IPSWICH BASIN WATER MANAGEMENT ACT
PLANNING GRANT FY18 – BWR2018-01
DRAFT REPORT
MASSDEP SUBMITTAL

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TOWN OF DANVERS
TOWN OF MIDDLETON
TOWN OF HAMILTON
LYNNFIELD CENTER WATER DISTRICT
TOWN OF TOPSFIELD
TOWN OF WENHAM

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A Report Prepared for:

The Town of Danvers, MA

In partnership with:

Town of Middleton, MA
Town of Hamilton, MA
Lynnfield Center Water District
Town of Topsfield, MA
Town of Wenham, MA
Massachusetts Water Works Association

IPSWICH BASIN WATER MANAGEMENT ACT
PLANNING GRANT FY18
DRAFT REPORT

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0 EXECUTIVE SUMMARY

IPSWICH BASIN WATER MANAGEMENT ACT PLANNING GRANT FY18 – BWR2018-01

The Ipswich River Basin includes all or part of 22 different communities in northeastern Massachusetts. The watershed has a population of approximately 160,000 people and supplies municipal water to approximately 350,000 people (EOEA, 2003). The Basin has been studied for decades, as perennial low flow conditions in the summer challenge the reliability of small supply systems, primarily groundwater sources that rely on winter and spring replenishment. An estimated 75% of Basin water withdrawals are exported, either as wastewater flow, or for potable water use, outside of the Basin, and so return flows are minimal. Over the next 20 years, the Basin population is estimated to increase by about 5% and climate trends are likely to reduce summer flows even further, both of which are likely to place additional pressures on local water supplies.

Following a pronounced drought in 2016, six community public water suppliers in the Ipswich River Basin (Danvers, Middleton, Hamilton, Topsfield, and Wenham, and the Lynnfield Center Water District) conceived of this project in partnership and in collaboration with the Massachusetts Water Works Association (MWWA). Most of these Grant Partner communities are some of the smallest communities in the Basin with fewer resources, and fewer water supply options. Most are close to or projected to exceed "baseline" withdrawal limits (as defined in 310 CMR 36) and some have already been actively working on exploring other water supply options, including the purchase of water from the Massachusetts Water Resources Authority (MWRA).

The Grant Partners sought to improve understanding of the current and future water supply constraints and challenges facing the Basin's municipal public water suppliers—particularly those who maintain groundwater sources—and, to identify potential regional solutions that could allow for improvement of resiliency and environmentally sustainable growth. The first phase of the project was completed in June 2017, with Kleinfelder providing technical and engineering consulting support. This second phase of the project, as presented in this report, builds upon the results of the first phase to further explore options for both in-Basin water management and potential water importation into the Basin. Both phases have been 80% funded under a Water Management Act grant provided by MassDEP; with 20% of the work funded by Grant Partner cash and in-kind contributions.

While the first phase characterized conditions, and established a framework for understanding future supply stressors, this second phase aimed to address several overarching questions:

1) Is there enough water within the Basin to satisfy water supply needs, even if it is not always at the right place at the right time?
2) How do current water withdrawal regulations[1] affect water availability?
3) How does the uncertainty from prior studies on groundwater-surface water dynamics affect the long-range viability of the Basin as a self-sufficient source of supply?
4) How can future conditions such as increased demand and climate change affect water availability throughout the Basin?
5) Do interlocal / regional solutions exist in concept that could help alleviate the risk of local supply shortfalls?
6) As an alternative to within-Basin supply, how (and where) could MWRA water be imported in a cost-effective way that balances the resources and environmental needs within the Basin with the reliability and cost of MWRA water?

Building on the scientific data sets available from the United States Geological Survey (USGS) Hydrological Simulation Program Fortran (HSPF) model that has been used since the early 2000s to characterize various forms of yield throughout the Basin (Zarriello and Ries, 2000), Kleinfelder developed the Ipswich Integrated Operations Model (IIOM) to rapidly test hydrogeologic uncertainties from earlier studies, identify specific areas of vulnerability in the Basin, and screen operational alternatives to address these vulnerabilities. The IIOM coupled the natural hydrologic output of the HSPF model with current demand trends, climate patterns, and operational opportunities basin wide. improved

The results presented in this report do not necessarily constitute recommendations for infrastructure investment or inter-municipal agreements, but rather, help support ongoing deliberations with additional information on the potential opportunities within the Basin and beyond its borders to enhance the long-term reliability of its water supply. The key findings can be summarized as follows:

- On average, the Basin can currently provide approximately 98% of the combined demand of its communities from sources within the Basin itself. Generally, the Basin contains enough water to satisfy all authorized needs under current demand conditions, although the water is not

[1] *This study examines water withdrawal (Water Management Act) regulations. Other regulations (i.e. local zoning and land use regulations, groundwater discharge permits, beaver leg trapping ban, interbasin transfers, land conservation) may also influence availability of water, but they were beyond the scope of this study.*

always “in the right place at the right time”. Communities reliant on groundwater sources are less resilient than those with access to surface water reservoirs.

- Overall, the Basin is not very sensitive to uncertainty regarding the connectivity between surface water and ground water. While lag time between groundwater withdrawals and the corresponding depletion of streamflow, as well as the amount of actual streamflow depletion may affect local resources, they have little impact on the overall reliability of the Basin supply.
- During droughts of equal to or greater severity than those experienced in the early 1980s and again in 2002 (the two droughts within the available data modeled time frame), the Basin’s efficacy as a self-sufficient supply is strained.
- Climate models predict drier summers and more frequent and severe droughts, and Basin population growth estimates average 7%, with some communities twice as high. Climate change and growth are both expected to significantly diminish Basin supply reliability in the future, with modeled decreases in reliability ranging from 1% to 9%.
- Of the various management alternatives evaluated, the following conclusions were drawn:
    - Demand reduction in the past 10 years has already improved individual system reliability but on its own will not solve the problem long term. A year-round demand reduction of 10% (likely infeasible for many communities) results in only a 1 - 2% improvement in supply reliability over current conditions, both Basin-wide and individually. This finding was similar to that of the USGS (Zimmerman et.al, 2010). Incremental benefits of additionally stringent conservation or increasing restrictions on groundwater withdrawals are likely to be overwhelmed by growth pressures and/or climatic effects. Requiring water suppliers to chase these ‘diminishing returns’ may be increasingly costly and restrictive of economic growth.
    - Additional storage may provide some local or regional buffers against supply shortfalls, but the potential for water shortfalls is greatest in communities without storage, which again points to the issue of the water not being available locally during droughts.
    - There is additional physically available water in the Basin for some communities in their respective subwatersheds, and hence, a regional potential for water sharing within the Basin. This study looked at some conceptual opportunities for two or more communities to form regional partnerships in which total authorized withdrawals for participants could be pooled. In such a partnership, water could be distributed from where it is available to where it is needed without exceeding currently authorized aggregate withdrawal amounts. Such arrangements would require regulatory consent, and potentially additional infrastructure and incentives to promote cooperation. Despite the long-standing tradition of home rule decision making and localized water infrastructure in the

basin, these may become viable alternatives to the importation of water from outside the Basin

- MWRA water is a reliable alternative for communities whose supplies are vulnerable during dry or even normal conditions. Alternative routes for delivery of MWRA water were evaluated for three of the Grant Partners. The cost of MWRA water and associated the infrastructure, as well as the long-term reliability, should be compared to the costs and efficacy of in-Basin water sharing. The flow in the Ipswich River can serve as a reliable trigger for identifying when MWRA water should be brought in, without waiting too long during dry periods (and increasing the risk of shortfalls) or engaging the connection too early when dry conditions appear imminent (and not taking advantage of the local supplies to the extent possible).

1 BACKGROUND

1.1 INTRODUCTION AND PURPOSE

During 2017, six community public water suppliers in the Ipswich River Basin (the Basin): the Towns of Danvers, Middleton (supplied by Danvers), Hamilton, Topsfield, and Wenham, and the Lynnfield Center Water District conceived of this project in partnership and in collaboration with the Massachusetts Water Works Association (MWWA). These Grant Partner communities have a number of specific challenges. Most of them are some of the smallest communities in the Basin with fewer resources, and fewer water supply sources and therefore reduced operational flexibility. Most are close to or projected to exceed “baseline” withdrawal limits (as defined in 310 CMR 36) and some have already been actively working on mitigation activities. Many are struggling to fund costly water treatment solutions while managing the administrative and operational requirements of their Water Management Act (WMA) permit conditions.

The Grant Partners sought to improve understanding of the current and future water supply constraints and challenges facing the Basin’s municipal public water suppliers—particularly those who maintain groundwater sources—and, to identify potential regional solutions that could allow for improvement of resiliency and environmentally sustainable growth. The first phase of the project was completed in June 2017, with Kleinfelder providing technical and engineering consulting support. This second phase of the project builds upon the results of the first phase to further explore options for both in-Basin water management and potential water importation into the Basin. Both phases have been 80% funded under a Water Management Act grant provided by MassDEP; with 20% of the work funded by Grant Partner cash and in-kind contributions. The Phase 1 2017 findings and scope of the 2018 Phase 2 project are described below.

1.2 BACKGROUND & PROJECT SCOPE

1.2.1 2017 Study and Summary of Findings

The Ipswich River Basin includes all or part of 22 different communities in northeastern Massachusetts. The watershed has a population of approximately 160,000 people and supplies municipal water to approximately 350,000 people (EOEA, 2003). An estimated 75% of Basin water withdrawals are exported, either as wastewater flow, or for potable water use, outside of the Basin. Over the next 20 years, the Basin population is estimated to increase by about 5%. As the region's population continues to experience growth, increased water supply demands are likely. Phase 1 of the project sought to use existing information to answer the following questions:

- What are the constraints governing the hydrology of the Ipswich Basin?
- How are the Basin water resources being used?
- What opportunities are there to better manage water in the Basin?
- Is there enough water for future municipal public water supply needs?
- What are the Basin water supplier needs and challenges, particularly for Grant Partner communities?
- What are some solutions to improve resiliency for groundwater suppliers in the Basin?

The 2017 analysis conducted a literature review, compiled available water usage data from MassDEP Annual Statistical Reports (ASRs) for the municipal permitted and registered water suppliers, and conducted a survey of municipal water supply practices to assess what demand management and alternative source management options were feasible and being utilized by the municipal suppliers. Key findings of the 2017 study are summarized below. For detailed results the reader is referred to the full report: https://www.danversma.gov/ipswich-basin-water-management-act-planning-grant-final-report/ .

1.2.1.1 Basin Characteristics and Water Usage Practices

Since the 1960s, the water resources of the Ipswich Basin have been discussed and studied. With its low-lying topography, high groundwater table, and humid climate, almost half of Basin annual precipitation is lost to evapotranspiration before it can recharge the groundwater and replenish stream baseflow. USGS modeling showed that simulated flows (even without domestic water withdrawals) indicate the River is naturally characterized by summer low flows (Zarriello and Ries, 2000). Recent studies have emphasized the powerful influence of evapotranspiration and wetlands on the Basin's hydrology (e.g. Claessens et al., 2006; Schwalbaum, 2006, Zarriello and Ries, 2000). Claessens et.al. found that land use change had a negligible effect on evapotranspiration; attributing the increase entirely to climate changes and noting this was specific to the Ipswich study area and atypical of urbanization trends. As climate change is predicted to lead to more frequent and prolonged droughts (NECIA, 2006), the effect of underlying natural processes on streamflow is only expected to increase.

The Basin's limited sand and gravel aquifers are situated primarily within river and stream valleys and so since the early 1900s, the primary locations for municipal groundwater wells have naturally been historically sited close to streams and rivers. In the last 10 years the use of some of the wells thought to be causing the most impact has ceased, yet low flows in the Ipswich River are still observed during dry periods. Lack of available suitable aquifers in undeveloped areas away from headwater streams has led to very limited success by municipal suppliers in identifying new groundwater sources. As a result, use of surface water and purchase of water from outside of the Basin has been increasing as the use of groundwater sources has decreased.

Whereas groundwater made up half of total municipal water supply in 1960, current municipal groundwater withdrawals from the Basin have dropped to below 1960 volumes, and surface water represents over 75% of the total water withdrawn from the Basin. While overall Basin withdrawals more than doubled from 1960 to the late 1980s, and population has continued to increase, total current municipal withdrawals have remained steady at late 1980s rates. This appears to indicate that in general the municipal Basin water suppliers have made significant gains in demand reduction.

1.2.1.2 Demand Management

Water supply demand management best practices appear to be widely used amongst Basin groundwater suppliers. The eight municipal groundwater-supplied communities responding to the 2017 survey reported that almost all feasible enhanced conservation and demand management practices were in use. The 2017 demand management survey responses are provided in Appendix A. Communities are doing well meeting the residential water use standard of 65 residential gallons per capita per day (RGPCD), with 12 of 14 Basin communities consistently meeting the standard (average over the 2011-2017 period). In 2016 the basin-wide average was 56.8 RGPCD, while the statewide average was 58.1 RGPCD; in 2017 the basin-wide average was 54.5 RGPCD, consistent the statewide average of 54.4 RGPCD. Compliance with the ‘unaccounted-for water’ (UAW) standard of 10 percent remains a challenge for water systems across the state, especially those with older systems. In the Ipswich Basin, 5 of 14 communities are consistently meeting the standard when evaluating their average over the 2011-2017 time period. While compliance with the UAW standard varies among the communities and even varies year to year, the basin-wide average in 2016 was consistent with the statewide average (14.5 for the Basin and 14.1 statewide).

A 2010 United States Geological Survey (USGS) study (Zimmerman et. al, 2010) scaled up water saving results from Ipswich Basin pilot programs that used four different water conservation techniques including:

- Installation of “smart” irrigation controllers on municipal athletic fields sprinkler systems
- Application of moisture-retaining soil amendments at municipal athletic fields
- Installation of large (800-gallon) rainwater harvesting systems for irrigation

- Implementing municipal residential incentives (free indoor water use audits, water reducing kits, and rebates for low flow toilets and washing machines.

The study found that hypothetical water use reductions ranged from 1.4 to 8.5% but that reductions in this range (less than 10%) had negligible effects on simulated low flows in the Basin. The physical / hydrologic dynamics of the Basin and recent modeling studies suggest that as the climate warms, incremental benefits of additionally stringent conservation or increasing restrictions on groundwater withdrawals could be overwhelmed by climatic effects (Claessens, et.al, 2006; Zimmerman et.al., 2010). Requiring water suppliers to chase these 'diminishing returns' may be increasingly costly and restrictive of economic growth.

1.2.1.3 Water Management Act Permit Constraints

All permitted groundwater suppliers in the Basin are subject to stringent permit restrictions that were intended to reduce summer seasonal impacts on surface water resources in order to improve aquatic habitat for freshwater fish that depend on streamflow. These restrictions have been the subject of debate in part because they were developed using a reference river with much higher flow than the Ipswich, and to be protective of species which include stocked fish species that may not be native to the Ipswich (Armstrong et. al, 2001) . Almost all groundwater suppliers responding to the 2017 survey reported significant operational and administrative challenges in attempting to comply with permit restrictions. In terms of optimizing supplies with more advanced alternative strategies to minimize environmental impact, most groundwater suppliers responding indicated that most strategies were infeasible to implement, primarily due to physical (hydrologic) constraints. The exceptions were suppliers who also had access to surface supply storage for moderating the use of wells during summer.

1.2.1.4 Wastewater and Stormwater Management

Other ways to improve Basin recharge and stream low flows through stormwater retrofit projects and low impact development have been explored and studied in the past decade. A 2010 USGS study (Zimmerman et. al, 2010) concluded that while potentially beneficial in certain localized situations, and likely beneficial to water quality, on a Basin-wide scale low impact development and stormwater retrofit efforts will be volumetrically insignificant for improving stream low-flows. Due to the large volume of wastewater export from the Basin, the capture and return of wastewater to the Basin would represent the best way to truly balance the hydrologic budget in the long term. However, due to the infrastructure already in place, cost to create a new system, and potential detriment to surface and groundwater quality, this solution is likely infeasible for the foreseeable future.

1.2.1.5 2017 Conclusions: Future Needs and Potential Solutions

The 2017 study concluded that given that current municipal use (representing over 95% of total withdrawals) is about 21.7 MGD, and the established MassDEP Basin Safe Yield is 29.4 MGD, usage would have to increase by over one-third to exceed the safe yield level. With population projections estimating on the order of 5% growth through the next twenty-five years, it appears that as a whole, the Basin can supply foreseeable domestic water demands as well as accommodate modest growth. Due to hydrogeologic and land use limitations alone, however, significant expansion of groundwater supplies in the Basin will not be a solution for the future. Therefore, responsible expansion of regional supplies and of surface water options should be explored and permitted. On the other hand, if regulators decide to adopt even more stringent protections with the goal of achieving the river flows as recommended by the Ipswich River Fisheries Restoration Task Group, studies have indicated that reservoirs would fail to fill to capacity to meet demands for public water supply (Zarriello, 2002).

The 2017 study recommended examining the feasibility of increased use of surface water and potential in-Basin water-sharing strategies. The other option recommended for further evaluation was the importation of water from out of the Basin or expanded use of the Massachusetts Water Resources Authority (MWRA) Water System supply.

1.2.2 Current (FY18) Project Scope

The current FY18 project scope builds from the prior study with the intent of meeting the following primary objectives:

- Further understand and define the vulnerabilities within the Basin
- Develop a Basin-wide integrated operational model to evaluate conceptual benefits, impacts, and feasibility of management strategies.
- Quantitatively evaluate in-Basin and out of Basin (MWRA import) water supply alternatives

The Notice to Proceed with the project was issued by MassDEP on February 20, 2018. The project scope includes the following tasks:

Task 1 – Stakeholder Engagement: Two workshop meetings with Grant Partners to discuss goals, approach, and project findings. Other Basin municipal water suppliers were also invited to participate.

Task 2 – Integrated Basin Operations Model: A new systems model created using existing hydrologic models (USGS Ipswich model) with capability to rapidly test water use alternatives impact and benefit.

Task 3 – Regional Credit / Trading Approach: Development of a conceptual framework to allow trading or selling of water or permit credits.

Task 4 – Evaluation of MWRA Importation Strategy: Using the Operations Model (Task 2), evaluate conditions under which importation of MWRA would be advisable for Grant Partners.

Task 5 – Evaluate MWRA Transmission Route(s): Compare potential alternative transmission routes to extend MWRA water to Grant Partner communities expressing interest. Both direct transmission and wheeling will be evaluated in relation to feasibility, permitting, and construction cost.

Task 6 – Reports: Prepare Draft and Final reports for review by Grant Partners and MassDEP.

1.2.3 Ipswich Basin Integrated Operations Model Purpose and Approach

We have used an approach in this project that reflects a national trend in integrated planning. Cities and towns across the United States have increasingly relied on simple tools to dynamically illustrate how possible decisions would likely affect each water sector, in the Ipswich Basin's case; the focus was primarily on drinking water (groundwater and surface water) and the residual instream flows for aquatic habitat. One such tool is a systems or operations model which can help decision makers understand how water management decisions in one sub-basin can influence those in others, so that the value or risk of given alternatives can be understood and weighed against each other using equivalent metrics. For this study, the following key questions were posed:

- Is there enough water in the Basin for human needs (i.e. without WMA permit constraints), for current and future conditions?
- Is there enough water for human needs when fully constrained (for current and future conditions)?
- How does availability change in response to in-Basin alternatives?
- When does importing water from MWRA make sense?

For the Ipswich Basin, a detailed hydrologic model, the USGS's Hydrological Simulation Program-FORTRAN (HSPF) Ipswich Basin precipitation-runoff model already exists and has been well documented (Zarriello and Ries, 2000). The approach for this study, was to integrate the existing

USGS HSPF model, along with updated withdrawal and operations data, into a new systems modeling platform. The goal was a model that, once developed, would easily allow for modifying changes in demand or supply scenarios, and rapidly screen operational alternatives for local and regional water management while tracking the impacts of simulated decisions throughout the Basin. Ideally the model would relatively quickly allow for evaluation of the effect of changes in water sharing, storage, regulatory constraints, as well as natural water availability.

Kleinfelder developed the Ipswich Integrated Operations Model (IIOM) using a software package called STELLA® (Stella Architect, Isee Systems). STELLA® is a dynamic systems simulation tool used commonly used around the world for studying the behavior of interconnected systems and the decisions that affect them. Using STELLA® as a tool allows the dynamic exploration of model results and identification of key variables affecting the behavior of the system.

Several recent examples of the use of STELLA® include:

- South Florida Water Management District: A STELLA® model was developed to integrate existing output from hydrologic, groundwater, and water quality models into a network flow model for water and phosphorus moving though canals and constructed wetlands before entering Lake Okeechobee. This tool was credited for identifying the most promising configuration of alternatives for natural phosphorus removal, and its recommendations were used to fund the construction of treatment wetlands.

- City of Franklin, TN: A STELLA® model was developed as the basis of an Integrated Resource Plan (IRP) to study tradeoffs and combinations of alternatives for water supply, wastewater management, stormwater, and reclaimed water. The tool helped build understanding and consensus and led to funding of the recommended alternatives.

- Oklahoma City, Oklahoma Water Resources Board, and the Choctaw and Chicasaw Tribal Nations: A STELLA® model was developed and adopted as the basis of alternatives evaluation during federal mediation of a dispute over water in the Kiamichi River Basin. The model allowed all parties to examine alternative operating rules for the production of water supply and the preservation of lake levels and instream flow for aquatic habitat. The agreement was finalized in 2016 and signed into law by President Obama.

- Medway, MA: A STELLA® model was developed to assist with an Integrated Water Resources Management Plan to help identify a combination of management measures with meaningful benefits across the water, wastewater, and stormwater spectrum.

The process of integrating the USGS HSPF model flows into the IIOM is described in detail in Section 2.

1.2.4 Water Management Act - Water Suppliers in the Ipswich Basin

This study focuses on the regulated water suppliers in the Basin for which water usage data is available and which represent the largest source of water use in the Basin (over 90%). Limited data available for other sources of water use in the Basin (private residential wells, unregulated private commercial wells) was reviewed and is discussed in Section 2.3.3. A separate grant-funded study of unregulated withdrawals is currently underway, and data were not yet available for incorporation into our study. These suppliers, their authorized withdrawal amounts, and registered and/or permit pumping restrictions summarized in Table 1-1 below. Section 2.3 provides a detailed description of the development of the water demand values used in the Ipswich model.

Table 1-1: Ipswich Basin regulated Water Suppliers, Authorized Ipswich Source Withdrawal Volumes

	Number and Type of Sources	Registered Days of Operation	Ipswich Sources Authorized Withdrawal Volumes (MGD as ADD)			Surface Withdrawal Pumping Restrictions		Groundwater Withdrawal Restrictions	
			Registered*	Permitted	Total	Time of Year	Gauge	Gauge-based	Seasonal Cap
Municipal Suppliers									
Danvers**	2 GW, 1 SW	365	3.14	0.58	3.72	None	SW limited to 3.51 MGD Firm yield	Daily Pumping > 44.5 cfs; Alternate Day: 18.7-44.5 cfs; Shutoff <18.7 cfs @ S. Middleton	May 1-Sept.30, 587.52 MG
Hamilton	7 GW	365	0.92	0.11	1.03			None	May 1-Sept.30, 107.1 MG
Ipswich	3 GW	365	0.2		0.2				
Lynn	1 SW	365	2.62		2.62	Dec.1-May31	10 MGD		
Lynnfield Center Water District	2 GW	365	0.29	0	0.29			None	May 1-Sept.30, 114.75 MG
North Reading	4 GW	365	0.96		0.96				
Peabody	2 GW, 3 SW	365	3.89		3.89	Dec.1-May31	10 MGD		
Reading	9 GW	365	2.57		2.57				
Salem-Beverly Water Supply Board	4 SW	365	10.17	2.27	12.44	Dec.1-May31	28 MGD		
Topsfield	2 GW	365	0.43	0.17	0.6			None	May 1-Sept.30, 84.15 MG
Wilmington	5 GW	365	2.91		2.91				
Wenham	2 GW	365	0.29	0.1	0.39			None	May 1-Sept 30, 61.2 MG
subtotal Municipal suppliers			**28.39**	**3.23**	**31.62**				
Registered Private									
Bostik	1 SW	365	0.79		0.79				
Corliss	1 SW	147	0.22		0.22				
Meadow Brook GC	1 GW	90	0.16		0.16				
Myopia	1 SW	100	0.17		0.17				
Sagamore Spgs GC	2 SW	122	0.12		0.12				
Sheraton Ferncroft	1 SW	153	0.12		0.12				
Thomson Club	1 GW, 1 SW	210	0.15		0.15				
subtotal registered Private			**1.73**		**1.73**				
TOTALS			**30.12**	**3.23**	**33.35**				

Notes:

* Based on an annual average; may be exceeded as long as the annual average daily volume is not exceeded by more than 0.1MGD

** Includes Middleton

Not applicable (grey shading)

2 INTEGRATED OPERATIONS MODEL DEVELOPMENT

2.1 MODEL DEVELOPMENT OVERVIEW

The Ipswich Basin Integrated Operations Model (IIOM) was developed using systems model software and existing hydrologic data and flow relationships generated by the USGS Ipswich River Basin HSPF model. IIOM employs a representation of the river and tributary network, simplified representation of reservoirs, and a representative influence factor of groundwater withdrawals on surface water flows. Current domestic water usage (2009 – 2016) was superimposed over historic hydrology to create a probabilistic platform for evaluating current and future conditions. The result is a visual platform for rapid operational screening of conditions and alternatives. Model development and validation is described in greater detail in the following sections:

- Section 2.2 describes the use of the USGS HSPF model for obtaining flow data for use in the integrated operations model.
- Section 2.3 describes the water withdrawal data used for input into the IIOM.
- Section 2.4 provides a detailed description of the development of the IIOM in STELLA®
- Section 2.5 describes the validation of the IIOM using Ipswich River flow gauge data.

2.2 USGS HSPF MODEL AND FLOW DATA

2.2.1 Model Overview and Available Data

The purpose of the Ipswich Integrated Operations Model was to provide a platform for rapid screening of operational and condition variables without recreating well-established hydrologic patterns in the basin. While a detailed rainfall-runoff model exists to simulate precipitation, shallow and deep infiltration, evapotranspiration, runoff, and baseflow (USGS HSPF model as cited), it does not facilitate rapid experimentation to determine the sensitivity of water availability to operational, regulatory, climate, or infrastructure changes. A simple platform was developed to use the hydrologic data already available from the HSPF model in a platform which could quickly address the driving questions about what constrains water availability in the basin (geography, hydrology, infrastructure, climate, and/or regulations), and what management alternatives might offer reasonable potential to offset some of the specific vulnerabilities.

The IIOM was developed using existing streamflow data from the USGS HSPF model as the primary input. The HSPF model and its components are described in detail in the Zarriello and Ries, 2000 USGS report. Since the time of the 2000 report, the USGS has updated the HSPF model and the period of climatological record to shift the emphasis from safe yield of supplies to climate vulnerability for the basin (USGS, personal communication 2018). When studying safe yield and water availability in the earlier version, the model used climate input data from 1961-1995. As the HSPF evolved to examine climate trends and vulnerability, the period of record was adjusted to include more recent data, and potentially to correspond to climate change models and datasets. The current HSPF model, which was adapted for use in this study as the source of unimpacted streamflow data, uses historic climate data from 1975-2005. The current HSPF model available from USGS no longer contains data from 1961-1974.

While the most recent model no longer includes the 1960s presumed drought of record, the 1975-2005 period includes the two significant droughts of the early 1980s and of 2002, which are useful and more recent indicators of water supply vulnerability. While the 1960s drought is often considered the drought of record for large systems because it lasted for four years and gradually depleted large storage reserves, the cumulative rainfall deficits in the 1980s and 2002 were in some places more sudden and pronounced than the gradual trend of the 1960s, rendering the later droughts as more severe to some smaller systems based on their short-term impacts. For this reason, it is important to evaluate and plan for droughts based on system-specific response rather than regional climate indicators (Westphal, *et al*, 2007)

The basis for the input data into the IIOM is unimpacted natural hydrologic streamflow in each reach of the river. The USGS HSPF model has already been configured to simulate natural hydrology using historical climate inputs, with no impacts of withdrawal. These results were re-created and extracted from the HSPF model and used as the primary input to the IIOM. All other input data for the IIOM was developed through other sources by Kleinfelder as described in Sections 2.3 and 2.4.

The HSPF model is described in detail in the report cited above as well as other derivative reports by the USGS. Fundamentally, it divides the basin into sub-watersheds and reaches, and computes infiltration, evapotranspiration, base flow, and runoff for each basin, combining the results into streamflow in the associated river/tributary reach. The hydrologic responses vary based on land use distribution and soil type. The Ipswich Basin USGS model is divided into 67 discrete sub-watersheds and associated reaches as shown in Plate 1 – Ipswich Basin Hydrology and Regulated Withdrawals. Kleinfelder's IIOM uses the same set of reaches to divide the Ipswich River Basin.

The most current version of the HSPF model uses meteorological data provided to the USGS by the Marine Biological Laboratory in Woods Hole, MA in the form of hourly time steps from January 1, 1975 through December 31, 2005. The meteorological data set was developed using 30 National Weather Service (NWS) stations in the vicinity of the Ipswich River Basin. Mean annual precipitation was determined to vary by less than 8% across the Basin, other meteorological variables showed even less spatial variation. Due to the large sampling errors associated with precipitation data and the relatively low spatial variations of each variable, basin-wide averages were considered adequate for the HSPF model inputs (Zarriello and Ries, 2000). The model converts climate inputs into hourly streamflow estimates in each reach for the 30-year period of record.

HSPF model files were provided to Kleinfelder by USGS staff from the Northborough, Massachusetts office. Kleinfelder ran the model with historic climate data and extracted the available hourly cumulative streamflow time series generated by the model for each reach over the 30-year time period of January 1, 1975 through January 1, 2005. Streamflow data extracted from the USGS files in the hourly time-step format was then averaged over each 24-hour day in order to obtain an average streamflow value for each day within the time series for input into the IIOM. This was done for the following reasons:

- Reduced file size significantly expedites rapid screening of local vulnerabilities and operational alternatives.
- A daily time step is appropriate for operational simulation, as reservoirs respond on a scale of days and weeks more dynamically than on a scale of hours.
- Daily data are sufficient to compare with USGS streamflow records without creating impressions that the simplified model is accurate hour-to-hour over thirty years. Most results from the IIOM are aggregated into summary statistics and daily time series in order to answer the questions in this study regarding availability of water, areas of vulnerability, and operational opportunities.

2.2.2 Headwater Flows

Streamflow time series for the headwater reaches (those reaches which have no upstream reach draining into them) in the absence of water withdrawals, were extracted directly from the HSPF Model. After computing daily averages, these time series were then entered directly into the STELLA model as the headwater flows. Validation of the cumulative reconstruction of streamflow is discussed in Section 2.5.

2.2.3 Incremental Natural Inflows & Outflows

As described above, cumulative streamflow data for the USGS scenario with no water withdrawals was extracted from the HSPF model as an hourly time series for each reach over the available data period of January 1, 1975 through January 1. 2005. As reported from the HSPF output files, flow in each downstream reach is cumulative. However, since the IIOM applies variables that can affect downstream flow throughout the network (withdrawals and other operations), simply inputting the cumulative natural downstream flow would have negated any potential to study operational impacts. Therefore, incremental flows were computed for each reach by subtracting each immediate upstream cumulative flow value (or values). In this way, the natural hydrologic contribution from the sub-watershed associated with each reach were preserved and added into the IIOM as natural incremental flows for each reach. This allows natural flows, the impact of withdrawals, and the impact of storage operations to propagate downstream and affect streamflow and water availability throughout the basin in aggregate. These calculations were automated, and Kleinfelder performed a direct mathematic check of the data series by hand calculating a portion of the results and matching them against computer generated outputs. Section 2.5 describes the comprehensive validation process for recreating natural flows throughout the river network, and their accumulation moving upstream to downstream.

Examination of this data set revealed that some reaches had occasional negative incremental flow values. This was interpreted as representing conditions in which water is lost from a reach, most likely caused by evapotranspiration from exposed water surfaces exceeding the incremental runoff draining directly to the particular reach. Kleinfelder performed an analysis of the reaches within which the negative values were most prevalent and determined that the areas with the most frequent occurrences of negative flows were reaches with complex hydrology such as large wetlands and reservoir systems. It is assumed that under varying precipitation and weather conditions, water can be either gained or lost within these reaches of the basin. Within the IIOM, each reach contains two time series for streamflow data: one time series containing all the positive values (inflows), and one series containing all the negative values (outflows). Natural inflows are added to the flow network, and natural losses are simply subtracted from it. Loss instances are very localized – most reaches only include positive inflows. Additional discussion of the influence of wetlands in the model is provided in Section 2.4.4.

The streamflow values reported from the HSPF model include the influences of both surface runoff and groundwater flow into the stream. Groundwater was not modeled explicitly in the IIOM as the groundwater contributions to river flow are already embedded in HSPF streamflow outputs used as input to the IIOM. Instead, following the structure of the HSPF model, within the IIOM groundwater withdrawals are satisfied with the water available in the stream channel from the reach in which they are made. The influence of groundwater withdrawals on streamflow was then simplified as a streamflow depletion percentage with a user-adjustable lag time. It was not the goal of the IIOM to predict or refine estimates of streamflow depletion factors based on groundwater withdrawals or the potential lag times but rather, to understand how sensitive water availability is to assumptions made about these phenomena. Accordingly, user variables were employed to vary the amount of streamflow depletion associated with each groundwater withdrawal, and to assign a lag time between the withdrawal and depletion of streamflow. Discussion of the sensitivity of these variables is included in Section 3.2.

