 (including UAW)		Residential, commercial, industrial, municipal, UAW (WWD data)

Input Data	Units	21034	24098	Notes
Demand for each user for each day	MG/time step	See model interface for time series		-Monthly water pumping time series (2000-2004), scaled up to current (2010-2014) and DCR project 20-year demand -Percent of water use by type based on WWD data
Percent consumptive use for each water user for each month	%	Oct-Mar 4%; April 6%; May-Sept 20-29% (see model interface for specific monthly values)		Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Nonpotable water				
Maximum percent demand that can be met by nonpotable water for each user	%	Ranges from 4 to 90%, see model interface		Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Percent consumptive use for nonpotable water for each user for each month	%	Ranges from 1 to 24%, see model interface		Based on data in Amy Vickers (2002) Handbook of Water Use and Conservation
Septic				
Percent septic use for public water user draining inside the study area	%	100	100	Based on % demand by subbasin from population and assuming all septic discharge
Percent septic use for public water user draining outside the study area	%	0	0	Based on % demand by subbasin from population and assuming all septic discharge
Surface Water				
Reservoir Storage				
Initial reservoir volume	MG	0	No reservoirs	
Minimum reservoir volume	MG	0		
Current maximum reservoir volume	MG	0		
Capital construction cost	$/MG	0		
O&M costs	$/MG	0		
Streamflow				
Inflow from external surface water	cfs	0		Headwater subbasins, therefore no inflow from upstream
Minimum in-stream flow standards	cfs	See model inputs	See model inputs	Values set based on 2000-2004 flows plus needed improvements to reach various minimization targets

Input Data	Units	21034	24098	Notes
Minimum surface water discharging outside of study area	cfs	Not used	Not used	
Private withdrawals of surface water	MG/time step	SYE/MWI derived data disaggregated to daily time series, see report for details on methodology		Outputs from Massachusetts Sustainable Yield Estimator (SYE)
Private discharge of surface water	MG/time step			
Groundwater				
Groundwater recession coefficient	1/time step	0.056	0.026	Calibration value
Initial groundwater volume	MG	3,840	1,265	Back calculated based on SYE streamflow for day 1 of time series and groundwater recession coefficient
Minimum volume	MG	0	0	Default setting
Maximum volume	MG	38,400	12,650	A default value as to not limit recharge
Flow from external groundwater	cfs	0	0	Headwater subbasins, therefore no inflow from upgradient areas
Private withdrawals of groundwater	MG/time step	SYE/MWI derived data disaggregated to daily time series, see report for details on methodology		Outputs from Massachusetts Sustainable Yield Estimator (SYE)
Private discharge of groundwater	MG/time step			
Interbasin Transfer				
Purchase price for IBT potable water	$/MG	$727		Cost per gallon of Wrentham water based on WDPW's water budget and annual gallons pumped
Initial cost for new/additional IBT potable water	$/MGD	$5,787,037		Cost assumption to represent building a new well and treatment plant in a non-source subbasin or and MWRA connection
Maximum additional capacity for water and wastewater	MGD	0.15		Maximum withdrawals from Blackstone subbasin before change of category occurs
Infrastructure				
Planning horizon	years	20		Default
Interest rate	%	3%		
Water Treatment Plant				
Customer's price for potable water	$/HCF	$15		WWD 2014 rate for all user types.
Gw pumping – Capital construction cost	$/MGD	$5,787,037		Based on prior WMOST application to LWD developing additional well capacity

