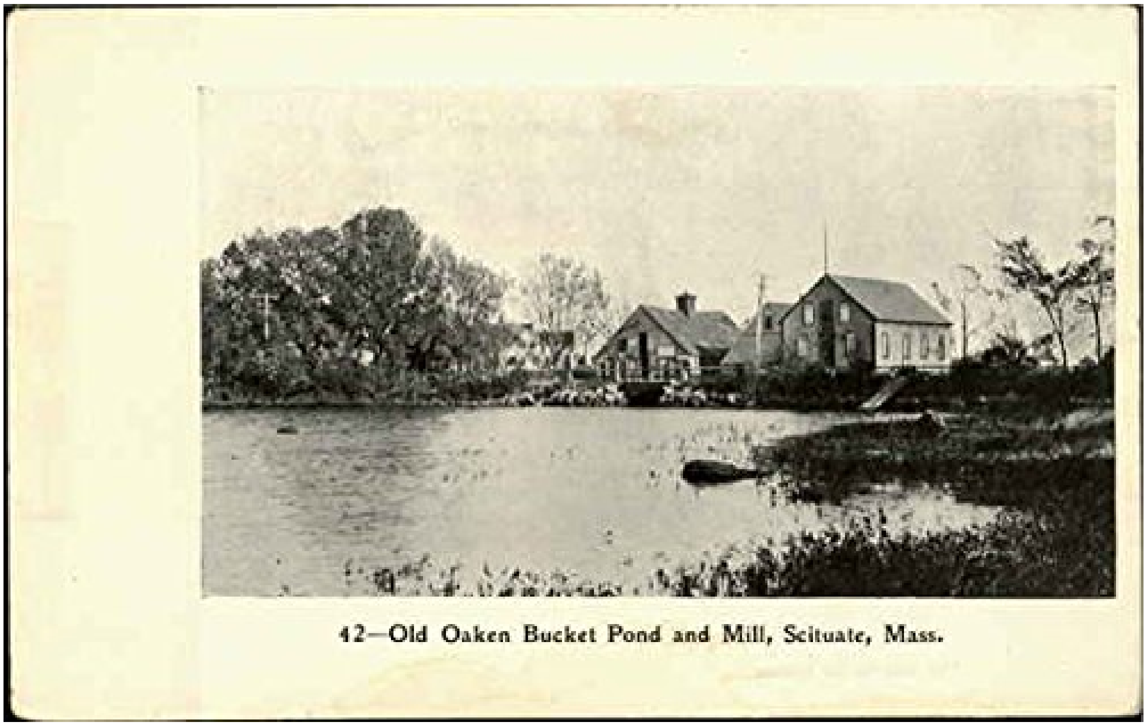
APPENDIX A WEAP MODEL UPDATE

Scituate Water Supply Reliability

Prepared for the Town of Scituate, Massachusetts

Contract 18-WA-16



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Technical Memorandum

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Executive Summary

The Town of Scituate has used a Water Evaluation and Planning (WEAP) integrated water resources model to evaluate the effects of management options on environmental and water supply objectives since 2009. In 2018, as part of a project to begin permitting structural changes to the Reservoir dam to raise its full storage elevation by 1.5 feet, the WEAP model was used to evaluate existing and potential changes to operations and management of the water supply system for both the current and potential future dam configurations. The project was funded by a Dam, Levee and Coastal Foreshore Protection Repair and Removal grant from the Massachusetts Executive Office of Energy and Environmental Affairs to the Town of Scituate.

Twenty-seven new model scenarios investigated the impact of the following management options on water supply reliability and environmental performance under a 1.5 foot increase in the full storage elevation of Scituate's main reservoir:

1. moving the discharge of Well 17 from Old Oaken Bucket Pond to Tack Factory Pond,
2. increasing annual demand to account for routine ice pigging and flushing,
3. water ban and streamflow cutoff triggers,
4. updated and adjusted seasonal aquatic habitat flows,
5. balancing water storage between the Reservoir and Old Oaken Bucket Pond to optimize fish ladder performance, and
6. Reservoir fish ladder operational water levels.

Based on set of system performance and environmental indicators, a preferred scenario was identified for both current and future dam configurations. Both preferred scenarios delivered adequate water to supply the Town's needs during the drought of record with Reservoir storage buffers of 28 and 60 MG, respectively. Total Outdoor Water Bans occurred on average 8-12 summer days per year. An average of 67-80% of years had no summer days under the Total Outdoor Water Ban. Both preferred scenarios resulted in zero streamflow in First Herring Brook for less than 1% of days over the period of record and met seasonal BioQ90 flow release goals 79-100% of days. Seasonal fish ladder success in the future dam configuration ranged 82-98% for both ladders. In the current dam configuration the Reservoir ladder remained structurally inoperable and the Old Oaken Bucket Pond fish ladder continued to have lower success during the fall outmigration period (66% successful fall days).

Key operational aspects of the preferred current dam configuration scenario are:

1. The Total Outdoor Water Ban is triggered when the Reservoir water level is 4 feet below its full storage elevation.
2. When the Reservoir water levels drops to 5 feet below full storage elevation, enforcement and publicity of the Total Outdoor Water Ban produces greater water conservation results (water demand drops to 25% lower than average monthly demands). This water conservation outcome is key to maintaining resilience of the water system to extreme droughts.
3. Groundwater sources produce 1 mgd. The system's drought resilience is sensitive to reductions in groundwater yield of as little as 0.1 mgd on an annual average.
4. Updated BioQ90 seasonal aquatic habitat releases are provided in the report and should be incorporated into the Interim and Final Operating Plans. These releases are generally lower than previous versions, indicating that the last 16 years have been drier than the previous 38.

5. BioQ90 seasonal aquatic habitat releases cease when the Reservoir water level is 5.5 feet below the Reservoir's full storage elevation.
6. In the current Reservoir dam configuration, fish ladder releases should be provided at Old Oaken Bucket Pond only.
7. In the current dam configuration, providing Old Oaken Bucket fall fish ladder flows is likely to remain a challenge during dry years. Pulsed releases may be considered if juvenile fish are seen attempting to exit the system.

In addition to numbers 1-5 above, operational considerations for the preferred future scenario include:

1. Both fish ladders should be operated to provide spring and fall migration fish ladder releases. Note that the Reservoir's fish ladder baffles will need to be actively managed to achieve these flows. The minimum operational water level for the Reservoir's fish ladder will be 36.2 ft. (WEAP datum; equivalent to 35.1 ft. NAVD88). Note: the WEAP model's elevation datum is 1.1 ft. lower than the North American Vertical Datum of 1988 (NAVD88). Elevations in this report reference the WEAP model datum, except where otherwise noted.
2. Water levels in Old Oaken Bucket Pond should be managed to enable fish ladder releases when Reservoir water levels are high enough to operate the Reservoir fish ladder, particularly during the fall migration period, so that fish may enter and exit the entire system.

Note that the Bio Q90 aquatic habitat release shut off and the Total Outdoor Watering Ban are relative to the full storage elevation of the Reservoir in both the current and future dam configuration scenarios (i.e., 1.5 feet higher in elevation in the future dam configuration).

Information regarding changes in water level frequency durations are provided to support wetlands permitting discussions for the increase in the Reservoir's full storage capacity. A comparison of system yield estimates is also provided to inform future planning efforts.

Recommendations:

1. Update the *Interim Operational Plan* to reflect the updated BioQ90 seasonal aquatic habitat flows and associated water depth indicators.
2. Review relevant bylaws and operating procedures to implement the Total Outdoor Water Ban at 4 feet below the full storage elevation of the Reservoir.
3. Review relevant bylaws and operating procedures to implement the Streamflow Cutoff threshold at 5.5 feet below the full storage elevation of the Reservoir.
4. Continue with permitting and construction to increase the full storage elevation of the Reservoir by 1.5 feet and update the fish ladder and spillway capacity. Develop a *Final Operational Plan* to help water department staff operate the new structures to meet water supply and environmental performance goals.
5. Investigate opportunities to improve water conservation results during a declared Total Outdoor Water Ban, such as direct communication with high water users, increased publicity, education and enforcement. Track efforts and results over time to gain an understanding of the factors affecting the town's water use elasticity.
6. Complete, test and refine the adaptive management tool being develop by the North and South Rivers Watershed Association to regularly monitor the surface water supply and provide management guidance for water bans and streamflow, especially during abnormal conditions.

7. Continue to plan for the Town’s future water needs:
    a. Develop customer messaging strategies to improve water conservation during Outdoor Water Bans.
    b. Complete a local water demand projection that evaluates the potential for existing residential lot subdivision and seasonal population increases, among other factors.
    c. Evaluate the effect of changing precipitation patterns on Scituate’s drought resilience and water storage buffer.
    d. Investigate new well locations or capacities.

Background

This report is the seventh in a series of reports that provide detailed analyses of alternative scenarios for restoring stream flow and aquatic habitat to First Herring Brook in Scituate, Massachusetts while maintaining or improving the reliability of the Town's water supply. The analysis uses the Water Evaluation and Planning (WEAP) integrated water resources planning tool to evaluate the effects of management options on environmental and water system objectives. This report describes the effect of increasing the full storage capacity of Scituate's Reservoir dam by 1.5 feet and additional operational changes on the ability to meet the Town's demand for water and provide stream flow for aquatic habitat maintenance and seasonal fish ladder operation. It provides the basis for updating the Town's Interim Operational Plan as well as information about system yield and water level elevation durations to inform the permitting process.

This work was funded by a Dam, Levee and Coastal Foreshore Protection Repair and Removal grant from the Massachusetts Executive Office of Energy and Environmental Affairs to the Town of Scituate, MA in 2018. The funded project also included additional design and initial permitting for raising the full storage elevation of the Reservoir and lowering the fish ladder exit elevation.

Scituate's Water Resources

The Town of Scituate, Massachusetts is a coastal community that draws much of its water supply from surface and groundwater sources located in the First Herring Brook watershed, which drains approximately 6 square miles of largely residential neighborhoods underlain by glacial stratified deposits and till (MassGIS, 2015). The Town relies on a mix of surface and groundwater sources to meet its water supply needs and operates a treatment plant near Old Oaken Bucket Pond. The Town is currently authorized to withdraw up to 1.75 million gallons per day (mgd) from its surface and groundwater sources combined through August of 2020. There are three reservoirs on First Herring Brook that are used to store water: Tack Factory Pond, the Reservoir and Old Oaken Bucket Pond. State Route 3A divides Tack Factory Pond from the Reservoir, which has the largest storage capacity. Both the Reservoir and Old Oaken Bucket Pond are equipped with fish ladders and low level outlets for water management. During the summer, water is shuttled from storage in the Reservoir downstream to Old Oaken Bucket Pond, where it is withdrawn, treated and sent on to the distribution system. The Town's six groundwater wells, including three within the First Herring Brook drainage area, together yield approximately 1 mgd, and additional water demand is met with surface water withdrawals from Old Oaken Bucket Pond.

First Herring Brook is a small stream that that discharges into the North River in Scituate near its outlet to the Atlantic Ocean. As its namesake suggests, First Herring Brook once supported a thriving herring run as well as populations of eel, smelt and other native aquatic species (The Nature Conservancy et al., 2010). The installation of the dams at Old Oaken Bucket Pond (1640, rebuilt in 1970) and the Reservoir (1968) contributed to the decline of the herring run in First Herring Brook. Prior to implementation of the Interim Operational Plan by Scituate's Water Department in 2011, the last confirmed sighting of herring in the river occurred in 1996 downstream of Old Oaken Bucket Pond (Hurley, 2008). In addition to managing water resources to meet the Town's water needs, the initial project goals were also to restore a herring run and maintain flows for native aquatic species in First Herring Brook.

The WEAP Model

The Stockholm Environment Institute's Water Evaluation and Planning (WEAP) model was first set up to help evaluate Scituate's water resource management options in 2009. The initial project report, 'First Herring Brook Environmental Flows Project, Scituate, Massachusetts' (The Nature Conservancy et al., 2010) describes the full model setup and calibration and is included as Attachment 1 to this report. In brief, the WEAP model integrates stream flows in First Herring Brook and its tributaries, storage and operation of the three reservoirs (the Reservoir, Tack Factory Pond and Old Oaken Bucket Pond), operation of the town's wells, water supply delivery and stream flow releases for aquatic habitat and fish ladder operation (Figure 1). Scituate's WEAP model is a mass balance model that integrates estimates of natural stream flow and groundwater availability with hydraulic characteristics of the dams and fish ladders to allow the town to model the effects of new water management operational scenarios on stream flow in First Herring Brook, reservoir storage, fish ladder operation, water demand and conservation. For more detailed information about the WEAP model setup, please refer to the following earlier reports:

- *First Herring Brook Environmental Flows Project, Scituate, Massachusetts* (The Nature Conservancy et al., 2010)
- *First Herring Brook Environmental Flow Project: Addendum Report.* (The Massachusetts Division of Ecological Restoration, 2010)
- *First Herring Brook Interim Operational Plan* (Kearns, 2011)
- *First Herring Brook Priority Project WEAP Model Scenarios* (Kearns, 2012)
- *Improving Fish Passage and Environmental Stream Flows In First Herring Brook, Scituate, MA.* (Kearns, 2013)
- *Reservoir Dam Water Storage Modeling* (Kearns, 2017)

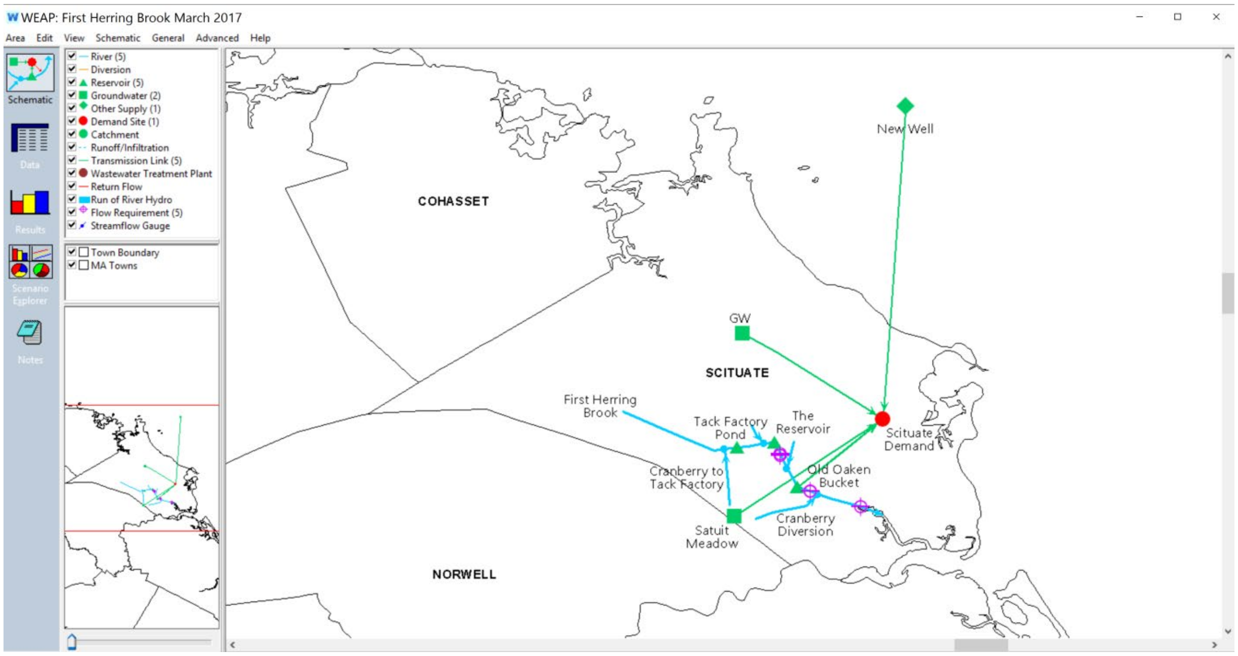


Figure 1. WEAP model schematic

Modeling Process

As part of the permitting effort to raise the full storage elevation of the Reservoir dam, the project team identified a number of current and imminent changes to the system that could affect the evaluation of drought resiliency and environmental impact. Model scenarios were run to test these concepts (Phase 1), and preliminary results were discussed with project team members in January of 2019. Based on these discussions, the number of scenarios was reduced to those most likely to be implemented, and additional scenario components were incorporated to improve environmental performance (Phase 2).

In Phase 1, the system's sensitivity to current and imminent management changes was tested by evaluating the amount of water supplied to the town, storage reserves during the drought of record and environmental performance indicators. The scenario components that were explored in Phase 1 included:

1. Increasing Reservoir storage by increasing the full storage elevation by 1.5 feet,
2. New ice pigging water demands,
3. Moving Well 17's discharge from Old Oaken Bucket Pond to Tack Factory Pond,
4. Total outdoor water conservation ban triggers at 3 and 4 feet below the full Reservoir storage elevation, and
5. Streamflow cutoff triggers at 5.5 and 8 feet below full Reservoir storage.

Based on the results of Phase 1, Phase 2 scenarios were developed to simplify the streamflow and outdoor water ban trigger options, improve fish ladder performance and increase drought resiliency. Phase 2 scenarios were evaluated using the same system demand, drought storage and environmental performance metrics as Phase 1. Phase 2 scenarios tested the following scenario components:

1. Lower Reservoir fish ladder operational elevations,
2. Improved water storage balance between the Reservoir and Old Oaken Bucket Pond (i.e., increased flows in the Old Oaken Bucket Augmentation Rule), and
3. Updated aquatic habitat bioperiod releases, including reduced May releases downstream of Old Oaken Bucket Pond.

Each scenario component tested is described in detail below and summarized in Table 1. Scenario names for Phase 1 scenarios begin with the "Updated Baseline", "Ice Pigging", or "Well 17 Redirect" components, followed by three ordered numbers representing, in order:

1. Reservoir full storage elevation (current condition 40.0; future condition 41.5)
2. Outdoor Water Ban trigger level (3 or 4 feet below Reservoir full storage elevation)
3. Stream flow cutoff trigger level (5.5 or 8 ft. below Reservoir full storage elevation)

For example, the scenario titled "Ice Pigging 41.5-4-8" represents the inclusion of water demand for seasonal ice pigging, the future Reservoir full storage elevation after raising it by 1.5 feet, an Outdoor Water Ban trigger of 4 feet below the future full storage elevation and a streamflow cutoff threshold of 8 feet below the future full storage elevation.

In the Phase 2 scenarios, the number '36.2' at the end of the scenario name indicates the minimum Reservoir water level elevation required to operate the Reservoir's fish ladder.