Once a complete daily time series of the inflows and outflows from each reach were input into the integrated model, Kleinfelder checked the output of the integrated model against the output of the HSPF model in order to verify that flows were being accurately simulated by the integrated model. This validation process is presented in Section 2.5.

2.2.4 Synthesis of HSPF Flows Missing from Downstream Reaches

The Ipswich River Basin HSPF model file provided by the USGS did not contain any simulated streamflow data for the area downstream of the Ipswich USGS streamflow gauge at the Willowdale Dam (Reaches 57-67). Zarriello and Ries, 2000 does not comment on the omission of streamflow data for this portion of the basin. It is assumed that output data was not generated for these reaches because they are generally dominated by wetlands and there is no USGS streamflow gauge downstream of these reaches to which simulated flows can be calibrated. Although no streamflow output was available for these reaches, the model did contain the total land area and land uses within each of these downstream reaches. Kleinfelder used the available land use data to estimate streamflow for the missing reaches using the process described below.

For the eleven reaches for which streamflow data was not available, Kleinfelder examined the land use distribution and compared it to that of upstream reaches for which the HSPF model did generate streamflow data. In order to simplify this comparison, the 20 specific land use types defined in the HSPF model were aggregated into six general land use types: open/forest, low density residential, high density residential/commercial, water, wetland, and impervious. A graphic chart showing the percent of the total land area assigned to each of the six land use categories was then developed for each reach. A visual inspection was then performed in order to identify an upstream reach with similar land use distribution to the reaches which did not have output data. An example of the graphics used in this comparison is shown below in Figure 2-1.

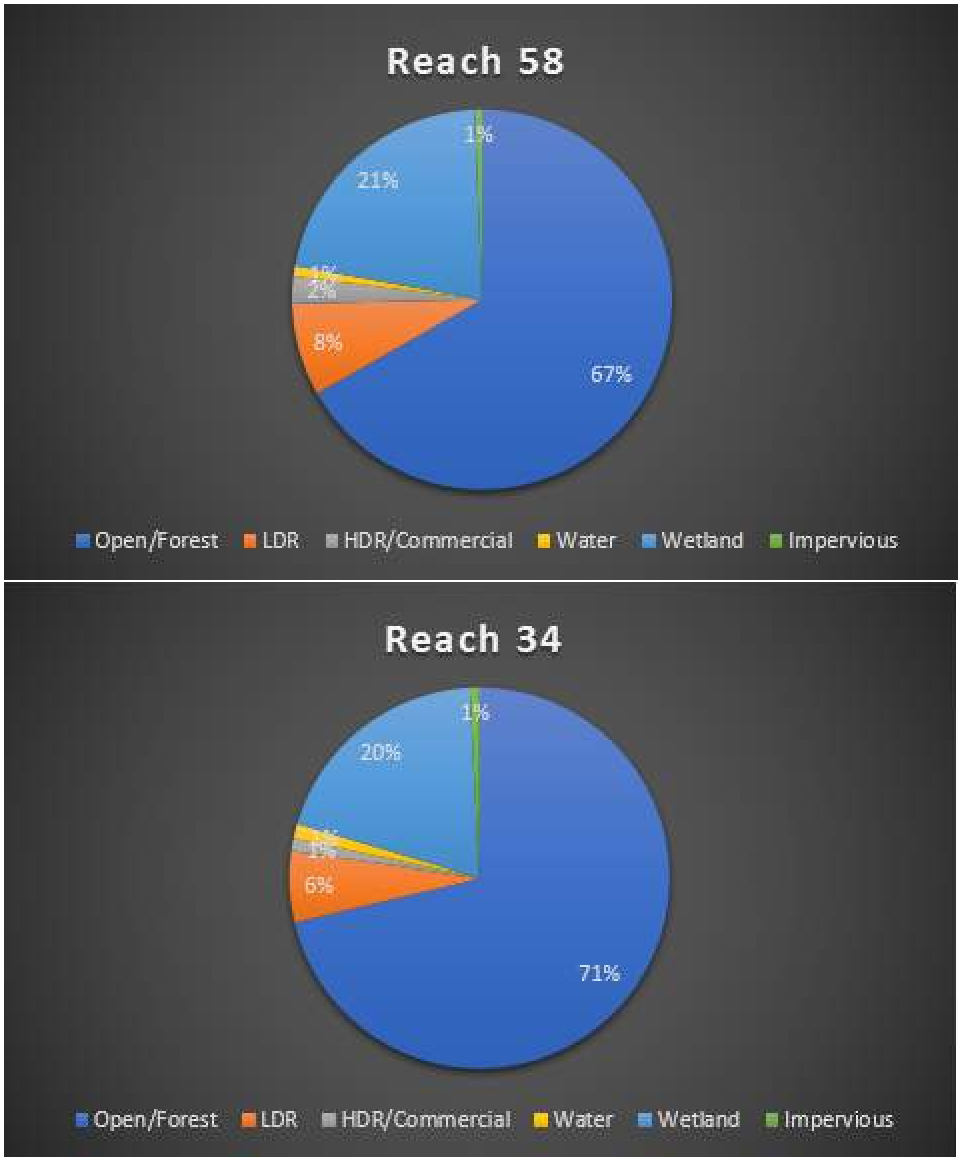

Figure 2-1: Land Use Comparison for Reaches 58 (no flows) and 34 (flows available)

Once an upstream reach with similar land use distribution was identified, a ratio of the total drainage area contributing to the two reaches was developed. The total drainage area ratio of the reaches was then applied to the HSPF streamflow output for the upstream reach in order to develop a streamflow estimate for the downstream reach based on the relative size of the two reaches. This process was completed for each of the 11 downstream reaches for which HSPF streamflow data was not available. While there are no field measurements or other data with which to validate this approach, it represents a simple, standard practice for planning-level hydrologic evaluations when streamflow data are not available.

2.3 WATER DEMAND DATA

Water demand was entered into the model as a 30-year daily time series, which was developed for each modeled public water supplier (PWS) and reach within the IIOM from water use data available from MassDEP. The process of developing the demand time series for various types of users and withdrawal types is described in detail in the following sections.

2.3.1 Municipal Public Water Supplies (Permitted and/or Registered)

Water use data for the years 2009-2016 was available through the MassDEP's eASR database. Pumping records are available by Source ID, a unique code assigned to each withdrawal point by MassDEP. Using the reach boundaries shown on Plate 1 and available MassGIS data layers, Kleinfelder developed a list of all the withdrawal points located within each reach which was then used to segregate the available demand data by reach and PWS using the unique Source ID codes.

Once withdrawal data was grouped by PWS and reach number it was used to generate a daily demand time series for input into the IIOM. Using the available monthly e-ASR data Kleinfelder calculated the total monthly withdrawal from each reach by each PWS for a given year. For example, Wilmington had two active groundwater wells in Reach 13 over the 2009-2016 period of record, these two sources were combined to obtain a total withdrawal volume from Reach 13 for Wilmington for each month in the record. Once total volumes were obtained, monthly totals were averaged to generate a representative year of average monthly current demand. In some cases, data obtained for surface water suppliers required the removal of sources of double counting that occur due to transfers between reservoirs. Specific details on the modeling approach for each reservoir system are provided in Section 2.4.

The end result was a data set containing the 2009-2016 average monthly withdrawal from each reach by each PWS. These values were then divided by the number of days in the month in order to generate an average daily demand (ADD) volume for the same period. This data set was then repeated to generate a 30-year demand time series which was entered into the IIOM. Data was validated by comparing the ADD of each PWS to their actual reported ADD over the 2009-2016. Due to the way data was averaged and consolidated an exact match was not obtained in all cases, however all are considered to be within the range acceptable for use in a model of this nature. Data used for validation is presented in Table 2-1 below.

Table 2-1: Historic Municipal Water Use Data and Integrated Operations Model Inputs

	2009-2016 Average Actual Use[1] (MGD as ADD)	Model Input (MGD as ADD)
Municipal Suppliers		
Danvers[2]	3.24	3.26
Hamilton	0.55	0.56
Ipswich	0.25	0.23
Lynn	1.42	2.61
Lynnfield Center Water District	0.37	0.37
North Reading	0.52	0.53
Peabody	3.22	2.97
Reading	*Reading no longer using Ipswich sources*	0
Salem-Beverly Water Supply Board	9.20	9.21
Topsfield	0.4	0.4
Wilmington	1.89	1.81
Wenham	0.34	0.33
TOTALS	**21.40**	**22.28**

Notes:

1- From MassDEP e-ASR database, raw withdrawal as average daily demand, unless otherwise noted

2- The Danvers water system also supplies the Town of Middleton.

As shown above, the IIOM inputs for both Peabody and Lynn differ significantly from their reported 2009-2016 ADD. Operational data from Lynn's reservoir system was not available. Therefore, the IIOM conservatively estimates that Lynn withdraws its total authorized volume each year. For Peabody, the model input shown was developed from reservoir withdrawal data and the volume removed from the reservoirs for treatment and distribution. The 2009-2016 actual use volume is calculated using Peabody's withdrawals directly from the Ipswich River. It is presumed that some of this discrepancy can be attributed to evapotranspiration that occurs while water is stored in the reservoirs system prior to use. Additional details on the modeling approach and data inputs for each reservoir system are provided in Section 2.4.4.

2.3.2 Private Registered Users

In addition to the municipal suppliers, the IIOM also includes withdrawals made by other registered non-municipal users. These users include golf courses, industrial facilities, and other uses in excess of 100,000 GPD which require a registration with the MassDEP. Using available MassGIS data layers and the reach boundaries shown on Plate 1, Kleinfelder developed a list of registered non-municipal users within each reach. Water use data for such users is not available in MassDEP's eASR database. Kleinfelder obtained hardcopy water usage data for each private registered user from MassDEP and used this data to develop water use time series in the same manner as was done for the municipal users as described above in Section 2.3.1, converting multiple years of monthly data into an average monthly data set and then into a daily time series. In some cases the full record of interest (2009-2016) was not available for each registered private user and in some cases data outside of the record of interest was available. Kleinfelder used best available data to generate the monthly average dataset for each user. Historic data and the IIOM inputs are shown in Table 2-2.

Table 2-2: Historic Registered Private Water Use and Integrated Operations Model Inputs

	2009-2016 Average Actual Use[1] (MGD as ADD)	Model Input (MGD as ADD)
Registered Private		
Bostik, Inc	0.0013	0.0013
Corliss Brothers	0.0183	0.0184
Meadow Brook GC	0.0314	0.0271
Myopia Hunt Club	0.0819	0.0825
Sagamore Springs GC	0.0355	0.0357
Sheraton Ferncroft CC	0.0352	0.0355
Thomson CC	0.0613	0.0617
TOTALS	**0.26**	**0.26**

Notes:

1- From data provided by MassDEP, raw withdrawal as average daily demand, unless otherwise noted

2.3.3 Private Unregulated Withdrawals

A separate grant-funded study of unregulated withdrawals is currently underway by MassDEP and Comprehensive Environmental Inc, howeverdata were not yet available for incorporation into our study. We reviewed the limited data currently available to estimate demand from private unregulated withdrawals.

The IIOM includes an estimate of withdrawals from private residential wells. To develop an estimate for this volume Kleinfelder reviewed available MassGIS data layers for private groundwater wells and the Ipswich River Watershed Association (IRWA) 2016 memorandum "Analysis of Private Well Water Usage in the Ipswich River Watershed". Preliminary review of these two data sources suggested that the MassGIS data layer containing private wells was largely incomplete.

The available data set was used to determine the spatial distribution of private groundwater wells with the assumption that the number of wells was underestimated, but that the relative distribution of wells was sufficiently representative to determine the reaches that contained the highest concentration of private wells. Kleinfelder then used the average household size within the Ipswich Basin (2.63 people, US Census) and an estimated 65 residential gallons per capita per day (RGPCD) to determine the total estimated water use from private domestic wells in each reach. Using this method resulted in a much lower estimate of residential well use (0.2 MGD) compared with IRWA's estimate (1.2 MGD). IRWA also estimated an additional 1.2 MGD is used by other non-regulated sources (e.g. commercial and agricultural). Data was not readily available at the time of this report to verify this estimate. Future analysis will consider updated information as it becomes available.

Kleinfelder used tools within the IIOM to increase the estimated demand from private unregulated wells up to a conservative estimate of 5 MGD to model the impact on future scenarios. This process and its application in the various alternative scenarios is described in more detail in Section 3.

2.4 IPSWICH BASIN INTEGRATED OPERATIONS MODEL STRUCTURE AND LOGIC

2.4.1 Model Resolution and Primary Components

The Integrated Operations Model of the Ipswich Basin was developed using STELLA software, distributed by ISEE Systems. STELLA stands for "Systems Thinking, Experimental Learning Laboratory with Animation," and is a dynamic, visual platform for simulating complex and interconnected systems over time. It has been used across the United States (including New England) for water resource planning, river basin analysis, integrated planning, and urban planning. The goal of the software is to integrate data from other sources with sufficient resolution to characterize planning-level dynamics and risks, and to track the impacts of management decisions throughout the interconnected systems. In this way, it is frequently used to screen systems for specific (localized) vulnerabilities and to test dozens or hundreds of ways of tuning operations to mitigate risks or address specific weaknesses.

Mathematically, STELLA functions much like a spreadsheet in that the user is provided with a blank workspace in which to draw a system and define its data and functionality from scratch. The only pre-built equation in the model is the continuity equation for storage elements, whereby a change in storage is automatically computed as the difference between inflows and outflows in each time step.

STELLA as used in the IIOM, includes four building blocks, which are commonly used in environmental, urban, and economic systems:

- Flows: Vector elements direct flow of any defined variable (water, people, money) from one point to another within the system
- Stocks: Storage elements (reservoirs, bank accounts, etc.) accumulate inflows and are depleted by defined outflows.
- Converters: Originally named for their utility in converting units, these can best be described as either cells or entire columns in a spreadsheet. They may contain information in one of four forms:
    - Raw data
    - Mathematical equation using numbers or other model variables
    - Logical expressions (min/max, if-then-else, etc.)
    - Time series of data (analogous to a column in a spreadsheet).
- Connectors: vector elements that link the previous three elements together.

These four basic elements are used to visually represent a system, connect elements together either to represent physical connections or to enable a logical dependency, and track variables as they move/flow through the system or systems. Examples of the visual nature of STELLA and these elements are included in subsequent sections below. Note that the single line (usually red) arrows do not represent flow, but rather, mathematical or logical dependency. Flow in a STELLA model is represented by double-line arrows. Stocks are represented as rectangles with flows entering and leaving, and converters are small circles that can be used anywhere to inject or modify information in the model.

STELLA also contains a user interface which allows the user to adjust variables within the model to test alternative rules, conditions, or assumptions clearly and rapidly.

2.4.2 Natural Flow through River Network

Natural river flows, in the absence of water withdrawals, were developed from the USGS HSPF model as described above in Sections 2.2.2 through 2.2.4. Incremental flows were input into the model with converters, which were then linked to the appropriate flow vectors. The resulting flow for each reach is equal to the water flowing in from the previous reach plus any natural inflow, minus any natural outflow, and minus any withdrawals (or impact of nearby groundwater withdrawals). An example of the natural streamflow construct without any water withdrawals is shown in Figure 2-2.

The two left most reaches shown are classified as headwater reaches as they do not have reaches preceding them in the flow network. Inflows and outflows generated from the USGS HSPF model are shown throughout STELLA as green flow vectors. The resulting streamflow vectors are shown in blue. The streamflow construct shown in Figure 2-2 was completed for each of the 67 reaches in the basin which were then linked together to create the integrated operations model of the Ipswich River Basin.

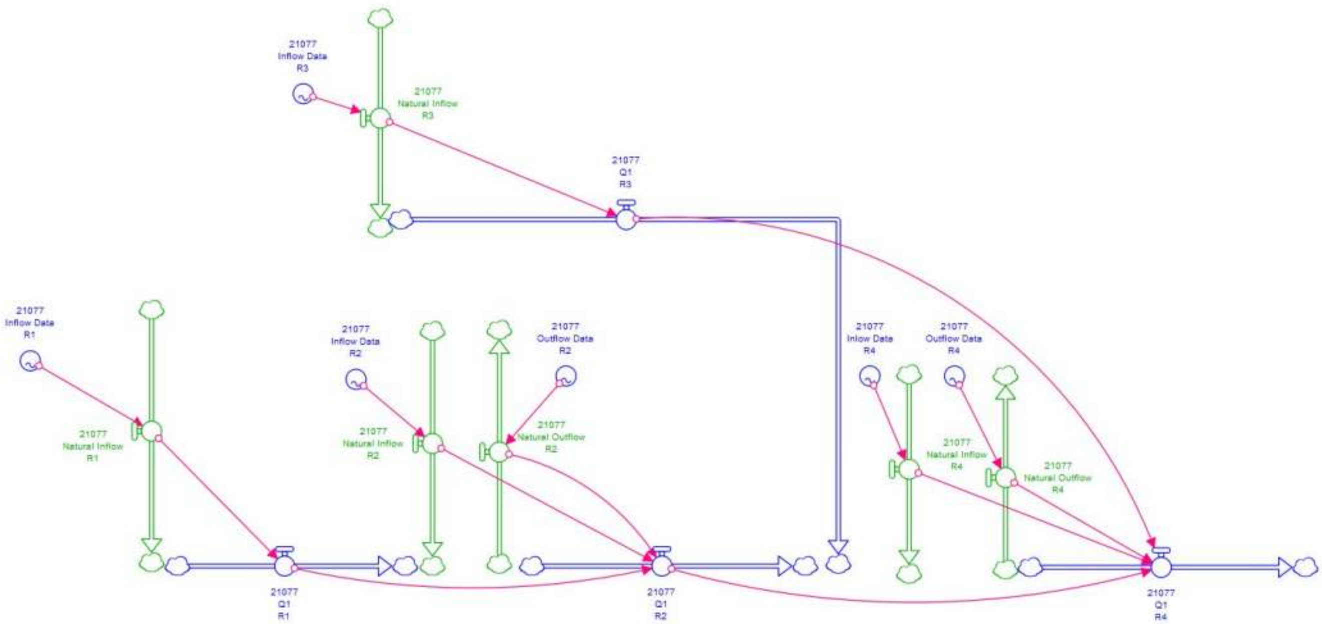

Figure 2-2: Example STELLA Natural Streamflow Construct

2.4.3 Groundwater Withdrawal Simulation and Logic

The next step in developing the IIOM was to input all the groundwater withdrawal data for both public and private users basin-wide. Private users include registered users such as golf courses and industrial facilities as well as domestic wells. Available withdrawal data from 2009-2016 were used to create a 30-year withdrawal data series as described in Section 2.3, which was then input into the IIOM via converters. These converters are denoted in the model as groundwater demand (GWD) converters. GWD converters are then linked to flow vectors which represent the depleting impact of groundwater withdrawals (GWW) on streamflow. Logic is input into the GWW vectors which instructs them to remove the minimum value of the GWD converter or the amount of water available in the reach. This logic prevents the wells from withdrawing more water than is available in the stream channel at any given time (and tracking of this is summarized in the supply reliability statistics used in the subsequent basin evaluations). An example of the streamflow construct with groundwater withdrawals in shown in Figure 2-3. GWW vectors are shown throughout the model as orange flow vectors.

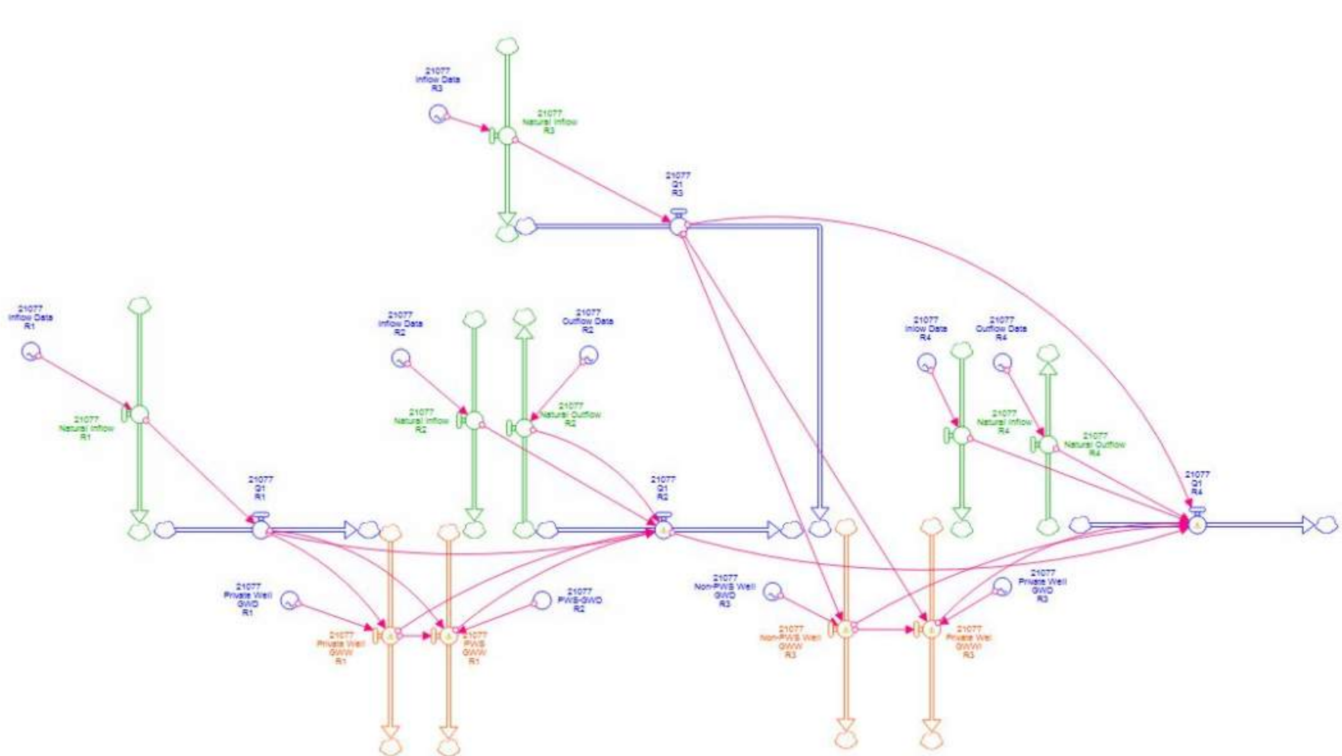

Figure 2-3: Example STELLA Streamflow Construct with Groundwater Withdrawals

Regulatory restrictions on groundwater users are implicit in the IIOM because demand patterns are based on post-2009 operations, confined by all current regulatory constraints. For this reason, it would have been redundant to build in the restrictions explicitly. Rather than building groundwater user's permit limits into the IIOM, Kleinfelder developed counters to evaluate the historic average ADD of each PWS. For each alternative scenario that is run, an output of each user's ADD is generated which can then be compared to current permit limits. Counters developed for use in the IIOM are described in detail in Section 2.4.5. This approach can be easily modified in the future to simulate other potential withdrawal scenarios and their limitations, with logic similar to that employed for the surface water users in the basin, as described in the following sections.

2.4.4 Surface Water Withdrawals and Reservoir Systems

There are two types of surface water withdrawals within the IIOM, surface water withdrawals made directly from the Ipswich River (to fill reservoirs) and surface water withdrawals from reservoirs (for consumption). These two types of surface water withdrawals are handled differently in terms of the governing logic within the IIOM. The logic of each reservoir system, and the associated surface water withdrawals are described in the following sections.

2.4.4.1 Middleton Pond & Emerson Brook Reservoir

Middleton Pond and Emerson Brook Reservoir are two surface water supplies operated by the Danvers Water Department. Emerson Brook Reservoir has a usable storage volume of approximately 176 MG. Middleton Pond is the terminal storage location of the system and has a usable storage volume of approximately 705 MG. Water is transferred to Middleton Pond from both Emerson Brook Reservoir and Swan Pond as needed to supply water to Danvers' water treatment plant which is located at the eastern end of Middleton Pond. A review of historical pumping records and Danvers' "Water Supply Operations Plan" (SEA Consultants Inc., 2002) shows that water transfers from Swan Pond to Middleton Pond occur infrequently and in relatively small volumes. Additionally, since the HSPF model does not define a reach which drains into Swan Pond there is currently no data on hydrologic inflows into Swan Pond. For these reasons Swan Pond is not considered an influential piece of Danvers' water supply system and is not included in the IIOM (a conservative simplification). Evaluations of Danvers' reservoir system presented in Section 3.4 also suggest that the available storage in Swan Pond has little impact on Danvers' ability to meet demand. The layout of Danvers' reservoir system within STELLA is shown in Figure 2-4.

Unlike other reservoir systems in the Ipswich Basin, Danvers' reservoir system is not supplied by surface water withdrawals directly from the Ipswich River. Instead, Emerson Brook Reservoir is supplied by the runoff associated with Emerson Brook (Reach 30) and Middleton Pond is supplied by the runoff associated with Reach 26 as well as operational transfers from Emerson Brook Reservoir. Any water that flows into either reservoir in excess of the max storage volume is lost over the spill way and routed downstream.

As shown in Figure 2-4, there are a number of factors that govern operational transfers from Emerson Brook Reservoir to Middleton Pond. In general, the goal of operation of Emerson Brook Reservoir is to pump water to Middleton Pond anytime there is storage space available (SEA Consultants, Inc., 2002). Therefore, in the IIOM, transfers from Emerson Brook Reservoir to Middleton Pond are initiated anytime that Middleton Pond drops below full storage capacity and water is available in Emerson Brook Reservoir. In the IIOM, the specific volume transferred is dependent on the current volume in Emerson Brook Reservoir, the given month, and the capacity of the two transfer pumps as outlined in Table 2-3.

The primary pump (PP) has a maximum capacity of 5.6 MGD and the jockey pump (JP) has a maximum capacity of 1.3 MGD.

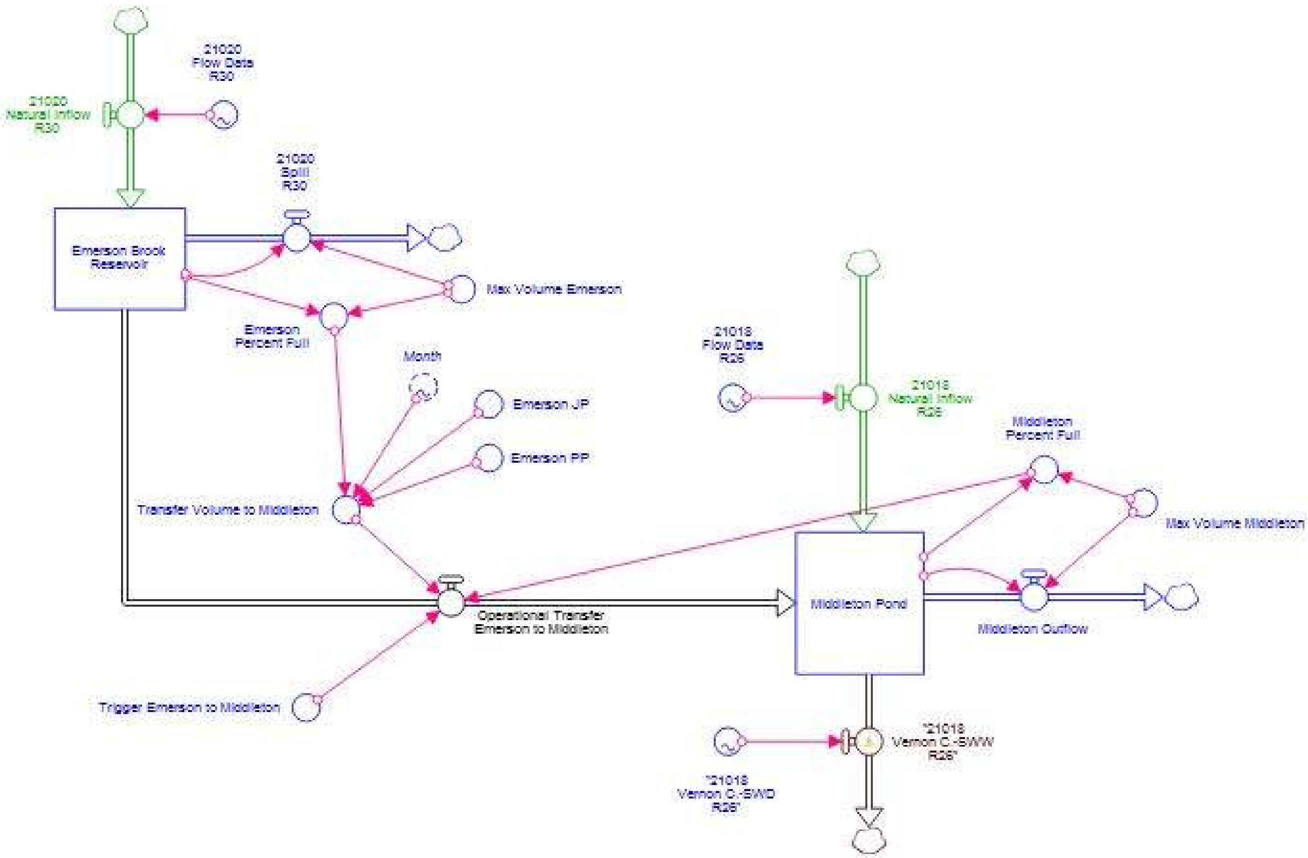

Figure 2-4: Danvers Reservoir System IIOM Construct

Table 2-3: Danvers Surface Water Transfer Logic (SEA Consultants, Inc. 2002)

<table>
<tr><td></td><td colspan="4">Emerson Brook Reservoir Level</td></tr>
<tr><td></td><td>0-12 inches below spillway</td><td>12-24 inches below spillway</td><td>24-27 inches below spillway</td><td>> 27 inches below spillway</td></tr>
<tr><td>January</td><td>PP</td><td colspan="2">JP</td><td>OFF</td></tr>
<tr><td>February</td><td>PP</td><td colspan="2">JP</td><td>OFF</td></tr>
<tr><td>March</td><td>PP</td><td colspan="2">JP</td><td>OFF</td></tr>
<tr><td>April</td><td>PP</td><td colspan="2">JP</td><td>OFF</td></tr>
<tr><td>May</td><td>PP</td><td colspan="2">JP</td><td>OFF</td></tr>
<tr><td>June</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
<tr><td>July</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
<tr><td>August</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
<tr><td>September</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
<tr><td>October</td><td colspan="3">JP</td><td>OFF</td></tr>
<tr><td>November</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
<tr><td>December</td><td colspan="2">PP</td><td>JP</td><td>OFF</td></tr>
</table>

Withdrawals made from Middleton Pond for treatment and distribution are governed in the IIOM by the data series developed for the Vernon Russell Water Treatment Plant using 2009-2016 withdrawal data as described in Section 2.3.1.

2.4.4.2 Lynn Reservoir System

The Lynn Water & Sewer Commission operates a complex reservoir system that consists of four separate impoundments, Walden Pond, Breeds Pond, Birch Pond, and Hawkes Pond. Water is withdrawn directly from the main stem of the Ipswich River to supply the reservoir system. Lynn also has the ability to supply their reservoir system from the Saugus River which is located in the North Coastal Basin. For this effort, however, details on the reservoir operating rules and local runoff were not available. The system is located entirely outside the Ipswich River Basin, which means that local runoff into reservoirs was not available via the HSPF model. Estimating local reservoir runoff would be possible with historic records of reservoir elevation and withdrawals, but these data were not available for this study, partly due to the short time frame and partly due to ongoing discussions between Lynn and MassDEP regarding operation of this system. Lastly, the system also draws water from the Saugus River, and without details on historical withdrawals or operating rules, it is not possible to recreate a credible representation of the Lynn System. Therefore, Lynn's reservoir system is not depicted in the model. Instead, their withdrawals from the Ipswich River are conservatively estimated using logic defined by their authorized withdrawal volume and streamflow restrictions. The layout of Lynn's surface water withdrawal within the STELLA model is shown below in Figure 2-5.

As shown below, there are a number of factors that control Lynn's withdrawal of water from the Ipswich River in the IIOM. Lynn currently holds a registration that limits them to an average daily withdrawal of 2.62 MGD. However, Lynn is only allowed to withdraw water from the Ipswich River between the months of December through May. This means that for half of the year their average daily withdrawal is 0 MGD, effectively allowing them to double their withdrawal volume to 5.24 MGD between the months of December and May and remain within their authorized volume. These conditions are applied in the IIOM via the converters shown above.