Input Data	Units	21034	24098	Notes
Gw pumping -O&M costs	$/MG	%727		WWD overall O&M costs for producing water in 2014
Gw pumping -Current max capacity	MGD	2.62	1.05	Maximum existing pumping capacity of wells in each subbasin
Gw pumping lifetime -remaining on existing construction	years	25		Values set higher than planning horizon to exclude replacement costs from analysis
Gw Pumping lifetime- new construction	years	35		
Sw pumping – Capital construction cost	$/MGD	$453,885		Based on previous Danvers-Middleton MA case study (EPA 2013)
Sw pumping -O&M costs	$/MG	$31,772		7% of capital cost based on LWD estimate for O&M costs as 5-10% of capital costs
Sw pumping -Current max capacity	MGD	0		No existing capacity
Sw pumping lifetime -remaining on existing construction	years	0		
Sw Pumping lifetime- new construction	years	35		Values set higher than planning horizon to exclude replacement costs from analysis
Wtp - Capital construction cost	$/MGD	$6,229,186		
Wtp -O&M costs	$/MG	$436,043		7% of capital cost based on LWD estimate for O&M costs as 5-10% of capital costs
Wtp lifetime -remaining on existing construction	years	25		Values set higher than planning horizon to exclude replacement costs from analysis
Wtp lifetime- new construction	years	35		
Wtp-Current max capacity	MGD	3.02	0.95	Maximum pumping capacity of wells in each subbasin
Capital cost of survey & repair	$	$0		Assume no initial survey and repair, only yearly replacements
O&M costs for continued leak repair	$/year	$88,7885	$88,7885	O&M is part of WMA standard conditions, therefore not included here
Maximum percent of leaks that can be fixed	%	99	99	Initial estimate for analysis
Wastewater treatment plant				
Customer's price for wastewater	$/HCF	Not applicable		
Capital construction cost	$/MGD	Not applicable		

Input Data	Units	21034	24098	Notes
Charges based on water or wastewater	water or wastewater	Not applicable		
O&M costs	$/MG	Not applicable		
Lifetime remaining on existing construction	years	0		
Lifetime of new construction	years	35		Values set higher than planning horizon to exclude replacement costs from analysis
Current maximum capacity	MGD	0		No existing capacity
Initial groundwater infiltration into WW collection system	%	0		Since newly built, no infiltration, assume sufficient O&M to maintain low levels of I/I
Water reuse facility				
Capital construction cost	$/MGD	$18,644,791		Values from Littleton study (Abt Associates, 2013)
O&M costs	$/MG	$1,305,135		
Lifetime remaining on existing construction	years	0		No existing capacity
Lifetime of new construction	years	35		Values set higher than planning horizon to exclude replacement costs from analysis
Current maximum capacity	MGD	0		No existing capacity
Nonpotable water distribution system				
Consumer cost for nonpotable water	$/HCF	$3		Values from Danvers-Middleton case study (EPA 2013)
Capital construction cost for nonpotable distribution system	$/MGD	$12,529,440		
O&M cost for nonpotable distribution system	$/MG	$1,716		
Aquifer Storage and Recovery				
Capital construction cost	$/MGD	$1,965,727		Values from Danvers-Middleton case study (EPA 2013)
O&M costs	$/MG	$538		
Lifetime remaining on existing construction	years	0		No existing capacity
Lifetime of new construction	years	25		Values set higher than planning horizon to exclude replacement costs from analysis
Current maximum capacity	MGD	0		No existing capacity
Measured flow				
Measured flow	cfs	Time series of modeled streamflows for 2000-2004		SYE flows adjusted for withdrawals and discharges with MWI data

B.3 Input Data References

DeSimone, LA, Walter, DA, Eggleston, JR, and Nimroski, MT, 2002. *Simulation of Ground-Water Flow and Evaluation of Water-Management Alternatives in the Upper Charles River Basin, Eastern Massachusetts*. Water-Resources Investigations Report 2002-4234. U.S. Geological Survey, Westborough, Massachusetts.

U.S. Environmental Protection Agency (EPA) 2010. *Stormwater Best Management Practices (BMP) Performance Analysis.* Prepared by TetraTech for United States Environmental Protection Agency – Region 1, Boston, Massachusetts. Fairfax, Virginia.