Table 1. 2019 WEAP model scenarios (Phase 1 scenarios above the black line, Phase 2 scenarios below the black line)

Scenario Name	Reservoir Full Storage Elevation *(ft.)*	Water Ban Trigger *(ft. below Reservoir full storage elevation)*	Streamflow Cutoff Threshold *Reservoir water level elevation (ft.)*	Ice Pigging	Reservoir Fish Ladder Operational Elevation *(ft.)*	Updated Habitat Flows	Old Oaken Bucket Augmentation Rule Flow (cfs)
Reservoir 40 IOP Baseline	40.0	4	8	No	NA	No	0
2019 Updated Baseline 40-4-8	40.0	4	8	No	NA	No	0
Ice Pigging 40-4-8	40.0	4	8	Yes	NA	No	0
Well 17 Redirect 40-4-8	40.0	4	8	No	NA	No	0
2019 Updated Baseline 40-4-5.5	40.0	4	5.5	No	NA	No	0
Ice Pigging 40-4-5.5	40.0	4	5.5	Yes	NA	No	0
Well 17 Redirect 40-4-5.5	40.0	4	5.5	No	NA	No	0
2019 Updated Baseline 40-3-8	40.0	3	8	No	NA	No	0
Ice Pigging 40-3-8	40.0	3	8	Yes	NA	No	0
Well 17 Redirect 40-3-8	40.0	3	8	No	NA	No	0
2019 Updated Baseline 40-3-5.5	40.0	3	5.5	No	NA	No	0
Ice Pigging 40-3-5.5	40.0	3	5.5	Yes	NA	No	0
Well 17 Redirect 40-3-5.5	40.0	3	5.5	No	NA	No	0
Ice Pigging 41.5-4-8	41.5	4	8	Yes	37.3	No	0.66
Well 17 Redirect 41.5-4-8	41.5	4	8	No	37.3	No	0.66
Ice Pigging 41.5-4-5.5	41.5	4	5.5	Yes	37.3	No	0.66
Well 17 Redirect 41.5-4-5.5	41.5	4	5.5	No	37.3	No	0.66
Ice Pigging 41.5-3-8	41.5	3	8	Yes	37.3	No	0.66
Well 17 Redirect 41.5-3-8	41.5	3	8	No	37.3	No	0.66
Ice Pigging 41.5-3-5.5	41.5	3	5.5	Yes	37.3	No	0.66
Well 17 Redirect 41.5-3-5.5	41.5	3	5.5	No	37.3	No	0.66
2019 Final Baseline with OOB Aug Rule	40.0	4	5.5	Yes	NA	Yes	1.0
2019 Final Well 17 Redirect OOB Aug Rule	40.0	4	5.5	Yes	NA	Yes	0.66
2019 Future Baseline	41.5	4	5.5	Yes	35.5	Yes	1.0
2019 Future Well 17 Redirect	41.5	4	5.5	Yes	35.5	Yes	1.0
2019 Future Well 17 Redirect 36.2	41.5	4	5.5	Yes	36.2	Yes	1.0
2019 Future Baseline 36.2	41.5	4	5.5	Yes	36.2	Yes	1.0

Scenario Component Descriptions

New scenarios were built from a set of components that were included or excluded to create a group of potential water management alternatives. Twenty-six new scenarios were developed in the 2019 WEAP modeling initiative (Table 1). Each of the new scenarios included a climatic period of record from 1961 – 2016 and water use assumptions reflecting 2011-2016 average monthly consumption to reflect current use. Updated and additional scenario components are described below.

1. Reservoir Full Storage Elevation

A set of scenarios was developed for the current Reservoir dam configuration, with a full storage elevation of 40.0 ft. and a storage capacity of 155 million gallons (MG). Similar scenarios were run for the proposed future dam configuration, with a full storage elevation of 41.5 ft. and full storage capacity of 192.4 MG.

The increase in full storage elevation was represented in the WEAP model with:

- an extended storage elevation curve,
- adjustments to aquatic habitat and fish ladder flow release triggers, and
- adjustments to triggers for the Total Outdoor Water Ban and Streamflow Cutoff Threshold.

2. Ice Pigging

Scituate's Water Department began ice pigging in late 2018 as part of its program to help control brown water episodes. Ice pigging is used to clean water pipes and involves pumping an ice slurry through a section of pipe to dislodge sediment and biofilms that have accumulated. It is anticipated that ice pigging will be a regular seasonal activity each year for the foreseeable future, rotating through different sections of the distribution system. To minimize the impact of ice pigging on water supply availability, the process will occur when Reservoir water storage is generally high and demand is generally low in the spring and fall, Mondays-Thursdays. The Town estimates that ice pigging will require 0.2 mgd of water and occur on average 20-40 days per year. The ice pigging season modeled runs from March 27 - April 30 and September 27 - October 31 and provides an average of 40 days per year of ice pigging, for a total increase in annual demand of 8 million gallons per year (MGY) (Figure 2). It is assumed that this additional water demand will also account for the use of water for regular system flushing.

Ice pigging was represented in the WEAP model by increasing the average 2011-2016 annual demand by 8 MG and adjusting the seasonal variation curve to reflect the timing of the additional water use.

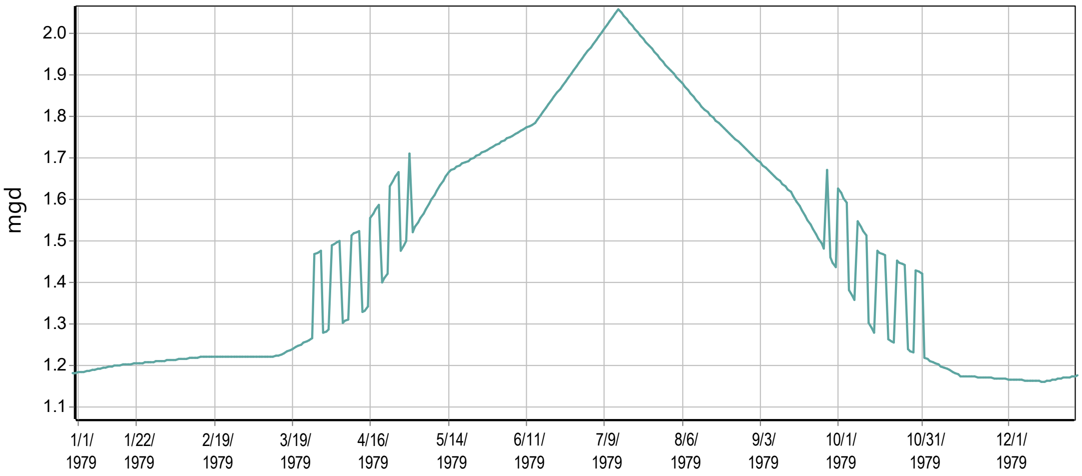


Figure 2. Daily water supply demands reflecting spring and fall ice pigging and 2011-2016 monthly average water use

3. Well 17 Redirection

Well 17 (265 gpm, 0.38 mgd) is currently being discharged to Old Oaken Bucket Pond to dilute high manganese concentrations. However, in previous model scenarios, Well 17's discharge was piped directly to the water treatment plant. The baseline scenarios were updated to reflect Well 17's discharge directly to Old Oaken Bucket Pond.

At the beginning of this study in 2018, the Town was considering moving Well 17's discharge from Old Oaken Bucket Pond to Tack Factory Pond to further dilute the high manganese levels and also potentially make this water available for Reservoir aquatic habitat maintenance and fish ladder or habitat releases. Even though the Town eliminated this change from further consideration, the WEAP model scenarios rerouting Well 17 to Tack Factory Pond were already evaluated in this study.

This change was represented in the WEAP model by adding a transmission link from a new groundwater node representing Well 17 to Old Oaken Bucket Pond to reflect the addition of 0.38 mgd (265 gpm) of pumped groundwater to the surface water system and by reducing the total amount of groundwater that can be withdrawn to directly satisfy Scituate's demand from 1.0 mgd to 0.62 mgd. In effect, this change transfers the volume pumped by Well 17 from a groundwater source to a surface water source. However, the depletion of streamflow entering Tack Factory Pond due to groundwater pumping still reflects the full pumped volume from all upstream wells including Well 17 (0.69 mgd total (479 gpm)). An additional 0.31 mgd (215 gpm) of groundwater is still available from wells outside the Old Oaken Bucket Pond drainage area (i.e., Wells 10, 11 and 18).

4. Total Outdoor Watering Ban Trigger

The current *Interim Operating Plan* and WEAP model assume that the Total Outdoor Water Ban is enacted when the water level in the Reservoir drops 4 feet below the spillway. Previous modeling (2017) indicated that moving the trigger to 1 foot below the spillway resulted in nearly continuous water ban conditions, while a trigger of 5 feet below the spillway impacted environmental flows for fish migration. Scenarios for both 3 and 4 foot triggers were modeled in 2019 to assist the town in determining an appropriate balance between number of days residents must conserve water and the environmental performance of the system. A 4-foot trigger was applied in Phase 2 Scenarios to provide moderate results for the duration of water bans as well as environmental performance.

Based on previous modeling and Scituate's water use during the 2016 drought, all of the Phase 1 and Phase 2 scenarios assume 6% below average monthly water use when the Total Outdoor Water Ban is first enacted and 25% below average water use when the water level in the Reservoir drops one additional foot, reflecting the effect of increased publicity and enforcement on actual water conservation behavior as seen during the 2016 drought.

The Total Outdoor Water Ban trigger levels are set in the WEAP model by adjusting the variables 'OWBT Trigger 1' and 'OWBT Trigger 2' to reflect the trigger elevations for the initial ban announcement and subsequent enforcement (one foot lower), as well as the 'OWBT Level 1' and 'OWBT Level 2', which reflect the water conservation savings assumptions.

5. Streamflow Cutoff Trigger

The current *Interim Operating Plan* and model assume that all downstream releases to First Herring Brook cease when the water level in the Reservoir drops 8 feet below the full storage capacity of the Reservoir. In Phase 1 scenarios, two stream flow cutoff triggers were tested: 5.5 and 8 feet below the new full storage capacity. Over the model's period of record from 1961-2016 the Reservoir only dropped 8 feet below the full storage elevation during the 1965-1966 drought of record in the baseline scenarios. The 5.5-foot level was also triggered during the most extreme phases of the 1980-1981 and 2016 drought conditions. The 5.5-foot trigger level was used for the Final Baseline and Well 17 Redirect scenarios as well as all of the Phase 2 scenarios.

The streamflow cutoff trigger in WEAP was adjusted by setting the streamflow targets below the Reservoir and Old Oaken Bucket Pond to zero at the appropriate Reservoir water level elevation trigger.

6. Fish Ladder Operation

In all Phase 1 and Phase 2 model scenarios for the future dam configuration, the fall fish ladder flow goals for the Reservoir were adjusted to reflect operation of the weir baffles to maintain an average fall flow of 0.60 cfs. Previous model scenarios for Reservoir fish ladder flows were based on the depth of water over ladder, with a minimum flow of 0.45 cfs in the fall.

Spring fish ladder flows and fish ladder flows out of Old Oaken Bucket Pond were unchanged from the previous model scenarios. These flows were based on the minimum width and depth needed to pass adult fish during the spring migration and juvenile fish during the fall migration, as provided by the MA Department of Marine Fisheries (Table 2). However, in the scenarios for the current dam configuration (as opposed to increasing the full storage elevation in the future), active releases at the Reservoir were not included because the ladder cannot provide successful fish passage without structural modifications.

Table 2. Fish ladder flow goals (cfs) (bold = revised value)

Reservoir		*Old Oaken Bucket Pond*	
Apr-May	*Sep-Oct*	*Apr-May*	*Sep-Oct*
2.56	***0.60***	*2.56*	*0.45*

In addition to updating the Reservoir ladder fall releases, the minimum operational elevation of the Reservoir fish ladder was lowered from 37.3 ft. in Phase 1 scenarios to 35.5 ft. in the '2019 Future

Baseline' and '2019 Future Well 17 Redirect' scenarios to improve the ability of the system to successfully pass fish at the Reservoir and Old Oaken Bucket Pond during periods of low water levels, particularly during the fall herring migration season. In the '2019 Future Baseline 36.2' and '2019 Future Well 17 Redirect 36.2' scenarios, the minimum Reservoir fish ladder operational level was raised slightly to a more moderate 36.2 ft. to reduce the cost of dam modifications while still meeting fish passage performance goals.

A new 'Baffle_Min_water_level' variable was created in the WEAP model to represent the minimum operational water level elevation in the Reservoir. Previously, ladder flows were based on a minimum depth over the ladder's exit elevation; however, with the proposed fish ladder modifications a series of baffles will be managed to provide an average of 0.60 cfs at all water level elevations above the minimum operating level.

7. Old Oaken Bucket Augmentation Rule

Previous model results indicated that the Reservoir's fish ladder was operational during the fall migration season much more frequently than Old Oaken Bucket Pond's fish ladder. As a result, a rule was created to balance water storage between Old Oaken Bucket Pond and the Reservoir to enable similar fish ladder effectiveness at both sites.

In some of the 2019 Phase 2 scenarios, the Old Oaken Bucket Augmentation Rule was increased to provide 1.0 cfs (0.54 mgd) instead of 0.66 cfs (0.36 mgd) from the Reservoir on any day during the fall migration period when the water level in the Reservoir is high enough to provide adequate depth for out-migrating fish but the water level in Old Oaken Bucket Pond is too low to provide adequate depth through its fish ladder. Overall, the rule results in the transfer of water stored in the Reservoir to Old Oaken Bucket Pond to raise the water level in Old Oaken Bucket Pond for successful fish ladder operation as needed during the fall outmigration period. The rule does not increase the amount of flow required to be released downstream from old Oaken Bucket Pond but does allow the ladder to be functional more frequently during the fall herring out-migration season.

8. Aquatic Habitat Bioperiod Releases

Stream flow goals for aquatic habitat bioperiods were modified slightly from previous modeling efforts to include the more recent period of record (1962-2016 vs. 1962-2000). The 90th percentile low flows for each bioperiod were recalculated over the longer period of record and used as minimum stream flow goals for the outlets of the Reservoir and Old Oaken Bucket Pond (Table 3).

A further change was made to reduce the aquatic habitat bioperiod flow goal in May downstream of Old Oaken Bucket Pond. This change was made to help retain water storage in the Reservoir during dry springs for water supply use the following summer while maintaining fish ladder operability and provide aquatic habitat flows similar to the month of May's 90th percentile low flow. Figure 3 compares the old and updated (new) monthly and bioperiod 90th percentile (Q90) flow statistics.

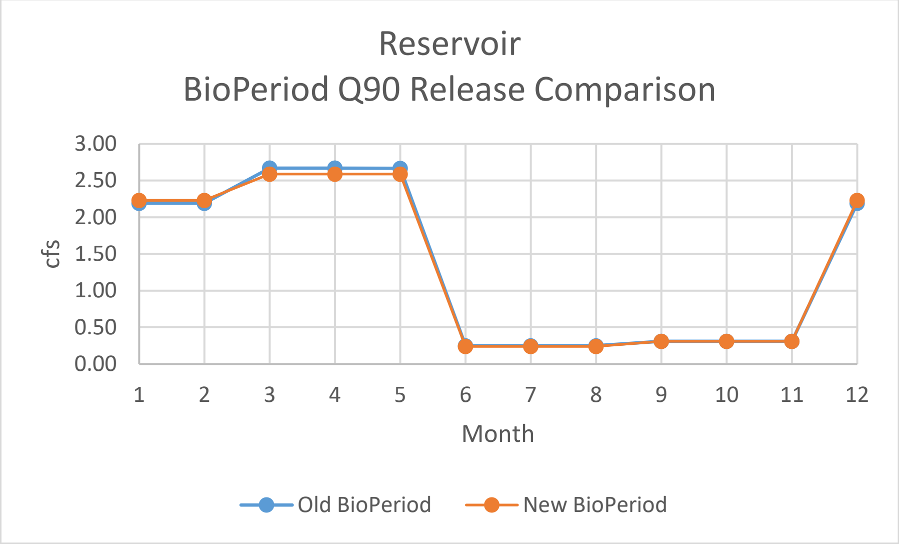
Table 3. New aquatic habitat (BioQ90) release goals (cfs/mgd)

'Old' statistics are based on unimpacted flow estimates for 1962-2000; 'New' statistics are based on unimpacted flow estimates for 1962-2016

Bioperiod	Reservoir (Old)	Reservoir (New)	Old Oaken Bucket Pond (Old)	Old Oaken Bucket Pond (New)
Dec - Feb	2.19 / 1.42	2.23 / 1.44	3.23 / 2.09	2.85 / 1.84
Mar-Apr	2.67 / 1.73	2.59 / 1.67	3.93 / 2.54	3.30 / 2.13*
May	2.67 / 1.73	2.59 / 1.67	3.93 / 2.54	2.56 / 1.65**
Jun – Aug	0.25 / 0.16	0.24 / 0.16	0.43 / 0.28	0.36 / 0.23
Sep – Nov	0.31 / 0.20	0.31 / 0.20	0.52 / 0.34	0.44 / 0.28

**March-May Q90 flows*

***Spring fish ladder flow*



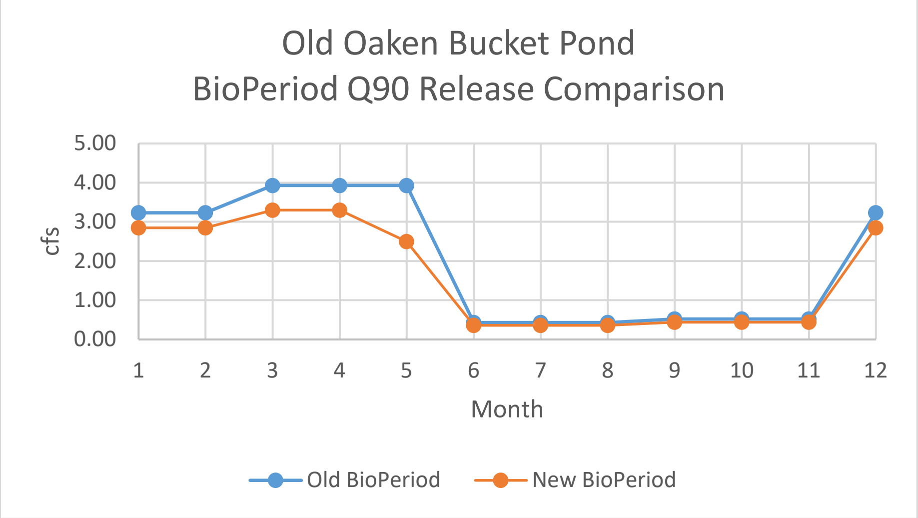


Figure 3. Comparison of old and new aquatic habitat bioperiod releases

Results

Phase 1 Results

All of the Phase 1 scenarios provided adequate water to meet the Town's needs during the drought of record, with the minimum remaining water storage in the Reservoir ranging from 2.1 – 54.4 MG (Table 4). Total Outdoor Water Bans were triggered on average 18-34 days in summer (Jun-Sep). In 40-62% of years across the period of record (1961-2016) the Total Outdoor Water Ban was not triggered at all during the summer. The main challenge with Phase 1 scenarios was the moderate performance of the fish ladders in the fall bioperiod, which ranged from 42-78% successful fish migration days. Spring fish ladder success was greater than 90% for all scenarios. Full performance results for Phase 1 are presented in Appendix C.

Table 4. Phase 1 scenarios' fish ladder performance (% of days with adequate flow) and minimum Reservoir water storage during the drought of record

Fish Ladder Success	Reservoir		OOB		Min Reservoir Storage
% of Days	Spring	Fall	Spring	Fall	MG
2017 Reservoir 40 IOP baseline	NA	NA	93%	50%	20.0
2019 Ice Pigging 40-3-5.5	NA	NA	91%	43%	30.3
2019 Ice Pigging 40-3-8	NA	NA	91%	42%	7.5
2019 Ice Pigging 40-4-5.5	NA	NA	91%	42%	21.7
2019 Ice Pigging 40-4-8	NA	NA	91%	42%	2.1
2019 Ice Pigging 41.5-3-5.5	98%	67%	97%	78%	32.8
2019 Ice Pigging 41.5-3-8	97%	67%	97%	78%	28.3
2019 Ice Pigging 41.5-4-5.5	98%	64%	97%	63%	45.1
2019 Ice Pigging 41.5-4-8	97%	64%	97%	62%	22.8
2019 Updated Baseline 40-3-5.5	NA	NA	92%	44%	32.8
2019 Updated Baseline 40-3-8	NA	NA	92%	44%	9.2
2019 Updated Baseline 40-4-5.5	NA	NA	92%	44%	22.4
2019 Updated Baseline 40-4-8	NA	NA	92%	43%	4.5
2019 Well 17 Redirect 40-3-5.5	NA	NA	92%	42%	33.2
2019 Well 17 Redirect 40-3-8	NA	NA	92%	42%	12.2
2019 Well 17 Redirect 40-4-5.5	NA	NA	92%	42%	22.3
2019 Well 17 Redirect 40-4-8	NA	NA	92%	42%	6.1
2019 Well 17 Redirect 41.5-3-5.5	98%	74%	97%	64%	54.4
2019 Well 17 Redirect 41.5-3-8	97%	74%	97%	64%	36.4
2019 Well 17 Redirect 41.5-4-5.5	98%	66%	97%	60%	45.2
2019 Well 17 Redirect 41.5-4-8	97%	66%	97%	60%	27.1

Phase 2 Results

Based on the results from Phase 1, Phase 2 scenario components focused on strategies to improve fall fish ladder performance and moderate the number of summer days and years under a Total Outdoor Water Ban.