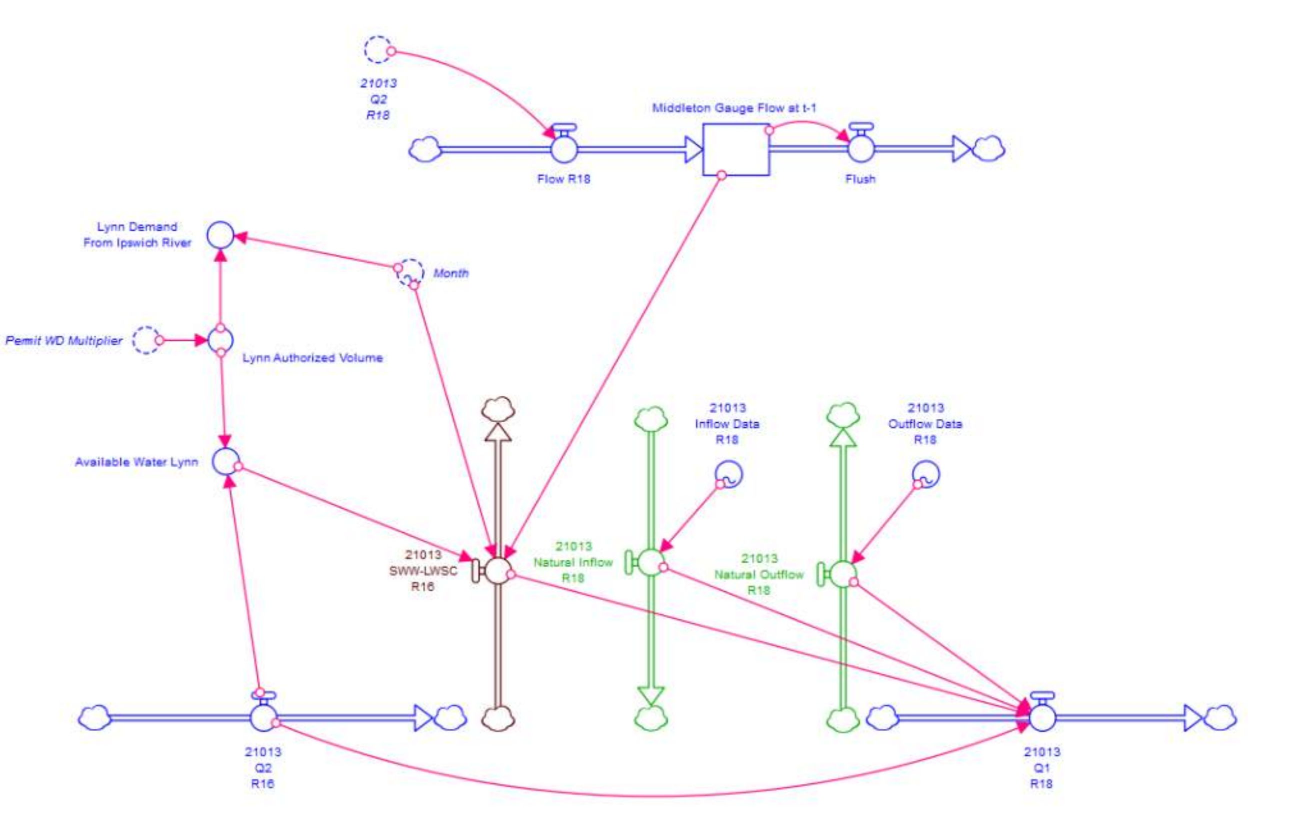

Figure 2-5: Lynn Surface Water Withdrawal IIOM Construct

In addition to being limited by their authorized withdrawal volume, Lynn is also limited by the streamflow at the South Middleton gauge, and is only allowed to make withdrawals from the Ipswich River if the flow at the Middleton gauge is greater than 10 MGD. The model checks this requirement each simulated day (as an approximation) by referring to the streamflow at the very end of the previous day.

Using the converters and logic described above, the IIOM will conservatively allow Lynn's surface water withdrawal (shown in brown) to remove the total allowable volume of 5.24 MGD any time that flow at the South Middleton gauge is in excess of 10 MGD between the months of December and May. If the flow is below 10 MGD, or the current month is June through November, the model will not allow Lynn to withdraw any water from the Ipswich River. This is a highly conservative approach given that available data suggests that Lynn withdrew less than half of their total authorized volume over the 2009-2016 period.

2.4.4.3 Peabody Reservoir System

Peabody maintains two surface water impoundments within the Ipswich Basin, Winona Pond and Suntaug Lake. Water is withdrawn directly from the main stem of the Ipswich River into Suntaug Lake. The two reservoirs are linked by a short channel that allows water from Suntaug Lake to be gravity fed into Winona Pond. This transfer ensures that Winona Pond is maintained at the maximum level as long as there is sufficient water is available in Suntaug Lake. The two reservoirs have a total combine usable storage volume of 940 MG. Since the two reservoirs are so closely connected they are combined into one reservoir in the IIOM for simplicity. Water can also be transferred from Suntaug Lake to a small reservoir system in the North Coastal Basin that is operated by Peabody. This transfer is summed with the water withdrawn from Winona Pond for treatment to get a total surface water withdrawal volume from Peabody's Ipswich Basin reservoir system. This withdrawal time series is the mechanism through which Peabody's storage is depleted within the IIOM. It is shown in brown in the layout of Peabody's reservoir system presented below in Figure 2-6 .

Similar to Lynn, Peabody is only allowed to withdraw water from the Ipswich River between the months of December and May when streamflow at the South Middleton gauge is above a defined threshold. Since Peabody's withdrawal location is located downstream of the South Middleton gauge they are not authorized to withdraw any volume that would reduce the South Middleton gauge below 10 MGD. For example, if flow at the South Middleton gauge is 12 MGD, then Peabody would be allowed to withdraw water into its reservoir system only at a rate of 2 MGD for that day. Peabody must also remain within their authorized average daily withdrawal volume of 3.89 MGD.

The operational rules for Peabody's reservoir system within the IIOM are almost identical to those defined for the Lynn system described in the previous section. Since Peabody's withdrawals are limited to half of the year, the model will allow them to withdraw as much as twice their authorized daily average (7.78 MGD) any time that the South Middleton gauge is above the required threshold of 10

MGD, provided that the withdrawal doesn't result in a depletion of flow below this threshold (as described above). Withdrawals into Peabody's reservoir system are only initiated when a sufficient amount of storage is available in the system.

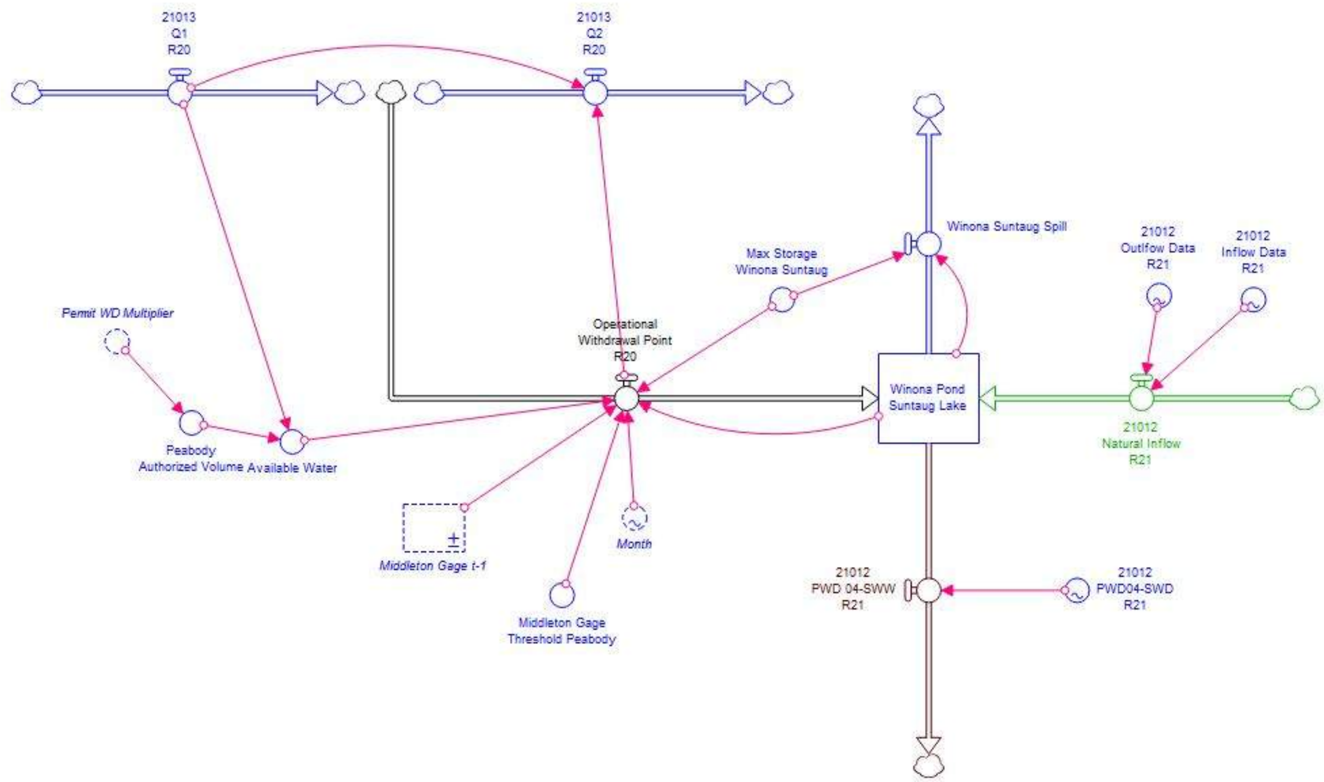

Figure 2-6: Peabody Reservoir System IIOM Construct

2.4.4.4 Salem-Beverly Water Supply Board Reservoir System

The Salem-Beverly Water Supply Board (SBWSB) operates reservoir system that consists of three impoundments in the Ipswich Basin. This system is made up of Wenham Lake (1,200 MG usable storage), Longham Reservoir (55 MG usable storage), and Putnamville Reservoir (2,300 MG usable storage). SBWSB operates a canal which withdraws water directly from the Ipswich River and transfers it into Putnamville Reservoir or Wenham Lake. Wenham Lake can also receive transfers from Longham Reservoir. Wenham Lake is the system's terminal supply. A treatment plant is located at the southern end of the reservoir. In the IIOM, withdrawals from the reservoir system are made from this location based on a time series developed using 2009-2016 withdrawal date from the treatment plant Source ID as described in Section 2.3.1. The layout of the SBWSB reservoir system is shown in Figure 2-7.

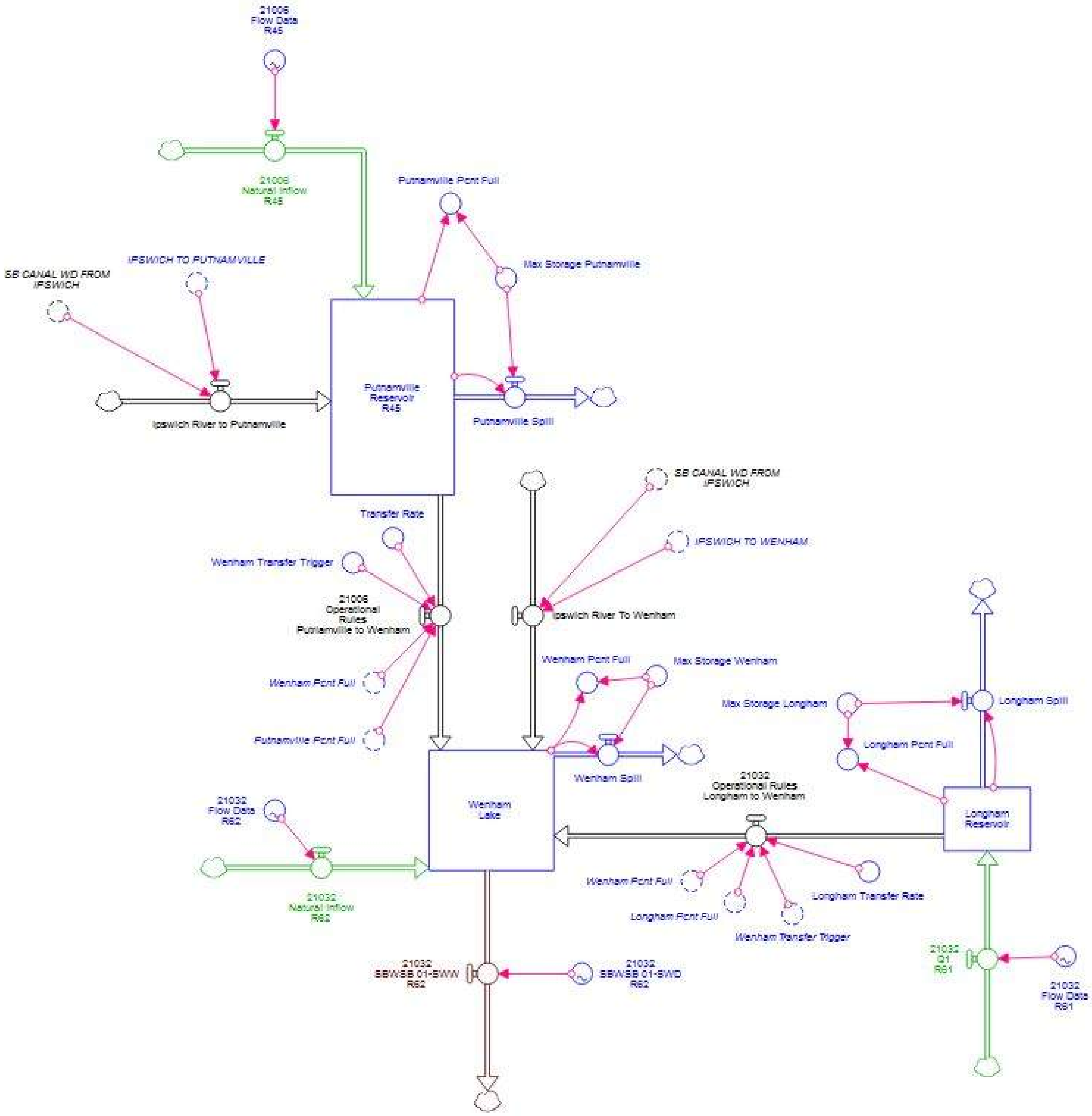

Figure 2-7: Salem-Beverly Water Supply Board Reservoir System IIOM Construct

Logic within the IIOM for the SBWSB system is the most complex of the systems modeled. All three of the reservoirs receive local runoff from the reach in which they reside, this runoff value is equal to the streamflow time series that was developed from the USGS HSPF data. Additionally, Wenham Lake and Putnamville Reservoir can be filled with water withdrawn from the Ipswich River through the Salem-

Beverly Canal. The SBWSB is only authorized to make withdrawals from the Ipswich River when flow at the USGS Ipswich gauge is above 28 MGD, and only between the months of December and May. Between their authorized and permitted withdrawal volumes, the SBWSB can withdraw 12.44 MGD on an average daily basis. Similar to the other reservoir systems, the IIOM will allow them to withdraw as much as twice this amount in any given day since they are restricted to a six-month withdrawal period.

When water is diverted out of the river and into the SBWSB reservoir system, a decision must be made on whether to send the water to Putnamville Reservoir or to Wenham Lake. Logic built into the model will transfer water to which ever reservoir has the larger percentage of its storage capacity available. If both reservoirs are at greater than 98% of their maximum storage capacity, the IIOM will not initiate a withdrawal from the Ipswich River regardless of the streamflow or month. Once water is removed from the Ipswich River into the SBWSB reservoir system, there is additional logic that governs transfers between reservoirs.

Withdrawals from Wenham Lake for distribution (shown in brown) deplete the reservoir year round as defined by the demand time series. The Integrated Operation Model will initiate a transfer from Longham Reservoir to Wenham Lake at an estimated rate of 5 MGD any time that Wenham Lake drops below 90% of its storage capacity so long as Longham Reservoir has the water available. The same rules apply to transfers from Putnamville Reservoir to Wenham Lake with an estimated transfer rate of 10 MGD. These transfer rates were estimated by Kleinfelder. The purpose of this logic within the model is to maintain supply in Wenham Lake to satisfy the system demand.

2.4.4.5 Other Storage Features

Within the IIOM there are two additional storage features that are not true reservoirs but are modeled as such because they store large volumes of water that are available to local groundwater wells (effectively slowing the rate of transfer downstream away from these wells and serving to elevate the local water table). These two features are Pleasant Pond and Wenham Swamp. While building the IIOM and running test simulations without any simulated storage in the affected reaches, it became apparent that the Wenham Water Department and Hamilton Water Department wells located in the vicinity of Pleasant Pond and Wenham Swamp (Reach 49) were not able to withdraw enough water to meet demand if access to water was simulated purely as access to passing streamflow. Based on confirmation from these participating communities that Wenham and Hamilton generally are able to satisfy demand even during drought conditions (though systems may draw down significantly enough to affect water quality), simulated storage elements were added to the relevant tributary reaches in order to more accurately depict the retention of water to which these communities have access:

- Pleasant Pond was simulated with a storage volume of 280 MG based on an area of 43 acres and an average estimated depth of 20 feet.
- Wenham Swamp was simulated as a storage element with an area of approximately 615 acres (based on wetland coverage data in the USGS HSPF model) and an approximated average depth of 6 inches, for a total simulated volume of 222 MG.

Water that spills over from Pleasant Pond storage is routed downstream into Reach 49, which includes Wenham Swamp. Water from this simulated retention of water (and effective impact of elevated groundwater tables in the vicinity of Hamilton's wells) is made available to the groundwater wells for Hamilton for their five wells which are located within the Wenham Swamp area.

This technique of adding storage to headwater (low flow) reaches that are known to include natural storage elements (a pond and a wetland) effectively retains runoff in the vicinity of the wells and acts as a surrogate for elevated water tables as an actual consequence. Water is then available within the model from the collective volume of stored runoff, which is assumed to represent the interconnected surface and groundwater of the subwatershed.

2.4.5 Estimation of Water Availability vs. Demand

Once all of the physical and operational features of the Ipswich Basin were entered into the Integrated Operation Model it became necessary to develop a tool for quickly evaluating each alternative scenario described in Section 3 and the impacts on the various PWS ability to meet demands. To do this Kleinfelder developed a counter for each PWS in the basin that measures the ADD, the percentage of the demand volume met, and the percentage of time that each PWS was able to fully meet demand. An example of this counter is shown in Figure 2-8.

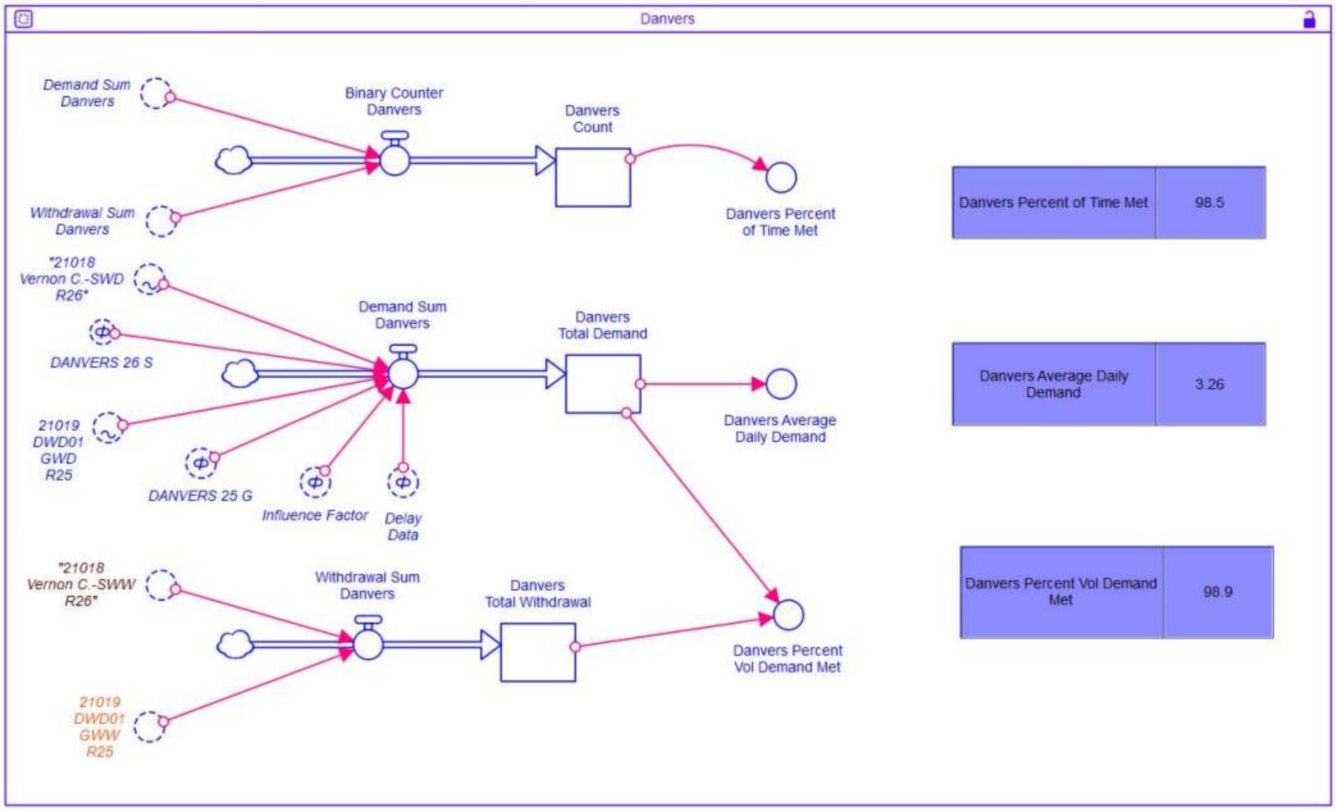

Figure 2-8: Example IIOM Statistical Counter

The ADD counter for each PWS takes all of the demand series for the supplier and sums them using one flow. The flow then goes into a stock which has no mechanism for emptying it. This stock simply aggregates all of the supplier demand over the model period. The following converter divides the value in the stock by the number of days that have passed in the model in order to generate an ADD value which is then presented in the box to the right.

The % Volume Met counter takes all the withdrawals made by the supplier and sums them into a single flow. That flow is then transferred into a stock which has no outflows. This generates a total volume withdrawn by the PWS inside the stock. The following converter divides the amount in the total demand stock by the amount in the total withdrawal stock in order to generate a percentage of the demand satisfied over the model period. This percentage is then displayed in the box to the right.

Finally, the % Time Met counter takes the demand sum flow and the withdrawal sum flow from the previous two counters and routes them into a third flow that functions as a binary counter. If the withdrawal sum is equal to the demand sum the flow is instructed to deposit one counter into the stock. If the withdrawal sum is less than the demand sum, the counter will not deposit anything in the stock.

As a result the stock will maintain a count of the number of times that each PWS was able to satisfy demand over the 30-year model period. The following converter then divides this value by the number of time steps that have passed in the model to determine the percentage of time steps for which each PWS was able to meet their full demand volume. It is important to note that even if a PWS meets 99% of their demand for a given time step that the counter will record this as a day in which the demand volume was not met.

2.5 MODEL VALIDATION

2.5.1 HSPF Model and Integrated Operations Model – No Withdrawals

In order to confirm that the IIOM accurately reproduced the flows extracted from the USGS HSPF Model, Kleinfelder compared the output of both models at the South Middleton and Ipswich gauges. The IIOM output, withdrawals excluded, was compared to the HSPF flows (which also do not include withdrawals). These comparisons are presented below in Figure 2-9 and Figure 2-10. As shown, the IIOM accurately reproduces the flow trends at both gauges. At the Ipswich gauge, the IIOM often has significantly larger flows then the HSPF model during the high flow periods. This is because the HSPF model under-simulates periods of high flow but this does not impact the analysis since the periods of low flow are most critical to the objective of this modeling effort.

2.5.2 Historic USGS Gauge Measurements and Integrated Operations Model

In addition to validating the model against the HSPF flows, Kleinfelder also compared the IIOM outputs (including withdrawals) against observed historical flows at the USGS gauges. This was done in order to validate that the model was accurately simulating observed conditions properly once the addition of withdrawals was made to the model. These comparisons are presented below in Figure 2-11 and Figure 2-12. As shown, the flow trends and low-midrange flows are simulated accurately at both gauges when the withdrawal data is applied in the model.

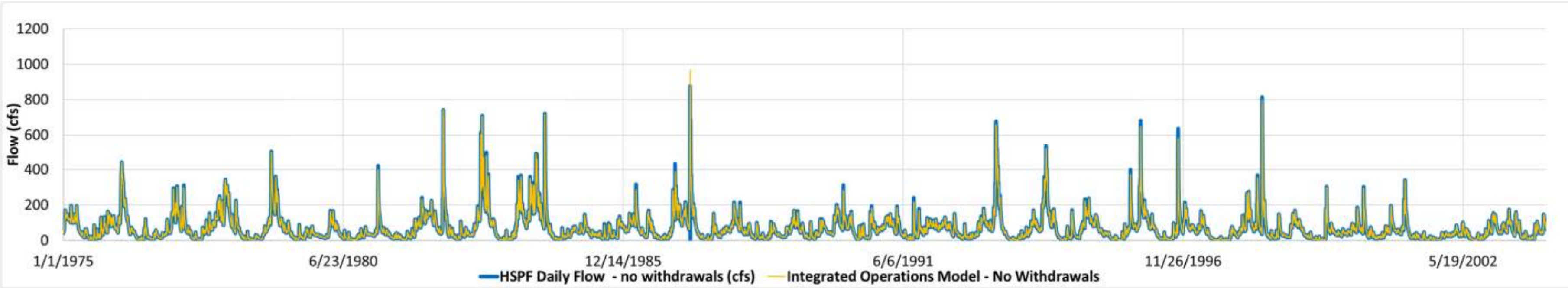

Figure 2-9: South Middleton Gauge, HSPF and Integrated Operations Model Flow Comparison – No Withdrawals

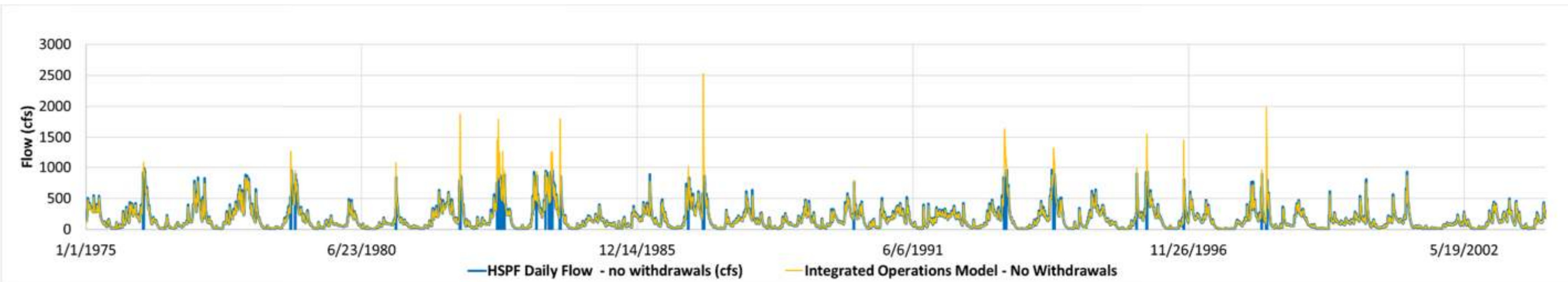

Figure 2-10: Ipswich Gauge, HSPF and Integrated Operations Model Flow Comparison – No Withdrawals

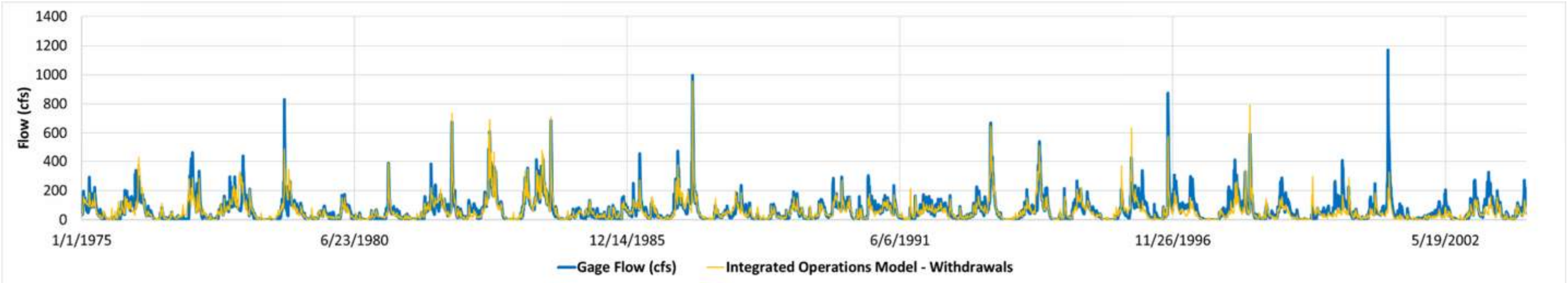

Figure 2-11: South Middleton Gauge, Observed Flow and Integrated Operations Model Comparison

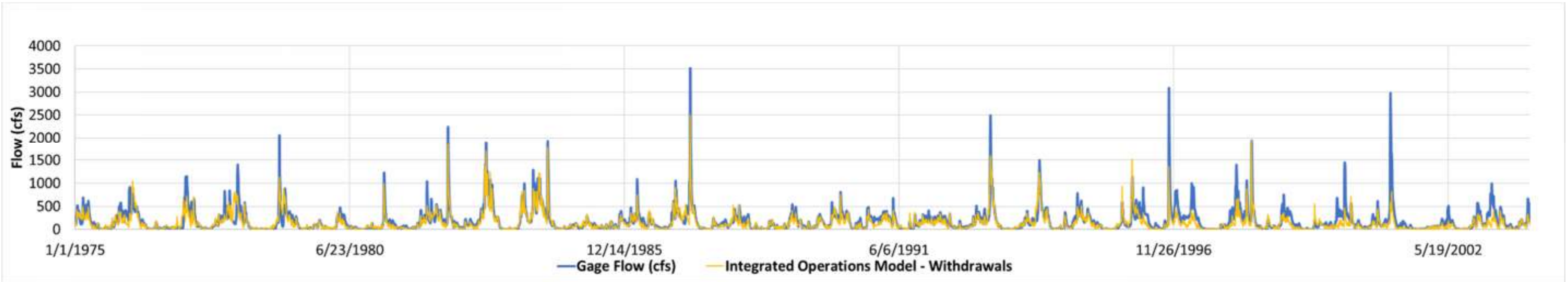

Figure 2-12: Ipswich Gauge, Observed Flow and Integrated Operations Model Comparison

3 MODEL RESULTS

To help answer the questions presented in Section 1.2.3, we modeled several scenarios, which are summarized in Table 3-1 and described in greater detail in Sections 3.1 through 3.4. The current conditions scenario is simulating the existing conditions in the Basin. A set of sensitivity evaluations and experimental management scenarios helped answer questions about water availability in the Basin, the effect of increased population and climate change projections, and potential management or water sharing opportunities.

Draft sensitivity evaluations and some of the future conditions and experimental management results were presented during the second stakeholder workshop. The feedback received from the communities during the workshop helped lead to some improvements in the way the model represented certain elements of the system and helped frame additional scenarios to confirm that the current conditions scenario reflects the reality of each community.

Table 3-1: Modeled Scenario Names and Descriptions

Scenario Name	Scenario Description
Current	Scenario of existing conditions based on flow, demand, and operational data
Sensitivity Evaluations	
90dGWL	90-day groundwater lag time
SD80%	Streamflow depletion 80%
90dGWL&SD80%	Combining the 90-day groundwater lag time and streamflow depletion scenarios
Permit_NoQ	Remove gauge flow restrictions for surface water withdrawals
Permit_NoTOY	Remove time of the year restrictions for surface water withdrawals
Future Condition Scenarios	
ADD+10%	Increase public demand by 10%
Demand+	Increase public and registered private demand by 10% and increase private demand to 5 MGD (current 1.2 MGD)
CC_low	Climate change scenario based on predictions of low increase in greenhouse gas emissions

Scenario Name	Scenario Description
CC_high	Climate change scenario based on predictions of high increase of greenhouse gas emissions
CC_high&D	Climate change based on high increase of greenhouse gas emissions and public and private demand increase
Experimental Management Scenarios	
ADD-10%	Decrease public and registered private demand by 10%
RS+10%	Increase available storage capacity for all reservoirs in the model by 10%
Water Sharing	Evaluate opportunities for balancing water between suppliers

3.1 CURRENT CONDITIONS SCENARIO

The current conditions scenario represents the known flow, demand, and operational conditions in the Ipswich Basin from data and information available to us from MassDEP, the USGS HSPF model, and the Ipswich River Basin communities. Data inputs were described in Section 1.2.4. The scenario superimposes demand (based on 2009-2016 water usage) over a 30-year period of hydrologic record and measures reliability two ways:

1) **% Volume Met** as the ratio of total withdrawals to total demand over the simulation period, and

2) **% Time Met** as the probability that demand volume will be met on any given day in the 30-year simulation period. This frequency metric measures all the days when the water demand is fully met and can help communities identify which periods of time their demand is not fully met. Basin-wide, this metric is the sum of all the days demand is not fully met from all the communities, and hence can be significantly less than % Time Met of individual communities.

One way to understand the difference in these two metrics is this: if for one year a community was able to extract 90 percent of its needed water every day, over the course of the year they would realize 90 percent of the desired water volume. However, in no single day would the demand be entirely satisfied, so the frequency of fully satisfying demand would be 0 percent. This is an important distinction commonly used in water supply planning to understand the magnitude of potential shortfalls and their distribution in time.

The current conditions scenario will serve as the basis for comparison with all other scenarios presented in Section 3.

Under current demand conditions, the model indicates that some communities are more resilient that others in being able to meet their water needs, as shown in Figure 3-1 and Figure 3-2. SBWSB, Wenham, Hamilton, and Ipswich can meet 100 percent of their current water volume needs 100 percent of the time. These four water suppliers have either surface water withdrawals and/or natural wetland storage capacity. Although Danvers has surface water storage, Danvers' is the only supplier with instream flow Permit restrictions which limit pumping of their groundwater sources. The IIOM simulated that Danvers cannot fully meet its water needs with local sources during droughts that are similar or greater in intensity as the 1982 and 2002 droughts.