U.S. Geological Survey (USGS). 2010. Effects of Water Use and Land Use on Streamflow and Aquatic Habitat in the Sudbury and Assabet River Basins, Massachusetts, Scientific Investigations Report 2010–5042, (prepared by Phillip J. Zarriello, Gene W. Parker, David S. Armstrong, and Carl S. Carlson)

Appendix C WMOST Description

The following is an excerpt from WMOST Version 1 Theoretical Documentation and is intended to provide an introduction to WMOST. For more details, please refer to the full documentation available from the following EPA website: http://www2.epa.gov/exposure-assessment-models/wmost-10-download-page.

C.1 Objective of the Tool

The Watershed Management Optimization Support Tool (WMOST) is a public-domain software application designed to aid decision making in integrated water resources management. WMOST is intended to serve as an efficient and user-friendly tool for water resources managers and planners to screen a wide-range of strategies and management practices for cost-effectiveness and environmental sustainability in meeting watershed or jurisdiction management goals (Zoltay et al 2010).

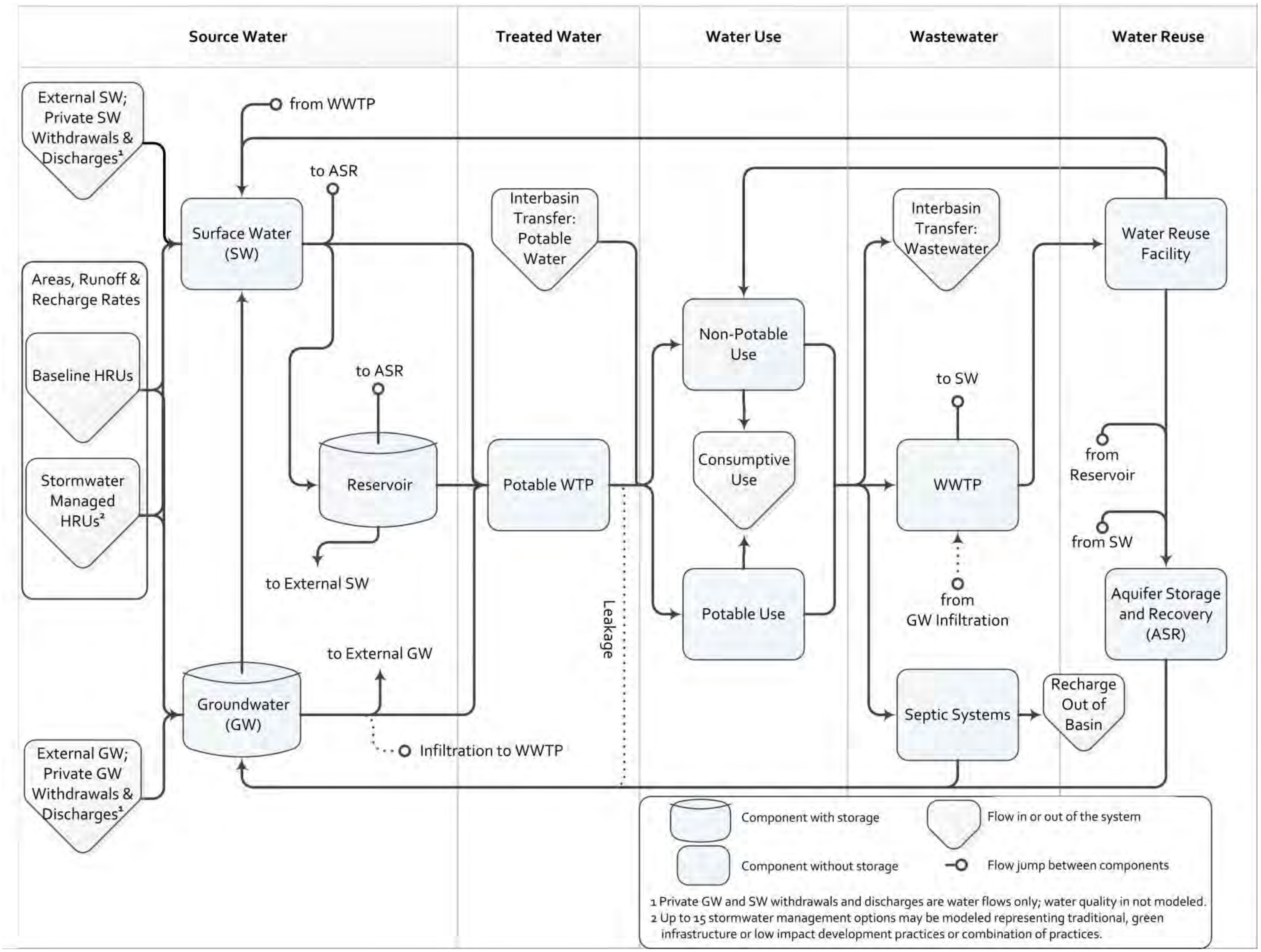
WMOST identifies the least-cost combination of management practices to meet the user specified management goals. Management goals may include meeting projected water supply demand and minimum and maximum in-streamflow targets. The tool considers a range of management practices related to water supply, wastewater, nonpotable water reuse, aquifer storage and recharge, stormwater, low-impact development (LID) and land conservation, accounting for the both the cost and performance of each practice. In addition, WMOST may be run for a range of values for management goals to perform a cost-benefit analysis and obtain a Pareto frontier or trade-off curve. For example, running the model for a range of minimum in-streamflow standards provides data to create a trade-off curve between increasing in-streamflow and total annual management cost.