Water Demand

In the 2019 model scenarios, the Total Outdoor Water Ban frequency and water conservation assumptions reduced the amount of water delivered to the Town by varying amounts, while the ice pigging and flushing assumptions increased demand. The 2019 scenarios delivered a total average annual volume of 535-537 MGY, with water ban enforcement and more aggressive Outdoor Water Ban triggers resulting in up to 64 MGY lower demand for water during dry years (Table 5). Compared to the original model's 1999 – 2007 average of 614 MGY this is a considerable savings, due in part to the implementation of the outdoor irrigation restriction as well as the trigger levels and assumptions about water savings due to the Total Outdoor Water Ban. In years with no water ban, the maximum demand was 543 MGY for all Phase 2 scenarios due to the additional 8 MGY demand for ice pigging and flushing. All of the Phase 2 scenarios were able to fully supply the Town's demands for water every year, even through the drought of record.

Table 5. Annual water supply delivered (MGY)

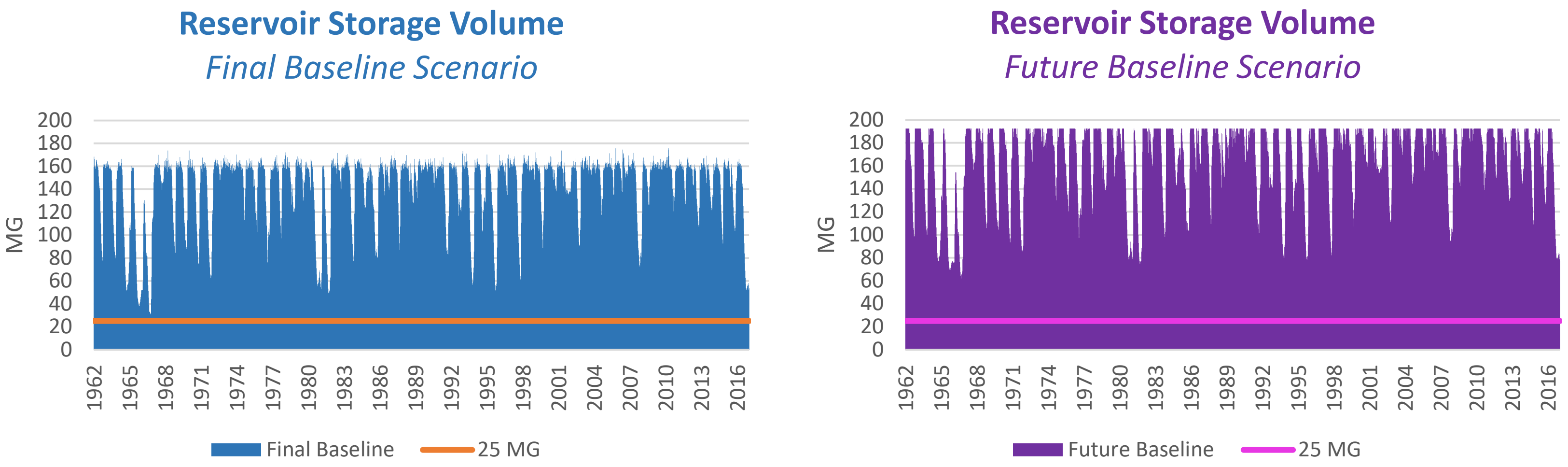
Scenario	Min	Mean	Max
2019 Final Baseline with OOB Aug rule	478	536	543
2019 Final Well 17 Redirect OOB Aug rule	486	537	543
2019 Future Baseline 36.2	471	535	543
2019 Future Well 17 Redirect 36.2	481	536	543

Drought Resilience

All of the Phase 2 scenarios provided adequate water to meet the Town's needs with some water storage buffer even during climatic conditions similar to the drought of record. Phase 2 scenarios generally had greater drought resilience than Phase 1 scenarios, with minimum remaining water storage buffers in the Reservoir ranging from 28.7 – 60.4 MG (Table 6). The Scituate Department of Public Works (DPW) cited a comfort level of 25 MG as a minimum Reservoir storage buffer to allow for emergency use (fire, etc.) during drought conditions. All of the Phase 2 scenarios were able to provide this level of drought resilience (Figure 4). Another rule of thumb used by the DPW to gauge the likelihood of a summer water shortage is at least 154 MG of water in the Reservoir on June 8. In the current dam configuration ('2019 Final Baseline' scenario), this threshold was met 73% of years over the period of record (1961-2016), with many years hovering close to 154 MG and a maximum of 167 MG (Figure 5). In the future dam configuration scenarios ('2019 Future Baseline 36.2' and '2019 Future Well 17 Redirect 36.2' scenarios) June 8 Reservoir storage was at least 154 MG in 87% of years, with a maximum of 192 MG (Figure 5).

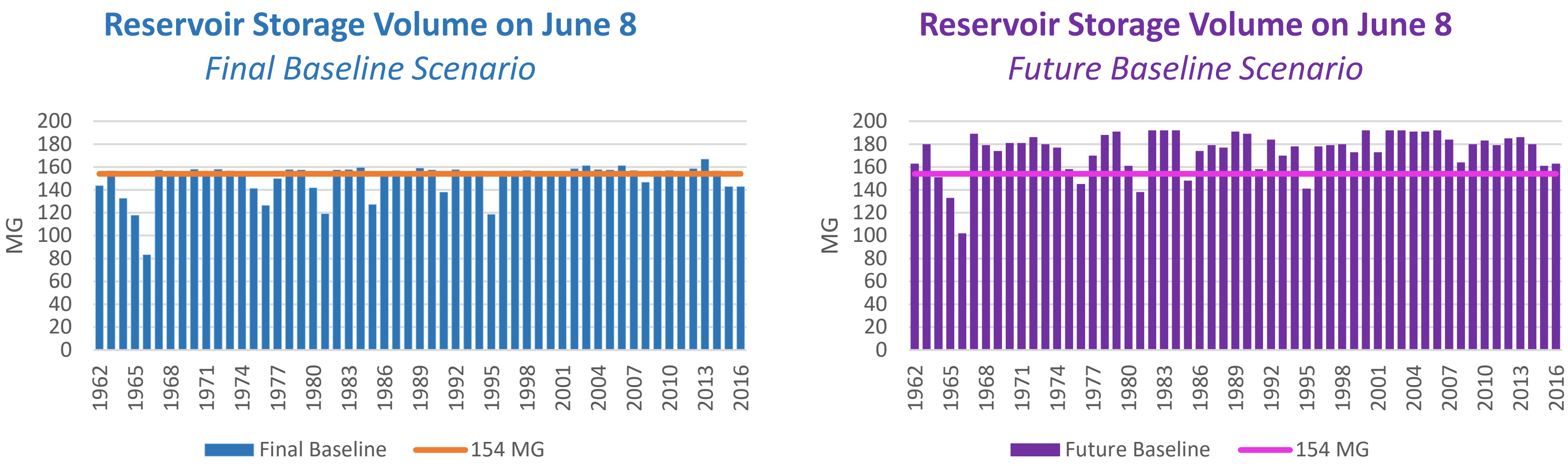
Table 6. Phase 2 scenarios' minimum storage volumes in the Reservoir

Scenario	Minimum Reservoir Storage (MG)
2019 Final Baseline with OOB Aug rule	28.7
2019 Final Well 17 Redirect OOB Aug rule	42.9
2019 Future Baseline 36.2	60.4
2019 Future Well 17 Redirect 36.2	63.7


Reservoir Storage Volume
Final Baseline Scenario

Reservoir Storage Volume
Future Baseline Scenario

Figure 4. Daily Reservoir storage volume under current (Final Baseline) and future (Future Baseline) dam configurations


Reservoir Storage Volume on June 8
Final Baseline Scenario

Reservoir Storage Volume on June 8
Future Baseline Scenario

Figure 5. Reservoir storage on June 8 under current (Final Baseline) and future (Future Baseline) dam configurations

Total Outdoor Water Bans

Total Outdoor Water Bans were triggered in Phase 2 scenarios for fewer summer days than in Phase 1 scenarios (8-12 days in summer (Jun-Sep)), with less than 1 week of enforced conditions per year on average (Table 7). No Total Outdoor Water Ban was triggered in 67-80% of years across the period of record (1961-2016). Some Total Outdoor Water Ban days did occur outside of the summer period; these are not reported here because they would have less impact the quality of life for Scituate residents than bans occurring during the main outdoor water use season.

Table 7. Phase 2 scenarios' Total Outdoor Water Ban summer occurrence

Scenario	Average # Jun-Sep Days per Year Under Water Ban	Average # Jun-Sep Days Per Year Under Enforced Water Ban	Average % of Years With No Water Ban Days Jun-Sep
2019 Final Baseline with OOB Aug rule	8	5	80%
2019 Final Well 17 Redirect OOB Aug rule	8	4	80%
2019 Future Baseline 36.2	12	6	67%
2019 Future Well 17 Redirect 36.2	12	5	67%

Fish Ladder Performance

The success of the fish ladders at the Reservoir and Old Oaken Bucket Pond was assessed based on the percent of days during the migration periods in which the fish ladder flow goals (Table 2) were met, the percent of years with greater than 80% successful migration days and the percent of years with no successful migration days. In the current dam configuration scenarios ('2019 Final Baseline' and '2019 Final Well 17 Redirect'), the Reservoir fish ladder was not operable due to its current exit elevation, which is located at the same level as the current spillway elevation and precludes successful fish passage.

Phase 2 scenario changes in the Reservoir fish ladder operational level, Old Oaken Bucket Augmentation rule and aquatic habitat flows improved the performance of the fish ladders in the fall to 52-89% successful days. The poorest fall fish ladder performance (52%) was at the Old Oaken Bucket Pond fish ladder in the '2019 Final Well 17 Redirect OOB Aug Rule' scenario. Spring flows at both ladders and fall flows at the Reservoir fish ladder had greater than 80% successful days. Years with highly successful fish ladder flows (>80% of migration days with adequate flow) occurred in 84-96% of years at the Reservoir and at Old Oaken Bucket Pond in the spring. In the fall, the Old Oaken Bucket Pond fish ladder had highly successful fish ladder success in 42-47% of years. In 2% of years (i.e., 1.4 years over the 1961-2016 period of record), ladders at both the Reservoir and Old Oaken Bucket Pond had 0 days of successful fish ladder flow in the fall (Table 8). This statistic indicates that during climatic conditions similar to the drought of record, there would be no successful juvenile herring migration out of the system in the fall (Sep-Oct).

Table 8. Phase 2 scenarios' fish ladder success

Fish Ladder Daily Success	% of Days With Adequate Flow			
	Reservoir		Old Oaken Bucket Pond	
Scenario	Spring	Fall	Spring	Fall
2019 Final Baseline with OOB Aug rule	NA	NA	96%	66%
2019 Final Well 17 Redirect OOB Aug rule	NA	NA	96%	52%
2019 Future Baseline 36.2	98%	88%	97%	82%
2019 Future Well 17 Redirect 36.2	98%	89%	98%	71%

Fish Ladder Annual Success	% of Years With >80% Successful Days			
	Reservoir		Old Oaken Bucket Pond	
Scenario	Spring	Fall	Spring	Fall
2019 Final Baseline with OOB Aug rule	NA	NA	98%	44%
2019 Final Well 17 Redirect OOB Aug rule	NA	NA	98%	58%
2019 Future Baseline 36.2	96%	84%	89%	42%
2019 Future Well 17 Redirect 36.2	96%	87%	98%	47%

Fish Ladder Annual Failure	% of Years with 0 Successful Days			
	Reservoir		Old Oaken Bucket Pond	
Scenario	Spring	Fall	Spring	Fall
2019 Final Baseline with OOB Aug rule	NA	NA	0%	0%
2019 Final Well 17 Redirect OOB Aug rule	NA	NA	0%	31%
2019 Future Baseline 36.2	0%	2%	0%	2%
2019 Future Well 17 Redirect 36.2	0%	2%	0%	2%

Stream Flow

The effect of each management option on stream flow was evaluated using the number of zero flow days, the percent of days that met the seasonal minimum flow releases and the percent of days that aquatic habitat flow goals were met compared to natural conditions.

Zero Flow Days

Initial modeling of unimpacted streamflow (i.e., natural conditions) near the outlets of the Reservoir and Old Oaken Bucket Pond indicated that First Herring Brook is a perennial stream in this reach, with no days of zero flow experienced during the period of record. Phase 2 scenarios included an adjustment of the streamflow cutoff threshold up from 8 feet below the spillway to 5.5 feet below the spillway. This change resulted in some periods of no flow during portions of the 1960’s, 1980’s and 2016 extreme droughts. In the phase 2 scenarios, First Herring Brook was modeled to have zero flow for 1-62 days downstream of the Reservoir (< 0.1% of days) and 116-195 days downstream of Old Oaken Bucket Pond (0.6 – 1.0% of days) over the period of record (Table 9).

Table 9. Number of zero flow days during the period of record (1961-2016)

Scenario	Downstream of Reservoir	Downstream of Old Oaken Bucket Pond
2019 Final Baseline with OOB Aug rule	62	116
2019 Final Well 17 Redirect OOB Aug rule	2	150
2019 Future Baseline 36.2	13	195
2019 Future Well 17 Redirect 36.2	1	177

BioQ90 Seasonal Aquatic Habitat Releases

During the 2019 modeling effort, the BioQ90 seasonal aquatic habitat releases were updated based on a longer period of record extending from 1961-2016, as described above. The modified minimum flow goals were generally slightly lower than the previous versions, and the May bioperiod downstream of Old Oaken Bucket Pond was reduced to the fish ladder flow goal, which was similar to the May BioQ90 (lower than the Mar-May BioQ90 that was previously used). The modified BioQ90 flow goals were met for 79-100% of days for the Phase 2 scenarios (Table 11). The greatest success was downstream of the Reservoir during the summer bioperiod, where BioQ90 goals were met 100% of days. During this period, greater releases occur to shuttle water downstream to Old Oaken Bucket Pond to meet summer water demands. The spring bioperiod downstream of Old Oaken Bucket Pond had the lowest BioQ90 flow achievement rate in scenarios with the current dam configuration. However, even in these scenarios minimum flows were met for 79% of spring days over the period of record.

Table 10. Percent of bioperiod meeting the seasonal (BioQ90) minimum streamflow goals

	Reservoir				Old Oaken Bucket Pond				
Scenario	Dec - Feb	Mar- May	Jun – Aug	Sep – Nov	Dec - Feb	Mar- Apr	May	Jun – Aug	Sep – Nov
2019 Final Baseline with OOB Aug rule	90%	95%	100%	79%	90%	79%	96%	90%	92%
2019 Final Well 17 Redirect OOB Aug rule	95%	96%	100%	92%	90%	79%	96%	90%	90%
2019 Future Baseline 36.2	92%	98%	100%	88%	90%	92%	97%	90%	94%
2019 Future Well 17 Redirect 36.2	96%	98%	100%	94%	90%	91%	97%	90%	92%

Median Aquatic Habitat Flow Goals

Loftier median bioperiod streamflow goals were determined by the First Herring Brook working group in the initial 2009 modeling effort (Table 11). An assessment of minimum water depths in First Herring Brook was used to adjust the bioperiod medians using select monthly median values to provide at least 6 inches of depth for herring and native aquatic species movement in the river in all months.

Table 12 provides a summary of the percent of days in each bioperiod that met or exceeded the aquatic habitat flow goals compared to unimpacted conditions downstream of the Reservoir and Old Oaken Bucket Pond. Downstream of the Reservoir, summer and early fall releases to meet the Town’s demand resulted in greater success meeting the aquatic habitat goals than the unimpacted condition while fall flows only met the aquatic habitat flow goals about half as often. Downstream of Old Oaken Bucket

Pond, summer aquatic habitat flow goals were met infrequently (26-35% as often as under unimpacted conditions) while other bioperiods provided these flows approximately 46-62% as often as unimpacted conditions. Differences in aquatic habitat flow goal achievement were also smaller between scenarios than between bioperiods downstream of Old Oaken Bucket Pond.

Table 11. Median aquatic habitat flow goals

Bioperiod	Downstream of Reservoir (cfs)	Downstream of Old Oaken Bucket Pond (cfs)
Dec – Feb	5.31	7.76
Mar - Apr	4.03	10.41
May	4.03	5.9
Jun – Aug	0.83	1.83
Sep	0.80	2.63
Oct - Nov	1.56	2.63

Table 12. Median aquatic habitat flow goal achievement

	Reservoir BioPeriod					Old Oaken Bucket Pond BioPeriod				
Scenario	**Dec - Feb**	**Mar - May**	**Jun - Aug**	**Sep**	**Oct-Nov**	**Dec - Feb**	**Mar-Apr**	**May**	**Jun-Aug**	**Sep-Nov**
2019 Final Baseline with OOB Aug rule	70%	79%	150%	153%	51%	52%	53%	56%	26%	46%
2019 Final Well 17 Redirect OOB Aug rule	81%	88%	155%	184%	64%	58%	57%	58%	26%	46%
2019 Future Baseline 36.2	78%	96%	151%	124%	54%	59%	62%	56%	35%	48%
2019 Future Well 17 Redirect 36.2	79%	109%	157%	179%	73%	60%	62%	55%	34%	47%

Water Level Change in the Future Dam Configuration

As part of the permitting process to raise the full storage elevation of the Reservoir, wetland impacts due to changing water level elevations and durations will be considered. To support these decisions, Reservoir water level durations were compiled for current and future Reservoir full storage elevation conditions (Figure 6). On average, Reservoir water levels will be 1.1 feet higher in the future dam configuration, while at lower water levels the future configuration will be up to 2.3 feet higher.

A wetlands vegetation study is being conducted to assess impacts resulting from the higher proposed reservoir levels. As shown on Figure 7, WEAP model results for the 2019 Future Baseline 36.2 scenario indicate that the 2011-2016 period are representative of the entire 1966-2016 period.