Information on the Lynn reservoir system was unavailable during this study, and so the model used the maximum amount of registered volume withdrawn from the Ipswich River for transfer to the Lynn Reservoir System. Because the Lynn reservoirs are not modeled, there was no way for this model to "know" when the reservoirs would be full, or when local runoff could offset the need for Ipswich River withdrawals. Hence, the model applies a conservative approach: simulated Lynn withdrawals from the Ipswich River approach the maximum registered volumes even though the demand on the river would frequently be much less than this. As a result, the Lynn reliability measures are reported as slightly less than 100%, but this should be interpreted only in the context of this conservative assumption of attempting full authorized withdrawals. The other benefit of this conservative approach is that all downstream users are subjected to the river flows that would result if Lynn were to extract its full authorized volume whenever possible.

Communities that rely exclusively on groundwater withdrawals for their water needs are less resilient based on the IIOM estimates. The following communities are known to buy water from outside the basin or have additional water sources to meet their demand:

- Wilmington purchases from MWRA to supplement Ipswich Basin groundwater sources.
- North Reading purchases from MWRA and Andover to supplement their Ipswich Basin wells.
- LCWD has North Coastal Basin groundwater sources and been able to manage demands so that total Ipswich Basin withdrawal does not exceed registration plus threshold volume; however, they are exploring other sources including potential connection to MWRA (see Section 5).
- Topsfield experiences water quality decline and is potentially interested in MWRA water to supplement Ipswich Basin Wells (see Section 5).
- Danvers has needed to purchase water from SBWSB in times of drought or groundwater wells being out of service.

Although the IIOM estimates communities that rely on groundwater withdrawals to meet over 90 percent of their volume needs (except LCWD, which has groundwater sources in the North Coastal basin to supplement supply), the percent of time they are predicted to fully meet their water needs are significantly lower, as seen in Figure 3-2.

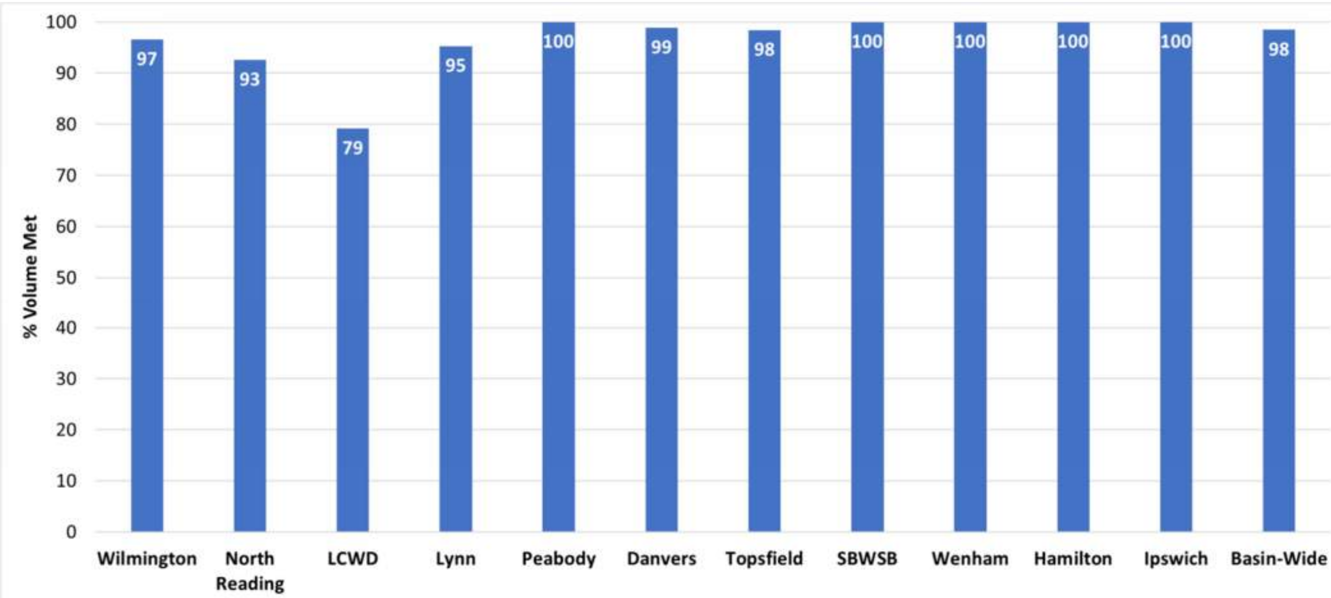

Figure 3-1: Current Conditions - % Volume Met

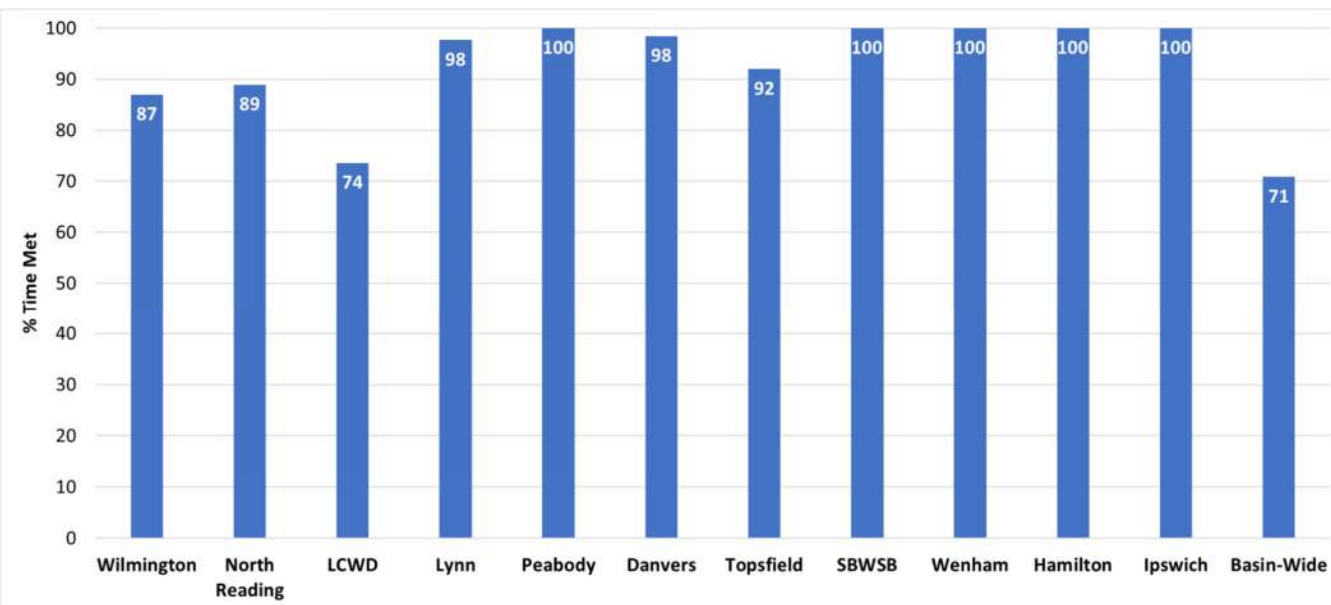

Figure 3-2: Current conditions - % Time Met (with Basin-Wide as Aggregate from All Communities)

3.2 SENSITIVITY EVALUATIONS

The purpose of the sensitivity analysis was to examine physical and regulatory variables that have been the subject of debate to determine how critical they are to influencing overall water supply reliability in the Basin.

We evaluated how sensitive the River flow and supply reliability are to:

(1) Uncertainties in the impacts of groundwater withdrawals on river flow, in terms of actual stream depletion and the lag time (or the time between the groundwater extraction and the corresponding reduction in streamflow). This has been studied by the USGS, but conclusive findings and consensus on these phenomena do not appear to exist. As such, this study did not attempt to add clarity to the hydrogeologic science, but instead, focused on the question of how much this uncertainty really matters in understanding basin-wide supply reliability.

(2) Existing regulatory constraints for surface water withdrawals. Currently, surface water suppliers are limited to withdrawing water from the Ipswich River between December 1 and May 31, provided that a minimum flow is observed at the gaging stations. Flow at the South Middleton gauging station must be above 10 MGD for Lynn and Peabody to withdraw. Flow at the Ipswich gauging station must be above 28 MGD for SBWSB to withdraw water.

We simulated five sensitivity scenarios as experiments. These are not attempts to refine the science or to suggest alternative regulations – instead, they are experiments to determine how much the current scientific uncertainty and regulatory constraints affect water supply reliability measures:

- **90dGWL (90-day groundwater withdrawal lag time)** – for this scenario, the effects of all groundwater withdrawals on river flow (public and private wells) were delayed by 90 days.
- **SD80% (streamflow depletion 80%)** – for this scenario, the impact of groundwater withdrawals was assumed to deplete streamflow by 80 percent of the extracted groundwater volume at all times (a variation on the assumption that there is a 1:1 relationship between groundwater extraction and stream depletion).
- **90dGWL+SDL80** – this scenario combines the previous two scenarios
- **Permit_NoQ** – for this scenario, we removed the gauge flow restrictions for surface water withdrawals. We modified the model to allow Peabody, Lynn, and SBWSB to withdraw from the Ipswich River irrespective of the flow.
- **Permit_NoTOY** – for this scenario, we removed the time of the year restrictions for surface water withdrawals. We modified the model to allow Peabody, Lynn, and SBWSB to withdraw from the Ipswich River year-round, and therefore distributed the total volumetric authorization

equally throughout the year (understanding that this would not necessarily be the optimal distribution of withdrawals).

As seen in Figure 3-3, which shows the simulations of % Volume Met for all the Ipswich Basin communities evaluated in this study and Figure 3-4, which shows the simulations of % Time Met for all six scenarios we considered in this section, the impact of the groundwater lag time and streamflow depletion factor is minor, as the percent changes from the current scenario in time and volume are in the low single digits. In other words, while there is an observable influence, these are not driving factors for overall supply reliability in the Ipswich Basin. Figure 3-5 and Figure 3-6 show the same information as the previous figures, but the results of the simulations are separated and shown by individual community

The Basin supply reliability does not appear to be sensitive to the surface water withdrawal restrictions. For the removal of stream flow gauge restrictions and time of year withdrawal restrictions also in Figures 3-3 and 3-4, Lynn is the only community in which the model showed an effect. This is an artifact of the fact that since operational information for Lynn's system was not available for this study, their withdrawals from the Ipswich River are conservatively estimated by spreading Lynn's authorized withdrawals evenly through the year as described in Section 2.4.4. Therefore, the model simulates that there would be many summer months in which the averaged authorized withdrawal would not be available. Peabody and Salem-Beverly, the other two surface water providers whose withdrawals are conditioned on the Ipswich River gauges, can satisfy 100% of demand (volume and time). For Peabody and SBWSB, supply reliability is determined in the model largely by the storage in their reservoirs, which are included since they are in the basin and operational protocols were available to the study team.

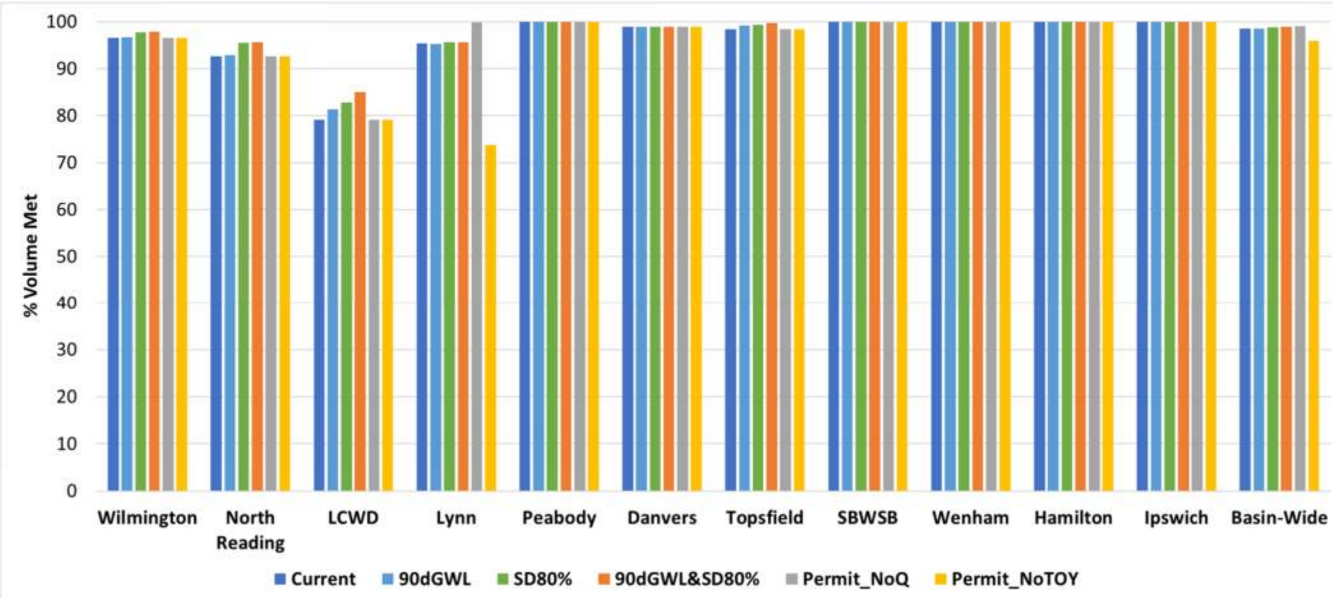

Figure 3-3: Sensitivity Evaluations - % Volume Met for the Ipswich Basin Communities

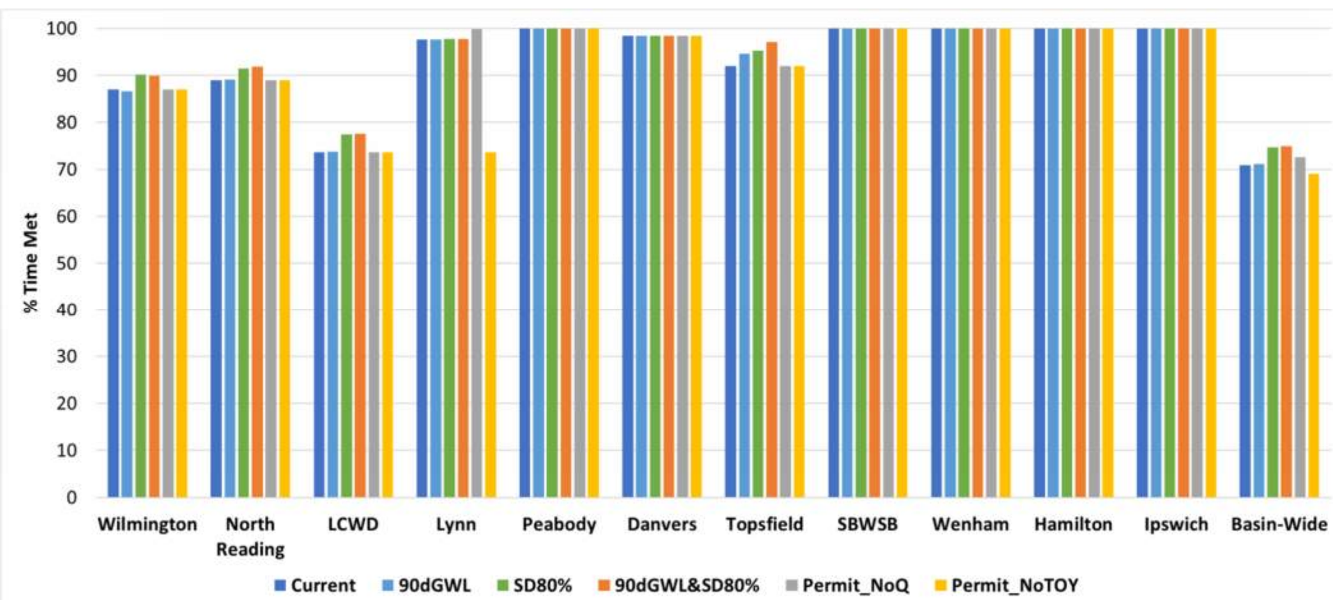

Figure 3-4: Sensitivity Evaluations - % Time Met for the Ipswich Basin Communities (with Basin-Wide as Aggregate from All Communities)

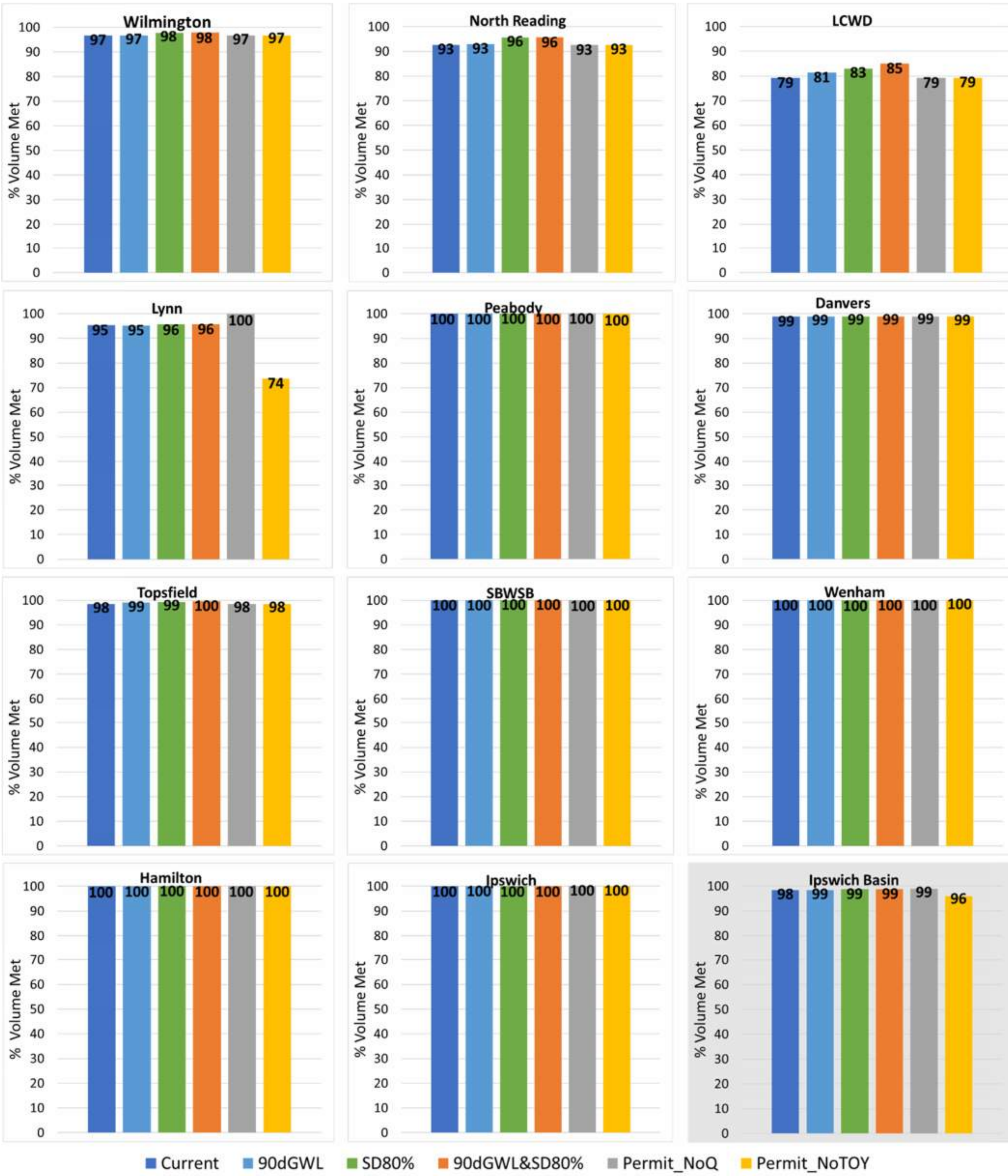

Figure 3-5: Sensitivity Evaluations - % Volume Met in the Ipswich Basin by Community

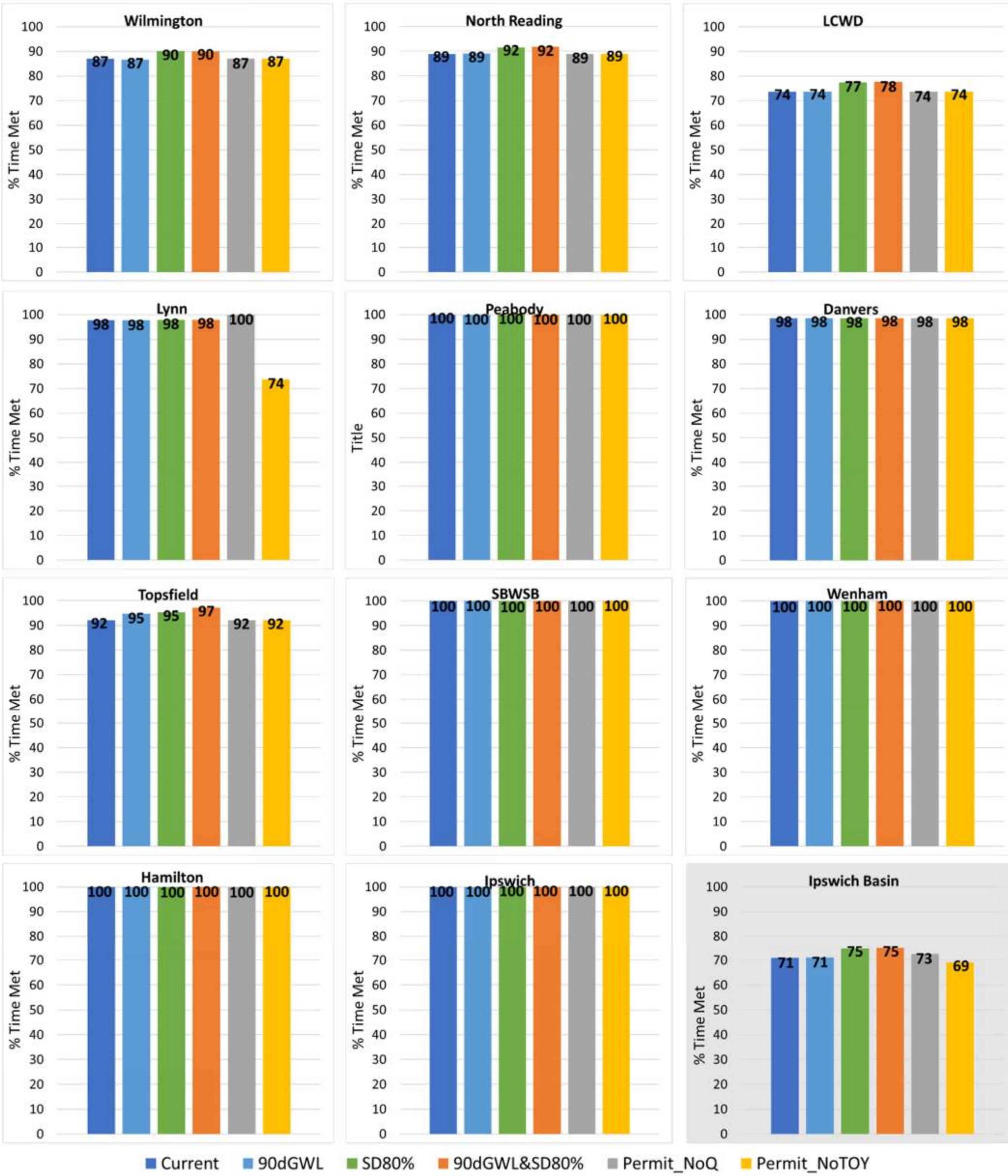

Figure 3-6: Sensitivity Evaluations - % Time Met in the Ipswich Basin by Community (with Basin-Wide as Aggregate from All Communities)

Effects of the sensitivity evaluations on the river were simulated as the percent of time when the Ipswich River flow is below 52.5 cfs (34 MGD) at the Ipswich Gauge, as seen in Figure 3-7. The flow of 52.5 cfs is a regulatory trigger established by the MassDEP based on a fish habitat study (Armstrong et al, 2001). This trigger has been subject to criticism (among other reasons) as it was derived from streamflow levels protective of stocked fish species (trout) . Use of the 52.5 cfs threshold in this report is not intended to comment on its validity, only to assess changes relative to an existing regulatory benchmark that some permittees are operationally held to. Based on the results of the HSPF model for natural hydrology (no storage and no withdrawals), the river naturally drops below this trigger 27 percent of the time (Zarriello & Ries, 2000). The IIOM estimates that under current conditions, which includes storage and withdrawals, the flow at the Ipswich Gauge is lower than 52.5 cfs approximately 35 percent of the time.

The ground water withdrawal scenarios (90dGWL, SD80%, and combined) indicate that the River is not sensitive to these influences (0 to 1% change). Removing the existing regulatory constraints for surface water withdrawals slightly increases the simulated percent of time that the river flow is below 34 MGD, by 3 to 5 percent.

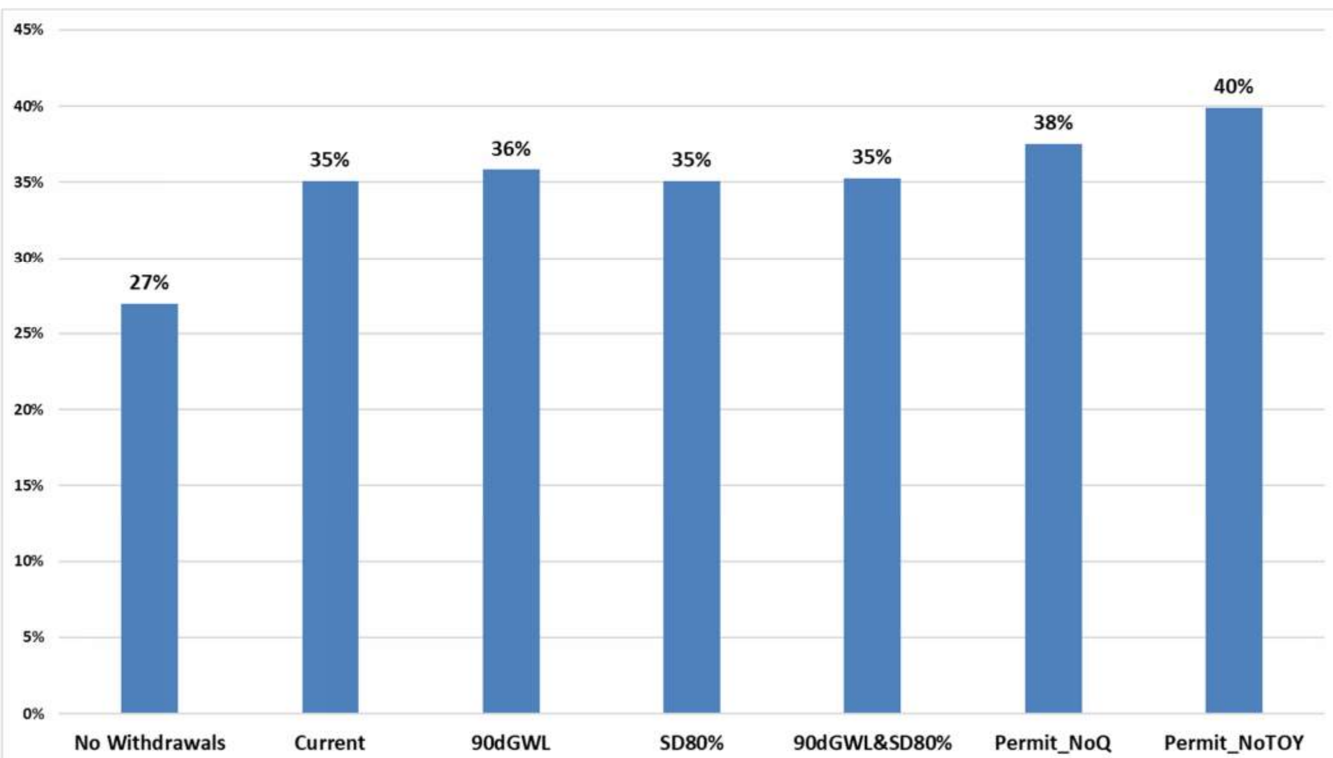

Figure 3-7: Sensitivity Evaluations - Percent of Time Streamflow Below 52.5 cfs at the Ipswich Gauge

The simulated environmental impacts on the flow are minimal when groundwater withdrawals and demands are delayed by 90 days and reduced to a streamflow depletion factor of 80%, as seen in Figure 3-8, which compares the River flow under simulated conditions with the regulatory trigger 52.5 cfs for the full period of record. The bottom graph in this figure represents a zoomed in view of the same data from the top graph, but only for flows below 100 MGD.

Similarly, Figure 3-9 shows the comparison of the River flow when the flow gauge restrictions for surface water withdrawals are removed for the full period of record (top graph) and for flows below 100 MGD (bottom graph). As seen from these graphs, the simulated environmental impacts on the flow are minimal in this scenario as well.

The impact of the 2002 drought on the simulated flows is shown in Figure 3-10, and the IIOM simulates that removing the flow gage restrictions does not improve the flow in the River during times of drought at the Ipswich gauge.