WMOST is intended to be used as a screening tool as *part* of an integrated watershed management process such as that described in EPA's watershed planning handbook (EPA 2008), to identify the strategies and practices that seem most promising for more detailed evaluation. For example, results may demonstrate the potential cost-savings of coordinating or integrating the management of water supply, wastewater and stormwater. In addition, the tool may facilitate the evaluation of LID and green infrastructure as alternative or complementary management options in projects proposed for State Revolving Funds (SRF). As of October 2010, SRF Sustainability Policy calls for integrated planning in the use of SRF resources as a means of improving the sustainability of infrastructure projects and the communities they serve. In addition, Congress mandated a 20 percent set-aside of SRF funding for a "Green Project Reserve" which includes green infrastructure and land conservation measures as eligible projects in meeting water quality goals.

C.2 Overview

WMOST combines an optimization framework with water resources modeling to evaluate the effects of management decisions within a watershed context. The watershed system modeled in WMOST version 1 is shown in Figure 1. The exhibit shows the *possible* watershed system components and *potential* water flows among them.

Figure 1: Schematic representation of potential water flows in WMOST



The principal characteristics of WMOST include:

- Implementation in Microsoft Excel 2010© which is linked seamlessly with Visual Basic for Applications (VBA) and a free, linear programming (LP) optimization solver, eliminating the need for specialized software and using the familiar Excel platform for the user interface;
- User-specified inputs for characterizing the watershed, management practices, and management goals and generating a customized optimization model (see Table 1 for a list of available management practices and goals);
- Use of Lp_solve 5.5, a LP optimization solver, to determine the least-cost combination of practices that achieves the user-specified management goals;
- Spatially lumped calculations modeling one basin and one reach but with flexibility in the number of hydrologic response units (HRUs)[38], each with an individual runoff and recharge rate;
- Modeling time step of a day or month without a limit on the length of the modeling period;[39]
- Solutions that account for both the direct and indirect effects of management practices (e.g., since optimization is performed within the watershed system context, the model will account for the fact 1) that implementing water conservation will reduce water revenue, wastewater flow and wastewater revenue if wastewater revenue is calculated based on water flow or 2) that implementing infiltration-based stormwater management practices will increase aquifer recharge and baseflow for the stream reach which can help meet minimum in-streamflow requirements during low precipitation periods, maximum in-streamflow requirements during intense precipitation seasons, and water supply demand from increased groundwater supply);
- Ability to specify up to fifteen stormwater management options, including traditional, green infrastructure or LID practices;
- A sustainability constraint that forces the groundwater and reservoir volumes at the start and end of the modeling period to be equal;
- Enforcement of physical constraints, such as the conservation of mass (i.e., water), within the watershed; and
- Consideration of water flows only (i.e., no water quality modeling).