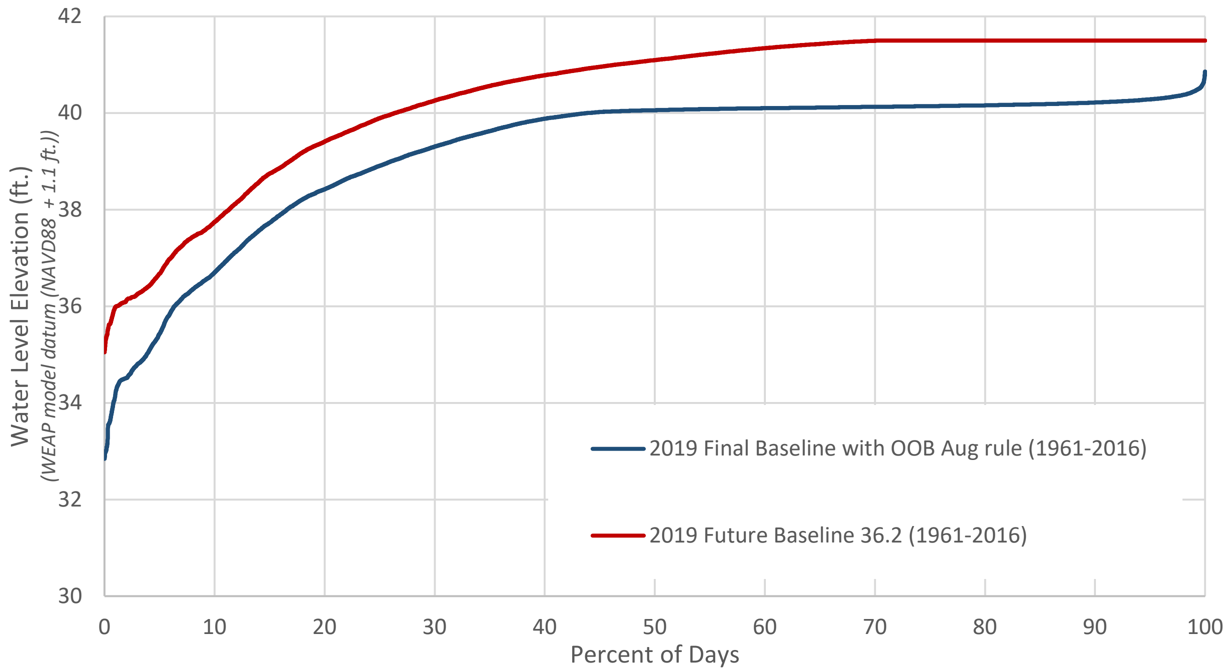
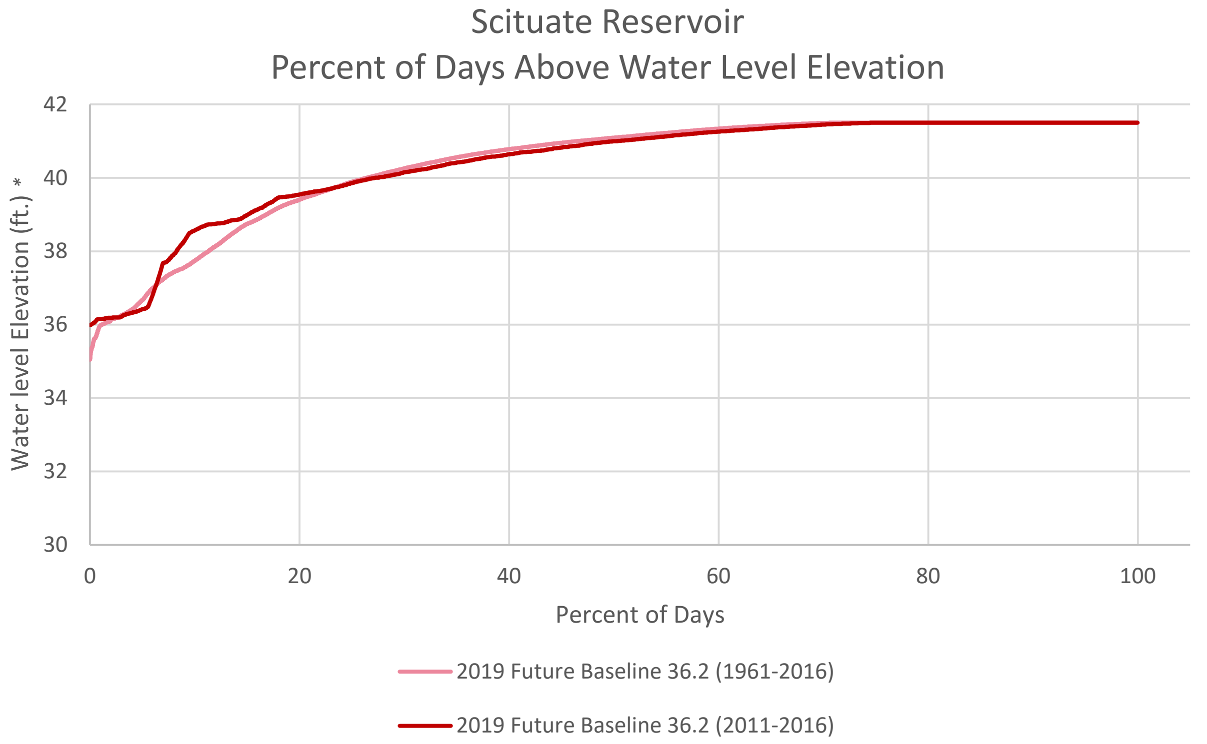


Figure 6. Scituate Reservoir percent of days above water level elevation (WEAP model datum)



*NAVD88 datum

Figure 7. Scituate Reservoir percent of days above water level elevation for the model period of record vs. 2011-2016 for the future dam configuration (NAVD88 datum)

System Yield

The total yield of Scituate's surface and groundwater supply system is a function of each of the components of water demand and operational management detailed above as well as climatic conditions. Rather than increasing system yield per se, the goals of the effort to raise the full storage elevation of the Reservoir were to increase drought resilience by providing a larger buffer during dry periods as well as to improve environmental performance by providing sustainable seasonal flows for aquatic habitat and fish ladder operation. That said, an estimate of total yield can be made by adding the water supply delivered to meet town demands during the drought of record (1966) from both surface and groundwater supplies to the minimum Reservoir storage that year (Table 13). For the current dam configuration, the system would yield 506.6 MGY; moving to the future dam configuration would add approximately 25 MGY, for a total system yield during the drought of record of 531.9 MGY. Note that the water supply delivered for the current and future dam configurations is able to meet all of the town's current water needs, as modified by water conservation and environmental release assumptions, at an annual average daily rate of approximately 1.3 mgd during the drought of record. At this rate of consumption, the additional 25 MGY provided by the future dam configuration represents approximately an additional 19 days of water supply.

Table 13. System yield estimates

Scenario	Total Water Supply Delivered (MGY)	Minimum Reservoir Storage (MG)	Total System Yield (MGY)	Surface Water Supply Delivered (MGY)	Surface Water Yield (MGY)	Surface Water Yield (mgd)
2019 Final Baseline with OOB Aug Rule	477.9	28.7	506.6	112.9	141.6	0.39
2019 Future Baseline 36.2	471.5	60.4	531.9	245.2	166.9	0.46

The MassDEP (1996) guidance document defines the firm yield of a single reservoir as the maximum yield that results in the complete depletion of the reservoir's usable storage for no more than one month of a period of record. The firm yield relative to the Water Management Act (WMA) does not include groundwater sources. The original WEAP model report (The Nature Conservancy, 2010) for then-current operations without aquatic habitat or fish ladder releases stated that "… The currently permitted yield of the reservoir system plus upstream groundwater wells is 1.79 mgd. Our model estimated a virtually identical yield of 1.77 mgd, a high degree of correlation that helped provide confidence in our ability to accurately model the Scituate water supply system and First Herring Brook hydrology…". The average groundwater pumping rate in the 2010 model, as in the current model, was 1 mgd resulting in a 0.77 mgd Firm Yield for the reservoir. However, the 2010 scenario that included aquatic habitat flows in addition to then-current operations resulted in a yield of 1.2 mgd (i.e., 0.2 mgd Reservoir yield) and resulted in complete Reservoir depletion and inability to meet the Town's water supply demand. Subsequent modeling sought to eliminate Reservoir failure, provide both aquatic habitat and fish ladder flows and identify beneficial water conservation strategies, resulting in the 2019 preferred scenarios. The 2019 WEAP model results for the 1966 drought of record provide a Reservoir firm yield of 0.39 mgd for the existing dam configuration and operation (2019 Final baseline with OOB Aug Rule) and 0.46 mgd for the future dam configuration and operation (2019 Future Baseline 36.2) while providing aquatic habitat and fish ladder flows and additional drought resilience in the form of a buffer of water in the Reservoir during the drought of record. Complete documentation of the Firm Yield for the future dam configuration (i.e., proposed Project) is presented in DEIR Appendix J, Water Management Study.

Conclusions

System sensitivity

Modeling indicated that the performance of Scituate's water system was only incrementally impacted by changing the location of Well 17's discharge and increasing water demand for ice pigging and flushing. Additional scenarios run on an ad hoc basis and not fully reported here indicated that the system is more sensitive to changes in the amount of groundwater available for use; a change from 1.0 to 0.9 mgd groundwater withdrawal produced a noticeable drop in minimum Reservoir storage during the drought of record, thus reducing the Town's resilience to extreme droughts. Previous modeling also revealed the system's sensitivity to water conservation assumptions during the Total Outdoor Watering Ban and the need for increased publicity and enforcement during droughts to affect residents' behavior.

Preferred Scenarios

Two sets of workable scenarios emerged that balanced drought resilience with environmental performance: one with Well 17 discharging to Tack Factory Pond and one with the well discharging to Old Oaken Bucket Pond. During the course of the project, the Town determined that moving Well 17's discharge to Tack Factory Pond was not feasible, leaving a single preferred scenario for both current and future dam configurations ('2019 Final Baseline with OOB Aug Rule' and '2019 Future Baseline 36.2', respectively). Both preferred scenarios delivered adequate water to supply the Town's needs during the drought of record with Reservoir storage buffers of 28 and 60 MG, respectively. Total Outdoor Water Bans occurred 8-12 summer days per year with an average 67-80% of years having no summer days under the Total Outdoor Water Ban. Both preferred scenarios resulted in zero streamflow in First Herring Brook for less than 1% of days over the period of record and met seasonal BioQ90 flow release goals 79-100% of days. Seasonal fish ladder success in the future dam configuration ranged 82-98% for both ladders. In the current dam configuration the Reservoir ladder remained structurally inoperable and the Old Oaken Bucket Pond fish ladder continued to have lower success during the fall outmigration period (66% successful fall days).

Key operational aspects of the preferred scenarios are:

1. The Total Outdoor Water Ban is triggered when the Reservoir water level is 4 feet below its full storage elevation.
2. When the Reservoir water levels drops to 5 feet below full storage elevation, enforcement and publicity of the Total Outdoor Water Ban produces greater water conservation results (water demand drops to 25% lower than average monthly demands). Achieving this water conservation outcome is key to maintaining the resilience of the water system to extreme droughts.
3. Groundwater sources produce 1 mgd. The system's drought resilience is sensitive to reductions in groundwater yield of as little as 0.1 mgd on an annual average.
4. Updated BioQ90 seasonal aquatic habitat releases provided in the report should be incorporated into the Interim and Final Operating Plans. These releases are generally lower than previous versions, indicating that the last 16 years were drier than the previous 38.

5. BioQ90 seasonal aquatic habitat releases cease when the Reservoir water level is 5.5 feet below the Reservoir's full storage elevation. The *Interim Operational Plan* should be updated accordingly.
6. In the current Reservoir dam configuration, fish ladder releases should be provided at Old Oaken Bucket Pond only. Once the Reservoir dam and fish ladder are updated, both ladders should be operated to provide spring and fall migration fish ladder releases. Note that the Reservoir's fish ladder baffles will need to be actively managed to achieve these flows (some automation may be possible). The minimum operational water level for the Reservoir's fish ladder will be 36.2 ft. (WEAP datum; equivalent to 35.1 ft. NAVD88).
7. Water levels in Old Oaken Bucket Pond should be managed to enable fish ladder releases when Reservoir water levels are high enough to operate the Reservoir fish ladder, particularly during the fall migration period, so that fish may enter and exit the entire system.
8. In the current dam configuration, providing Old Oaken Bucket fall fish ladder flows is likely to remain a challenge during dry years. Pulsed releases may be considered if juvenile fish are seen attempting to exit the system.

The Way Forward

One of the considerations in permitting the raising of the full storage elevation of the Reservoir dam is the extent of wetland change due to changes in water inundation, both in aerial coverage and duration of inundation. At moderate water level elevations (above approximately 36 ft. (WEAP datum)), water levels are expected to be about 1.1 feet higher, while lower water levels will increase up to 2.3 feet. The shape of the frequency-elevation curve is similar in the current and future dam configurations, indicating that while the water depth will increase, the period of periods of inundation are similar. This information will be used in concert with an analysis of wetland plant community change to inform permitting decisions for the structural dam changes.

One of the benefits of increasing the full storage elevation of the Reservoir by 1.5 feet, in addition to improved environmental performance, will be a greater storage buffer in the Reservoir during extreme droughts like the 1960's drought of record (60 MG vs. 29 MG). The Town will need to determine how to allocate this additional water storage buffer during dry periods to best suit its needs moving forward. One option is to maintain the additional storage as a buffer in case of an unforeseen emergency such as a large fire or leak during an extreme drought, while another option is to allow the town's demand for water supply to increase as new connections to the system are established, thus reducing the drought buffer. Although the approaches to defining system yield in the WEAP model and in the Massachusetts DEP's Water Management Act permitting process are not equivalent, evaluation of the WEAP model results suggests that the Town's currently permitted withdrawal volume (1.75 MGD / 638.75 MGY through 8/31/2020 (without Humarock)) is not sustainable during a drought of record using only existing sources. However, the model also indicates that if the system and outdoor water use are managed according to the set of rules outlined in the preferred scenario, there is adequate water supply from existing sources to meet the needs of the current population in both the current and future dam configurations. The decision of how much of the buffer to allocate to drought resilience should be made, in part, based on detailed projections of future demand and future water availability. Predicted changes in regional rainfall-runoff patterns and residential lot sub-divisions are two factors that have been identified as significant variables affecting Scituate's future water supply security that require additional consideration and planning.

Results of the 2019 WEAP modeling effort can be used to inform water supply and water conservation planning efforts, such as adjusting Total Outdoor Water Ban trigger levels and increasing the full storage elevation of the Reservoir but are somewhat less useful for managing daily operations because they rely on hard and fast management rules that do not account for unusual events or limiting circumstances. An adaptive management daily operational tool has been developed by the North and South Rivers Watershed Association that uses current reservoir levels and surface water pumping rates to project when the water ban and streamflow cutoffs might be reached, given low precipitation and releases of streamflow according to the IOP. Similar to the rule of thumb of having 154 MG of water storage on June 8, this tool will help provide early identification of developing water shortages and can be also be used to measure system recovery.

Recommendations

1. Update the *Interim Operational Plan* to reflect the updated BioQ90 seasonal aquatic habitat flows and associated water depth indicators.
2. Review relevant bylaws and operating procedures to implement the Total Outdoor Water Ban at 4 feet below the full storage elevation of the Reservoir.
3. Review relevant bylaws and operating procedures to implement the Streamflow Cutoff threshold at 5.5 feet below the full storage elevation of the Reservoir.
4. Continue with permitting and construction to increase the full storage elevation of the Reservoir by 1.5 feet and update the fish ladder and spillway capacity. Develop a *Final Operational Plan* to help water department staff operate the new structures to meet water supply and environmental performance goals.
5. Investigate opportunities to improve water conservation results during a declared Total Outdoor Water Ban, such as direct communication with high water users, increased publicity, education and enforcement. Track efforts and results over time to gain an understanding of the factors affecting the town's water use elasticity.
6. Complete, test and refine the adaptive management tool being develop by the North and South Rivers Watershed Association to regularly monitor the surface water supply and provide management guidance for water bans and streamflow, especially during abnormal conditions.
7. Continue to plan for the Town's future water needs:
    a. Develop customer messaging strategies to improve water conservation during Outdoor Water Bans.
    b. Complete a local water demand projection that evaluates the potential for existing residential lot subdivision and seasonal population increases, among other factors.
    c. Evaluate the effect of changing precipitation patterns on Scituate's drought resilience and water storage buffer.
    d. Investigate new well locations or capacities.

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Appendix A. Storage-Elevation Tables

Table 14. Reservoir storage elevation table for current (full storage elevation 40.0 ft.) and proposed future (full storage elevation 41.5 ft.) conditions

Elevation (ft.)	Volume (MG)	% Full Current	% Full Future
27.0	0	0	0
30.0	1	1%	1%
32.0	18	11%	9%
32.5	24	16%	13%
33.0	31	20%	16%
33.5	37	24%	19%
34.0	44	28%	23%
34.5	52	33%	27%
35.0	60	38%	31%
35.5	68	44%	35%
36.0	76	49%	39%
36.5	85	55%	44%
37.0	95	61%	49%
37.5	104	67%	54%
38.0	114	73%	59%
38.5	124	80%	64%
39.0	134	87%	70%
39.5	145	93%	75%
40.0	155	100%	81%
40.5	167	107%	87%
41.0	179	115%	93%
41.5	192	124%	100%
42.0	207	133%	107%

Table 1915. Old Oaken Bucket storage elevation table

Elevation (ft.)	Volume (MG)	% Full
11.3	0	0%
15	0.3	3%
16	0.8	8%
17	1.2	13%
18	4.2	44%
20	9.5	100%
21	14	147%

Appendix B. Phase 1 Scenario Performance Indicators – Full Results

Demand

Table 16. Phase 1 Scenario results: Annual water supply delivered (MGY)

	MGY		
Scenario	**Min**	**Max**	**Mean**
2019 Ice Pigging 40-3-5.5	449	543	527
2019 Ice Pigging 40-3-8	428	543	527
2019 Ice Pigging 40-4-5.5	463	543	532
2019 Ice Pigging 40-4-8	439	543	531
2019 Ice Pigging 41.5-3-5.5	444	543	524
2019 Ice Pigging 41.5-3-8	423	543	524
2019 Ice Pigging 41.5-4-5.5	455	543	531
2019 Ice Pigging 41.5-4-8	435	543	531
2019 Updated Baseline 40-3-5.5	443	535	520
2019 Updated Baseline 40-3-8	423	535	520
2019 Updated Baseline 40-4-5.5	458	535	525
2019 Updated Baseline 40-4-8	434	535	524
2019 Well 17 Redirect 40-3-5.5	445	535	520
2019 Well 17 Redirect 40-3-8	429	535	520
2019 Well 17 Redirect 40-4-5.5	459	535	525
2019 Well 17 Redirect 40-4-8	435	535	524
2019 Well 17 Redirect 41.5-3-5.5	440	535	518
2019 Well 17 Redirect 41.5-3-8	427	535	518
2019 Well 17 Redirect 41.5-4-5.5	454	535	524
2019 Well 17 Redirect 41.5-4-8	433	535	524

Drought Resilience

Table 17. Phase 1 scenario results: Minimum storage volumes in the Reservoir

Scenario	Min Reservoir Storage (MG)
2019 Ice Pigging 40-3-5.5	30.6
2019 Ice Pigging 40-3-8	7.5
2019 Ice Pigging 40-4-5.5	21.7
2019 Ice Pigging 40-4-8	2.1
2019 Ice Pigging 41.5-3-5.5	32.8
2019 Ice Pigging 41.5-3-8	28.3
2019 Ice Pigging 41.5-4-5.5	45.1
2019 Ice Pigging 41.5-4-8	22.8
2019 Updated Baseline 40-3-5.5	32.8
2019 Updated Baseline 40-3-8	9.2
2019 Updated Baseline 40-4-5.5	22.4
2019 Updated Baseline 40-4-8	4.5
2019 Well 17 Redirect 40-3-5.5	33.2
2019 Well 17 Redirect 40-3-8	12.2
2019 Well 17 Redirect 40-4-5.5	22.3
2019 Well 17 Redirect 40-4-8	6.1
2019 Well 17 Redirect 41.5-3-5.5	54.4
2019 Well 17 Redirect 41.5-3-8	36.4
2019 Well 17 Redirect 41.5-4-5.5	45.2
2019 Well 17 Redirect 41.5-4-8	27.1

Total Outdoor Water Bans

Table 18. Phase 1 scenario results: Total Outdoor Water Ban summer occurrence

Scenario	Average # Jun-Sep Days per Year Under Water Ban	Average # Jun-Sep Days Per Year Under Enforced Water Ban	Average % of Years With 0 Jun-Sep Water Ban Days
2019 Ice Pigging 40-3-5.5	29	16	49%
2019 Ice Pigging 40-3-8	29	16	49%
2019 Ice Pigging 40-4-5.5	18	9	62%
2019 Ice Pigging 40-4-8	18	10	62%
2019 Ice Pigging 41.5-3-8	34	19	40%
2019 Ice Pigging 41.5-4-5.5	21	10	58%
2019 Ice Pigging 41.5-4-8	21	10	58%
2019 Updated Baseline 40-3-5.5	28	16	51%
2019 Updated Baseline 40-3-8	28	16	51%
2019 Updated Baseline 40-4-5.5	18	9	62%
2019 Updated Baseline 40-4-8	18	9	62%
2019 Well 17 Redirect 40-3-5.5	28	16	51%
2019 Well 17 Redirect 40-3-8	28	16	51%
2019 Well 17 Redirect 40-4-5.5	18	9	62%
2019 Well 17 Redirect 40-4-8	18	9	62%
2019 Well 17 Redirect 41.5-3-5.5	33	18	40%
2019 Well 17 Redirect 41.5-3-8	33	18	40%
2019 Well 17 Redirect 41.5-4-5.5	21	9	58%
2019 Well 17 Redirect 41.5-4-8	21	10	58%