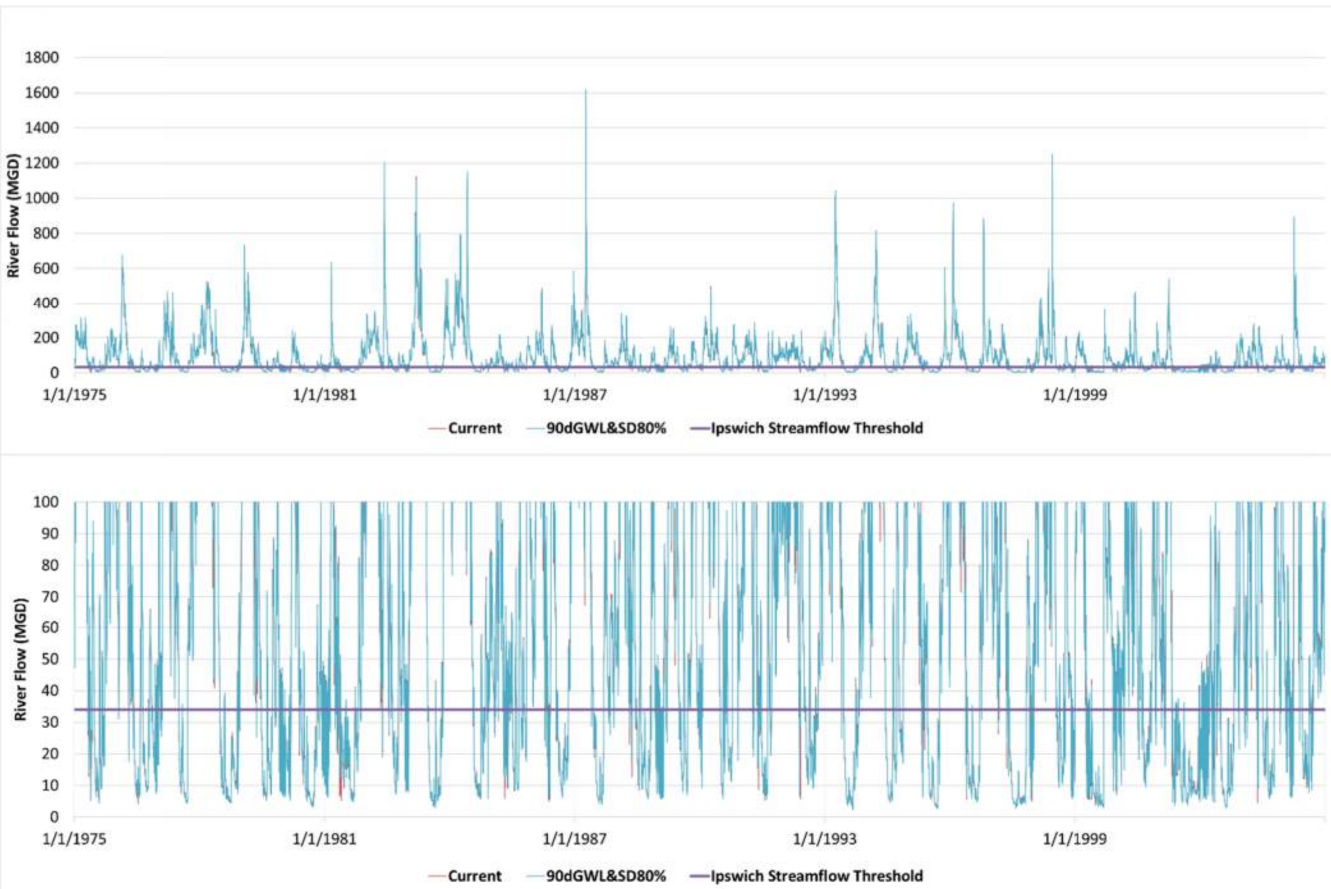

Figure 3-8: Modeled Ipswich River Flow at Ipswich Gauge – Groundwater Withdrawal Scenario 90gGWL%SD80%

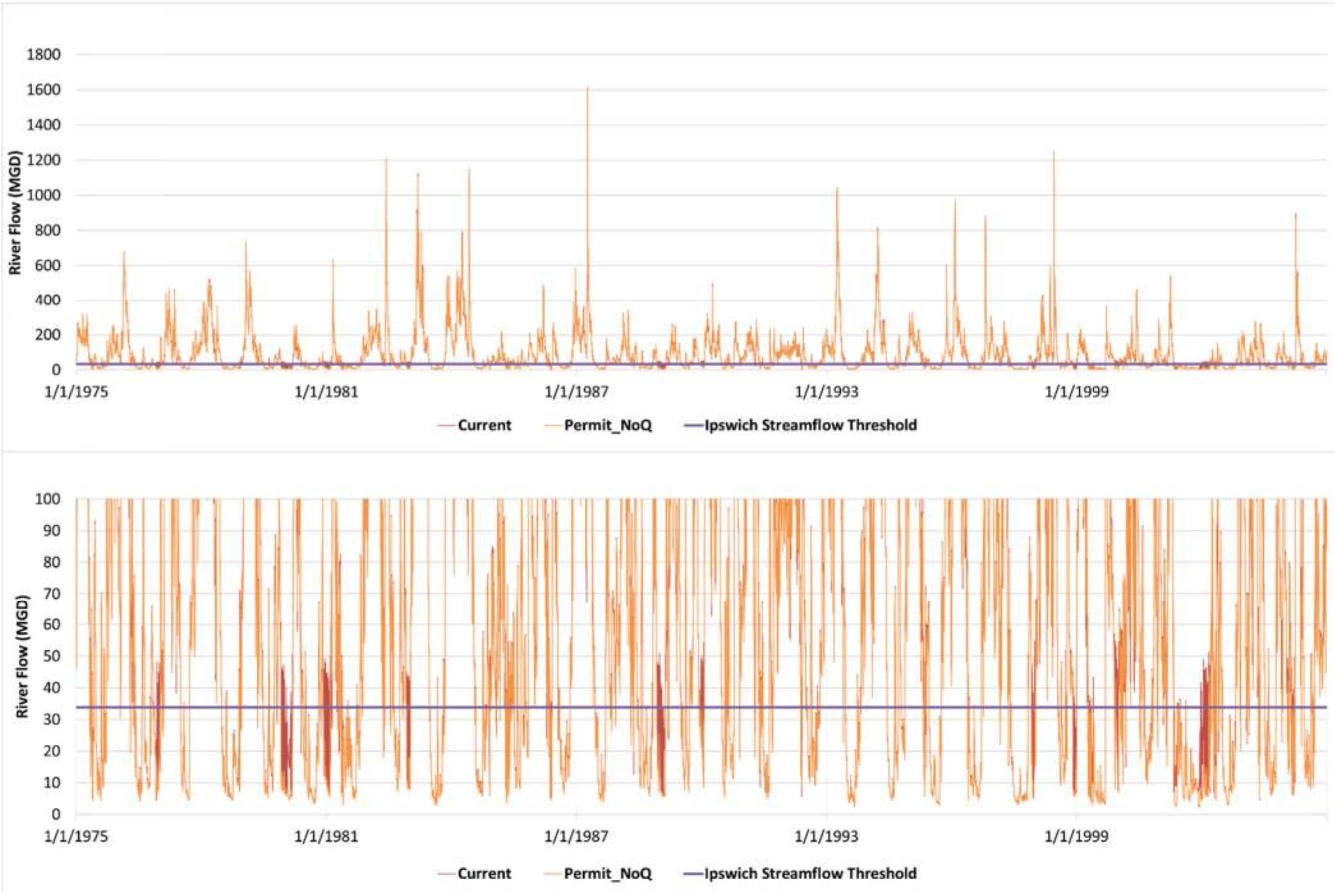

Figure 3-9: Modeled Ipswich River Flow at Ipswich Gauge – Gauge Flow Restriction Removal Scenario Permit_NoQ

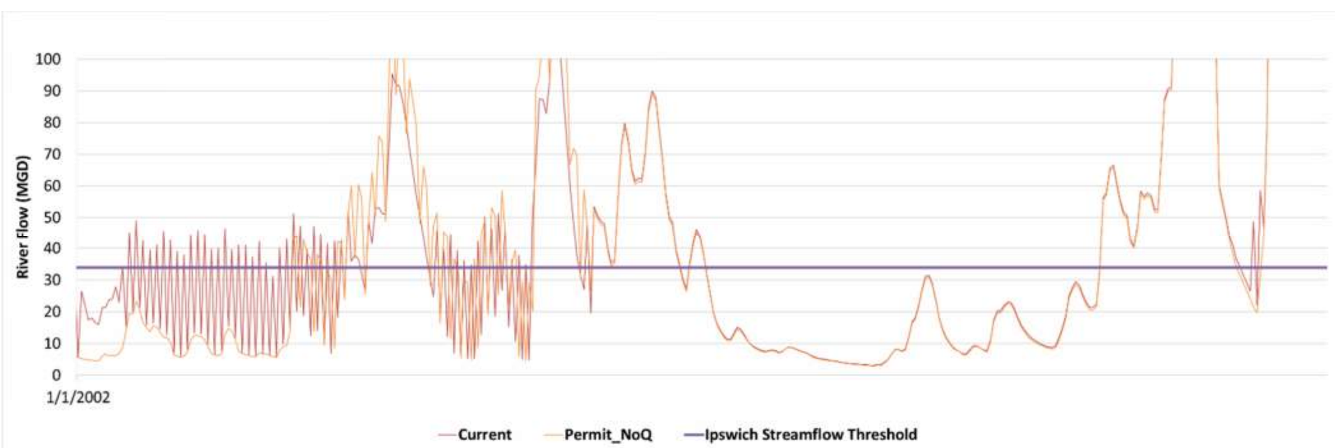

Figure 3-10: Modeled Ipswich River Flow at Ipswich Gauge - 2002 Drought for Permit_NoQ

3.3 FUTURE CONDITIONS SCENARIOS

One of the main questions our study is trying to answer is if there will be enough water in the Basin in the future. Based on projections for population increases in the region and climate change effects on stream flow, we modeled the following scenarios:

- **Add+10% (increase public demand 10%)** - for this scenario, all the public demand was increased by 10 percent. This increase is conservative, as it exceeds the estimated 5 percent population increase projections in the region.
- **Demand + (increase private and public demand)** - for this scenario, we increased the public and registered private demand by 10% and increased the private well demand to 5 MGD. Private well demand under current conditions was estimated as discussed previously in Section 2.3.3, and after conversations with some of the Ipswich Basin communities, we decided to increase this demand as a proxy for other withdrawals in the basin we have no data for.
- **CC (climate change)** – we modeled two scenarios to account for climate change under two greenhouse gas (GHG) emissions predictions: low and high increase in GHG. These are labeled as **CC_low** and **CC_high**, respectively, in the figures from this section.
- **CC_high&D** – this scenario simulates the combined effect of predicted high GHG emissions (CC_high) and increase in private and public demand (Demand+)

Because the IIOM does not recreate runoff from climate data, we had two options for simulating the potential impacts of climate change throughout the basin:

- Apply climate-adjusted output from the USGS HSPF model, or,
- Apply knowledge from other studies on future climate patterns in the Northeast U.S. to adjust the natural streamflow data in the model.

Because the use of the HSPF model and process of extracting data and formatting it for use in the IIOM is so time consuming, we elected the second option, which effectively offers broader flexibility as a secondary benefit. We relied on data presented in the Northeast Climate Impact Assessment (NECIA) 2006 report “Climate Change in the U.S. Northeast” (NECIA, 2006), which used three climate models (GFDL, HadCM3, and PCM) to estimate changes in streamflow across the Northeast given climate change scenarios. The report provides a comparison of historical streamflow (1961-1990) to the average streamflow from the three models (2070-2099 high emissions climate scenarios) over the period May 21-October 31. This “baseline” of historic streamflow is appropriate to use since there is little evidence of “consistent changes in the timing or magnitude of late summer/early fall low flows during the 20th Century.” (NECIA, 2006).

According to the NECIA report, the Northeast U.S. can expect to see changes in summer streamflow under future climate scenarios. We incorporated this potential variation into the IIOM as time series multipliers with values taken from the report and presented in Table 3-2. In this way, drier summers are modeled in each year of our simulation, with the two-fold benefit of synthesizing more frequent and severe droughts, and also standing as a surrogate for another commonly used climate change metric - consecutive dry days.

Table 3-2: Flow Model Multipliers for Two climate change scenarios

Month	**CC_low Scenario Multiplier**	**CC_high Scenario Multiplier**
January	1	1
February	1	1
March	1	1
April	1	1
May	0.95	0.85
June	0.9	0.7
July	0.9	0.7
August	0.985	0.95
September	0.97	0.9
October	0.9	0.7
November	1	1
December	1	1

As seen in Figure 3-11 and Figure 3-12, demand increases have a small but negative effect, making communities and the basin between 1 to 5% less resilient. Surface water communities or communities with reservoirs can still meet their water needs. A similar trend can be observed for both climate change scenarios. Combined, the “worst-case” scenario (CC_high&D) shows that the stress in the basin will intensify with the % Time met decreasing by 9% basin-wide. Figure 3-13 and Figure 3-14 show the % Volume Met and % Time Met results of the future conditions scenarios by community.

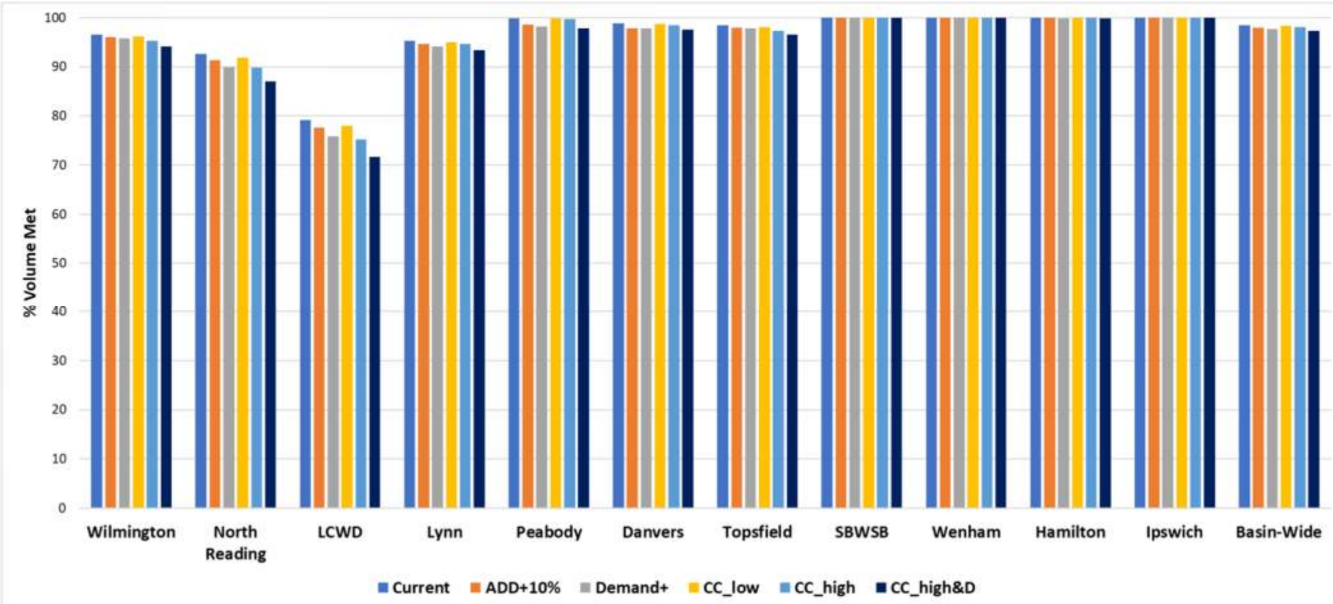

Figure 3-11: Future Conditions Scenarios - % Volume Met for the Ipswich Basin Communities

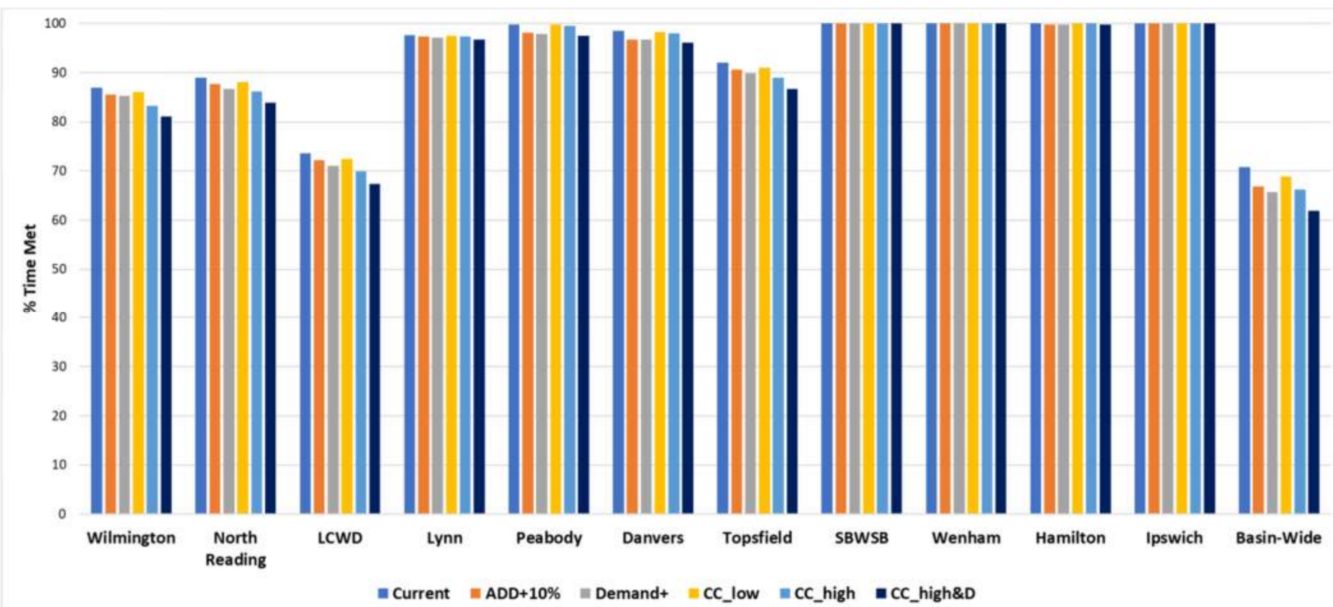

Figure 3-12: Future Conditions Scenarios - % Time Met for the Ipswich Basin Communities (with Basin-Wide as Aggregate from All Communities)

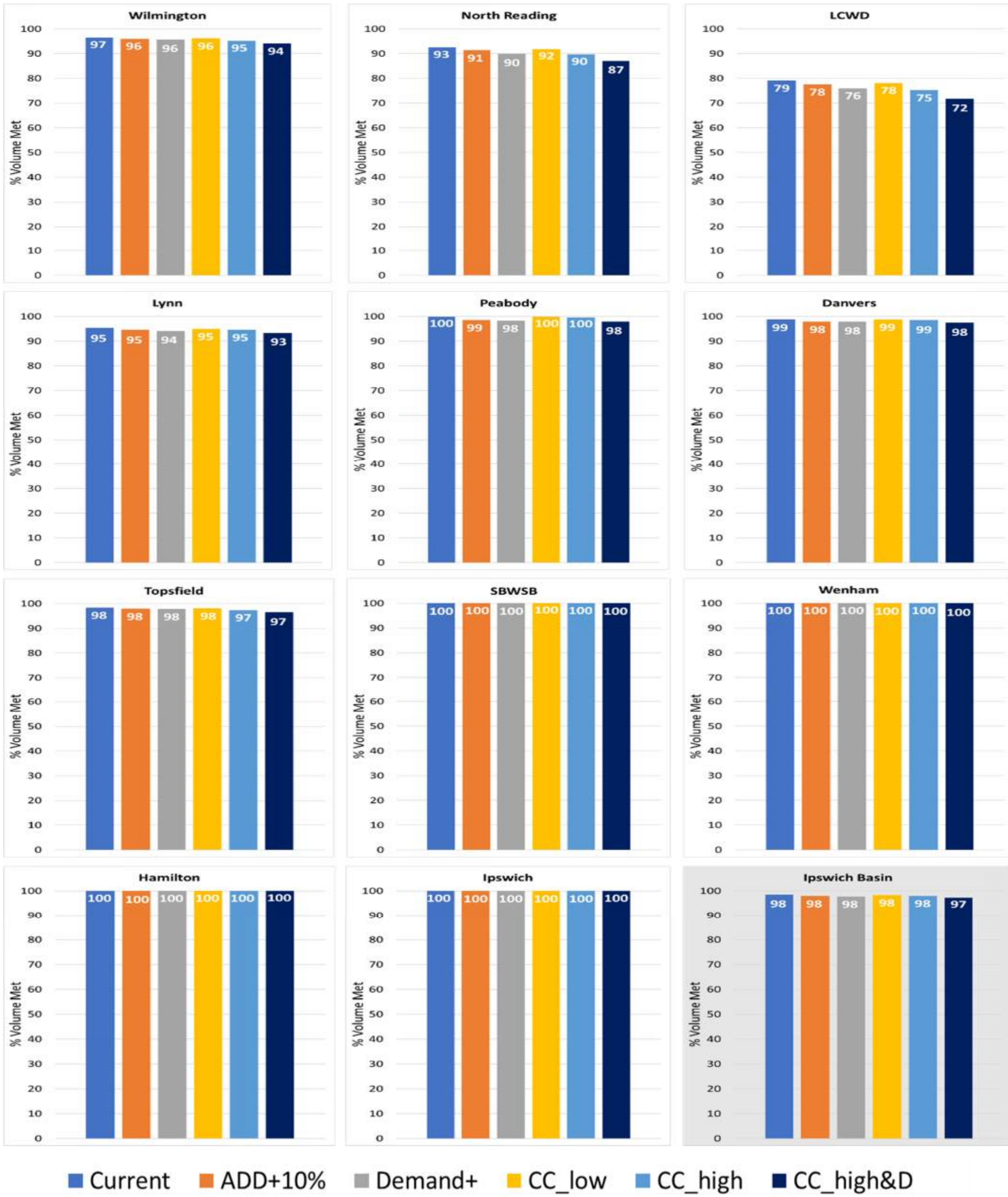

Figure 3-13: Future Conditions Scenarios - % Volume Met by Community

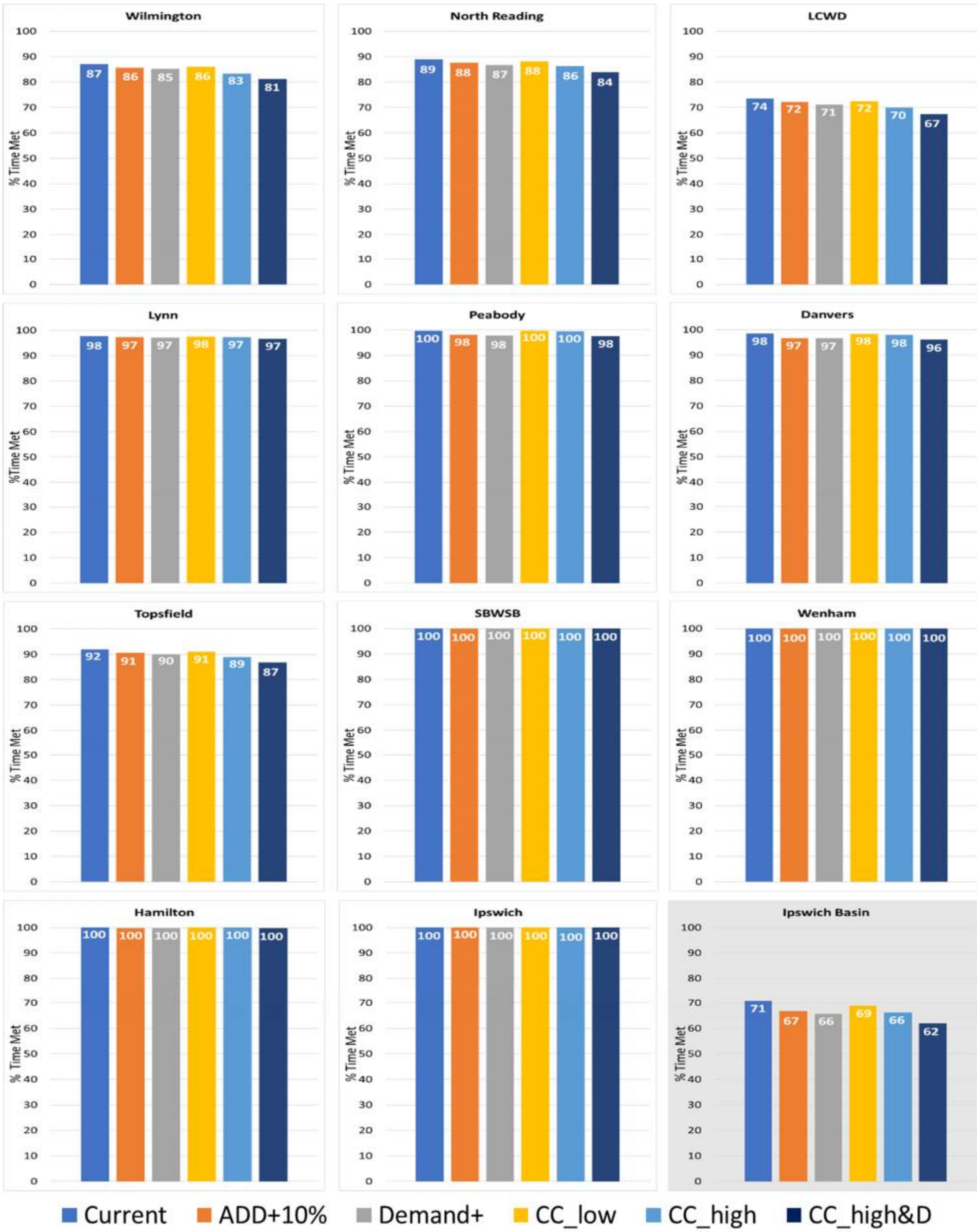

Figure 3-14: Future Conditions Scenarios - % Time Met by Community (with Basin-Wide as Aggregate from All Communities)

Effects of the future conditions scenarios on the river were simulated as the percent of time when the Ipswich River flow is below 52.5 cfs (34 MGD) at the Ipswich Gauge, as seen in Figure 3-15.

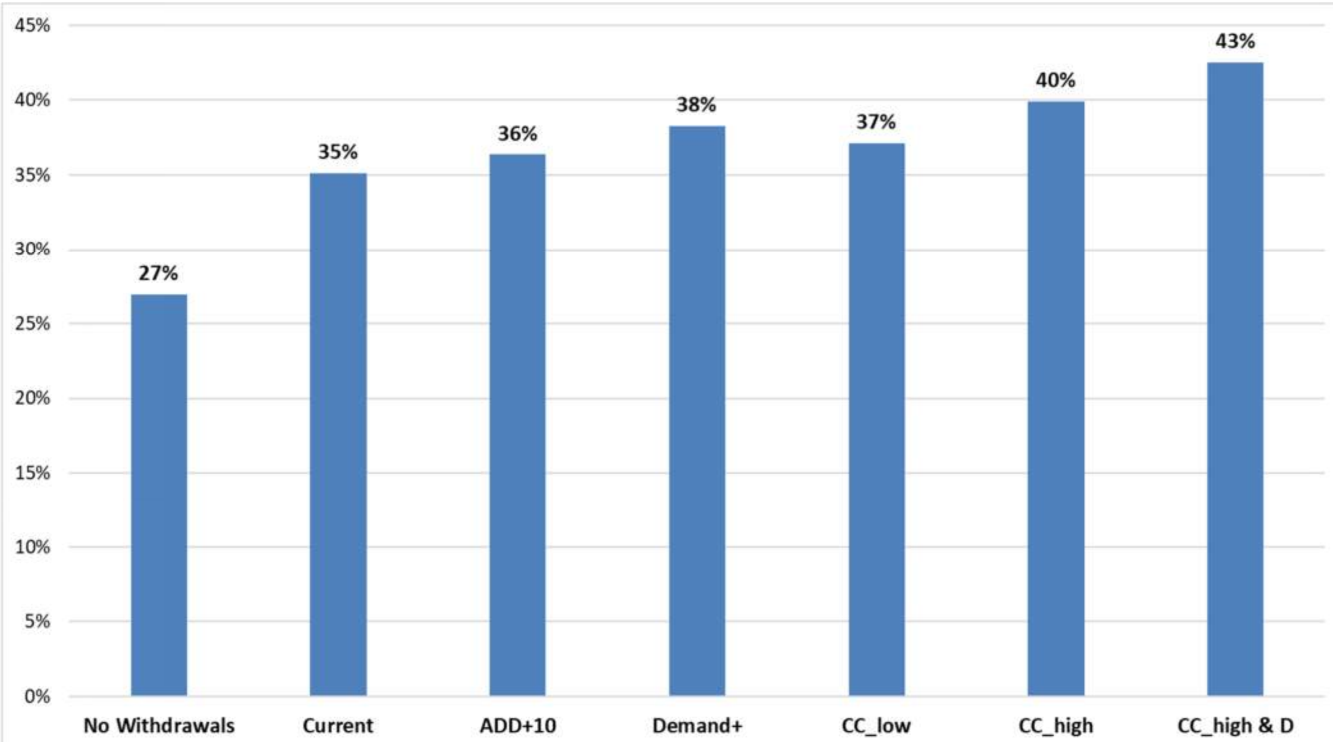

Figure 3-15: Future Conditions - Percent of Time Streamflow Below 52.5 cfs at the Ipswich Gauge

Increasing the demand in the Basin has a small (1 to 3 percent) increase in the simulated percent of time that the river flow is below 52.5 cfs. The river is most sensitive to the combined effect of high greenhouse gas emissions climate change predictions and private and public demand increase in the future (CC_high&D). The simulated environmental impacts on the Ipswich River flow for this scenario can also be seen in Figure 3-16, which compares the River flow under simulated conditions with the regulatory trigger of 52.5 cfs for the full period of record. The bottom graph in this figure represents a zoomed-in view of the same data from the top graph, but only for flows below 100 MGD.

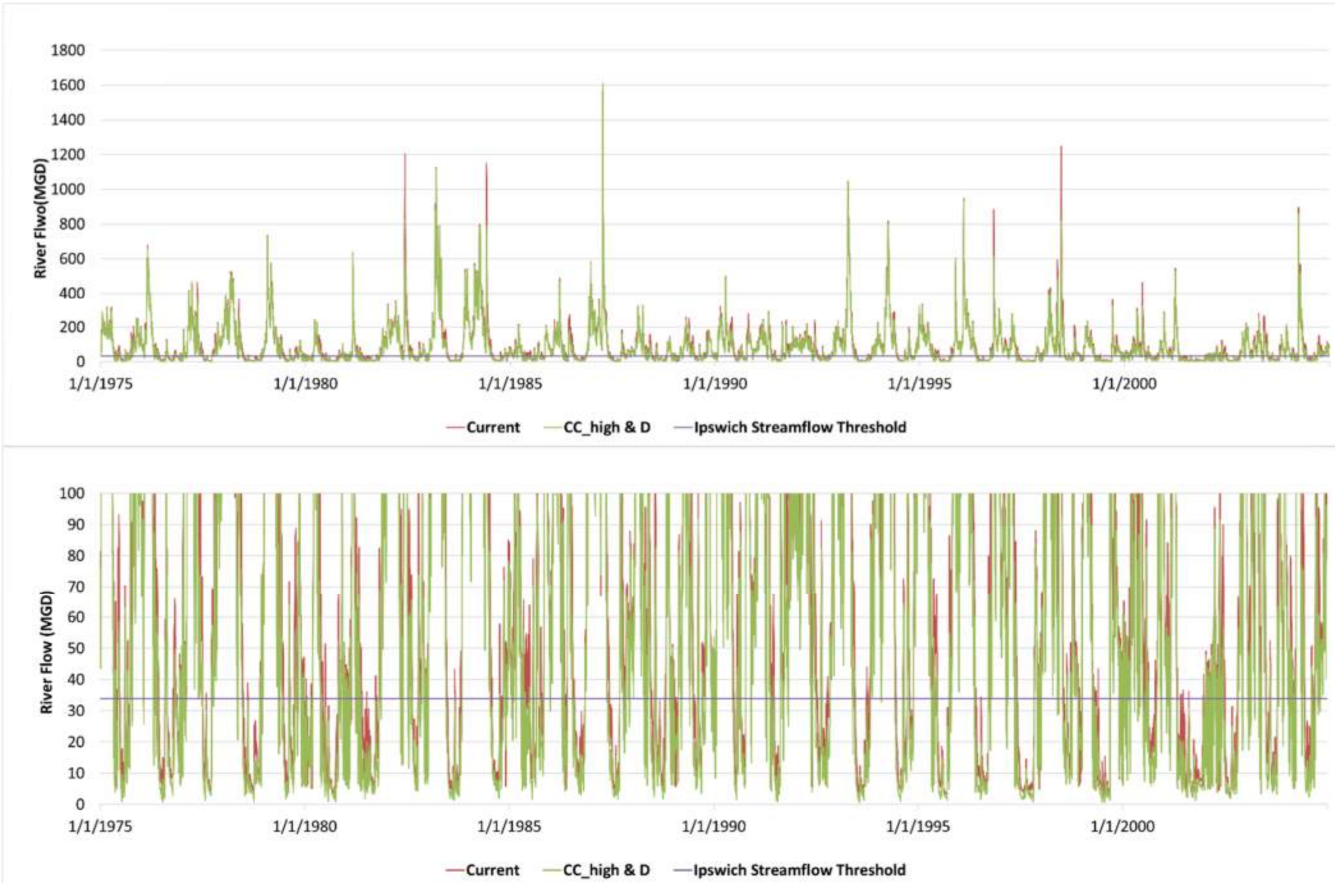

Figure 3-16: Modeled Ipswich River Flow at Ipswich Gauge – Increased Demand and Climate Change Scenario CC_high & D

3.4 POTENTIAL MANAGEMENT SCENARIOS

The Ipswich Basin communities that are less resilient are considering the most efficient and effective water management alternatives that will ensure their water needs are met without negative impacts to the ecosystem and the environment. For this reason, we simulated four types of alternative management scenarios:

- Increased storage throughout the basin
- Demand reduction
- Sharing of water between communities within currently authorized volumes
- Utilizing imported water (e.g. MWRA water) as a secondary source

These scenarios are not presented in the form of recommendations – far more detailed evaluations would be required to examine the technical feasibility, permitting requirements, legal issues, public acceptance, and environmental impacts of any of these. Rather, they are examined as ways of discerning if and where in-basin solutions to potential water shortfalls may be available, and how imported water could help alleviate some of the vulnerabilities in various groundwater communities. First, we examined the impacts of increasing storage and reducing demand with the following two scenarios:

- **RS+10% (increase reservoir storage 10%)** – for this scenario, the available capacity of all the reservoirs in the model (including Pleasant Pond but excluding Wenham Swamp) was increased by 10 percent.
- **ADD-10% (Lower demand 10%)** – for this scenario, all regulated municipal and registered private demand was reduced by 10 percent.

As can be seen in Figure 3-17 and Figure 3-18, increasing the available capacity of the reservoirs in the model has no positive or negative impacts on water supply reliability.

Reducing demand for all municipal and registered private water suppliers collectively by 10 percent has the result of increasing both % Volume Met and % Time Met for Wilmington, North Reading, LCWD, Lynn, Danvers, Topsfield, and for the Basin overall. This increase is small, however, and ranged from 1 to 2 percent which indicates that demand reduction alone will not be able to solve the future water needs of the Basin. As expected, no positive or negative impacts were identified for communities already satisfying demand at 100 percent.