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[38] Land cover, land use, soil, slope and other land characteristics affect the fraction of precipitation that will runoff, recharge and evapotranspire. Areas with similar land characteristics that respond similarly to precipitation are termed hydrologic response units.

[39] While the number of HRUs and modeling period are not limited, solution times are significantly affected by these model specifications.

Table 1: Summary of WMOST management goals and management practices

Management Practice	Action	Model Component Affected	Impact
Land conservation	Increase area of land use type specified as 'conservable'	Land area allocation	Preserve runoff & recharge quantity & quality
Stormwater management via traditional, green infrastructure or low impact development practices	Increase area of land use type treated by specified management practice	Land area allocation	Reduce runoff, increase recharge, treatment
Surface water storage capacity	Increase maximum storage volume	Reservoir/Surface Storage	Increase storage, reduce demand from other sources
Surface water pumping capacity	Increase maximum pumping capacity	Potable water treatment plant	Reduce quantity and/or timing of demand from other sources
Groundwater pumping capacity	Increase maximum pumping capacity	Potable water treatment plant	Reduce quantity and/or timing of demand from other sources
Change in quantity of surface versus groundwater pumping	Change in pumping time series for surface and groundwater sources	Potable water treatment plant	Change the timing of withdrawal impact on water source(s)
Potable water treatment capacity	Increase maximum treatment capacity	Potable water treatment plant	Treatment to standards, meet potable human demand
Leak repair in potable distribution system	Decrease % of leaks	Potable water treatment plant	Reduce demand for water quantity
Wastewater treatment capacity	Increase MGD	Wastewater treatment plant	Maintain water quality of receiving water (or improve if sewer overflow events)
Infiltration repair in wastewater collection system	Decrease % of leaks	Wastewater treatment plant	Reduce demand for wastewater treatment capacity
Water reuse facility (advanced treatment) capacity	Increase MGD	Water reuse facility	Produce water for nonpotable demand, ASR, and/or improve water quality of receiving water
Nonpotable distribution system	Increase MGD	Nonpotable water use	Reduce demand for potable water
Aquifer storage and recovery facility capacity	Increase MGD	Aquifer storage and recovery facility	Increase recharge, treatment, and/or supply
Demand management by price increase	Increase price by specified %	Potable and nonpotable water and wastewater	Reduce demand
Direct demand management	Percent decrease in MGD	Potable and nonpotable water and wastewater	Reduce demand
Interbasin transfer – potable water import capacity	Increase or decrease MGD	Interbasin transfer – potable water import	Increase potable water supply or reduce reliance on out of basin sources
Interbasin transfer – wastewater export capacity	Increase or decrease MGD	Interbasin transfer – wastewater export	Reduce need for wastewater treatment plant capacity or reduce reliance on out of basin services

Table 1: Summary of WMOST management goals and management practices

Management Practice	Action	Model Component Affected	Impact
Minimum human water demand	Specifies the water demand that must be met (MGD)	Groundwater and surface water pumping and/or interbasin transfer	Meet human water needs
Minimum streamflow	Specifies the minimum flow conditions that must be met (ft^3/sec)	Surface water	Meet in-streamflow standards, improve ecosystem health and services, improve recreational opportunities
Maximum streamflow	Specifies the maximum flow conditions that must be met (ft^3/sec)	Surface water	Meet in-streamflow standards, improve ecosystem health and services by reducing scouring, channel and habitat degradation, and decrease loss of public and private assets due to flooding