Fish Ladder Performance

Table 19. Phase 1 scenario results: Fish ladder success

Fish Ladder Success	Reservoir		OOB	
% of Days	Spring	Fall	Spring	Fall
2017 Reservoir 40 IOP baseline	NA	NA	93%	50%
2019 Ice Pigging 40-3-5.5	NA	NA	91%	43%
2019 Ice Pigging 40-3-8	NA	NA	91%	42%
2019 Ice Pigging 40-4-5.5	NA	NA	91%	42%
2019 Ice Pigging 40-4-8	NA	NA	91%	42%
2019 Ice Pigging 41.5-3-5.5	98%	67%	97%	78%
2019 Ice Pigging 41.5-3-8	97%	67%	97%	78%
2019 Ice Pigging 41.5-4-5.5	98%	64%	97%	63%
2019 Ice Pigging 41.5-4-8	97%	64%	97%	62%
2019 Updated Baseline 40-3-5.5	NA	NA	92%	44%
2019 Updated Baseline 40-3-8	NA	NA	92%	44%
2019 Updated Baseline 40-4-5.5	NA	NA	92%	44%
2019 Updated Baseline 40-4-8	NA	NA	92%	43%
2019 Well 17 Redirect 40-3-5.5	NA	NA	92%	42%
2019 Well 17 Redirect 40-3-8	NA	NA	92%	42%
2019 Well 17 Redirect 40-4-5.5	NA	NA	92%	42%
2019 Well 17 Redirect 40-4-8	NA	NA	92%	42%
2019 Well 17 Redirect 41.5-3-5.5	98%	74%	97%	64%
2019 Well 17 Redirect 41.5-3-8	97%	74%	97%	64%
2019 Well 17 Redirect 41.5-4-5.5	98%	66%	97%	60%
2019 Well 17 Redirect 41.5-4-8	97%	66%	97%	60%

Fish Ladder Success % of Years With >80% Successful Days	Reservoir		OOB	
	Spring	Fall	Spring	Fall
2017 Reservoir 40 IOP baseline	NA	NA	93%	42%
2019 Ice Pigging 40-3-5.5	NA	NA	87%	33%
2019 Ice Pigging 40-3-8	NA	NA	87%	33%
2019 Ice Pigging 40-4-5.5	NA	NA	87%	33%
2019 Ice Pigging 40-4-8	NA	NA	87%	33%
2019 Ice Pigging 41.5-3-5.5	95%	56%	98%	75%
2019 Ice Pigging 41.5-3-8	95%	56%	98%	75%
2019 Ice Pigging 41.5-4-5.5	95%	55%	98%	56%
2019 Ice Pigging 41.5-4-8	95%	53%	98%	55%
2019 Updated Baseline 40-3-5.5	NA	NA	89%	35%
2019 Updated Baseline 40-3-8	NA	NA	89%	35%
2019 Updated Baseline 40-4-5.5	NA	NA	89%	35%
2019 Updated Baseline 40-4-8	NA	NA	89%	35%
2019 Well 17 Redirect 40-3-5.5	NA	NA	89%	35%
2019 Well 17 Redirect 40-3-8	NA	NA	89%	35%
2019 Well 17 Redirect 40-4-5.5	NA	NA	89%	35%
2019 Well 17 Redirect 40-4-8	NA	NA	89%	35%
2019 Well 17 Redirect 41.5-3-5.5	95%	67%	98%	53%
2019 Well 17 Redirect 41.5-3-8	95%	67%	98%	53%
2019 Well 17 Redirect 41.5-4-5.5	95%	60%	98%	53%
2019 Well 17 Redirect 41.5-4-8	95%	60%	98%	53%

Fish Ladder Failure % of Years with 0 Successful Days	Reservoir		OOB	
	Spring	Fall	Spring	Fall
2017 Reservoir 40 IOP baseline	NA	NA	2%	0%
2019 Ice Pigging 40-3-5.5	NA	NA	2%	0%
2019 Ice Pigging 40-3-8	NA	NA	2%	0%
2019 Ice Pigging 40-4-5.5	NA	NA	2%	0%
2019 Ice Pigging 40-4-8	NA	NA	2%	0%
2019 Ice Pigging 41.5-3-5.5	0%	0%	0%	0%
2019 Ice Pigging 41.5-3-8	0%	0%	2%	0%
2019 Ice Pigging 41.5-4-5.5	0%	0%	0%	0%
2019 Ice Pigging 41.5-4-8	0%	0%	2%	0%
2019 Updated Baseline 40-3-5.5	NA	NA	2%	0%
2019 Updated Baseline 40-3-8	NA	NA	2%	0%
2019 Updated Baseline 40-4-5.5	NA	NA	2%	0%
2019 Updated Baseline 40-4-8	NA	NA	2%	0%
2019 Well 17 Redirect 40-3-5.5	NA	NA	2%	0%
2019 Well 17 Redirect 40-3-8	NA	NA	2%	0%
2019 Well 17 Redirect 40-4-5.5	NA	NA	2%	0%
2019 Well 17 Redirect 40-4-8	NA	NA	2%	0%
2019 Well 17 Redirect 41.5-3-5.5	0%	0%	0%	0%
2019 Well 17 Redirect 41.5-3-8	0%	0%	2%	0%
2019 Well 17 Redirect 41.5-4-5.5	0%	0%	0%	0%
2019 Well 17 Redirect 41.5-4-8	0%	0%	2%	0%

Zero Flow Days

Table 20. Phase 1 scenario results: Number of zero flow days during the period of record (1961-2016)

Scenario	Reservoir Release	Old Oaken Bucket Pond Release
Natural Flow	0%	0%
2017 Reservoir 40 IOP baseline	0%	0%
2019 Ice Pigging 40-3-5.5	0%	2%
2019 Ice Pigging 40-3-8	0%	0%
2019 Ice Pigging 40-4-5.5	0%	3%
2019 Ice Pigging 40-4-8	0%	1%
2019 Ice Pigging 41.5-3-5.5	0%	2%
2019 Ice Pigging 41.5-3-8	0%	0%
2019 Ice Pigging 41.5-4-5.5	0%	3%
2019 Ice Pigging 41.5-4-8	0%	0%
2019 Updated Baseline 40-3-5.5	0%	2%
2019 Updated Baseline 40-3-8	0%	0%
2019 Updated Baseline 40-4-5.5	0%	3%
2019 Updated Baseline 40-4-8	0%	0%
2019 Well 17 Redirect 40-3-5.5	0%	2%
2019 Well 17 Redirect 40-3-8	0%	0%
2019 Well 17 Redirect 40-4-5.5	0%	3%
2019 Well 17 Redirect 40-4-8	0%	0%
2019 Well 17 Redirect 41.5-3-5.5	0%	2%
2019 Well 17 Redirect 41.5-3-8	0%	0%
2019 Well 17 Redirect 41.5-4-5.5	0%	3%
2019 Well 17 Redirect 41.5-4-8	0%	0%

BioQ90 Seasonal Aquatic Habitat Releases

Table 21. Phase 1 results: Percent of bioperiod meeting the seasonal (BioQ90) minimum streamflow goals

	Reservoir				Old Oaken Bucket Pond			
Scenario	**Dec - Feb**	**Mar - May**	**Jun – Aug**	**Sep – Nov**	**Dec - Feb**	**Mar - May**	**Jun – Aug**	**Sep – Nov**
Unimpacted Flow	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
2017 Reservoir 40 IOP baseline	92.4%	96.8%	100.0%	100.0%	87.1%	85.2%	88.8%	89.3%
2019 Ice Pigging 40-3-5.5	93.8%	97.6%	100.0%	96.1%	87.1%	85.1%	88.7%	86.5%
2019 Ice Pigging 40-3-8	93.7%	97.4%	100.0%	98.9%	87.1%	85.1%	88.8%	88.8%
2019 Ice Pigging 40-4-5.5	93.8%	97.7%	99.9%	94.9%	87.1%	85.1%	88.1%	85.1%
2019 Ice Pigging 40-4-8	93.8%	97.5%	100.0%	98.9%	87.1%	85.1%	88.8%	88.8%
2019 Ice Pigging 41.5-3-5.5	97.1%	98.8%	100.0%	99.9%	87.6%	85.8%	88.8%	86.9%
2019 Ice Pigging 41.5-3-8	94.1%	98.7%	100.0%	96.3%	87.6%	85.8%	88.8%	88.9%
2019 Ice Pigging 41.5-4-5.5	94.1%	98.2%	100.0%	98.9%	87.5%	85.8%	88.2%	85.4%
2019 Ice Pigging 41.5-4-8	94.2%	98.8%	99.9%	95.1%	87.6%	85.7%	88.8%	88.8%
2019 Updated Baseline 40-3-5.5	94.2%	98.2%	100.0%	98.9%	87.1%	85.1%	88.8%	87.3%
2019 Updated Baseline 40-3-8	93.8%	97.4%	100.0%	96.3%	87.1%	85.1%	88.8%	88.8%
2019 Updated Baseline 40-4-5.5	93.7%	97.2%	100.0%	98.5%	87.1%	85.1%	88.3%	85.5%
2019 Updated Baseline 40-4-8	93.8%	97.5%	100.0%	94.6%	87.1%	85.1%	88.8%	88.8%
2019 Well 17 Redirect 40-3-5.5	93.7%	97.3%	100.0%	98.6%	87.1%	85.2%	88.8%	87.5%
2019 Well 17 Redirect 40-3-8	96.8%	98.9%	100.0%	99.8%	87.1%	85.2%	88.8%	88.9%
2019 Well 17 Redirect 40-4-5.5	96.9%	98.7%	100.0%	100.0%	87.1%	85.2%	88.3%	85.9%
2019 Well 17 Redirect 40-4-8	97.1%	98.9%	100.0%	99.5%	87.1%	85.2%	88.8%	88.8%
2019 Well 17 Redirect 41.5-3-5.5	97.0%	98.8%	100.0%	99.9%	87.6%	85.9%	88.8%	87.5%
2019 Well 17 Redirect 41.5-3-8	96.9%	99.0%	100.0%	99.8%	87.6%	85.9%	88.8%	89.2%
2019 Well 17 Redirect 41.5-4-5.5	96.9%	98.9%	100.0%	100.0%	87.6%	85.9%	88.4%	86.1%
2019 Well 17 Redirect 41.5-4-8	97.1%	99.0%	100.0%	99.5%	87.6%	85.9%	88.8%	88.8%

Median Aquatic Habitat Flow Goal Achievement

Table 22. Phase 1 results: Median aquatic habitat flow goal achievement

	Reservoir					Old Oaken Bucket Pond				
Scenario	**Dec - Feb**	**Mar - May**	**Jun - Aug**	**Sep**	**Oct-Nov**	**Dec - Feb**	**Mar-Apr**	**May**	**Jun-Aug**	**Sep-Nov**
Unimpacted Flow	50.0%	72.0%	63.0%	50.0%	67.0%	50.0%	50.0%	50.0%	50.0%	50.0%
2017 Reservoir 40 IOP baseline	69.5%	78.1%	134.0%	133.8%	51.4%	58.4%	58.1%	46.0%	24.0%	46.6%
2019 Ice Pigging 40-3-5.5	68.1%	81.9%	142.6%	128.3%	48.1%	49.3%	51.5%	41.8%	21.2%	41.1%
2019 Ice Pigging 40-3-8	67.9%	81.7%	143.2%	129.1%	47.8%	49.2%	51.4%	41.6%	21.2%	40.9%
2019 Ice Pigging 40-4-5.5	67.4%	82.0%	143.1%	149.6%	47.0%	48.6%	51.4%	41.8%	21.3%	40.1%
2019 Ice Pigging 40-4-8	67.2%	81.5%	144.0%	150.9%	46.8%	48.5%	51.2%	41.8%	21.3%	40.0%
2019 Ice Pigging 41.5-3-5.5	76.3%	115.7%	155.7%	196.5%	55.4%	56.5%	59.4%	52.3%	30.6%	41.7%
2019 Ice Pigging 41.5-3-8	75.5%	98.1%	145.2%	143.7%	44.5%	56.4%	59.2%	52.3%	30.6%	43.0%
2019 Ice Pigging 41.5-4-5.5	75.4%	98.0%	145.6%	144.3%	44.3%	56.4%	59.4%	52.3%	30.6%	41.6%
2019 Ice Pigging 41.5-4-8	75.3%	98.1%	145.8%	163.1%	43.5%	56.3%	59.1%	52.3%	30.6%	41.7%
2019 Updated Baseline 40-3-5.5	75.0%	97.6%	147.1%	163.3%	43.5%	49.2%	52.5%	52.3%	30.6%	41.7%
2019 Updated Baseline 40-3-8	68.5%	81.5%	142.9%	128.4%	49.1%	49.1%	52.1%	52.3%	30.6%	41.7%
2019 Updated Baseline 40-4-5.5	68.2%	81.4%	143.2%	128.6%	48.9%	49.0%	52.2%	52.3%	30.6%	41.7%
2019 Updated Baseline 40-4-8	67.7%	81.7%	143.5%	148.6%	47.9%	48.8%	52.0%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 40-3-5.5	67.5%	81.3%	144.1%	149.4%	47.7%	55.0%	55.7%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 40-3-8	78.3%	105.4%	154.8%	182.5%	57.8%	54.9%	55.7%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 40-4-5.5	78.2%	105.3%	154.8%	187.4%	57.7%	54.4%	55.7%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 40-4-8	78.0%	105.3%	155.0%	182.8%	56.7%	54.3%	55.6%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 41.5-3-5.5	77.5%	105.1%	155.0%	188.4%	56.5%	57.3%	60.3%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 41.5-3-8	77.4%	116.1%	155.5%	191.7%	57.5%	57.2%	60.3%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 41.5-4-5.5	77.2%	116.0%	155.5%	196.9%	57.4%	56.9%	60.3%	52.3%	30.6%	41.7%
2019 Well 17 Redirect 41.5-4-8	76.5%	116.0%	155.7%	190.9%	55.5%	56.8%	60.2%	52.3%	30.6%	41.7%

Attachment 1. 2010 WEAP Model Setup Report

First Herring Brook

Environmental Flows Project

Scituate, Massachusetts

A joint project of the

Scituate Water Resources Committee

and the

North and South Rivers Watershed Association

Produced by:

The Nature Conservancy

Stockholm Environment Institute

The MA Division of Ecological Restoration (formerly Riverways Program)

January 12, 2010

Contents

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I. Introduction & Background

The First Herring Brook Project was designed to develop a water budget model for the First Herring Brook, including Tack Factory Pond, the Main Reservoir and Old Oaken Bucket Pond impoundments and the Scituate Water Supply system as it affects this stream system. The purpose of the modeling effort is to help the Town of Scituate examine the feasibility of restoring flows between the two impoundments and downstream of Old Oaken Bucket pond in support of restoring aquatic habitat for river herring, native fishes, eel, smelt, macroinvertebrates and to improve the overall health of the aquatic system. The hydrologic modeling examines existing conditions, provides an understanding of how much water is necessary to restore adequate flows at the outflows of Tack Factory and Old Oaken Bucket Ponds and examines the feasibility of several water management alternatives to attain those flows.

A. Watershed and Biological Description

As described in the First Herring Brook Watershed Report (First Herring Brook Watershed Initiative, 2003: http://files.fhbwi.org/finalFHBWreport.pdf) the First Herring Brook watershed is between 4.8 and 5.9 square miles and discharges into the North River. The exact watershed boundaries are still uncertain given the flat nature of the area and lack of clear divide between adjacent watersheds. The report also states, "…the watershed contains a complex system of surface and ground water that serves as the primary source of Scituate's water supply. In addition, the watershed is a valuable natural resource that helps to define the rural character of Scituate, provide biologically rich wildlife habitat and maintain flood storage capacity to mitigate property damage caused by storm events."

As reported in the Draft Fisheries Summary (2008) "The stream originates in South Swamp along the Norwell/Scituate Line (which also drains into Bound Brook) and flows under First Parish Road and then into a small impoundment. It then flows through Norwell (a section which may have spring flow based on bordering topographic contours) and enters a swamp area in Scituate above Grove Street. It then crosses Maple Street and receives a tributary from the north that drains the Scituate High School area, passes by a town well area, and enters another area where spring flow is possible before entering Tack Factory Pond.

Tack Factory Pond also historically receives flow from a tributary ("Cranberry Brook") that runs through the cranberry bog next to Satuit Meadow swamp. Most of its flow was rerouted downstream of the water supply reservoir system due to water quality concerns when the cranberry bog was active. Tack Factory Pond is a shallow pond bordered by water willow. First Herring Brook then crosses route 3A, which is built over the dam for Tack Factory Pond, and then enters the Main Reservoir *(AKA First Herring Brook Reservoir),* where it is joined by Doctor's Brook, a small tributary from the North.

The Main Reservoir was built about 1968 and an old roadbed and stumps are visible when the pond is drawn down during unusually dry summer months. First Herring Brook then flows into Old Oaken Bucket Pond after receiving flow from Tan Brook, a small tributary draining parts of Brushy Swamp east of Country Way. Clapp Brook, another small tributary, flows directly into Old Oaken Bucket Pond from Brushy Swamp east of Country Way. A tributary that historically flowed directly into Old Oaken Bucket Pond from west of Route 3A was incorporated into the diversion system associated with the cranberry farm. It was rerouted to join First Herring Brook downstream of Old Oaken Bucket Pond.

Old Oaken Bucket Pond is an artificial, eutrophic pond. The outflow from the pond is regulated and can flow through a historic mill (Old Stockbridge Grist Mill, built 1640, rebuilt 1970). Downstream of the pond and mill, First Herring Brook crosses another road (the Driftway) before entering an estuarine area near the new Greenbush commuter railroad station. It then becomes the Herring River and ultimately enters the North River.

The water color is tea stained and on the acidic side (4.2 to 6.67, Layzer et al 1988). Due its use as a water supply the flow through Main Reservoir and Old Oaken Bucket Pond is regulated by the Scituate Water Division. During the summer months, the Main Reservoir to the east of Route 3A is often drawn down to ensure an adequate water supply to Old Oaken Bucket Pond." Water quality monitoring in spring during 1993-1994 identified low pH and low base flow as concerns for smelt spawning habitat in First Herring Brook (Chase, 2006). More recent water quality monitoring assessed the suitability of the two water bodies to support river herring spawning and nursery habitat during 2007 and 2008 (Chase, *pers. comm.*). The assessment relates river herring life history requirements to Massachusetts Surface Water Quality Standards. Exceedances of pH and dissolved oxygen criteria were measured in the Main Reservoir. The deep station in Old Oaken Bucket Pond had low DO during 7 of 8 sampling visits in the two years. During the June-September sampling visits water was not released from Old Oaken Bucket Pond or the Main Reservoir. This condition resulted in both water bodies being assessed as impaired for Fish Passage and Water Flow classifications for all visits and for Eutrophication during most visits. An anomalous high pH value was recorded during the 2007 drought.