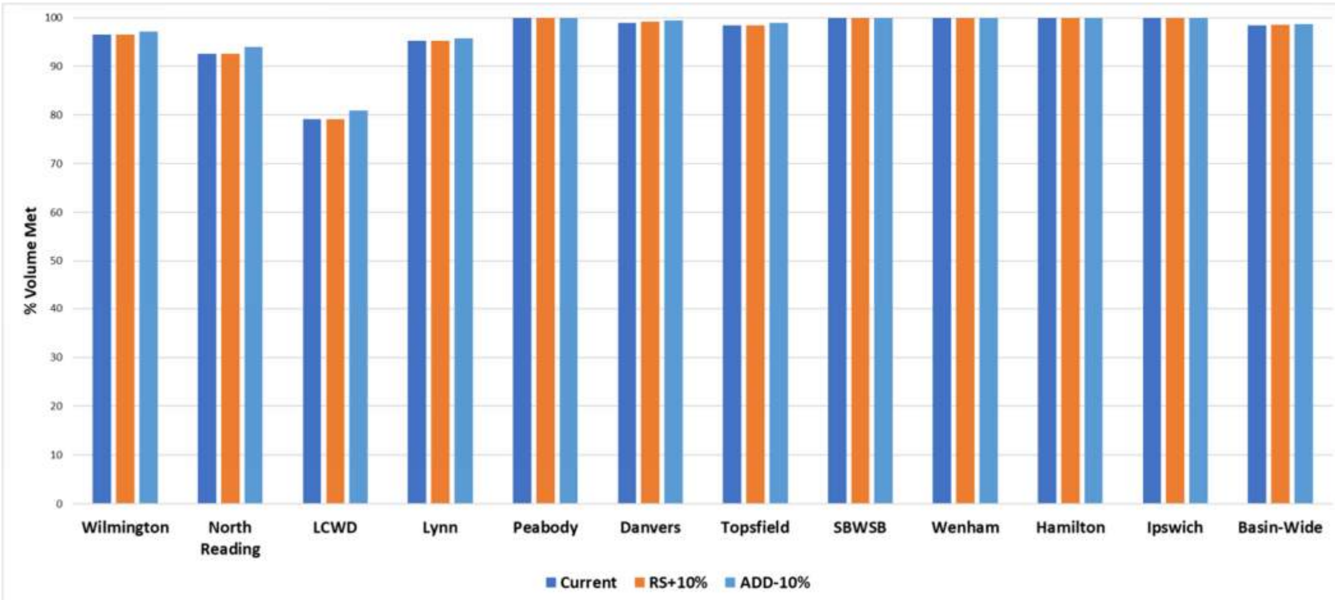

Figure 3-17: Potential Management Scenarios - % Volume Met for the Ipswich Basin Communities

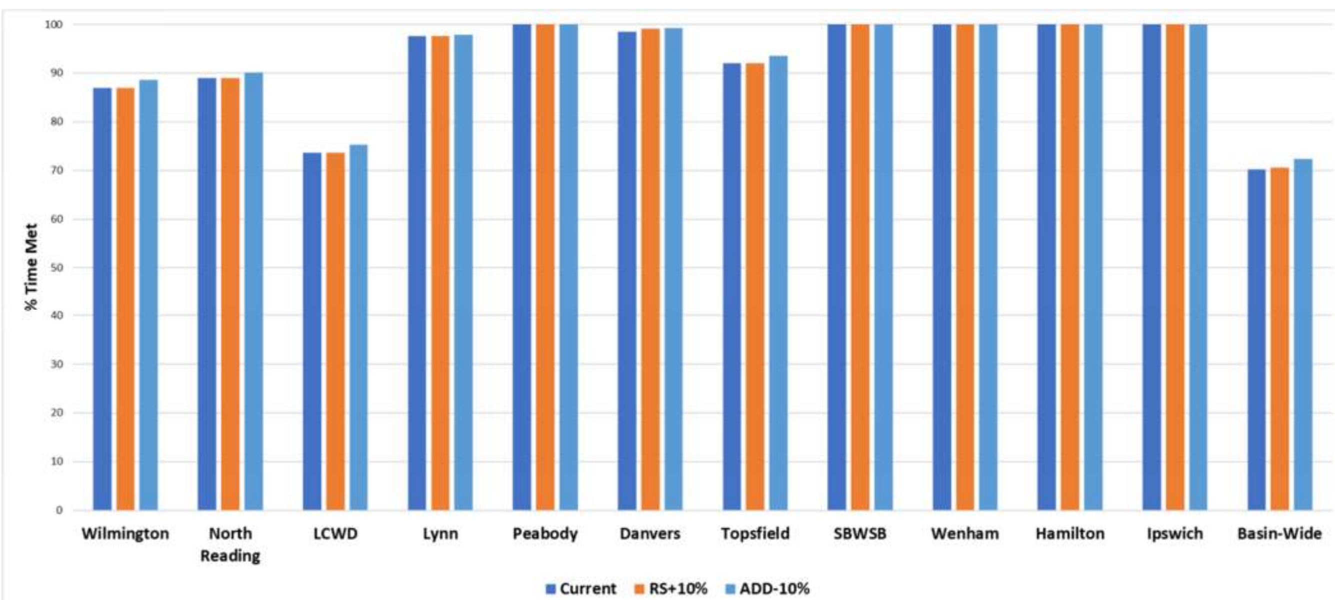

Figure 3-18: Potential Management Scenarios - % Time Met for the Ipswich Basin Communities (with Basin-Wide as Aggregate from All Communities)

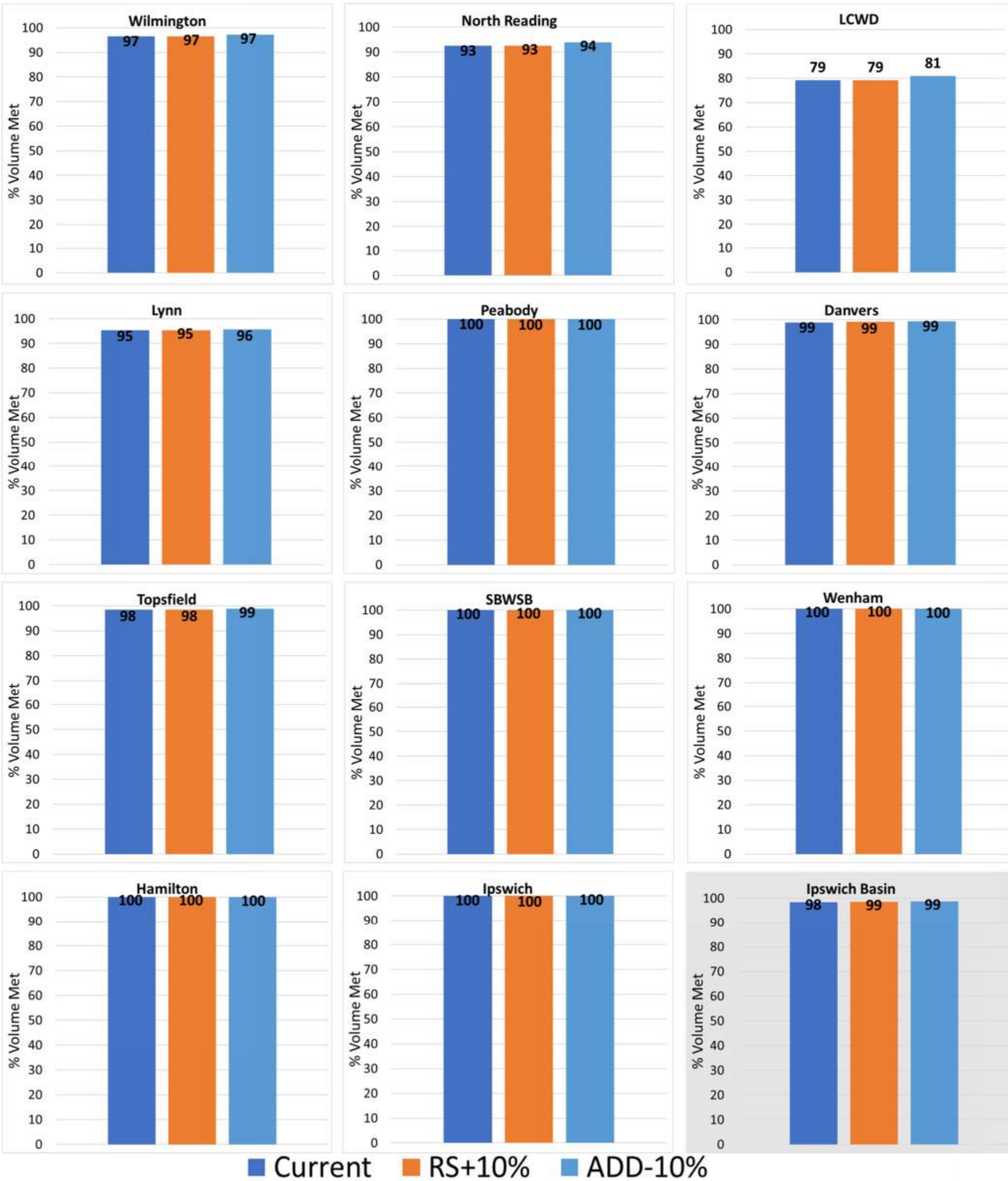

Figure 3-19: Potential Management Scenarios - % Volume Met by Community

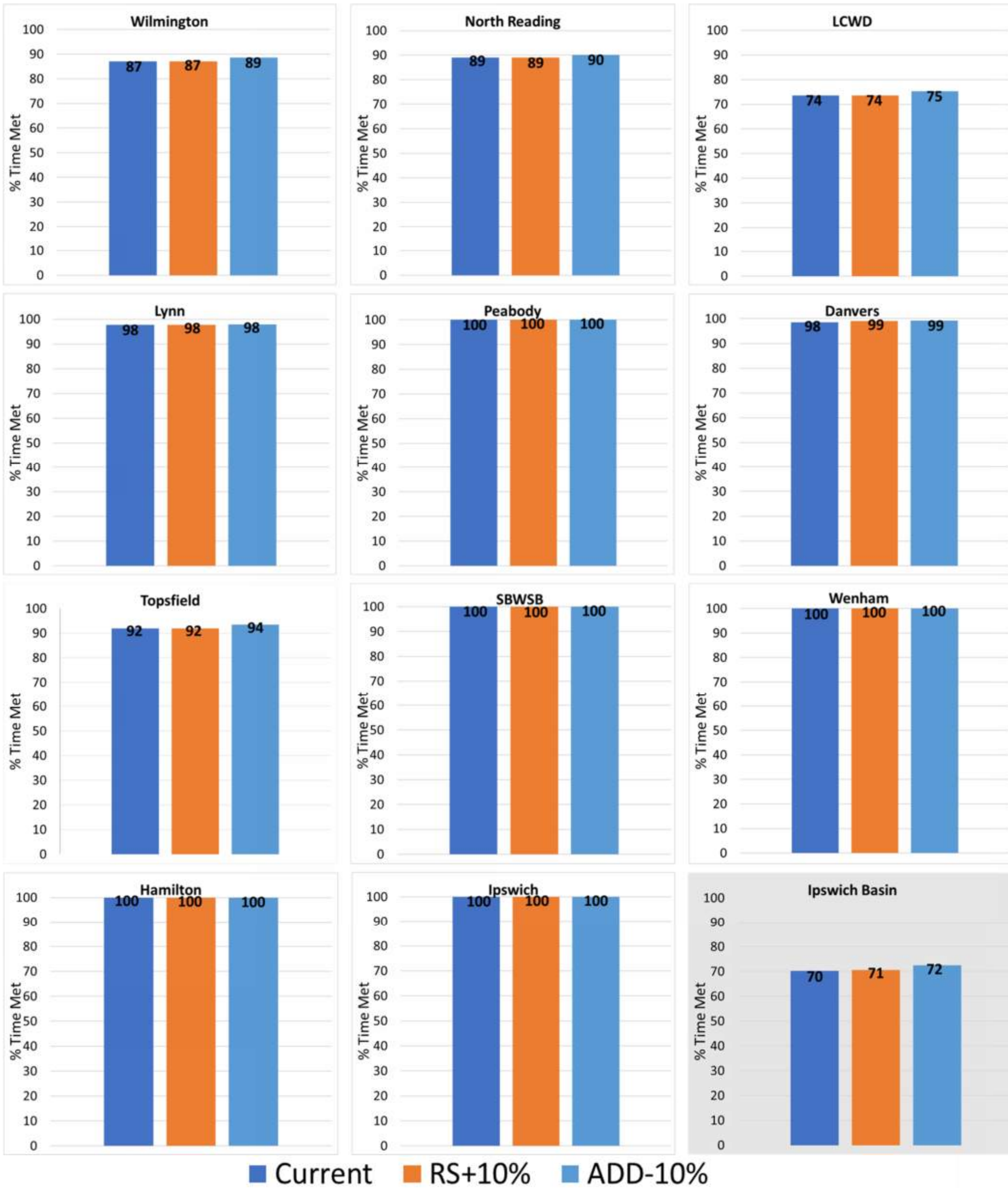

Figure 3-20: Potential Management Scenarios - % Time Met by Community (with Basin-Wide as Aggregate from All Communities)

Effects of the management scenarios on the river were again simulated as the percent of time when the Ipswich River flow is below 52.5 cfs (34 MGD) at the Ipswich Gauge, as seen in Figure 3-21. Increasing the available capacity for the reservoirs Basin or reducing public and registered private demand by 10 percent have no appreciable impacts on the percent of time that the simulated River flow is below 52.5 cfs. While this may be counterintuitive, it suggests that communities that struggle to extract enough water are probably taking about the same volume in the conservation scenario and providing a greater percentage of their lowered demand. This should not be construed as a full-scale or detailed conservation plan that distinguishes between essential and nonessential uses, or changes in demand patterns seasonally. It was a simplified "what-if" analysis to determine the potential to lessen the shortfalls in communities that struggle to produce sufficient water from the basin. Results suggest that conservation alone is not a complete solution.

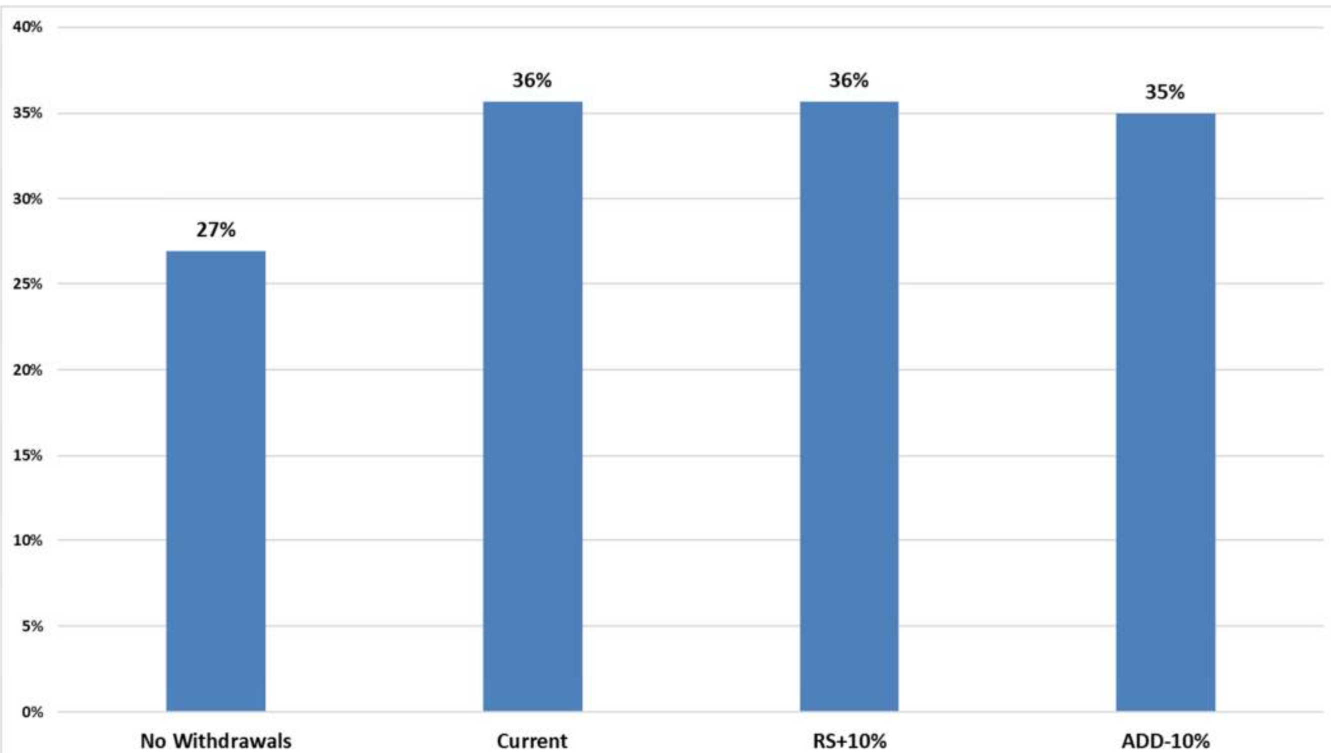

Figure 3-21: Management Scenarios - Percent of Time Streamflow Below 52.5 cfs at the Ipswich Gauge

3.4.1 Water Availability and Possible Sharing Within the Ipswich Basin

One of the initial questions posed at the beginning of this study was if there is enough water in the Ipswich Basin to meet both human and ecosystem/environmental needs. Based on our findings during the sensitivity evaluations and future conditions scenarios, we observed that some communities appear to have sufficient access to water to satisfy their current and future demand: SBWSB, Wenham, Hamilton, and Ipswich. These four communities are either surface water communities that have storage or are not currently withdrawing their maximum allowable withdrawal or are groundwater systems that that are not currently withdrawing their maximum allowable withdrawal. Note that while this study has examined a range of potential hydrologic and demand conditions, the evaluation has not been exhaustive, and the conclusions should be used for planning purposes only, and not as regulatory determinations of water supply adequacy.

The model was used to answer the following hypothetical question on the feasibility of regional or inter-municipal water sharing: if additional water is physically available from the River or aquifers in the vicinity of the withdrawal points for these four communities, could neighboring communities extract what they need in such a way that the collective withdrawals would not exceed the total authorized withdrawal for the Basin?

First, the study quantified the amount of total water available at the withdrawal locations for these four communities by increasing both demand and withdrawals until each community could no longer meet its adjusted respective demands. This quantity of water, which represents the daily volume of water that could be considered “physically available” in the vicinity of the four communities, was characterized as the ***regional offset potential***. The regional offset potential represents water that is physically available in the reaches of the River from these four communities and that could be used to help another community. Second, the study identified all the communities in which water is not always available to satisfy the authorized withdrawal and characterized this need as the ***local authorized shortfall***, or the amount of water that would be needed to fully extract authorized volume.

The IIOM simulated that water is available most of the time in the Basin, but that it is not always at the right place at the right time. The need for water is greater in the summer months when the flow in the River is low, as shown in the Basin-wide graph in Figure 3-22. An important finding is that the potential of water/permit sharing is limited during the two modeled droughts from 1982 and 2002 (and by extension, would likely also be limited during conditions similar to those of the 1960s drought, data for which were not available for this study).

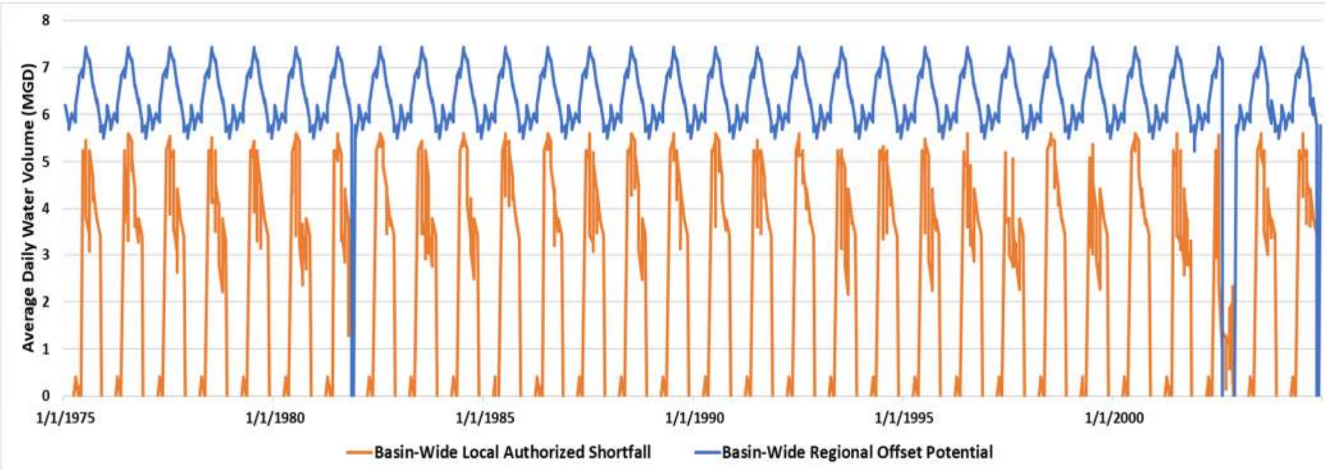

Figure 3-22: Water Sharing Potential in the Ipswich Basin

By comparing the regional offset potential to local authorized shortfalls, we can identify when water may be available in the reach or subwatershed of one community to help another community satisfy its needs, while remaining at or below total authorized withdrawal within the basin. We are not assuming that the regulatory environment is currently amenable to such an arrangement or that regional offset potential communities will share finished or stored water – rather, this was an experiment to address one of the fundamental questions framing this study: "Is there enough water within the Basin to meet demand if it were managed differently?"

In the model, we examined the effects of coupling a river reach (associated with a dependent community) that can satisfy more than the local authorized volume with a neighboring community in which water is not available to satisfy its authorized withdrawal. As an example of water sharing between two areas in the Basin, we conducted experimental simulations with LCWD because they appear to be the community with the most difficulty extracting sufficient groundwater to meet needs, and because they are currently considering importing water.

As we can see in Figure 3-23, although Wenham has regional offset potential within its subwatershed,, this is never sufficient to meet LCWD's shortfall. Two other reach subwatersheds – the Town of Ipswich (Figure 3-24) and SBWSB (Figure 3-25) – have regional offset potential that could offset LWCD's local shortfall. Under a hypothetical joint-permit agreement, LCWD could potentially withdraw directly from where water is available to these two communities, with the combined withdrawals remaining at or below the total authorized volumes.

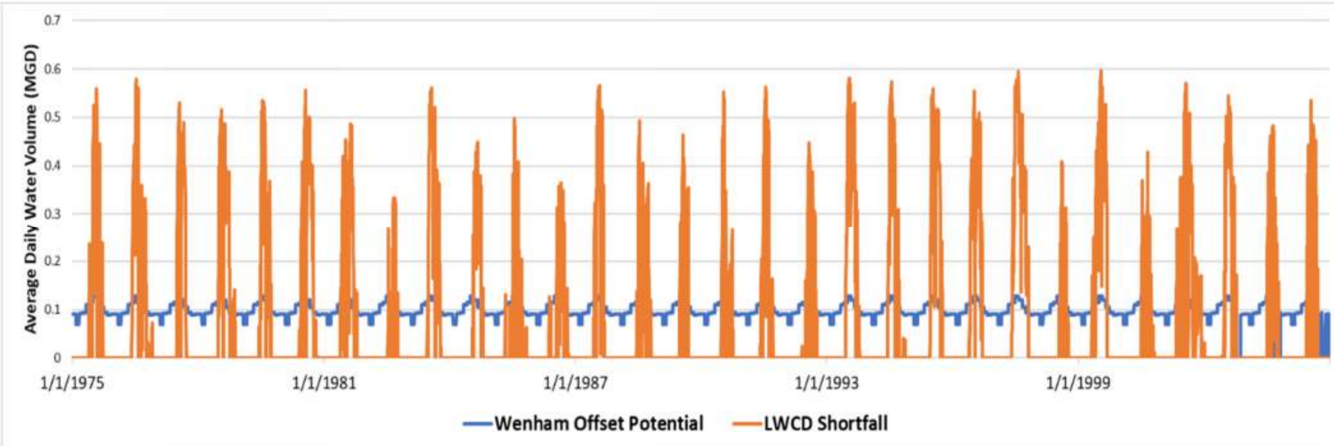

Figure 3-23: Water Sharing Potential between LCWD and Wenham Subwatersheds

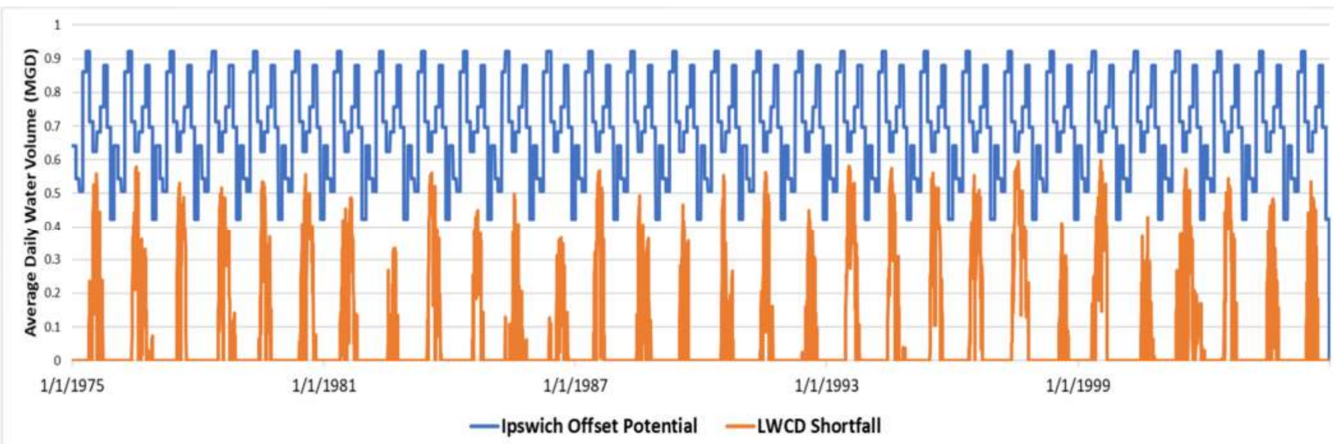

Figure 3-24: Water Sharing Potential between Town of Ipswich and LCWD Subwatersheds

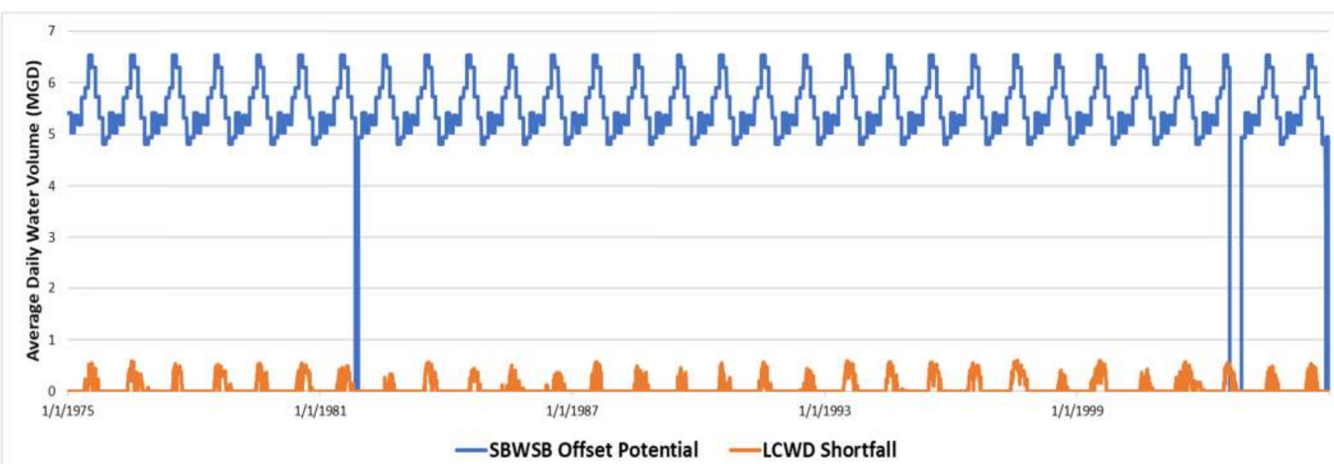

Figure 3-25: Water Sharing Potential between SBWSB and LCWD Subwatersheds

3.5 MWRA TRIGGERS

We have demonstrated that water is likely to be physically available throughout the basin to offset local shortfalls. However, getting that water to the right place at the right time would require significant investment in infrastructure and the restructuring of permits and registrations, even without increases in total authorized withdrawals. As an alternative to local solutions, some communities are considering purchasing water from MWRA.

Following the second workshop, three communities expressed interest in identifying flow triggers that would warrant importation of MWRA water: Danvers, LCWD, and Topsfield. Because all these communities are upstream of the Ipswich gauge, we used the flow measured at the South Middleton gauge as a potential trigger for importing MWRA water. We tested various trigger levels at the gauge that would switch demand from local supplies to MWRA water, with the implied understanding that operational practices might allow blending of the sources together instead of relying on an all of one or all of the other approach. The triggers were varied until all the "requested" supply from the Ipswich Basin could be met and calculated the remaining demand that would be satisfied with MWRA water.

Table 3-3: Flow Triggers at South Middleton Gauge - MWRA Water Importation

	South Middleton Gauge MWRA Trigger Flow (MGD)	Demand from Ipswich Basin (%)	ADD from Ipswich Basin (MGD)	ADD from MWRA (MGD)
Danvers	3	90	2.93	0.33
LCWD	26	41	0.152	0.219
Topsfield	6	81	0.323	0.074

Note: These thresholds represent the experimental minimum flow thresholds that would allow these communities to extract sufficient supply from the Ipswich Basin when the Ipswich River flow is higher than these values. If the communities waited until the river flow was lower, they would likely experience shortfalls before introducing MWRA water.

Table 3-3 shows the flow triggers at South Middleton gauge for Danvers, LCWD, and Topsfield to import water from the MWRA. The table can be interpreted (using LCWD as an example) this way: if LCWD switches from local supply to the MWRA when the river drops below 26 MGD at the South Middleton gauge, it can satisfy all of its needs reliably – on average, approximately 41 percent of its annual yield would come from the basin, and the remaining 59 percent would come from the MWRA. For Danvers and Topsfield, the average dependence on MWRA water to help provide full reliability would be less – only 10 and 19 percent of their respective needs. It may be wise to apply a safety factor to these thresholds, but this experiment indicates the potential value (achieving supply reliability) and average level of dependence that these communities could experience by connecting to MWRA water.

Looking at the historical data and our simulated current flow conditions, the flow at the South Middleton gauge is almost never under 3 MGD, rarely under 6 MGD, and a third of the time under 26 MGD. These reduced flow conditions are observed during the summer months. Table 3-4 shows the simulated percentages the flow at South Middleton gauge is below the triggers for each of the three communities under current conditions and accounting for future human needs and environmental changes. For all three communities, projected growth and climate change will decrease their ability to meet their water needs with exclusively local sources.

Table 3-4: Simulated Frequency of Flow Below Triggers at South Middleton Gauge

Community	Flow Trigger (MGD)	Percent of Flow Under the Trigger		
		Current Conditions	Demand +	CC_high&D
Danvers	3	0%	1%	3%
Topsfield	6	4%	7%	11%
LCWD	26	27%	29%	32%

Based on these simulations, LCWD will need to rely on water suppliers outside of the Ipswich Basin to meet their demand approximately one third of the time. Figure 3-26 shows the demand in LCWD (blue line) and the periods in time when they are not able to meet the demand – periods when they could potentially import MWRA water – in yellow boxes. These periods are seasonal – they appear almost every year in the summer months – and the three figures below show only four years out of the full period of record as an example.

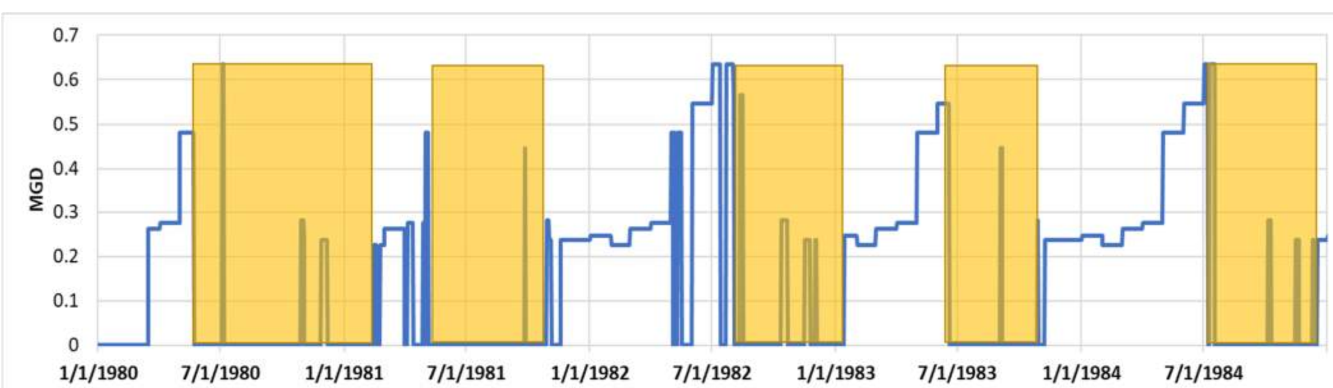

Figure 3-26: Simulation of LCWD Demands from Ipswich Basin for MWRA Water Importation

Similar water need trends are observed for Topsfield (Figure 3-27) and Danvers (Figure 3-28), but the magnitude of the yellow boxes is narrower, which means that the period of time when these two communities need to rely on water from other suppliers is smaller. Section 5 provides an evaluation of alternate routes for importing water from MWRA to serve Danvers, LCWD, and Topsfield.

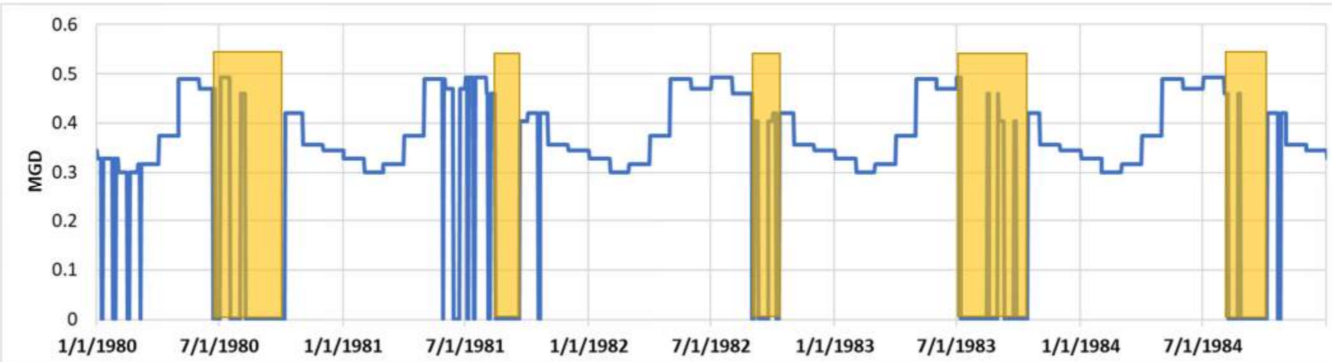

Figure 3-27: Simulation of Topsfield Demands from Ipswich Basin for MWRA Water Importation

Figure 3-28: Simulation of Danvers Demands from Ipswich Basin for MWRA Water Importation

3.6 SUMMARY OF RESULTS

- On average, the Basin can currently provide approximately 98% of the combined demand of its communities from sources within the Basin itself. Generally, the Basin contains enough water to satisfy all authorized needs under current demand conditions, although the water is not always "in the right place at the right time". Communities reliant on groundwater sources are less resilient than those with access to surface water reservoirs.
- Overall, the Basin is not very sensitive to uncertainty regarding the connectivity between surface water and ground water. While lag time between groundwater withdrawals and the corresponding depletion of streamflow, as well as the amount of actual streamflow depletion may affect local resources, these phenomena have little impact on the overall reliability of the Basin supply.
- Basin supply reliability did not change ~~much~~ when streamflow targets were relaxed, or when additional months were added to allowable surface withdrawals.
- During droughts of equal to or greater severity than those experienced in the early 1980s and again in 2002 (the two droughts within the available data time frame), the Basin's efficacy as a self-sufficient supply is strained.
- Climate models predict drier summers and more frequent and severe droughts, and Basin population growth estimates average 7%, with some communities twice as high. Climate change and growth are both expected to significantly diminish Basin supply reliability in the future, with modeled decreases in reliability ranging from 1% to 9%.
- Of the various management alternatives evaluated, the following conclusions were drawn:
    - Demand reduction in the past 10 years has already improved individual system reliability but on its own will not solve the problem long term. A year-round demand reduction of 10% (likely infeasible for many communities) results in only a 1 - 2% improvement in supply reliability over current conditions, both Basin-wide and individually. This finding was similar to that of Zimmerman et. al. (2010) which looked at piloted conservation programs in the Ipswich Basin and found that the potential for reductions ranged from 1 to 9% but that these would have negligible effect on simulated Basin low flows. Incremental benefits of additionally stringent conservation or increasing restrictions on groundwater withdrawals are likely to be overwhelmed by growth pressures and/or climatic effects. Requiring water suppliers to chase these 'diminishing returns' may be increasingly costly and restrictive of economic growth.
    - Additional storage may provide some local or regional buffers against supply shortfalls, but the potential for water shortfalls is greatest in communities without storage, which again points to the issue of the water not being available locally during droughts.