First Herring Brook is known to have supported a run of river herring for which the brook is named. River herring is a name for two similar diadromous fish species: alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis),* that have similar life cycles and look almost identical. Diadromous fish are species that live part of their lives in freshwater rivers and ponds and part of their lives in the estuarine and marine environments. River herring spawn in freshwater ponds and streams and migrate out to the ocean for most of their adult life, and then return to the pond or stream of their birth to spawn. Alewives were numerous in First Herring Brook around 1900 (Hurley, 2008) and there are anecdotal reports that in the late 1960's, when a newly restored Old Oaken Bucket fish ladder was in good repair and operated that river herring were plentiful in Old Oaken Bucket Pond (Grader, pers. comm.). The last confirmed sighting of alewife was in 1996 below Old Oaken Bucket Pond (Hurley, 2008). There are no known reports of blueback herring in First Herring Brook, so when this report uses the term "river herring" it is referring to alewife.

Rainbow smelt and American eel are other diadromous fish that have been found in First Herring Brook. American eel (*Anguilla rostrata)* can be found throughout the watershed while rainbow smelt has been documented to be spawning below Old Oaken Bucket Pond (Chase, 2006).

A range of other resident fish, macroinvertebrate, reptile, amphibian and bird species and communities depend on First Herring Brook and its floodplain. More information on these species can be found in The First Herring Brook Watershed Report (FHBWI, 2003), Hurley (2008), and from the Massachusetts Division of Ecological Restoration. Further treatment of the biological resources of First Herring Brook for purposes of this project can be found in Section 3.

B. Water Supply System Description

The Town of Scituate Water Supply System is comprised of two actively managed surface water impoundments and a series of groundwater wells. The two water supply impoundments are located along the First Herring Brook. The upstream impoundment is referred to in this report as the “Reservoir”, and the downstream impoundment is referred to as “Old Oaken Bucket” or “OOB”. Immediately upstream of the Reservoir across Rt 3A is the Tack Factory Pond, connected directly to the Reservoir through a weir structure. A weir structure on the upstream side of the culvert maintains the water levels in the pond so that it is not subject to the changing elevations of the Reservoir that result from water supply operations. The Reservoir dam has a 12” low level outlet pipe that is used to move water downstream when water levels fall below the spillway (Gene Babin, pers. comm.. 10/21/2008). According to the Water Management Act permit, the yield of this surface water system, which does not include any requirements for downstream flow, is 790,000 gallons/day (.79 million gallons per day (mgd)).

The water supply system also includes: 6 wells, numbered 10, 11, 17A, 18B, 19 & 22, of which 19, 22, & 17A are within the First Herring Brook watershed. Combined with the surface water system, the town is authorized to withdraw up to 1.85 mgd (million gallons per day) under its water management permit, or 2.01 mgd if and when the Humarock neighborhood is supplied from the town’s sources (water supply for Humarock is currently purchased from the Town of Marshfield due to its location as a peninsula off of Marshfield). Figure 1 depicts the water supply system and Massachusetts Division of Ecological Restoration, River Instream Flow Stewards (a.k.a RIFLS) streamflow monitoring locations.

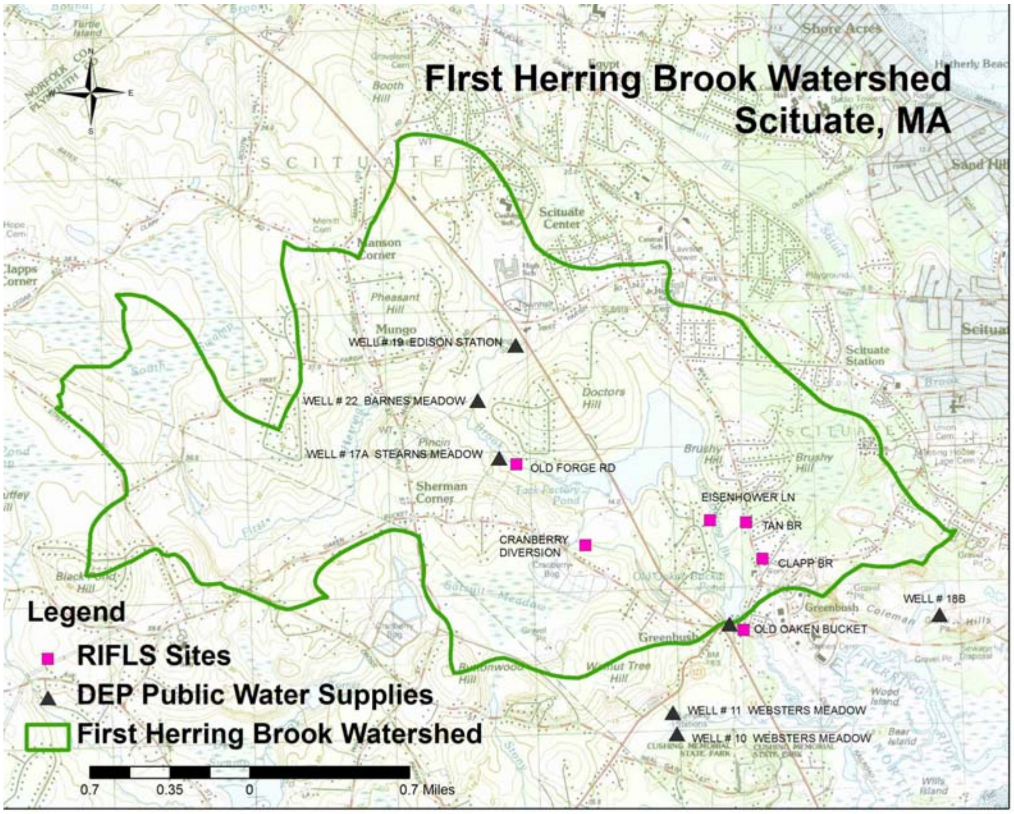

Figure 1. First Herring Brook watershed, water supply withdrawal locations and RIFLS streamflow gauging stations

C. Water Supply Operations

Generally, with regard to operation of the surface water component of the system, water is withdrawn from Old Oaken Bucket into the water treatment plant. Water from the Reservoir is moved downstream to keep Old Bucket at or near full so that water is always available to be transferred to the treatment plant and into the water distribution system.

Therefore, the current operation results in different flow regimes below the Reservoir and below OOB. Below OOB, flows are primarily a result of 'spills' over the dam during times of high water. Below the Reservoir, flows are a result of both spills and a result of the transfer of water downstream by the water division to OOB. Figure 2 shows this affect, with the blue line representing flows under current operations and pink line representing an estimation of natural flows (see Section 8.2.2 for information on how natural flows were estimated). Figure 2 shows how, in a typical year, First Herring Brook below Old Oaken Bucket receives water during the times when water spills over the spillway or down the fish ladder, but otherwise receives only flow from the Cranberry Diversion.

On the other hand, because water is 'shuttled' between the Reservoir and OOB to keep OOB full, the section of First Herring Brook below the Reservoir (Eisenhower Road) receives water from both spills when the Reservoir is full and from when the Scituate Water Division releases water downstream. This can been seen in Figure 3, with the blue line representing flows below the Reservoir under typical operations and the pink line representing estimated natural flows. The result is that the stream below the Reservoir often has more water than would be normal under unregulated conditions but also experiences times of low or no flow if the reservoir is not spilling and water is not needed at OOB by Scituate Water Division.

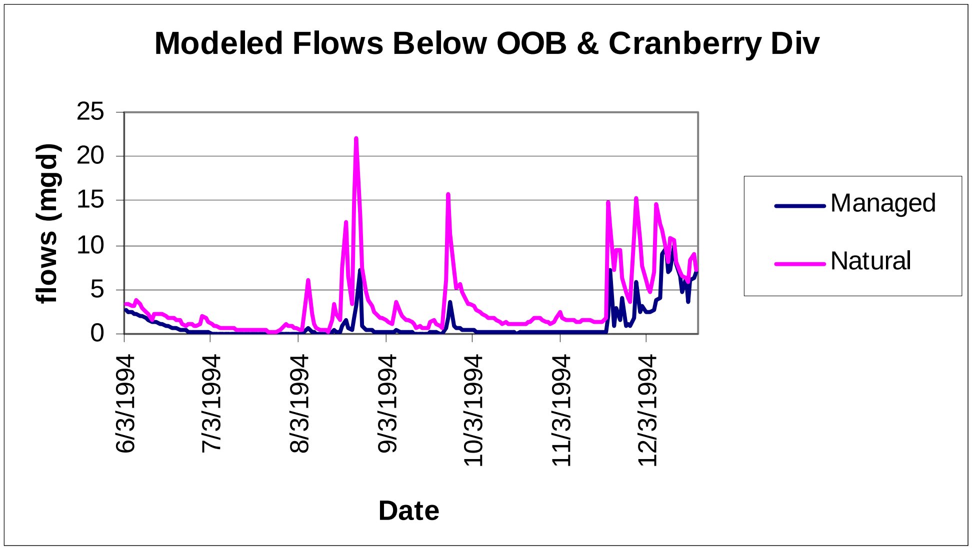

Figure 2. Modeled natural and managed flows under current water supply operations in First Herring Brook downstream of Old Oaken Bucket Pond and the Cranberry Diversion.

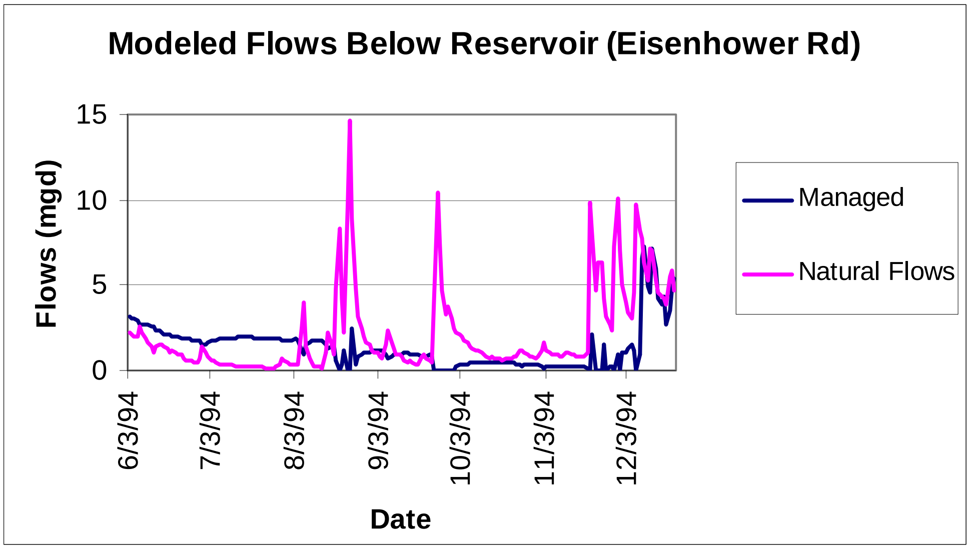

Figure 3. Modeled natural and managed flows under current water supply operations in First Herring Brook downstream of the Reservoir.

D. Water Use Restrictions

The current operations also include the use of water restrictions during times of water scarcity. Restrictions are implemented based on water levels in the Reservoir and OOB as summarized in Table 1.

Table 1. Scituate Water Restrictions Summary
Level 1- The Reservoir at elevation 30 – inches below spillway or 1 day of 24-hour OOBWTF operation:
Advise consumers and Water Commissioners that there is likely to be the need to establish mandatory restrictions in the near future.
Level 2- The Reservoir at elevation 45 – inches below spillway or 3 days of 24-hour OOBWTF operation:
Advise consumers and Water Commissioners that mandatory restrictions are now in effect. At this level, the use of outside water is restricted to 6am to 9am Monday through Friday based upon an odd / even system utilizing dates and street addresses.
Level 3- The Reservoir at elevation 60 – inches below spillway or 5 days of 24-hour OOBWTF operation:
Advise consumers and Water Commissioners that additional mandatory restrictions are now in effect. At this level, the use of outside water is prohibited except for necessary public health uses. Included in these permitted exceptions are outside use for vegetable gardens, marinas for filling potable water tanks, dust control at construction sites, and spray tank filling for mosquito control application

E. Fish Ladders

Access to freshwater pond and stream habitat is critical to the life cycle of river herring. In southeastern Massachusetts, river herring typically migrate upstream in April and May and juvenile herring typically migrate downstream to the ocean in September and October (Reback et al., 2005.). To promote river herring usage of upstream habitat in the First Herring Brook watershed, a concrete pool and weir fish ladder was included in the design of the Reservoir when it was constructed in 1968. Based on local accounts, during that same time period a new concrete pool and weir fish ladder was constructed at Old Oaken Bucket Pond, replacing one that was in complete disrepair (Grader, pers. comm.). These ladders consist of a series of constructed resting pools separated by weirs which allow fish to move upstream. The current ladder at Old Oaken Bucket apparently did work and allowed for a self-sustaining run of river herring during a period soon after construction. The ladder is operated by removing a wooden board at the reservoir end of the ladder to allow water to flow through the ladder. (see Figure 4). The fish ladder is not currently operated due to concerns about the amount of water required for it to operate (Babin, pers. comm.). There is no record of the ladder on the Reservoir ever passing fish and, based on recent assessment, it is possible that it never did due to poor design (Grader, pers. comm.).

Figure 4. Fish ladder and low level outlet structure at Old Oaken Bucket Pond.

It is unclear how effective either fish ladder was in passing juvenile herring downstream historically. It is unlikely they were effective because these fish ladders rarely have water in them during the downstream migration season (September-October). Spill events, which could help to pass fish downstream, are rare during September-October in this system.

It is important to note that a more modern fish ladder design could allow for more efficient passage in the First Herring Brook system (Grader, pers. comm.). A new design could require less water to operate and be more efficient at allowing fish to move upstream. Ladders of improved design, operating only during migration months, are introduced as part of the modeling effort described below. This type of ladder, however, is not suitable for downstream passage of juvenile herring. Also introduced in the modeling effort are weirs for downstream migration. In this context weirs are essentially notches in the dams that allow water to spill when water levels are below the top of the dam so that releases can be made to move juvenile alewife downstream.

II. Project Overview

This project was conceived and developed jointly by the Town of Scituate Water Resources Committee and the North and South Rivers Watershed Association. As a result of previous efforts by the workgroup to measure and assess stream flow patterns and document the ecological assets of the First Herring Brook System, the Town's Water Management Act permit from the Massachusetts Department of Environmental Protection requires the town to work with the Scituate Water Study Committee and First Herring Brook Watershed Initiative to evaluate the potential for minimum flow targets to restore fish passage within the First Herring Brook. This project supports the goal of this permit condition and the overarching goals of the local workgroup to protect and restore aquatic habitats in the First Herring Brook watershed.

The project was guided, and input was provided throughout, by a group of stakeholders comprised of representatives from the Town, the watershed association, federal and state agencies, and interested citizens. See Table 2 for a list of participants. The project management and modeling work was undertaken by a team from The Nature Conservancy, the Stockholm Environment Institute, and the MA Department of Fish and Game's Division of Ecological Restoration at no cost to the Town or the Watershed Association. TNC and SEI were supported through a grant from the U.S. Environmental Protection Agency and the Division of Ecological Restoration's staff is funded by the Dept. of Fish and Game.

Table 2. Scituate Water Resources Stakeholder Group

	PROJECT TEAM
Brian Joyce	Stockholm Environment Institute
Mark P. Smith	The Nature Conservancy
Colin Apse	The Nature Conservancy
Margaret Kearns	MA Riverways Program
Joanna Carey	MA Riverways Program
	STAKEHOLDERS
Melissa Grader	US Fish and Wildlife Service
Jeffrey Rosen	Scituate Water Resources Committee
Gene Babin	Scituate Water Dept.
Samantha Woods	North and South Rivers Watershed Association

Brad Chase	MA Division of Marine Fisheries
Steve Hurley	MA Division of Fisheries and Wildlife
Cindy Delpapa	MA Riverways Program
Joseph Norton	Town of Scituate Selectman
Sara Grady	Mass Bays Program
Steve Hallem	MA DEP
Leslie O’Shea	MA DEP
Kari Winfield	MA DEP
Vinny Kalishes	Scituate Conservation Commission
Elise Kline	Scituate Water Resources Committee
Kristine Van Lenten	First Herring Brook Watershed Initiative
Phil Brady	MA Division of Marine Fisheries
Jason Burtner	MA CZM
Mark Stewart	Scituate Conservation Commission
Garret Van Wart	First Herring Brook Watershed Initiative
Rick Murray	Town of Scituate Selectman

The model of the First Herring Brook system was developed using the Water Evaluation and Planning system (WEAP) developed by SEI and in use worldwide to provide decision support to water allocation issues. The model was used to analyze the water management alternatives that may be feasible to restore flows to allow herring passage at critical times in their life cycle and provide adequate seasonal aquatic habitat. The model evaluated the operation of the system over a flow modeling period of 1962 to 2000 in order to provide results that demonstrate the ability to balance water supply demands and flows for fish passage and resident fish and instream habitat over a wide range of conditions, including the drought of record.

III. Environmental Goal-Setting

The process of setting environmental flow goals on the First Herring Brook used approaches developed by The Nature Conservancy and other partners to develop flow ‘prescriptions’ to improve environmental conditions of rivers (see Richter et al, 2006). The project team led the stakeholder group through a process that involved the following tasks outlined in italics and with corresponding results below:

1. *Assemble and interpret existing biological and hydrological information from the First Herring Brook relevant to environmental flow goal setting.*

A summary of existing biological and hydrologic information was presented and discussed at the May 21, 2008 Stakeholder Meeting In addition, The Nature Conservancy completed Indicators of Hydrologic Alteration (IHA) analysis for key basin locations, which provided a statistical characterization of the unimpaired flow conditions in the basin. Detailed information is available, by request, from the project team.

2. *Gather and analyze baseline and current condition flow estimates for the First Herring Brook project site. Use the results of RIFLS monitoring and stream cross-section data to link flow and depth conditions relevant for fish habitat. Modeled results of current condition flow estimates from the WEAP were "groundtruthed" with RIFLS data.*

This work was completed, presented at the May 2008 meeting, and used for the analysis. The methods are further described in Section 8.2.2.

3. *Define a set of ecological targets for the purposes of the project.*

Ecological targets agreed upon by the stakeholders during a May 2008 meeting include:

- Alewife (river herring)
- American eel
- Rainbow smelt
- Native macroinvertebrate assemblage: characterized by a number of generalist species, high taxa richness, and records of rare taxa in the watershed including tubenet caddisfly & minnow mayfly.
- Freshwater fish assemblage

The group agreed that while these environmental targets could not be protected or restored solely through re-establishing a more natural flow regime, a more natural flow regime was an important element to restoring and maintaining ecosystem health.

4. *Define environmental flow goal-setting locations.*

The stakeholder group defined the following locations and associated ecological targets for which they felt it important that flows and reservoir level goals be established at the May 2008 Meeting (also depicted in Figure 5):

- **Location: "OOB Ladder": Fish Ladder into Old Oaken Bucket Pond. Target: alewife migration (& outmigration)**
- **Location: "Below OOB": First Herring Brook Downstream of Old Oaken Bucket Pond and Below Input from Cranberry Diversion to Tidal.   Target: all ecological targets.**
- **Location: "Reservoir Ladder": Fish Ladder into the Reservoir. Target: alewife migration (& outmigration).**

- **Location: "Below Reservoir": First Herring Brook between Reservoir and Old Oaken Bucket Pond. Target: all ecological targets except smelt.**

- Location: First Herring Brook Upstream of Reservoir and Tack Factory Pond (represented by Old Forge Rd RIFLS site). Target: all ecological targets except smelt.

- Location: Satuit Meadow Tributary Downstream of Cranberry Diversion. Target: all ecological targets except smelt. (It was recognized that this tributary is not in its natural channel and could potentially be moved into a new configuration. Our goal setting represented flows for current or future configurations.)

Though we analyzed results for all of these locations, in the main body of this report we report only a subset of these locations (those in bold). We limit our discussion to the fish ladders, the streams below the reservoir, and the reservoir and OOB water levels to limit the amount of data we present in the main report and because these are the most relevant to restoring river herring and improving the overall health of the system. However, the results of the analysis to the other areas are provided in Appendix B and can be examined within the town's WEAP model.

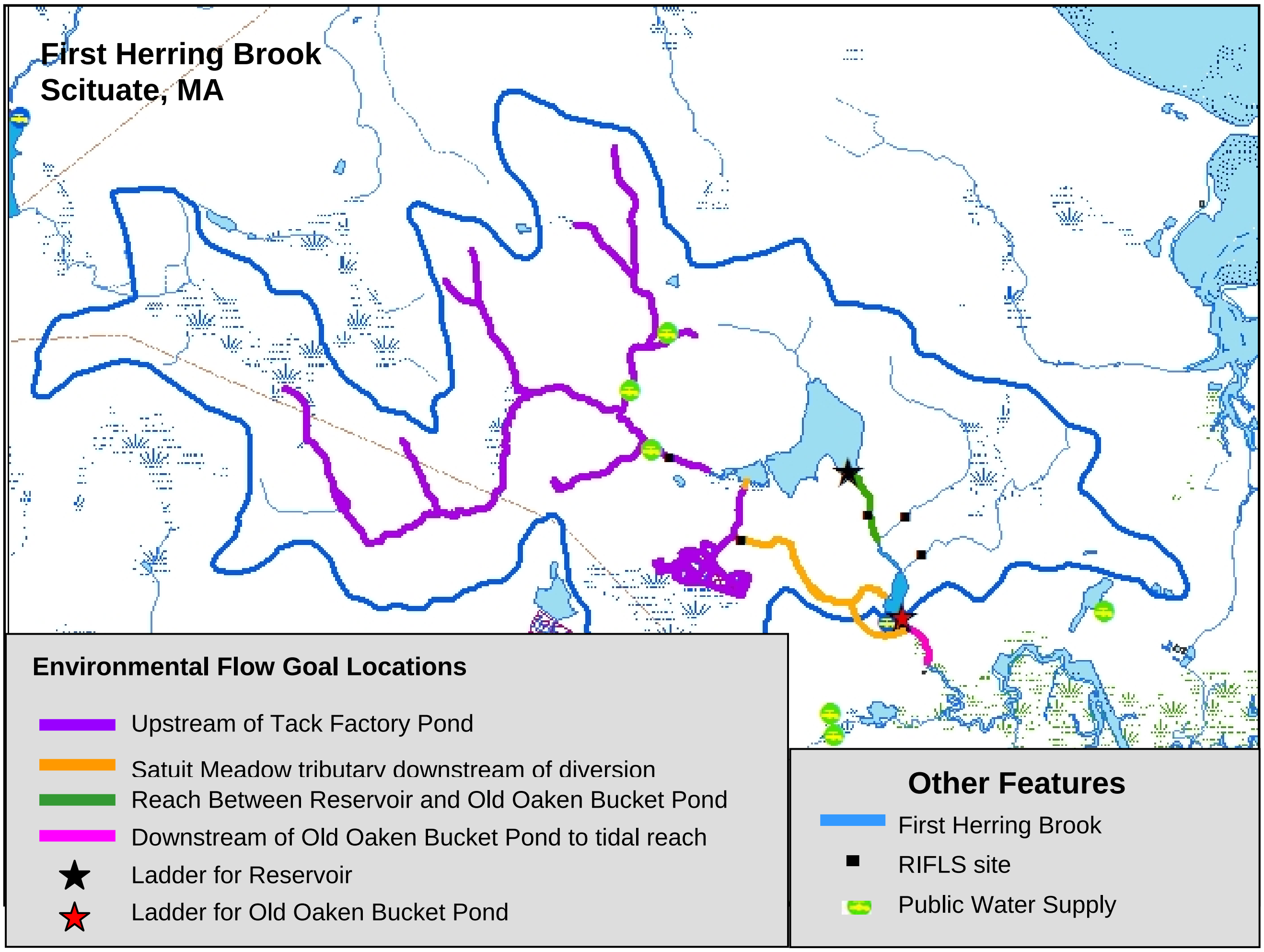

Figure 5. Environmental Flow Goal Locations

5. *Define environmental flow goals and revise if necessary.*

At the May 2008 stakeholder meeting an initial set of environmental flow goals was developed to evaluate water management scenarios modeled in WEAP. Key to this work was the decision of the committee to use bioperiods to structure flow goals. Bioperiods are biological 'seasons' that are defined by significant biological functions that occur during these times. The agreed upon bioperiods are:

- March-May: Migration and spawning for some residents, smelt & alewife. (At a subsequent meeting these dates were adjusted to Apr-May based on input from state fisheries experts).
- June-August: Rearing and Growth (including juvenile alewife), start of alewife outmigration.
- September-Nov: Adult eel migration, end of alewife outmigration.
- Dec-Feb: Overwintering.

In the case of impoundment levels, goals were defined for water levels in normal, wet and dry years.

The Committee agreed that the environmental goals they were setting were intended to achieve "good" habitat conditions- not necessarily ideal. In general, the goals were set using estimates of the natural flows, minimum depths of water across riffles, flows needed by the fish ladders, and reservoir depths that provided good or adequate habitat within the impoundments. In addition, the project team developed additional metrics with which to report results. The Committee also agreed that some uncertainty would need to be accepted and, through adaptive management, recommendations could be improved over time.

The initial environmental flow goals were revised by the Project Team based on WEAP modeling results and further discussions at the October 2008, January 2009, and April 2009 stakeholder meetings. One case in which these goals evolved substantially over time, was the case of spring flows below Old Oaken Bucket Pond. In the May 2008 meeting, the Committee had recommended a flow goal in March and April (17.7cfs) designed to maintain a fully wetted channel perimeter for maximum smelt spawning habitat. Due to lack of achievability of this goal, the flow goal was revised downward in subsequent Committee to represent adequate (not maximum) smelt spawning habitat and estimated natural hydrology. The new goal (10.41cfs) can be found in Table 3 and is also considered protective of environmental resources.

In addition, the project team developed some additional reporting metrics that helped to communicate the results of the model. These included the water 'yield' of the system (the amount of water available for use by the town) and the number of zero-flow days (days when the Brook or stream would be dry) and low flow days (Q90). The Q90 is a low flow statistic representing the flow value that is exceeded 90% of the time during a given time period. This statistic can also be thought of as representing the 10th percentile of flows during the period.

A. River Flow Goals

Environmental flow goals for the river locations: 1) First Herring Brook Downstream of Old Oaken Bucket Pond and Below Input from Cranberry Diversion and 2) First Herring Brook between the

Reservoir and Old Oaken Bucket Pond, are in Table 3 below. These goals are the monthly or bioperiod median flows or range of monthly median flows based on the estimated natural flow conditions at these locations during the modeling period of 1962-2000. In addition to the statistical basis of these goals, the depth of water that each flow goal provides over critical downstream riffles was evaluated. In general, six inches of depth over the deepest point of each riffle was considered the minimum needed for effective herring passage and habitat for native aquatic species. Section 6 includes the results of modeling runs relative to these goals.

Table 3: Environmental Flow Goals, based on 1962-2000

	FHB Below Old Oaken Bucket		**FHB Below Reservoir**	
Bioperiod	*Value in cubic feet per second (cfs)*	*Statistic*	*Value (cfs)*	*Statistic*
Mar - May	10.41	Mar-Apr median	4.03	May median
	5.9	May median		
Jun - Aug	1.83	bioperiod median	0.83 - 1.95	monthly median
Sep - Nov	2.63	bioperiod median	0.80 Sept 1.56 - 3.5 Oct-Nov	September median monthly medians
Dec - Feb	7.76	bioperiod median	5.31	bioperiod median

In addition, the project team evaluated all scenarios for the additional low flow metrics (Q90 and zero flow days) to assess how potential new operation of the system could improve low and no flow events within the system. These results are provided in Appendix B. Table 4 shows the Q90 values of modeled natural flow for the primary river locations. No zero flow days were estimated for either location under natural flow conditions.

Table 4: Bioperiod Q90 Low Flows (cfs), based on 1962 - 2000

Bioperiod	**Below OOB**	**Below Reservoir**
Mar-May	3.78	2.56
Jun-Aug	0.39	0.22
Sep-Nov	0.45	0.25
Dec-Feb	3.15	2.13

B. Fish Ladder and Weir Flow Goals

As mentioned above, the existing concrete pool and weir fish ladders on both Old Oaken Bucket Pond and the Reservoir are currently non-functional as a result of both inadequate flows and structural reasons. The inability to provide sufficient flows was re-affirmed by the modeling effort.

The existing ladder for Old Oaken Bucket Pond requires 6.8 cubic feet per second (cfs) of flow during days within the April-May migration season to reliably pass alewife upstream for spawning (U.S. Fish and Wildlife Service, pers. Comm.). Under natural flow conditions, 6.8 cfs is only present for 42% of the March – May bioperiod. In addition to the lack of adequate flow for effective operation of the ladders, a single board has been left in the fish ladder exit in recent years, which in itself precludes upstream fish passage even if adequate flow is available (Dick Quinn, USFWS, pers. comm.)

The Reservoir fish ladder was not built at the proper elevation to function correctly. The Reservoir fish ladder's exit and first few baffles were built at an elevation nearly equal to the elevation of the spillway. For this reason, the minimum depth of water required for the fish ladder to function would need to be provided over the entire 38-foot long spillway as well, resulting in a required flow of 65 cfs, significantly greater than any natural flow for this location! Even if this flow was provided, the excess flow over the spillway would create an "attraction flow" greater than that of the fish ladder so that alewife would have difficulty locating the ladder's entrance. The consensus of the stakeholders and the Project Team was that there essentially was no flow for which the Reservoir's fish ladder would be consistently functional as built. For these structural and hydraulic reasons, the flows necessary for operating the current ladders were not used.

Instead, with the advice of USFWS and consent of the stakeholders, the group considered the flow goals that would be required for new, more efficient fish ladders. The design selected for purposes of modeling new fish ladders is an "Alaska Steeppass" fish ladder at a 1:6 slope (D. Quinn, USFWS, pers comm.; Alaska Department of Fish and Game, 1962) (Fig. 6). The flow goal during the alewife in-migration period (April-May) is 2.2 cfs or more based on input from USFWS, which corresponds to 8 inches of depth in the ladder (D. Quinn, USFWS, pers comm.).

Fig. 6. Alaskan steeppass fish ladder at Unicorn Lake, MD (left). Upstream exit of Alaskan steeppass fish ladder, looking downstream, in the Parker River, MA (right).

In addition, the Project Team modeled weirs for downstream passage of juvenile alewife because steeppass ladders cannot be used for downstream migration. Weirs are structures (notches) that would be created below the spillway level for each dam in the system to allow juvenile alewife to pass from the impoundments to habitat downstream and to the ocean where they spend the majority of their life. The ability to use the existing low flow outlet at Old Oaken Bucket Pond and/or to install new weirs on each dam would need additional engineering evaluation. The hypothetical weir included in most of the water management scenarios is 2 feet below each of the current spillways and is 3 feet wide. In the current model, each weir has a set of 3 inch boards across it that are removed or inserted to provide a minimum of six inches of depth, equivalent to 3.39 cfs, during out-migration periods. Recent discussions with USFWS fisheries biologist indicate that a lower minimum depth of 4-5 inches, equivalent to 2.2 cfs, would be adequate, though not ideal, for downstream migration (D. Quinn, USFWS, pers. comm.). The flow goal evaluated for both the OOB and Reservoir weirs was thus 2.2 cfs or more although the model is set up to provide 3.39 cfs. A future model run could investigate the effects of lowering the weir release to 2.2 cfs for downstream migration purposes. These hypothetical weirs are modeled to operate only in September and October, the core of the juvenile downstream migration period according to fisheries biologists on the stakeholder group. Details on modeling of weir structures can be found in Section 8.

The team also noted the need to provide sufficient depth of flow in the stream channel as well as the fish ladders to effectively pass fish. Six inches of depth over riffles, the shallowest sections of stream with fast-moving water, was used as a benchmark for effective fish passage. Measurements of channel cross-sectional area, slope, and flow were used to calculate the flow required to provide six inches of depth over the deepest point of riffles downstream of the Reservoir and Old Oaken Bucket Pond. Both locations required approximately 0.37 cfs, which is available under natural conditions downstream of the Reservoir 100% of the March-May bioperiod and 86% of the September – November bioperiod and downstream of Old Oaken Bucket Pond for 100% of the March-May bioperiod and 92% of the September – November bioperiod.

C. Impoundment Water Level Goals

Both Old Oaken Bucket Pond and the Reservoir potentially provide habitat for river herring spawning and juvenile development. Therefore, the stakeholders worked to define environmental goals for water levels within the impoundments. However, the Committee and Project Team felt that for Old Oaken Bucket Pond, impoundment level goals were inappropriate due to required limitations on fluctuations in the impoundment for water supply purposes and the importance of meeting river flow goals below Old Oaken Bucket Pond. Reservoir level environmental goals were set and were defined based on three types of water years: normal, wet and dry. Recommendations were made primarily based on the amount of area that would be exposed at various water levels, using existing bathymetric map data from surveyed values in “Town of Scituate Drinking Water Supply and Demand Analysis, June 2003”, prepared by Comprehensive Environmental, Inc. (Table 5). The Reservoir spillway elevation used is 40 ft. It was recognized that additional work beyond the scope of this project would be necessary to further refine the goals based on habitat quality and availability. A side project to collect water quality information in both reservoirs over several seasons was begun as a result of these conversations.

Table 5: Reservoir Level Environmental Goals (using 40 feet as spillway elevation)	
Bioperiod	**Reservoir Level**
March-May	39+ feet in all year types
June-August	36-40 ft normal year 40+ ft in wet years 34-40 ft in dry year
September-November	Same as above
December-February	39+ feet in all year types; occasional spill events for water quality

IV. Alternatives Analysis

The project focused on evaluating alternatives that might achieve multiple objectives: 1) reliable water supply, 2) restoration of alewife to the river, and 3) protection of other ecological targets (e.g. resident fish). To this end, the Project Team and the stakeholder group identified a set of alternatives that focused on both augmenting the existing supply system and improving environmental outcomes These alternatives provide a set of building blocks that can be analyzed in different combinations to identify those that best meet the needs and goals of the Town and watershed association. The WEAP model remains available to the town to develop and model additional scenarios.

An initial water management option scenario development meeting with the stakeholders took place on October 31, 2008. After Project Team modeling analysis, results of initial scenarios were presented to stakeholders on January 13, 2009. This meeting lead to the refinement of water management scenarios, the results of which were presented at the final stakeholders meeting on April 7, 2009. The April 2009 meeting provided the Project Team with the input necessary to create the final set of water management scenarios which are presented in the body of this report. Selected other streamflow results from scenarios considered by the Project Team are available in Appendix B of this report.

A. Improve Environmental Conditions

1) **Improved Fish Ladders**

WEAP is programmed to evaluate the ability to provide sufficient flows to new fish ladders on Old Oaken Bucket Pond and the Reservoir as described above. Therefore, with the exception of the "Current Operations" scenarios, the models assume the presence of new, more efficient fish ladders at OOB and the Reservoir. More detail on the design and rationale for these ladders can be found in Sections 3 and 8.

2) Creation and Operation of Downstream Passage Weirs:

While the modeled Alaska steeppass fish ladders are effective for moving alewife and other anadromous fish upstream, this type of ladder is not useful in moving the fish downstream in the fall when they move back out into the ocean. During the alewife downstream migration period (September-October in the First Herring Brook) adequate flow also must flow through a downstream passage structure to attract and move fish downstream. For this project we assumed that new weirs would be added to each dam. As with improved ladders, downstream passage weirs were included on all scenarios in the main report other than "Current Operations".

3) **Improved Streamflow Releases**: Currently the system is not operated to regularly release water from Old Oaken Bucket or the Reservoir in order to protect and sustain resident and migratory fish. As described above, without prescribed releases the water only flows into the stream when the reservoirs are full and spill or when water is moved between the Reservoir and OOB. Improved streamflow release models improve habitat and water quality conditions in First Herring Brook by releasing water from the impoundments. The amount of the releases was based on simulating natural hydrology at those locations. The primary option examined is a bioperiod Q90 release, which models a release that is equivalent to the lowest 10% of flows during the period of record for the bioperiod. If inflow to the Reservoir or OOB is naturally below this level, then only the amount equal to the inflow is released. A second stream flow release was also modeled – using only the summer Q90 for all seasons – providing less water to the stream than the bioperiod Q90.

Table 6. Current and Modeled New Operations Included in Model

Strategy	Current Operations	Modeled Operations
1) Improve Fish Ladders	Flow Required: > 6.8 cfs (OOB)	Flow Required: > 2 cfs
2) Create & Operate Weirs	N/A	Flow Required: > 2.2 cfs
2) Improve Stream Releases	No release required (0)	Bioperiod Q90 (or Summer Q90)

B. Increase Water System Capacity

In addition to improving environmental conditions, the project team and stakeholder group also identified a number of improvements to the current water supply system that had the ability to augment existing water supply. These options included:

1) **Expand Storage Capacity by Dredging Reservoir(s)**: Based on the CEI Report (June 2003), the storage capacity of Old Oaken Bucket Pond could be expanded by 8 million gallons and the Reservoir's storage capacity could be expanded by 40 million gallons. New storage-elevation curves were developed for these scenarios that apportioned most of the additional storage at lower elevations in each reservoir.

2) **Develop a new groundwater source in the area of Satuit Meadow**. This would provide additional groundwater into the Town's water supply system. Though no information was available about the potential amount of water available from this site, we modeled two amounts of additional

water: 750,000 gallons/day (.75 mgd) and 350,000 gallons/day (.35 mgd). A well in this location would likely affect the flow of water within the Cranberry Brook Diversion, which can be seen in the additional results provided in Appendix B).

3) Drought management: In addition, the project team modeled the benefit to both water supply and environmental conditions by the use of water restrictions to reduce water use during times of water scarcity. By reducing water use during droughts through water use restrictions the overall reliability of the system can be improved. For scenarios including drought management, we included reductions as outlined in table 7 below. These demand reductions were designed to mimic the requirements of the Town of Scituate's current Water Conservation Protocol.

Table 7. Drought Management Protocols

Feet Below Reservoir Spillway	Scituate Water Conservation Protocol	WEAP Drought Management Rule
2.5	Advise consumers and Water Commissioners of mandatory restriction in near future.	None
3.75	6 – 9 AM odd/even watering	Reduce 20% of peak demand (base* + 80% of peak demand)
5	Outdoor water use prohibited, with some exceptions	Reduce 50% of peak demand (base + 50% peak demand)

* base = Median daily demand.

Details on each of these options are in Table 1. Additional capacities associated with structural modifications to the existing water system are shown in Table 8.

Table 8. Current and Modeled New Water System Capacity

1) Expand Storage Capacity	Current Capacity: OOB: 7.6 mg Reservoir: 133.7 mg Tack Factory 5.1 mg	Modeled Capacity: OOB: 15.6 (+8 mg) Reservoir: 173.7 (+40mg) Tack Factory: 5.1 mg
2) New Groundwater Source	Current Capacity: 0	Capacity: 750,000 gallons/day & 350,000 gallons/day

V. The WEAP Model

The Water Evaluation and Planning (WEAP) tool is an integrated water resources planning tool that is used to represent current water conditions in a given area and to explore a wide range of demand and supply options for balancing environment and development objectives. WEAP is widely used to support collaborative water resources planning by providing a common analytical and data management framework to engage stakeholders and decision-makers in an open planning process. Within this setting, WEAP is used to develop and assess a variety of scenarios that explore physical changes to the system, such as new reservoirs or pipelines, as well as social changes, such as policies affecting population growth or the patterns of water use. Finally the implications of these various policies can be evaluated with WEAP's graphical display of results.