- There is additional physically available water in the Basin for some communities in their respective subwatersheds, and hence, a regional potential for water sharing within the Basin. This study looked at some conceptual opportunities for two or more communities to form regional partnerships in which total authorized withdrawals for participants could be pooled. In such a partnership, water could be distributed from where it is available to where it is needed without exceeding currently authorized aggregate withdrawal amounts. Such arrangements would require regulatory consent, and potentially additional infrastructure and incentives to promote cooperation. Despite the long-standing tradition of home rule decision making and localized water infrastructure in the basin, these may become viable alternatives to the importation of water from outside the Basin.
- MWRA water is a reliable alternative for communities whose supplies are vulnerable during dry or even normal conditions. Alternative routes for delivery of MWRA water were evaluated for three of the Grant Partners. The cost of MWRA water and associated the infrastructure, as well as the long-term reliability, should be compared to the costs and efficacy of in-Basin water sharing. The flow in the Ipswich River can serve as a reliable trigger for identifying when MWRA water should be brought in, without waiting too long during dry periods (and increasing the risk of shortfalls) or engaging the connection too early when dry conditions appear imminent (and not taking advantage of the local supplies to the extent possible).
- Importing water from MWRA was examined for three communities that cannot always extract the desired amount of Ipswich Basin water, and who are already considering connections to the MWRA system; Danvers, Lynnfield Center, and Topsfield. The study suggests that augmenting their respective supply systems with MWRA water could provide sufficient amounts of water, and that the flow at the South Middleton Gauge could be a useful trigger of when to switch from local supplies to MWRA water. The triggers would be different for each community, as would the average dependence on MWRA water, but connections to MWRA using the South Middleton Gauge as a trigger could be a viable alternative for satisfying future demand.

4 REGIONAL PERMIT / CREDIT SYSTEM CONCEPT

4.1 CHALLENGES OF THE EXISTING PERMIT SYSTEM

The operational model developed for this project illustrates that the Basin can provide enough domestic water under current physical and permitted conditions. However, it may not always be ‘in the right place at the right time.’ The wheeling of water from one community to another may represent a potential in-Basin solution in certain cases. However, the financial and political barriers to more regionalized sharing of in-Basin supply, or the creation of new or expansion of existing reservoirs, may be too difficult to overcome in the foreseeable future.

Regionalization of water allocation permitting is one strategy that could help regulated water suppliers to achieve greater flexibility of operations and potential sharing of the administrative burden of complying with Water Management Act Permit restrictions. The concept of a watershed-based WMA permit which jointly permits two or more water suppliers will be explored in this section.

In areas where watersheds experience groundwater or streamflow depletion, regulatory agencies nationwide have increasingly implemented restrictions at the watershed scale intended to restore instream flow and minimize environmental impacts such as annual and/or daily withdrawal limits. As is the case for the Massachusetts WMA permittees in the Ipswich Basin, these can also include time of year withdrawal restrictions, groundwater pumping restrictions tied to river flow thresholds, seasonal cap requirements, and demand-management requirements (residential usage performance standards, establishment of water banks, etc.).

A key challenge is that the restrictions are imposed at the individual supplier scale. Suppliers vary in their size, resources, and ability to independently comply with regulatory mandates. Multiple utilities in close proximity operate in isolation. With the revised WMA regulations under the SWMI framework, this fragmentation will be increasingly highlighted as minimization and mitigation requirements are triggered and communities individually look for ways to implement solutions under the MassDEP mitigation credit system. If multiple utilities had incentives to collaborate in order to achieve compliance, there could be expanded opportunities to reduce costs, increase flexibility, and achieve greater environmental benefits than could be accomplished in isolation.

4.2 A WATERSHED-SCALE ‘CAP AND TRADE’ APPROACH FOR WATER PERMITTING

Systems of tradeable credits have been used widely in energy and pollution trading systems (‘cap and trade’). A review of literature suggests the use of such a system has not yet been applied for meeting water supply permit conservation goals. However, recently researchers at Stanford University published a study which applied this concept to a case study of communities in the Bay Area of California (Gonzales et. al, 2017, Water Resources Research) and concluded that economic benefits can be achieved when structures and incentives are appropriately defined. In Massachusetts, the planned implementation of watershed-based permits for nitrogen reduction may also serve as a precedent.

4.3 PRECEDENT IN MASSACHUSETTS: PLEASANT BAY DRAFT WATERSHED NITROGEN PERMIT

Nutrient reduction required by Total Maximum Daily Loads has been recognized nationally as an effort that can be implemented effectively using a program of watershed scale permits and accompanying credits or trading framework. This is because regulatory agencies have recognized that limiting efforts to municipal boundaries creates administrative, financial, logistical, and legal barriers which delay progress of implementation. Watershed-based nutrient permit programs have been successfully implemented in a number of states, including Connecticut and Maryland, based on the collective impacts to a receiving water body. This can be thought of as analogous to collective impacts on a water supply source.

Until recently, this framework had yet to be adopted in Massachusetts. However, it is just now underway in a pilot program on Cape Cod. In 2015, the Cape Cod 208 Plan Update (Cape Cod Commission, June 2015) was issued to establish a technical, planning, and regulatory basis for achieving nutrient load reduction from point and non-point sources. This document recommended as a central feature of its approach the development of a watershed permit to help achieve load reduction goals for Watershed Management Plans using a more regionalized and flexible approach.

MassDEP worked with stakeholder groups on development, and in March 2018, a draft pilot permit was created for the Pleasant Bay watershed. The Pleasant Bay Draft Watershed Permit includes a draft Intermunicipal Agreement (IMA) between the Towns of Brewster, Chatham, Harwich, and Orleans. The primary components of the Draft Pleasant Bay Watershed Permit include the following:

- The parties agree to be named as joint permittees, with nitrogen reduction requirements allocated at the same percentage as nitrogen loads.
- The parties agree to share on a fair and equitable basis the capital, operational, administrative, legal, and operational expenses for developing a regional watershed based nutrient management system.
- The parties agree to develop a fair and equitable method for a nitrogen trading mechanism, along with metrics and 'currency'.
- Parties may agree to mutually fund joint nitrogen reduction implementation efforts.
- Parties agree to cooperate to identify, secure, manage, and allocate funding.

4.4 A CONCEPTUAL FRAMEWORK FOR WATERSHED-BASED WATER MANAGEMENT ACT PERMITTING IN THE IPSWICH BASIN

Below we outline a preliminary conceptual framework for watershed-based WMA Permits that could cover multiple water suppliers in the Ipswich Basin:

Conceptual Watershed-Based Water Management Act Permit Framework, Ipswich Basin*
Benefits:
• **Promotes holistic basin water availability protection and opportunities for sharing of resources, administration, and technology between Partners.** • **Provides greater flexibility in management of sources.** • **Utilizes existing regulatory framework.**
Conceptual Provisions:
• **Two or more participating public water suppliers ('Partners') within the Ipswich Basin request to be jointly issued a WMA Permit.** • **Partners enter into a Inter-municipal Agreement to implement Permit provisions in a fair and equitable way.** • **Partners' individual groundwater and surface water sources are 'pooled' onto a single WMA Permit.** • **Maximum annual authorized withdrawal totals would apply <u>in the aggregate</u> for the pooled sources** • **Option to manage individual source maximum daily rates <u>in the aggregate</u> if one Partner can't satisfy local demand without exceeding the max but another Partner has water available either within its individual allowable threshold or within the combined aggregate allowable threshold of the Partners** • **Wellhead Protection; Zone II Delineation standards unchanged** • **Non-essential outdoor water use triggers remain unchanged** • **Individual source gauge or time of year restrictions unchanged.**

Conceptual Watershed-Based Water Management Act Permit Framework, Ipswich Basin*

- **Ipswich Performance standards apply in the aggregate for Partner sources**
    - **UAW 10%**
    - **RGPCD 65**
    - **Seasonal Water Cap**
- **Partners implement a joint enhanced Water Conservation Plan (promotes sharing of resources, administration, technology)**
- **Minimization Planning conducted in the aggregate for Partner sources**
- **Mitigation Planning conducted in the aggregate for Partner sources.**
- **For sources in same Net Groundwater Depleted sub-basin category, allow mitigation banking / credit trading**
    - **Direct**
        - **Wastewater offsets**
        - **Surface water releases**
        - **Stormwater recharge projects**
        - **I/I removal**
    - **Indirect**
        - **Dam removal**
        - **Streambank restoration**
        - **Fish ladders**
        - **Property acquisition for resource protection**

**Note: This framework is provided for discussion purposes only. Inclusion of the framework or any of the draft elements presented above does not imply acceptance by any of the Grant Partners jointly or individually.*

The full development of such a watershed-based Permit would require a series of discussions with MassDEP, interested suppliers, and other stakeholders. Ideally it could be accomplished under the existing regulations. Administration of a joint Permit could likely be handled via inter-municipal agreement, particularly if there are a limited number of joint permittees. For a more regional group of joint permittees, a Joint Power Entity may be needed to provide a separate neutral legal entity.

5 MWRA WATER SUPPLY

During the 2017 Ipswich Basin study, the importation of water supply from the MWRA Water System for the Basin communities was identified as a potential solution for supply shortages. This could be accomplished either via a new dedicated supply pipeline to one or more Ipswich Basin communities, or possibly by "wheeling" water through an MWRA-served community to an adjacent Basin community. The need or desire for certain communities to explore the purchase of water from the MWRA was clarified during the current project model development and stakeholder workshops. General requirements and benefits of admission to the MWRA Water System, along with water quality information, are described below in Sections 5.1 and 5.2. Three water suppliers expressed potential interest in MWRA water supply: Lynnfield Center Water District (LCWD), Danvers Water Department (serving Danvers and Middleton) and Topsfield. An alternatives evaluation for serving each (either directly, or via wheeling) is presented below in Section 5.3.

5.1 MWRA ADMISSION

5.1.1 Requirements

Communities that can demonstrate that they are unable to meet water demand with local in-basin options can become a member of the MWRA Water System. For a community to be admitted to the MWRA water system, it must provide thorough documentation complying with the MWRA's Enabling Act. The Act ensures the applicant community has undertaken extensive measures to meet drinking water demand with their local sources and is still unable to meet its needs. In addition to providing detailed documentation, the community must also provide the following based on the MWRA admission policy (Admission of New Community to MWRA Water System Policy #: OP.10):

- Approvals from the Secretary of Environmental Affairs through the MEPA permitting process, the Water Resources Commission through the Interbasin Transfer Act Process, the MWRA Advisory Board, the MassDEP on local source feasibility, the General Court, and the Governor
- Description of programs undertaken by the community related to water conservation and accountability.
- Plans for water conservation that follow the Commonwealth's water conservation standards.

- Municipal zoning and non-zoning provisions designed to conserve and protect the local water supply.
- Documentation of studies conducted on existing and potential local water safe yield, protection needs, threats of contamination, and future water demand predictions.
- A breakdown of the community total water consumption (residential, industrial, commercial, etc.)
- Local Water Supply Management Plan.

Once the application for admission is submitted to the MWRA, it reviews the documentation and analyzes the impact of the proposed additional water demand on the MWRA Water System. Once approved, a Water Supply Agreement establishes terms and conditions. Typically, the admitted community must pay all construction costs associated with the water system connection and an entrance fee and continue to implement water conservation measures proposed in the application.

5.1.2 Costs and Funding Sources

An entrance fee is charged to cover the new community's fair share costs of the MWRA water system at the time of entry to the system. Entrance to the MWRA water system can be paid either as one lump sum payment or over 25 years without interest and with a three-year grace period. Communities that need to increase their approved withdrawal amount are also eligible for the interest free payment plan. The estimated amount of water supply needed from the MWRA is based on a detailed analysis of historic water use trends in the applicant community's water system including future water demand projections, available local supply, and resulting supply deficit. If the new community is already under an MWRA emergency supply agreement and has been assessed payments for that agreement, then those costs will be treated as credits towards the entrance fee.

The current Net Asset Value (NAV) of the MWRA Water System is $907,530,000 (personal communication, MWRA, May 2018). The 2014-2018 average daily MWRA Water System water use is approximately 206 MG. Kleinfelder used the average use to calculate the total entrance fee for each community. In OP.10 the formula for the total entrance fee is 75% of NAV allocated to average use plus 25% of NAV allocated to peak six-month system use. The system connection fee for the average use is based on the ratio of the average daily supply provided to the new member community and the total MWRA system demand. For instance, if the water supply provided by the MWRA is 1% of the MWRA's average daily system demand the entrance fee will be 1% of the MWRA NAV. The 2018 estimated entrance fee for 1 MGD of MWRA water supply is $4.4 million (1 MG / 206 MG x $907,530,000), and the wholesale water rate per million gallons is approximately $3,900 for FY19.

Understanding that there are significant costs facing communities who wish to connect to the MWRA or other regional water supplies, the Massachusetts Legislature granted authority for additional financial incentives as outlined below.

> **MassDEP Drinking Water State Revolving Loan Fund regulations, 310 CMR 45.00***:* The SRF regulations were amended to include language incorporating language from SECTION 23 of Chapter 259 of the Acts of 2014. *(e) The department shall promulgate regulations under section 7 establishing the types of eligible projects and criteria that the department shall use to evaluate applications for additional financial assistance, including principal forgiveness and additional financial incentives, consistent with the sustainability criteria as determined by the United States Environmental Protection Agency as required by the Water Resources Reform and Development Act of 2014. The financial assistance and financial incentives provided under these regulations shall be made available to projects appearing in the department's intended use plan the year following the release of regulations by the department and subsequent years. Such criteria may include, the following requirements, any 1 of which shall be sufficient to qualify the project for assistance: (i) the project is pursuant to a regional wastewater management plan that has been adopted by a regional planning agency with regulatory authority;* ***(ii) the project is necessary to connect a local or regional local governmental unit to a facility of the Massachusetts Water Resources Authority, if the local or regional local governmental unit has paid or committed to pay the entry fee of that authority;*** *(iii) the project is a green infrastructure project, as definedin section 26A of chapter 21, with consideration being given to projects that effectively combine green infrastructure with wastewater infrastructure and drinking water infrastructure projects;* ***(iv) the project uses regional water resources to offset, by at least 100 per cent, the impact of water withdrawals on local water resources in the watershed Basin of the receiving community;*** *(v) the project is a direct result of a disaster affecting the service area that is the subject of a declaration of emergency by the governor; (vi) the project is intended to provide public water supply to consumers whose groundwater or public or private wells are impacted by contamination; or (vii) the program is an innovative water project utilizing new technology, which improves environmental or treatment quality, reduces cost, increases access and availability of water, conserves water or energy or improves management, in the areas of drinking water, wastewater, stormwater, groundwater or coastal resources; provided, that the project has not been fully implemented, other than as a pilot project, previously in the commonwealth.*

The above section of the law is intended to help communities defray the cost of the physical connection to the MWRA or other regional supplier. As discussed above, a new pipeline may be needed through Danvers to Topsfield; monies could be appropriated through the State Revolving Loan Fund to fund this project with principal forgiveness granted. Funding might also be secured to expand existing reservoirs if that expansion would allow for a community to offset their impact to the Basin.

> **Chapter 29, Section 2NNNN: Regional Water Entity Reimbursement Fund** *[Text of section added by 2014, 259, Sec. 17. See also, Section 2NNNN added by 2014, 286, Sec. 13, below.] Section 2NNNN. There shall be established and set up on the books of the commonwealth a separate fund to be known as the Regional Water Entity Reimbursement Fund, in this section called the fund. The fund shall be administered by the state treasurer and shall be funded by the commonwealth, by and through the state treasurer and subject to appropriation, to reimburse the Massachusetts Water Resources Authority for its costs: in providing cities and towns, within its sewer service area, financial assistance in the form of interest free grants and loans to rehabilitate collection systems in cities and towns; and to structurally reduce infiltration and inflow into the tributary to the treatment facilities owned by the authority. Such reimbursement shall be in addition to the contract assistance amounts in section 6 of chapter 29C, subject to the limit set forth in said chapter 29C, but shall not be greater than 10 per cent of the maximum amount set forth in said chapter 29C.*

The Basin's legislative delegation should be approached to support appropriation of funding authorized to assist communities who wish to pursue MWRA connection as an option for the future.

5.1.3 Benefits

The MWRA cites several community benefits for potential applicants to consider. According to information provided by MWRA (General Member Benefits, 2018) these include abundant supply, excellent water quality, and local assistance (technical, educational and financial). The MWRA has an abundant capacity to continue to serve existing areas along with new communities to support growth and development. MWRA's current demand is well below their registered volume of 311.9 MGD. With projected growth in the service area and reasonable expansions considered, even during a drought the MWRA would not need to impose mandatory water use restrictions due to the abundant amount of drinking water in the Quabbin and Wachusett Reservoirs.

The excellent water quality is due to protected watersheds and large reservoirs. The water leaving the reservoir is pure enough that the MWRA is not required by EPA rules to provide chemical filtration, unlike most other large water systems in the nation. The John J. Carroll Treatment Plant is fed from the Wachusett Reservoir and is treated with ozone, ultra-violet light, sodium carbonate, carbon dioxide, fluoride, and chloramines.

A Local Water System Assistance Program (LWSAP) is implemented by the MWRA. The program provides $210 million in interest free loans for water system improvement projects. The financial assistance from the MWRA helps local water systems to maintain and improve water quality. Fully supplied communities receive free water quality lab services from the MWRA because they are covered under MWRA's compliance and sampling plans. MWRA collects, analyzes, and reports on any samples including raw water samples. Along with the free lab services, the MWRA offers staff training at no cost. The training includes water quality, management of the distribution system, and public interest issues.

Another benefit the MWRA provides is technical and emergency assistance to communities in need. These services include emergency advice, troubleshooting and emergency disinfection equipment, special water quality sampling, modeling assistance, equipment loans and advice to communities that have storage tank and water age problems. The MWRA cites their working relationship with the DEP as helping to assist in resolving issues. The MWRA encourages water conservation and provides education along with a variety of related services.

5.2 MWRA WATER QUALITY COMPATIBILITY

The Quabbin Reservoir supports more than two million people with a capacity of 412 billion gallons of water. The water is transferred from the Quabbin Reservoir to the Wachusett Reservoir to provide water for Metro West and Metropolitan Boston. The water in the reservoirs is tested for over 120 contaminants. The MWRA performs several hundred tests on the system a year. The MWRA provides water that meets the standards of the EPA and Massachusetts DEP. Along with the testing, the MWRA monitors their raw water and treated water for various parameters including disinfection, corrosivity, and organic and inorganic material in the water. The pH and the alkalinity of the Wachusett water is adjusted by the MWRA to reduce corrosivity, minimizing lead and copper from getting into the water from service lines and home plumbing systems. MWRA's distribution pH is targeted at 9.3, while alkalinity is 40 mg/L. Through MassDEP requirements, samples from the plant must have a minimum pH level of 9.1 and 37 mg/L for alkalinity. Results from the samples must not be below these requirements for more than 9 days within a six-month period.

As previously stated, the MWRA water is treated with chloramines, unlike the finished water of LCWD, Danvers, and Topsfield, where the water is treated with chlorine. Obtaining MWRA supply in these water systems will create a mixing of water treated with chloramines and chlorine, which can cause water quality issues in the water system. Operators of distribution systems can blend chlorine and chloramine based on analysis and system modeling. The operators should also incorporate ammonia, nitrites, and monochloramines into the existing monitoring program to determine the chlorine status at different locations. The chlorine to chloramine ratio should be above 70:30 at all times based on the system's average daily use. Poor blending of chlorine and chloramine can result in taste and odor complaints. The towns that are interested in an MWRA connection may want to consider switching from chlorine to chloramine treatment for their existing sources to minimize the change for potential problems.

5.3 ALTERNATIVE PIPELINE ROUTES

As previously stated, the three Grant Partner water suppliers interested in potentially connecting to the MWRA system in the future are the LCWD, Danvers, and Topsfield. Potential pipeline connection routes were evaluated for each water system. Each alternative included costs associated with MWRA entrance fees, installation of water meter equipment, pump station(s), and allocations for engineering and contingency.

Cost estimates for these items are based on similar work by Kleinfelder and the MWRA. The MWRA entrance fee calculation is summarized in Section 5.1.2. MWRA is currently engaged in discussions with the City of Peabody which may result in extension of the the system to the west side of the City. and the cost estimate for the pipeline project is $1,430 per linear foot (construction cost). The proposed MWRA pipeline is 24 -inch diameter and the route is within Route 1 (see Figure 5-1). This cost estimate is reflective of the added complexity of the need for night work and traffic control on the highway as well as rock excavation and utility relocation adding to the high unit cost. A $1,430 per linear foot cost would be highly conservative if used to represent the cost to connect to the community water systems. Kleinfelder designed and oversaw construction for a 20-inch MWRA connection pipeline project in Woburn, which was bid by the Town of Wilmington at a construction cost of $450 per linear foot. To estimate the extension of the MWRA water system, for each community we used an estimated unit cost of $400 per linear foot to estimate the construction cost for a 12" ductile iron pipeline. We based our unit cost on a combination of MassDOT weighted average big costs, similar project experience, and engineering judgement.

Based on similar projects we used estimated costs of $300,000 for water metering equipment vault and $2,000,000 for each pump station. Kleinfelder included allocations of 25% of the construction cost for engineering and contingency at this conceptual planning stage. These two allocations were combined as one contingency amount and represented as 50% of the subtotal cost of each alternative. We then escalated costs to 2025 to account for a 7-year planning, permitting and design period.

It was assumed that for all alternatives, permitting will include the preparation of an Environmental Impact Report (EIR), a wetlands Notice of Intent (for work in buffer zone) and an Interbasin Transfer Act Decision. These costs were collectively estimated at $300,000.

5.3.1 Lynnfield Center Water District (LCWD)

The LCWD is interested in improving its water supply reliability and resiliency potentially via inclusion of MWRA supply. LCWD has three existing interconnections with the Town of Lynnfield, and interconnections with Wakefield and Peabody. These interconnections allow for emergency water supply and a potential to wheel MWRA water supply through these communities. The interconnections are located outside of wetland areas and priority habitats of rare species zones which makes them suitable for future construction.

5.3.1.1 LCWD Alternative 1

We evaluated two potential routes for the LCWD to connect to the MWRA system. Alternative 1 is a direct pipeline from the new MWRA distribution main the MWRA is planning to construct to the Town of Peabody to the existing interconnection on Summer Street in Lynnfield. Alternative 1 indicates LCWD entirely relies on MWRA for water and no longer uses other sources of drinking water. This alternative consists of 0.3 miles of pipeline along a residential road in Lynnfield (See Figure 5-1). Along with the pipeline construction costs, this alternative also requires installation of a pump station, and a water meter. For a volume of 0.75 MGD (summer demand), LCWD would be charged an MWRA entrance fee of $3.3 Million, as seen in Table 5-1. Other costs include the preparation of an Environmental Impact Report (EIR) cost along with permitting and applications to add up to $300,000.

Table 5-1: LCWD Alternative 1

Direct pipeline along Summer Street from Peabody town line to existing water system	
Activity	**Estimated Cost $**
Pump Station from MWRA 229 feet NAVD88 to Lynnfield Center 262 feet NAVD88	2,000,000
12" pipe 0.3 miles of new MWRA distribution pipe to LCWD interconnection	610,000
Meter at interconnection	300,000
Construction Sub-total	**2,910,000**
Engineering and Contingency Costs (50%)	1,455,000
Entrance fee to the MWRA System (0.75 MGD)	3,300,000
Permitting	300,000
TOTAL (2018)	**7,970,000**
TOTAL IN 2025 DOLLARS	**9,400,000**

5.3.1.2 LCWD Alternative 2

Another alternative for LCWD is to consider wheeling water through Lynnfield. Lynnfield is already a member of the MWRA, and three interconnections exist and are used for emergency water supply. This alternative requires LCWD to still enter the MWRA system, but the wheeling potential means little to no pipeline construction. Lynnfield already pumps water into their system meaning no pump needs to be installed to wheel the water. We did not have access to GIS information on Lynnfield Water District's system so for the purposes of this cost estimate no pipeline costs were included. An Interbasin Transfer Act Permit application must be filed to wheel the water through one town to supply another.

Table 5-2: LCWD Alternative 2

Wheeling water through Lynnfield to LCWD	
Activity	**Estimated Cost $**
Meter System at Interconnection	300,000
Construction Sub-total	**300,000**
Engineering and Contingency Costs (50%)	150,000
0.75 MGD Entrance fee to the MWRA System	3,300,000
Permitting and Applications	300,000
TOTAL (2018)	**4,050,000**
TOTAL IN 2025 DOLLARS	**4,780,000**

Alternatives 1 and 2 above assumes 100% of LCWD's demand being served by the MWRA. To decrease costs, LCWD could apply for 0.16 MGD, which would be used during peak demand times and the summer. This 0.16 MGD estimated entrance fee is $700,000 resulting in the total cost of connecting to the MWRA in this case to be about $5,370,000.

5.3.2 Danvers Water Department

Through historic data and modeling analysis, it has become apparent that Danvers has issues meeting demand during significant droughts. In the future, an MWRA connection could be used to supplement additional supply during shortages.

5.3.2.1 Danvers Alternative 1

The Danvers Water Department has already considered connecting to the MWRA as a potential option for their supply resiliency and growing service population (Danvers and Middleton). One possible route for Danvers to connect to MWRA water is through a direct pipeline from the new MWRA Peabody extension, north along Route 1, cross to Route 114 and connect to an already established interconnection at the Danvers-Peabody Townline. This alternative is shown in Figure 5-2. Like the LCWD direct connection, this alternative requires a pump station, and a metering system located at the town line. Kleinfelder has assumed Danvers may request 1 MGD from the MWRA, which corresponds with the entrance fee of $4.4 Million.

Under Alternative 1, construction of the pipe will take place along major roads and does not go through wetlands or priority habitats of rare species. The estimated length of the potential 24-inch pipe is 3.1 miles (refer to Figure 5-2).

Table 5-3: Danvers Alternative 1

Direct pipeline along Route 1 from Peabody Town line to Danvers Town line	
Activity	**Estimated Cost $**
Pump Station from MWRA 229 feet NAVD88 to Danvers 234 feet NAVD88	2,000,000
12" pipe 3.1 miles of new MWRA distribution pipe to Danvers interconnection	6,550,000
Meter System at Interconnection	300,000
Construction Sub-total	**8,850,000**
Engineering and Contingency Costs (50%)	4,420,000
1 MGD Entrance fee to the MWRA System	4,400,000
Permitting	300,000
TOTAL (2018)	**17,970,000**
TOTAL IN 2025 DOLLARS	**21,210,000**

5.3.2.2 Danvers Alternative 2

Another option Danvers for to obtain water from the MWRA is potentially wheeling water through the Town of Peabody's water distribution system to Danvers. Peabody and Danvers have an existing interconnection between the two towns, and currently Peabody has a partial/emergency arrangement with the MWRA. This alternative assumes that Peabody joins the MWRA along with Danvers. The tank elevation in the Town of Danvers is below the tank elevation of the Town of Peabody. This requires a control valve to control the flow of water between the two communities instead of installing a pump. This wheeling option requires an Interbasin Transfer Act permit similar to LCWD's second alternative.

Table 5-4: Danvers Alternative 2

Wheeling water through Peabody to Danvers	
Activity	**Estimated Cost $**
Proposed Control Valve	300,000
Meter System and pressure regulator station at Town line	300,000
Construction Sub-total	**600,000**
Engineering and Contingency (50%)	300,000
Entrance fee to the MWRA System	4,400,000
Permitting	300,000
TOTAL (2018)	**5,600,000**
TOTAL IN 2025 DOLLARS	**6,610,000**

5.3.3 Topsfield Water Department

The Topsfield Water Department is considering a connection to the MWRA for supplementing its water supply. The Town of Topsfield is not adjacent to an MWRA community so there are more complex options to connect it to the MWRA system. Topsfield is interested in a volume of 0.8 MGD for operational flexibility and for longer term growth.

5.3.3.1 Topsfield Alternative 1

Alternative 1 is a direct pipeline connecting the MWRA to the Topsfield at the town line. This alternative requires 6.3 miles of pipe along highways and residential roads as shown in Figure 5-3. This route avoids impacts to priority habitats of rare species and wetlands.

Table 5-5: Topsfield Alternative 1

Direct pipeline from Peabody Town line to Topsfield Town line	
Activity	**Estimated Cost $**
Pump Station from MWRA 229 feet NAVD88 to Topsfield 262 feet NAVD88	2,000,000
12" pipe 6.3 miles of new MWRA distribution pipe to Topsfield interconnection	13,310,000
Meter System at Interconnection	300,000
Construction Sub-total	**15,610,000**
Engineering and Contingency Costs (50%)	7,800,000
Permitting	300,000
0.8 MGD Entrance fee to the MWRA System	3,520,000
TOTAL (2018)	**27,230,000**
TOTAL IN 2025 DOLLARS	**32,130,000**

5.3.3.2 Topsfield Alternative 2

Alternative two is wheeling water through Peabody through Danvers to Topsfield. This alternative minimizes the amount of construction since these towns have existing connections with the adjacent towns. This alternative assumes that all three towns become members of the MWRA. The hydraulic grade line in Danvers is lower than Peabody's and will require a control valve since the system is gravity fed, unlike Topsfield, who is higher than Danvers, so a pump station will be required. Both interconnections will need a meter to monitor the amount of water entering and leaving each system.

This wheeling alternative also includes an Interbasin Transfer Act permit and an Environmental Impact Report (EIR).

Table 5-6: Topsfield Alternative 2

Wheeling water through Peabody through Danvers to Topsfield	
Activity	**Estimated Cost**
Proposed Pump Station	$ 2,000,000
Meter System at Interconnections (2)	$ 600,000
Proposed Control Valve	$ 300,000
Construction Sub-total	**$ 2,900,000**
Engineering and Contingency Costs (50%)	$ 1,450,000
0.8 MGD Entrance fee to the MWRA System	$ 3,520,000
Permitting	$ 300,000
TOTAL (2018)	**$ 8,170,000**
TOTAL IN 2025 DOLLARS	**$ 9,650,000**

5.3.3.3 Topsfield Alternative 3

Alternative three is wheeling water through Danvers to Topsfield, assuming Danvers has a direct connection (see Alternative D1). The location of the two towns makes wheeling between the two possible (Figure 5-4). This cost estimate includes all prices from Alternative D1 and cost of two meters and two pumps. This wheeling alternative also includes an Interbasin Transfer Act and an Environmental Impact Report (EIR).

Table 5-7: Topsfield Alternative 3

Wheeling water through Danvers to Topsfield, assumes Alt D1 pipeline happens	
Activity	**Estimated Cost**
2 Pump Stations: from MWRA 229 feet NAVD88 to Danvers 234 feet NAVD88; Danvers to Topsfield 262	$ 4,000,000
12" pipe 3.1 miles of new MWRA distribution pipe to Danvers interconnection	$ 6,550,000
Meter System at Interconnections (2)	$ 600,000
Construction Sub-total	**$ 11,150,000**
Engineering and Contingency Costs (50%)	$ 5,570,000
0.8 MGD Entrance fee to the MWRA System	$ 3,520,000
Permitting and Applications	$ 300,000
TOTAL (2018)	**$ 20,540,000**
TOTAL IN 2025 DOLLARS	**$ 24,240,000**

6 SUMMARY AND CONCLUSIONS

The results presented in this report do not necessarily constitute recommendations for infrastructure investment or inter-municipal agreements, but rather, help support ongoing deliberations with additional information on the potential opportunities within the Basin and beyond its borders to enhance the long-term reliability of its water supply. The key findings can be summarized as follows:

- On average, the Basin can currently provide approximately 98% of the combined demand of its communities from sources within the Basin itself. Generally, the Basin contains enough water to satisfy all authorized needs under current demand conditions, although the water is not always "in the right place at the right time". Communities reliant on groundwater sources are less resilient than those with access to surface water reservoirs.
- Overall, the Basin is not very sensitive to uncertainty regarding the connectivity between surface water and ground water. While lag time between groundwater withdrawals and the corresponding depletion of streamflow, as well as the amount of actual streamflow depletion may affect local resources, these phenomena have little impact on the overall reliability of the Basin supply.
- Basin supply reliability did not change when streamflow targets were relaxed, or when additional months were added to allowable surface withdrawals.
- During droughts of equal to or greater severity than those experienced in the early 1980s and again in 2002 (the two droughts within the available data time frame), the Basin's efficacy as a self-sufficient supply is strained.
- Climate models predict drier summers and more frequent and severe droughts, and Basin population growth estimates average 7%, with some communities twice as high. Climate change and growth are both expected to significantly diminish Basin supply reliability in the future, with modeled decreases in reliability ranging from 1% to 9%.
- Of the various management alternatives evaluated, the following conclusions were drawn:
    - Demand reduction in the past 10 years has already improved individual system reliability but on its own will not solve the problem long term. A year-round demand reduction of 10% (likely infeasible for many communities) results in only a 1 - 2% improvement in supply reliability over current conditions, both Basin-wide and individually. This finding was similar to that of Zimmerman et. al. (2010) which looked at piloted conservation programs in the Ipswich Basin and found that the potential for reductions ranged from 1 to 9% but that these would have negligible effect on simulated Basin low flows.

Incremental benefits of additionally stringent conservation or increasing restrictions on groundwater withdrawals are likely to be overwhelmed by growth pressures and/or climatic effects. Requiring water suppliers to chase these ‘diminishing returns’ may be increasingly costly and restrictive of economic growth.

- Additional storage may provide some local or regional buffers against supply shortfalls, but the potential for water shortfalls is greatest in communities without storage, which again points to the issue of the water not being available locally during droughts.
- There is additional physically available water in the Basin for some communities in their respective subwatersheds, and hence, a regional potential for water sharing within the Basin. This study looked at some conceptual opportunities for two or more communities to form regional partnerships in which total authorized withdrawals for participants could be pooled. In such a partnership, water could be distributed from where it is available to where it is needed without exceeding currently authorized aggregate withdrawal amounts. Such arrangements would require regulatory consent, and potentially additional infrastructure and incentives to promote cooperation. Despite the long-standing tradition of home rule decision making and localized water infrastructure in the basin, these may become viable alternatives to the importation of water from outside the Basin.
- MWRA water is a reliable alternative for communities whose supplies are vulnerable during dry or even normal conditions. Alternative routes for delivery of MWRA water were evaluated for three of the Grant Partners. The cost of MWRA water and associated the infrastructure, as well as the long-term reliability, should be compared to the costs and efficacy of in-Basin water sharing. The flow in the Ipswich River can serve as a reliable trigger for identifying when MWRA water should be brought in, without waiting too long during dry periods (and increasing the risk of shortfalls) or engaging the connection too early when dry conditions appear imminent (and not taking advantage of the local supplies to the extent possible).
- Importing water from MWRA was examined for three communities that cannot always extract the desired amount of Ipswich Basin water, and who are already considering connections to the MWRA system; Danvers, Lynnfield Center, and Topsfield. The study suggests that augmenting their respective supply systems with MWRA water could provide sufficient amounts of water, and that the flow at the South Middleton Gauge could be a useful trigger of when to switch from local supplies to MWRA water. The triggers would be different for each community, as would the average dependence on MWRA water, but connections to MWRA using the South Middleton Gauge as a trigger could be a viable alternative for satisfying future demand.

7 REFERENCES

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OVERSIZE FIGURES

Figure 5-1: Lynnfield Center Water District MWRA Alternative 1

Figure 5-2: Danvers MWRA Alternative 1

Figure 5-3: Topsfield MWRA Alternative 1

Figure 5-4: Topsfield MWRA Alternative 3

PLATES

1 Basin Hydrology and Regulated Withdrawal Points

0 0.2 0.4 0.8 1.2 1.6 Miles

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PROJECT NO. 20173509.002A
DRAWN: 6/01/2018
DRAWN BY: JND
CHECKED BY: KR
FILE NAME: Ipswich Basin.mxd

Lynnfield Center Water District (LCWD)
MWRA Potential Route
Alternative 1

Ipswich Basin FY17 Water Management Act (SWMI) Grant Project
Town of Danvers
Massachusetts

FIGURE
5-1

KLEINFELDER Bright People. Right Solutions. www.kleinfelder.com	PROJECT NO. 20173509.002A DRAWN: 6/01/2018 DRAWN BY: JND CHECKED BY: KR FILE NAME: Ipswich Basin.mxd	Danvers MWRA Potential Route Alternative 1 Ipswich Basin FY17 Water Management Act (SWMI) Grant Project Town of Danvers Massachusetts	FIGURE 5-2

KLEINFELDER Bright People. Right Solutions. www.kleinfelder.com	PROJECT NO. 20173509.002A DRAWN: 6/01/2018 DRAWN BY:	Topsfield MWRA Potential Route Alternative 1	FIGURE 5-3
	CHECKED BY: KR FILE NAME: Ipswich Basin.mxd	Ipswich Basin FY17 Water Management Act (SWMI) Grant Project Town of Danvers Massachusetts	

KLEINFELDER Bright People. Right Solutions. www.kleinfelder.com	PROJECT NO. 20173509.002A DRAWN: 6/01/2018 DRAWN BY:	Topsfield MWRA Potential Route Alternative 3	FIGURE 5-4
	CHECKED BY: KR FILE NAME: Ipswich Basin.mxd	Ipswich Basin FY17 Water Management Act (SWMI) Grant Project Town of Danvers Massachusetts	

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PROJECT NO. 20173509.002A		WMA GRANT IPSWICH BASIN	PLATE
DRAWN:	6/4/2018		
DRAWN BY:	TB		1
CHECKED BY:	KR	Basin Hydrology and Regulated Withdrawal Points	
FILE NAME:	Ipswich Basin.mxd		

APPENDIX A

2017 DEMAND MANAGEMENT SURVEY RESPONSES

Appendix A - Water Conservation and Demand Mangement Practices
2017 Responses to PWS Survey

Water Conservation/ Demand Management Practice	Danvers E	Danvers F	Hamilton E	Hamilton F	Ipswich E	Ipswich F	Lynnfield Center E	Lynnfield Center F	Middleton E	Middleton F	Topsfield E	Topsfield F	Wenham E	Wenham F	Wilmington E	Wilmington F
Source & Master Meters Calibrated Regularly?	Good		Good		Good		Good		Good		Good		Good		Good	
All Uses Metered and Authorized? Are there fines for water theft? Are they enforced?	Fair			Fair	Good		Good		Fair		Good		Good	Good	Good	
Meter Inspection / Testing / Replacement program?	Good		Good		Good		Good		Good		Good		Good		Good	
Method of meter reading?	Good		Good		Good		Good		Good		Good		Good		Good	
Data Management: Water Audits	Fair			Poor	Fair		Good		Fair		Good			Poor	Good	
Leak Detection and Repair	Good		Good		Good		Good		Good		Good		Good		Good	
Distribution System Improvements (Water Main Replacement Program? Water Master Plan? Date?)	Fair		Good		Good		Good		Fair		Fair			Good	Good	
Rate and Billing Structures that promote conservation?	Fair		Good		Good		Good		Fair		Good		Good		Good	
Quarterly or greater billing frequency	Good		Good		Good			Poor	Good		Good		Good		Good	
Water bills – Is consumption history provided? If so, is it reported in gallons?	Good		Good		Good			Fair	Good		Good		Good		Good	
Seasonal rate structure with higher rates May 1- Sept 30		Fair		Poor	Good			Poor		Fair		Fair		Poor		
Residential Indoor Demand Management (water saving device giveaway or / incentive or rebate programs?)	Fair			Fair	Fair		Good			Poor		Fair		Good		
Non-Residential Indoor Demand Management (e.g. Municipal building water saving fixtures?)	Good			Fair	Fair		Good		Good			Fair	Good		Good	
Outdoor Demand Management – rain barrel / other incentive?	Good			Good	Fair		Good		Good	Fair		Fair	Good		Good	
Irrigation best available technology bylaw?	Good		Good			Fair	Good		Good			Fair		Fair	Good	
Municipal Irrigation Alternatives	Fair			Fair	Good		Good		Good			Poor		Poor	Good	
Land Use Pattern Changes (Promotion / Incentives for Low impact development)		Poor		Fair	Good		Good			Fair		Fair		Fair	Good	
Additional Plumbing Code Restrictions or Rigorous Enforcement		Fair		Fair			Good			Good		Fair		Fair		
Non-essential Outdoor Water use Mandatory Restrictions?	Good		Good		Good		Good		Good		Good		Good		Good	
Limit Non-Essential Outdoor Water Use to 2 days / week	Good			Good				Fair	Good			Poor		Poor		
Limit Non-Essential Outdoor Water Use to 1 day / week	Good			Good				Poor	Good			Poor		Poor		
Private Well Use Bylaw		Poor	Good			Good		Poor		Poor	Good			Fair		
Private Well Non-essential Outdoor Use Restrictions		Poor	Good			Good		Poor		Poor	Good		Good			
Public Education & Awareness Conservation Program	Good			Fair	Fair		Good		Good	Good		Good	Good		Good	
Other not listed above	Good										Good	Good				

E (Effectiveness) or F (Feasibility) Rating:

Good
Fair
Poor

Note: An informational survey was sent to 13 Basin municipal water suppliers as part of the FY 17 study to inventory the use and effectiveness of water conservation and demand management practices. This table presents a summary of the response ratings. PWS were asked to rate the relative effectiveness (E) of the practice, if in use, or rate the relative feasibility (F) of implementing the practice if not in use, as either Good, Fair, or Poor.

APPENDIX B

WORKSHOP AGENDAS & NOTES

Ipswich River Basin SWMI Grant Workshop 1
February 27, 2018
1:30 – 4:00 PM
Danvers Town Hall-Toomey Room

1. Introductions

2. Review of the Project Scope (KLF)
   a) Refresher on key findings Phase 1
   b) Goals Phase 2
   c) Tasks & Objectives
   d) Opportunities & Constraints
   e) Data Needs
   f) Data Sharing – Sharepoint Site

3. SWMI Grant In-Kind Contributions and Financial Expectations (Jen P; Sharon)
   a) Tracking In-Kind Contributions
   b) Cash Contribution

4. SWMI Grant Schedule
   a) In-Kind Hours Report – March 31st
   b) Midterm Progress Report – April 1st
   c) MWRA Evaluation – April 30th
   d) Draft Regional Credit System and Model– May 1st
   e) Workshop 2 – Draft Model Presentation – May 16th or 17th?
   f) Model Finalized – June 1st
   g) In-Kind Hours Report - June 30th
   h) Report Delivery - June 30th

5. Next steps

6. Other

Workshop 1: February 27, 2018 Danvers Ipswich Basin WMA Grant Project
List of Attendees

Name	Organization	Title	email	phone
Andrew Goldberg	KLF		agoldberg@Kleinfelder.com	2069308918
PETER SMYRNIOS	SBWSB	SUPT.	PSSMYRNIOS @SBWSB.NET	978922-2600
GREG KROM	TOPSFIELD	WATER SUPR.	GKROM@TOPSFIELD-MA.GOV	978-767-5549
JOE LOBAO	Wilmington	Utility/Business Mang.	JLOBAO@Wilmington[illegible]	978-658-4711
[illegible] ROGERS	DANVERS	TOWN ENGINEER	[illegible]@DANVERSMA.GOV	978-777-2668
Ashley Keighley	LWSC	Engineer Tech	akeighley@lynnwatersewer.org	781-244-2762
Angie Multey	CDM Smith	PM	multeat@cdmsmith	617 4526561
Erik MANSFIELD	WENHAM WATER	SUPERINTENDENT	emansfield@wenhamma.gov	978-468-5520 x16
RYAN FERRARA	MIDDLETON	ASSISTANT TA	RYAN.FERRARA@MIDDLETONMA.GOV	978-777-3617
BOB LA BUFFIERE	"	SUPERINTENDENT	BOB.LABUFFIERE@MIDDLETONMA.GOV	
Sharon Clement	Danvers	Program Engineer	sclement@danversma.gov	
Teri Demers	Ipswich	Water & WW Engineer	tdemers@ipswichutilities.org	
Vicki HALMEN	IPSWICH	WATER & WW DIRECTOR	vhalmen@ipswichutilities.org	
Stephen King	DANVERS	CIVIL ENGINEER	S.King@danversma.gov	978-646-7398
Erik Mysliwy	Reading	Water Quality & Supply	EMysliwy@CI.Reading.MA.US	781-858-2566
David Lane	Danvers	DPW Director	dlane@danversma.gov	
Kirsten Ryan	Kleinfelder			
Jennifer Pederson	MWWA			

Ipswich River Basin SWMI Grant Workshop 1
February 27, 2018
1:30 PM
Danvers Town Hall-Toomey Room
Draft Meeting Minutes

1. Introductions (see attendance list)
   Jennifer Pederson, MWWA
   Sharron Clement, Danvers
   Kirsten Ryan, Kleinfelder
   Andrew Goldberg, Kleinfelder
   Rick Rodgers, Danvers
   David Lane, Danvers
   Greg Krom, Topsfield
   Joe Lobao, Wilmington
   Ashley Keighley, Lynn Water and Sewer Commission
   Angela Moulton, CDM Smith representing Lynnfield Center
   Eric Mansfield, Wenham
   Ryan Ferrara, Middleton
   Bob LaBossiere, Middleton
   Vicki Halmen, Ipswich
   Steve King, Danvers
   Peter Smyrnios, Salem Beverley Water & Sewer Board

2. Review of the Project Scope (Kirsten)
   a) Refresher on key findings Phase 1
      - Many data sources thanks to all the contributions from participants
      - Water usage – how is water being used in the basin; conserved; managed
      - Municipal domestic use is small relative to overall use; groundwater use
      - Water use has flattened since the 1980s; trend is less groundwater use; conservation is helping
      - River is experiencing low flow conditions
      - Recommendations:
        - Look at non-groundwater alternatives for growth of Ipswich
        - Regional sharing of resources to balance needs; evaluate constraints/barriers and possible solutions
   b) Goals Phase 2
      - Quantitatively evaluate and rank alternatives and recommend solutions

   c) Tasks & Objectives
      - Task 1 2 Stakeholder workshops
        - Task 2 System Model
          - Test multiple scenarios (hundreds) for water management

- Approach: In the middle of systems model and engineering model (traditional hydraulic model)
    - USGS Ipswich Model
        - Limitations: lag time between operations
            - Test both ways; see how much this matters
- Evaluate tradeoffs and influences of growth, climate change, management strategies on outcomes
- 1st goal is to simplify the basin to series of buckets (in, out, influence)
    - Diagram flow and influences
    - Example of process: Medway Water, Wastewater, Stormwater
    - Examine and quantify influences on outcomes by developing scenarios
- Key questions
    - How much water is available in the basin? How much is needed?
        - Conditions: now, future, climate change, emergency, etc.
        - Constraints: permit, operations
    - Evaluate how much conditions/constraints impact availability
- Probably going to be focused on MWRA for partner communities; start with partner communities; if time permits, do all
- Private water
- MWRA
- How do we pick final answer? KLF to run scenarios and evaluate feasibility, but report will capture the various outcomes and discussions from the group (desirable / undesirable)

▪ Task 3 Regional Credit / Trading Framework
- Communities can join together to better manage permits, water usage, etc.
    - Creative exercise informed by model and stakeholders
    - Could provide flexibility from Permit Constraints

▪ Task 4 – MWRA
- Find triggers / conditions under which it would make the most sense to
- Risk will be variable by stakeholders and resources (reservoir / well groundwater level)
- Routes; GIS analysis/desktop mapping approach to find route (cost, distance, politics) if this is a solution
- Alternatives analysis would be started (Environmental Impact Report)
    - Beth Card of MWRA will be participating in this process but could not attend today

d) Data Needs

- Will be sending a targeted data request in the next week or so; less substantial request than last year

- Private Wells – CEI is in the process of updating the Private Well / water use inventory in Parker and Ipswich thru the same Grant program; will check in on this progress

e) Opportunities & Constraints

    i. Opportunities (examples and discussion)

        1. Check and confirm that 1:1 ratio (well vs. river) is not true; ie: impact of groundwater pumping and river water levels
            a. Discuss withdrawals are 10 MGD below permitted volumes; 1% of withdrawals in summer…
            b. Ipswich river watershed association still positioning for further regulations of water suppliers
            c. Provide data and facts vs. rhetoric
        2. Do registered systems have excess capacity? Can downstream systems maintain their supply?
            a. Minimization/Mitigation requirements – opportunity to share
                i. Ie: dam removal for mitigation
            b. Not just a numbers game… Danvers stop pumping in summer; buy from SB
            c. Conservation mindset whether under permit or not
            d. Public education on Conservation to go statewide on non-essential outdoor water use (Wenham, Topsfield, Middleton)
                i. Social marketing
                ii. Next: Aquarion, Concord, West Springfield
        3. Can Wilmington take more water from MWRA?
            a. typically 20% MWRA; during drought they are at maximum from MWRA… with own supply + MWRA was at peak
            b. Wayne (IRWA) thinks there is a lot of low hanging fruit
                i. Private wells (unregulated)
                ii. Registered systems
                iii. Groundwater systems (demand management)
                    1. Public education on water use

    ii. Challenges/Constraints (for ranking and costs)

        1. Physical
            a. Wheeling/trading
                i. not just paper- interconnections
                ii. large distances; uni-directional
                iii. gradients
                iv. end of system = smallest diameter mains
                    1. capital costs for improving mains and infrastructure too
                v. Costs
            b. Connections
                i. Small
                ii. Haven't been tested

1. Pressure gradients are wrong sometimes
2. Need new designs

iii. Disinfection (chloramines)
1. >20%
2. Danvers is not chloramines
3. MWRA is chlorinated
a. Upset when 20%

iv. pH
1. MWRA is high pH

v. Piping
1. Lots of AC pipe
a. Water quality concerns

vi. Phosphates
1. Must be consistent

vii. Pressure

viii. Mixing

ix. # of connections
1. Ie: Danvers

c. Basin geography (relative to river / gw levels)

d. Regulation of Private wells?

2. Permit requirements

i. Big leap for DEP to write regional permit or allow for trading; DEP wants hook in each Basin

ii. Who gets Permit? Town vs. Water Supplier

iii. DEP was asked to send permits to Town Administrators / Selectmen due to major changes in capital costs; not just a water issue; it's a Town issue

iv.

f) Data Sharing – Sharepoint Site

i. Same as last year

ii. New participants will need setup from Kleinfelder (Lynn)

3. SWMI Grant In-Kind Contributions and Financial Expectations (Jen and Sharon)

a) Tracking In-Kind Contributions

i. Sharron provided packet with information for partners
1. Accountant form
2. Agreements between Partner and Danvers
a. Must sign agreement to pay asap
3. Printed form (data collection; meetings; prep; discussions with TA; report review)
a. Should be about ½ way done by March 30th

ii. 50 hours for Partners

iii. 100 hours for Danvers

b) Cash Contribution

        i. Approximately $4000

4. SWMI Grant Schedule
    a) In-Kind Hours Report – March 31st
        i. Each partner community must track and report (in-kind; consultant hours)
            1. 2 reports; March 31 and June 30
    b) Midterm Progress Report – April 1st
        i. KLF to send to MassDEP
    c) MWRA Evaluation – April 30th
    d) Draft Regional Credit System and Model– May 1st
    e) Workshop 2 – Draft Model Presentation – May 16th or 17th?
    f) Model Finalized – June 1st
    g) In-Kind Hours Report - June 30th
    h) Report Delivery - June 30th
        i. Send to partner communities prior; for 1 week of reviews

5. Next steps
    a) Data request from KLF to PWS; send sharepoint login instructions
    b) Confirm Workshop date 2 (Jen to send doodle)
    c) Deliverables – in progress (see above)
        i. Jen - Fact sheet; framing presentation; communication with media; politics
            1. Phase 1 and Phase 2 presentation to legislature

6. Regulatory Update
    a) DEP is going to be looking at PFAS/PFOA compounds
        i. EPA is not looking to move forward with MCL but MassDEP is reviewing health impacts proactively; going to convene health advisory committee
            1. Review scientific data around these
            2. Will decide on ORSG
            3. Concerns about communication
                a. Looking at 3 communities – over health advisory (70 ppt for PFOA/PFAS); from UCMR3
                b. Suggest looking at 5 chains… add up
            4. If you detected thru UCMR testing, you may go over the limit
                a. Approximately 10-20 systems on the radar
            5. Waste site side (cleanup standard for regulations Spring 2018), drinking water side as well
    b) EPA – draft Lead & Copper Rule regulation for August
        i. Questions… how difficult would it be to put a point of use filter
        ii. If you replace a water main… could you provide a pitcher and re-fill…
        iii. AWWA is commenting
    c) Draft Water Conservation Standards
        i. State Guidance for water regs; changes to UAW, lawn/landscaping, metering, etc.

            1. Come into play for permitting (IBA, IBTA)
    ii. Quarterly billing = standard; recommendation = monthly
    iii. Metering - guidance thru AWWA
    iv. UAW –
        1. Lots of input; water loss control (AWWA - M36 manual thru water audit)
        2. Still 10% UAW metric… not current thinking
    v. Comments – to be provided for MWWA based on drought / resiliency
    vi. Major changes: generally ok
    vii. Workshop on March 5th
d) State Drought Plan being updated
    i. Metrics to be provided March 14th

Concluded at approximately 2:45pm

Ipswich River Basin SWMI Grant Workshop 2
May 16, 2018
10 AM - Noon
Danvers Town Hall-Toomey Room

1. Introductions
2. Regional Water Use Model
    a. Model purpose & need
    b. Model development
    c. Model calibration & sensitivity analysis
    d. Basin-wide Scenarios
    e. Water surplus / deficit findings
    f. Alternative scenarios
    g. Discussion & Feedback
3. MWRA Alternatives Evaluation
4. Regional Permit / Credit System Concept
5. Fact Sheet Preparation
6. Legislative Outreach at Project Conclusion
7. Update SWMI Grant In-Kind Contributions and Financial Expectations
    a. Tracking In-Kind Contributions
    b. Cash Contribution
8. SWMI Grant Schedule
    a. Model Finalized; Draft Technical Report to Partners for Review – June 1st
    b. Comments on Draft Report to Kleinfelder by June 11th
    c. Final Draft Report to Partners & MassDEP by June 15th
    d. In-Kind Hours Report - June 30th
    e. Final Report Delivery to DEP - June 30th
9. Next steps
10. Other

Ipswich River Basin SWMI Grant Workshop 2
May 16, 2018
10 AM
Danvers Town Hall-Toomey Room
Draft Meeting Minutes

1. Introductions (see attendance list)
   Jennifer Pederson, MWWA
   Sharon Clement, Danvers
   Kirsten Ryan, Kleinfelder
   Lucica Hiller, Kleinfelder
   Rick Rodgers, Danvers
   David Lane, Danvers
   Greg Krom, Topsfield
   Joe Lobao, Wilmington
   Ashley Keighley, Lynn Water and Sewer Commission
   Elaine Sistare, CDM Smith representing Lynnfield Center
   Erik Mansfield, Wenham
   Ryan Ferrara, Middleton
   Kirk Westphal, Kleinfelder
   Davis Scribner, Peabody
   David Terenzoni, Peabody
   Vicki Halmen, Ipswich
   Steve King, Danvers
   Brad Perron, Salem Beverley Water Supply Board
   Erik Mysliwy, Reading
   Steve Bartha, Danvers
   Beth Card, MWRA
   Fred Brandon, MWRA

2. Regional Water Use Model – Kleinfelder walked the group through the following topics related to the model:
   a) Model purpose & need – There were four key questions that Kleinfelder sought to answer through the development of the model.
      i. Is there enough water in the basin for human needs (no permit constraints)?
      ii. Is there enough water for human needs when fully constrained?
      iii. How does this change in response to in-basin alternatives?
      iv. When does importing MWRA water make sense?
   b) Model development – Kleinfelder took the USGS HSPF model and extracted the data to import it into the STELLA model. The data does not include the 1960s drought as it was not available through the USGS model. Kleinfelder estimated area ratios to come up with reaches not covered by the HSPF model. Private residential well use was estimated by using the average household size and 65 gpcd Kleinfelder checked with DEP on the status of the ongoing private well study it was not yet available; will try to update if available before report is final. A question was asked if agricultural use has been factored in; response was, if it was registered

or permitted it was. It was noted by a town that they know of large agricultural uses pulling out of the river that are not permitted/registered.

c) Model calibration & sensitivity analysis – Kleinfelder described how they validated the model and they were able to reproduce the same results as the USGS model with no withdrawals. They were also able to reproduce the similar flow results to the USGS gage stations at South Middleton and Ipswich using recent demand trends to represent historic withdrawals. The patterns were repeatable, and this verified that Kleinfelder had accurately imported the data from the HSPF model into STELLA.

d) Draft Basin-wide Scenarios –Kleinfelder looked at what water suppliers might have surplus water, whose dependence on Ipswich Basin is marginal or unreliable and what factors drive the results. Water availability in the basin for human use is generally met, except during short periods that coincided with drought periods (1982, early 1990s, early 2000s, 2016). It should be noted that several suppliers have withdrawals in other basins and therefore are able to meet all their needs through use of all their supplies, but Ipswich sources were shown as marginally reliable. Kleinfelder evaluated stream depletion scenarios and delay factors (as an experimental test to help determine how impactful these uncertain phenomena actually may be) and over the 30-year period of record, these factors did not really have an impact on the towns' ability to get the water they need. Kleinfelder evaluated the probability of volume and the time water availability could be met. They showed an example that if there were 20 % less demand it would not always equate to 20% more water in the river throughout the basin since demand is a fraction of total flow. Likewise, for communities with marginal supplies from Ipswich sources, a theoretical 20% reduction in demand would not always equate to a 20% increase in the percent of needs met. Most of the time the volume is available, but by town, it might not be available at the right time or the right place.

e) Water surplus / deficit findings- The model shows that 23% of the time, the river goes below the WMA Permit threshold of 52.5 cfs (at the Ipswich gauge) with no withdrawals; with current demand patterns it is about 30% and if surplus water at one location is extracted to compensate for shortfalls in another, this metric increases only by about 0.5%. Surpluses of water within the basin, if used to potentially support shortfalls elsewhere, have a negligible impact on flow in the river. Kleinfelder used the registered and/or permitted volumes for the surface water suppliers to represent withdrawals from the Ipswich River, and aggregated 8 years of use for the groundwater systems and withdrawals from the surface water reservoirs. A question was asked about whether Salem-Beverly Water Supply Board's permitted use was used; the reply was yes. This may be conservative since SBWSB is not using this permitted volume; this is the same for others who might not be using their full registered/permitted volumes. A question was asked about the origin of the 52.5 cfs threshold; Kleinfelder stated they used what had been the Permit restriction given on several of the surface water systems who were required to maintain that amount in the river when they withdraw.

f) Alternative scenarios – Kleinfelder ran a number of scenarios to depict possible examples of water sharing that could theoretically occur. It was noted that these were provided just as draft examples and are not recommendations that Kleinfelder is making. It was just illustrative of the model's ability to test many scenarios. Release scenarios were discussed to support other water systems water availability, but had not been evaluated for whether they were even feasible and ultimately it was determined that the benefit was negligible (this was entirely experimental, and conducted to understand the sensitivity of releases, not to evaluate them as a potential management alternative, as results quickly showed the detrimental impact to local reservoir supplies). As stated above, other scenarios show lack of availability of water for some communities but that doesn't account for water that could potentially be available throughout the basin. Finally, Kleinfelder ran scenarios to show when it may be beneficial to bring MWRA water into the basin, using Lynnfield Center Water District as a test case. Kleinfelder stated this was a task still in process.

i. Discussion & Feedback – Kleinfelder asked for feedback on what had been presented. The group expressed concern on a few of the scenarios that were provided including reservoir releases. Water suppliers are concerned about potential impacts to system reliability if they are to release water from their reservoirs, so it may not be reasonable to show this experimental scenario. The suppliers stated that demand management scenarios provided were over-optimistic; the last grant project showed that many of these systems have already implemented all feasible demand management opportunities. Finally, any reference to manipulation of gage flow restrictions is of concern since that threshold was set when registrations were established in 1986 and registrations are grandfathered water use and therefore should not be subject to change. Kleinfelder noted that the scenarios were not intended to suggest that the gage flow restrictions be changed or lifted, but were evaluated specifically to answer the scope questions (i) and (ii) above:
    1. Is there enough water in the basin for human needs (no permit constraints)?
    2. Is there enough water for human needs when fully constrained?

3. MWRA Alternatives Evaluation -- Kleinfelder asked suppliers who believe they have an interest in MWRA water to let them know so they could run those specific scenarios.

4. Regional Permit / Credit System Concept - Kleinfelder discussed a conceptual framework that might be considered using a joint powers entity or intermunicipal agreement. Such a framework would allow trading or selling of authorized water use to promote holistic basin availability protection between partners. The concept was applied not to physically moving water but a Permit covering two or more suppliers jointly. A similar approach was approved on Cape Cod within the 2018 plan for nitrogen trading and reduction and therefore provides a model that DEP might replicate for the water management act program. Some felt a Joint Powers Agreement might be more applicable if many of the suppliers in the basin wanted to connect to MWRA.

5. Fact Sheet Preparation - MWWA will prepare a draft fact sheet once Kleinfelder has completed more of the model work. A draft will be circulated via email for comment by the communities. A question was asked about preparation of a press release; MWWA will handle that.

6. Legislative Outreach at Project Conclusion - MWWA discussed a summer legislative coffee to give a briefing to the legislative delegation in the basin on the findings of both grants. MWWA will work on scheduling.

7. Update SWMI Grant In-Kind Contributions and Financial Expectations

a) Tracking In-Kind Contributions – Communities were reminded to track and submit their hours to Danvers for reporting to DEP.
b) Cash Contribution – One community's payment is still in process.

8. SWMI Grant Schedule
    a) Model Finalized; Draft Technical Report to Partners for Review – June 1st
    b) Comments on Draft Report to Kleinfelder by June 11th
    c) Final Draft Report to Partners & MassDEP by June 15th
    d) In-Kind Hours Report - June 30th
    e) Final Report Delivery to DEP - June 30th

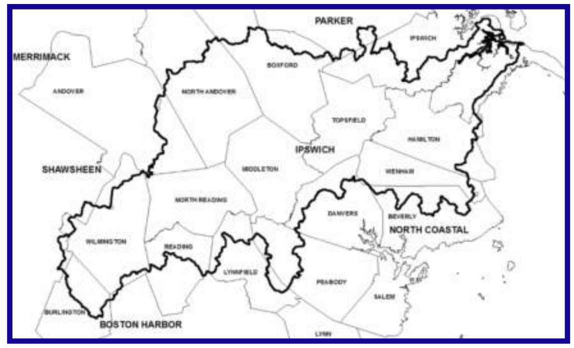
9. Next steps
    a) Comments on information presented at workshop 2 are due to Kleinfelder by May 23rd.

APPENDIX C

FACT SHEET

Water—Vital to our Communities

Study identifies challenges and possible solutions



Water suppliers in the Ipswich River Basin, including those with groundwater wells (Danvers, Middleton, Hamilton, Topsfield, Wenham and the Lynnfield Center Water District) have been evaluating their current and future water supply needs. These six communities embarked on a joint grant project, funded by MassDEP, to model current and future use and identify potential regional solutions that could allow for improvement of resiliency, future growth and protection of the environment.

POTENTIAL SOLUTIONS: REGIONAL OPPORTUNITIES

- With additional water physically available in the basin within some communities' respective watersheds, regional partnerships could be evaluated which may allow communities to share water resources for regulatory flexibility without the need to import water from outside the Basin.
- The Massachusetts Water Resources Authority (MWRA) is a wholesale regional water supplier for 61 metropolitan Boston communities.
    - MWRA water may be a reliable alternative for communities whose supply is vulnerable to dry conditions.
    - Some communities within the Basin already have connections to the MWRA.
    - For communities wishing to connect, approval is necessary by the state, an entrance fee is required by MWRA and infrastructure investments would need to be made before the community could purchase water.
    - The costs to a community could be substantial, but reliability would be greatly improved.
- In 2014 the Massachusetts Legislature authorized funding to assist communities who wished to pursue regional solutions, such as connection to MWRA or another regional supply. The Legislature should work to appropriate these funds for interested communities.

STUDY FINDINGS

WATER AVAILABILITY

- The model developed in this grant project shows that there is generally enough water in the basin to satisfy authorized uses under current demand conditions; however, water may not always be available at the right place and time.

SYSTEM RELIABILITY

- Communities reliant on groundwater sources are less resilient than those with access to surface water reservoirs.
- Demand reduction in the past 10 years has already improved individual system reliability, but on its own will not solve the problem long term.
- Additional storage may provide local or regional buffers against supply shortfalls, but storage options are limited for most communities.

DROUGHT IMPACT

- Climate models predict drier summers and more frequent droughts, which coupled with population growth, may reduce Basin supply reliability in the future.
- Droughts as severe or worse than those experienced in the 1980s, 2002 or 2016 cause strain on local water resources.

FOR A COPY OF THE FULL STUDY VISIT: WWW.DANVERSMA.GOV