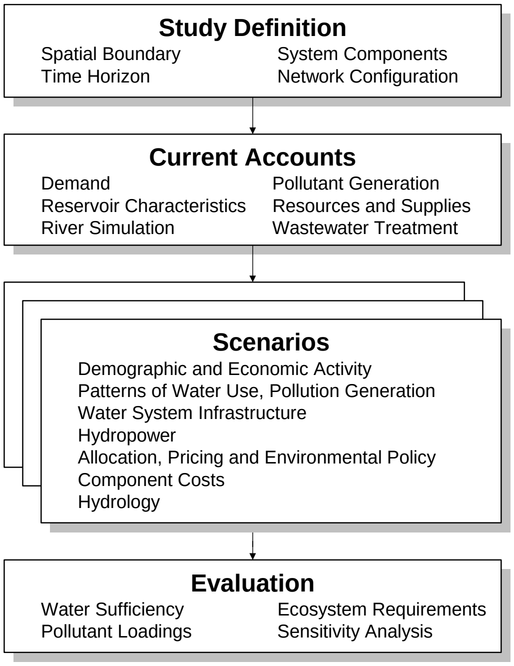

Fig 7. Developing a WEAP Application

A. Modeling Approach

The development of WEAP applications follows a common approach (see Figure 7). The first step in this approach is the study definition, wherein the spatial extent and system components of the area of interest are defined and the time horizon of the analysis is set. Following this initial assessment, the 'current accounts' is defined, which is a baseline representation of the system – including the existing operating rules for both supplies and demands. The current accounts serves as the point of departure for developing scenarios, which characterize alternative sets of future assumptions pertaining to policies, costs, and factors that affect demands, pollution loads, and supplies. Finally, the scenarios are evaluated with regard to water sufficiency, costs and benefits, compatibility with environmental targets and sensitivity to uncertainty in key variables.

The steps in the analytical sequence are described in greater detail in Appendix A.

VI. Scenarios and Results

The project team identified a set of 9 scenarios that included various combinations of the environmental improvements and water system capacity expansion options described in Section 4.

Two volumes of a new water supply source in the Satuit Meadow watershed were examined, with the intent of bracketing likely volumes that may result from new source(s) currently under investigation. As actual yields for these source(s) are determined in more detail, the Town may choose to rerun these scenarios with the more accurate data.

The scenarios are described below:

Table 9. Primary Scenarios

Scenario Name	Scenario Number & Abbreviation	Description
Natural	**Natural**	Flows as they would be without any dams or water withdrawals, given current landuse conditions.
Current Operations with No New Passage	**1. Current Ops**	Flows and water availability as they are under current system configuration and operations.
Current Operations New Passage	**2. Current Ops + Pass**	Flows and water availability with improved fish ladders and new weirs at both OOB and the Reservoir. New ladders require significantly less water to operate while being more effective in allowing fish to move upstream. Weirs allow downstream movement.
New Passage + Dredge Both Impoundments	**3. Dredge Both + Pass**	Flows and water availability with OOB and the Reservoir dredged to provide more storage capacity (8 and 40 mgd, respectively). New ladders & weirs added.
New Passage + Satuit 0.75 Withdrawal	**4. Satuit 0.75 + Pass**	Flows and water availability with the addition of a well in Satuit meadow that produces 750,000 gallons/day (.75 mgd). New ladders & weirs added.
New Passage + Bioperiod Q90 Release	**5. BioQ90 + Pass**	Flows and water availability with reservoir releases that maintain minimum streamflows according to typical low flows for each bioperiod, or inflow to reservoir(s) if it is lower. New ladders & weirs added.
New Passage + BioQ90 + Satuit 0.75	**6. BioQ90 + Satuit 0.75 + Pass**	Flows and water availability with reservoir releases that maintain streamflows according to typical low flows for each bioperiod and the addition of a 750,000 gpd well in Satuit meadow. New ladders & weirs added.
New Passage + Bio Q90 + Satuit 0.35 + Dredge Both	**7. BioQ90 + Satuit 0.35 + Dredge Both + Pass**	Flows and water availability with reservoirs releases that maintain streamflows according to typical low flows for each bioperiod and the addition of a 350,000 gpd well in Satuit meadow and dredging both OOB and the Reservoir. New ladders & weirs added.
New Passage + Bio Q90 + Satuit 0.35 + Drought Management	**8. Bio Q90 + Satuit 0.35 + Drought Mgmt + Pass**	Flows and water availability with reservoirs releases that maintain streamflows according to typical low flows for each bioperiod and the addition of a 350,000 gpd well in Satuit meadow and reduced demands during drought conditions. New ladders & weirs added.
New Passage + Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt	**9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt + Pass**	Flows and water availability with reservoirs releases that maintain streamflows according to typical low flows for each bioperiod, the addition of a 350,000 gpd well in Satuit meadow, reduced demands during drought conditions and dredging OOB. New ladders & weirs added.

A. Impacts on Water Supply Yield

For each of these options the WEAP model estimated the change in water availability for the town system (Table 10). For details on the model methodology, see Appendix A. The currently permitted yield of the reservoir system plus upstream groundwater wells is 1.79 mgd. Our model estimated a virtually identical yield of 1.77 mgd, a high degree of correlation that helped provide confidence in our ability to accurately model the Scituate water supply system and First Herring Brook hydrology.

As expected (see Table 10), providing water to improve environmental conditions reduces overall the water supply yield available for use by the town. Operating the fish ladders and weirs during in and out-migration periods reduces available yield by 230,000 gallons/day, or 13% of current system capacity. Providing minimum flow releases further decreases the yield by 340,000 gallons/day for the bioperiod Q90 release and 160,000 gallons/day for the summer Q90 releases. Respectively, these reduce available water by 32% and 22% from current system capacity.

The various water supply options augment the existing capacity of the system. Relative to current operations with new fish passage structures, dredging both reservoirs increases the water supply yield by 0.21 mgd (14%) and adding a new 0.75 mgd well in the Satuit Meadow increases yield by 0.64 mgd (42%). The inclusion of the new fish passage structures caused the yield increase to be somewhat less than the total pumping when considering additional supplies from Satuit Meadow. That is, a dedicated water supply source from Satuit Meadow reduced the total pumping from OOB, such that more water was available to flow downstream. Thus, increasing groundwater pumping had an indirect benefit of increasing streamflows.

Table 10. Water Supply Yield

Scenario Name	Million Gallons/Day	% Change
Natural	0	n/a
Current Operations	1.77	0%
Current Ops & New Passage	1.54	-13%
Dredge Both + Pass	1.75	-1%
Satuit 0.75 + Pass	2.18	+23%
Bio Q90 + Pass	1.2	-32%
BioQ90 + Satuit 0.75 + Pass	1.82	+3%
Bio Q90 + Satuit 0.35 + Dredge Both + Pass	1.63	-8%
Bio Q90 + Satuit 0.35 + Drought Mgmt + Pass	1.65	-7%
Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt + Pass	1.68	-5%
Summer Q90	1.38	-22%

Drought management responses were triggered as previously described in Table 7. Table 11 below shows the frequency of these actions and their associated average water savings.

Table 11. Results of Drought Management Actions

Scenario	% of Days in Drought Warning	Average Daily Demand Reduction for Drought Warning Days (mgd)	% of Days in Drought Emergency	Average Daily Demand Reduction for Drought Emergency Days (mgd)
BioQ90 + Satuit 0.35 + Drought Mgmt + Pass	9.8	0.05	6.7	0.14
BioQ90 + Satuit 0.35 + Dredge OOB + Drought Mgmt + Pass	3.8	0.08	5.6	0.09

B. Impacts on Reservoir Levels for Water Supply

In addition to the total amount of water available to the Town, reservoir levels play a key role in water supply management and ensuring a reliable supply under all conditions. For example, the town water division ties the initiation of water restrictions to the reservoir levels. Adequate depth of water above water supply intake pipes is also a crucial component of the water supply system.

Another important role of water levels, especially with regard to juvenile river herring, is having suitable aquatic habitat available within the OOB and the Reservoir. As described above, river herring migrate up stream in the spring to spawn in lakes and ponds. Juvenile herring, and other native fish species, rely on woody habitat (shrubs, fallen trees, etc.) along the shoreline for shading and protection from predation in the pond environment. Thus the water levels and water quality within these two water bodies are important considerations in the ability to restore these species to the First Herring Brook system.

Table 12 summarizes the impacts of the scenarios to Reservoir levels during extreme drought years (95% percentile water levels). The performance of the system during extreme drought years largely governs the water supply yield that the system will produce as well as the habitat availability for juvenile herring and other resident aquatic species. Overall, performance is best during winter and spring and most challenged during the fall bioperiod. Not surprisingly, scenarios with the larger additional groundwater source outperform current operations by maintaining higher summer and fall Reservoir levels during drought years. Dredging scenarios lead to lower average fall water levels than other options because the additional storage is modeled to be located in the lower elevations of the impoundment. Drought management scenarios increase summer and fall average Reservoir levels as less water is removed from the system for water supply. The BioQ90 scenario with no additional source of water performs particularly poorly during drought years, draining the Reservoir during the summer and fall bioperiods. For additional information on Reservoir levels, please see Appendix B.

Table 12. 95th Percentile Reservoir Elevation	> 34			
	33 - 34			
	< 33			
	Mar-May	Jun-Aug	Sep-Nov	Dec - Feb
Scenario (yield, mgd):				
Current Ops + Current Ladders (1.77)	40.04	37.57	34.54	37.19
Current Ops (1.54)	38.33	34.34	31.24	34.95
Dredge Both (1.75)	38.49	38.86	32.78	35.3
Satuit 0.75 (2.18)	40.04	38.98	38.8	40.04
BioQ90 (1.2)	35.62	27.00	27.00	31.08
BioQ90 + Satuit 0.75 (1.82)	38.54	36.53	35.61	36.66
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	38.37	34.7	33.11	34.43
Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	38.32	38.7	38.5	34.85
Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	38.79	35.2	33.93	35.23

C. Impacts on Reservoir Levels for Habitat

Table 13 below provides an assessment of how often reservoir levels achieved the defined habitat goals over the period of record. For the purposes of analysis, the wettest 25% of the period of record was considered “wet”, the driest 25% of the period of record was considered “dry”, and the middle 50% of the period of record was considered “normal”. White shading indicates bioperiods that met the reservoir habitat goals more often and darker shading indicates bioperiods that met the goals less often.

Winter, spring and summer Reservoir habitat goals were met fairly consistently (> 40% of the time) in most scenarios. Performance is best during winter and spring and is most challenged during fall wet and dry years. In several scenarios, the frequency of water spilling over the spillway in the fall bioperiod are greatly reduced. Similarly, several scenarios lead to fall reservoir levels lower than the dry year habitat targets for greater than 15% of the period of record.

For additional analysis and effects on extreme drought year reservoir levels, see Appendix B.

Table 13. Percent of Entire Period of Record that Reservoir Elevations Achieve Habitat Goals	Normal		Wet			Dry		
	> 40		> 10			> 90		
	25-40		> 5			> 85		
	< 25		< 5			< 85		
Scenario	Mar-May	Jun-Aug			Sep-Nov			Dec - Feb
	39+	Normal (36+)	Wet (40+)	Dry (34+)	Normal (36+)	Wet (40+)	Dry (34+)	39+
Current Ops + Current Ladders	100	98	25	100	79	31	98	94
Current Ops	93	90	18	99	93	10	86	92
Dredge Both	92	100	30	100	97	10	100	93
Satuit 0.75	100	100	48	100	100	70	100	100
BioQ90	80	72	14	88	48	7	69	66
BioQ90 + Satuit 0.75	90	98	24	100	94	11	100	89
Bio Q90 + Satuit 0.35 + Dredge Both	89	88	17	97	73	9	89	84
Bio Q90 + Satuit 0.35 + Drought Mgmt	88	87	17	97	68	7	91	83
Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt	92	92	27	98	82	12	94	89

D. Impacts on Streamflow

For each scenario the impact on the flow of goal-setting locations in the First Herring Brook watershed was modeled. One simple metric that helps to illustrate how each scenario affects the water in the stream is the number of days of zero flows in the stream segment. Dry streams are clearly an extremely negative result for the protection of First Herring Brook ecological targets, and thus provide a means to compare the 'worst case' outcomes of each scenario. Additional results are presented in Appendix B (Section 9).

Table 14 summarizes the number of zero flow days for each bioperiod across the period of record under each scenario. Note that the results are broken out by bioperiod and a shaded scale is included to emphasize the relative magnitude of impacts. To simplify presentation, only the two critical streamflow locations are included here (below OOB and the Reservoir).

Table 14. Impact on Streamflow	**Number of Zero Flow Days**			
First Herring Brook WEAP Model Results	Number of 0 flow days in bioperiod			
Legend:	0			
	1-180 (0 to ~5% of days)			
	> 180 (> ~5% of days)			
Streamflow Below Old Oaken Bucket Pond	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb
Number of days in bioperiod for period of record:	3588	3588	3549	3510
Scenario (yield, mgd)				
Natural	0	0	0	0
1. Current Ops + Current Ladders (1.77)	0	46	51	0
2. Current Ops (1.54)	0	46	51	0
3. Dredge Both (1.75)	0	46	43	0
4. Satuit 0.75 (2.18)	143	2407	725	154
5. BioQ90 (1.2)	0	0	0	0
6. BioQ90 + Satuit 0.75 (1.82)	0	0	0	0
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	0	0	0	0
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	0	0	0	0
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	0	0	0	0
Streamflow Below the Reservoir	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb
Number of days in bioperiod for period of record	3588	3588	3549	3510
Scenario (yield, mgd):				
Natural	0	0	0	0
1. Current Ops + Current Ladders (1.77)	15	48	591	163
2. Current Ops (1.54)	32	83	857	416
3. Dredge Both (1.75)	32	71	770	332
4. Satuit 0.75 (2.18)	3	74	965	55

5. BioQ90 (1.2)	0	0	0	0
6. BioQ90 + Satuit 0.75 (1.82)	0	0	0	0
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	0	0	0	0
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	0	0	0	0
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	0	0	0	0

The results demonstrate the value of providing a directed release from the Reservoir and Old Oaken Bucket Pond. Under current operations and existing ladders, completely dry stream segments would be expected to occur over 16% of the time below the Reservoir and a bit over 1% below Old Oaken Bucket Pond in the Fall bioperiod (September-November). Zero flow days occur in the other bioperiods as well under current conditions, but to a lesser extent. Scenarios designed to increase fish passage and water system capacity that do not include a streamflow release component only exacerbate an already problematic situation in most cases. Not surprisingly, no zero flow days occur once a directed release is included in a scenario.

The Project Team also completed a detailed analysis of how each scenario did or did not meet the environmental goals described in Section 3. Table 15 provides one metric for examining scenario performance against environmental flow goals: the percent of days within each bioperiod meeting or exceeding flow goals relative to what would have been achieved under natural flow conditions. In other words, how does a managed scenario perform with regard to the flow goals when natural flow conditions are taken into account?

Table 15. Streamflow Assessment

First Herring Brook WEAP Model Results

Percent of Days Achieving Flow Goals Relative to Natural Conditions

100 * (Days Exceeding Flow Goal / Natural Days Exceeding Flow Goal)

>66

33-66

< 33

Streamflow Below Old Oaken Bucket Pond	Mar-Apr	May	Jun-Aug	Sep-Nov	Dec Feb
Number of days in bioperiod	2379	1209	3588	3549	3510
Scenario (yield, mgd):					
Natural	100	100	100	100	100
1. Current Ops + Current Ladders (1.77)	80	89	24	47	80
2. Current Ops (1.54)	86	72	20	60	78

3. Dredge Both (1.75)	87	71	20	57	78
4. Satuit 0.75 (2.18)	75	64	35	69	75
5. BioQ90 (1.2)	81	73	20	51	68
6. BioQ90 + Satuit 0.75 (1.82)	85	60	25	87	69
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	87	60	21	62	74
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	78	50	19	66	65
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	88	61	21	55	76
Streamflow Below the Reservoir	Mar-May	Jun-Aug	Sep	Oct-Nov	Dec Feb
Number of days in bioperiod	3588	3588	1170	2379	3510
Scenario (yield, mgd):					
Natural	100	100	100	100	100
1. Current Ops + Current Ladders (1.77)	84	153	136	48	78
2. Current Ops (1.54)	101	148	168	36	76
3. Dredge Both (1.75)	95	148	170	37	77
4. Satuit 0.75 (2.18)	84	39	35	70	80
5. BioQ90 (1.2)	109	140	157	30	65
6. BioQ90 + Satuit 0.75 (1.82)	92	83	158	44	73
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	91	144	142	39	72
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	93	139	127	39	71
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	93	114	113	43	75

Examining the results from below Old Oaken Bucket, as expected none of the scenarios achieve the environmental flow goals at all times relative to natural flow performance (which, by definition, is 100%). To explain this, it is important to note that the environmental flow goals are focused on the median (or typical) flow conditions rather than the dry period when water conflicts are most apparent. The "Zero Flow Day" and "BioQ90 Exceedence" metrics are better at picking up this pattern.

Despite this discrepancy, differences in the achievement of flow goals are apparent below both the Reservoir and OOB among scenarios and across seasons.

During the summer bioperiod, any time water levels fall below the spillway elevations, only the BioQ90 release is made. This explains why average natural flow conditions are rarely met below Old Oaken Bucket Pond in the summer bioperiod. Only Scenario 4 (adding a new source from Satuit Meadow at 0.75mgd) meets environmental flow goals even 1/3 of the time in the summer. This increase in available water to the system from Scenario 4 leads to the poorest performance, however, when it comes to flows below the Reservoir. This is almost certainly due to the lack of need to move water downstream to OOB for treatment and consumption due to the relatively large quantity of water available from the hypothetical Satuit Meadow well source. In other scenarios, summer water supply operations lead to releases downstream of the Reservoir to Old Oaken Bucket Pond that cause flow goals to be achieved *more frequently* than would happen under estimated natural flow conditions.

During the fall bioperiod, less water is being shuttled to Old Oaken Bucket Pond and Reservoir water levels are often below the spillway and the bottom of the weir in most scenarios. These two factors result in BioQ90 flows for significant portions of the fall bioperiod, which helps to explain why fall flows below the Reservoir do not perform well when compared to natural average conditions. Fall improvements generally come with water system capacity improvements. A combination of both environmental improvements and water system capacity improvement performs well in all bioperiods other than fall. In Old Oaken Bucket Pond, water elevations are often above the bottom of the weir even in fall, so that some releases for herring out-migration are possible in most scenarios. This results in slightly better fall flows below Old Oaken Bucket Pond than below the Reservoir. Overall, below OOB the alternative scenarios provide limited improvement from current conditions in flow performance relative to environmental flow goals, fish ladders and weirs notwithstanding (see Section 6.4 for assessment of fish ladder and weir performance).

Future scenarios might explore how summer flows could be improved below Old Oaken Bucket and fall flows could be improved below the Reservoir in order to better achieve ecological protection.

Note that, although not included in these tables, significant decreases in flow occur in the “Cranberry Diversion” channel under Satuit withdrawal scenarios. The hydrologic impact of this flow decrease varies directly with the quantity taken from the potential well location and is most apparent in summer or early fall. See Appendix B for detailed results.

E. Impacts on Upstream and Downstream Fish Passage

As described above the current fish ladders are, in their configuration and design, ineffective in passing alewife. A key factor determining effectiveness of the fish ladders is that impoundment water levels must be sufficiently high so that adequate water can spill into the fish ladder. Water moves into the current fish ladders rarely due to a six inch board placed at the top of the OOB fish ladder and because the Reservoir ladder is set at the spillway elevation and impoundment levels are often drawn down in fall. In addition, when water moves through these ladders, due to their “pool and weir” design they must have at least eight inches of water in them to allow alewife, which do not jump, to move up the ladder (D. Quinn, USFWS, pers. comm.). The current ladder configuration was modeled by the Project Team under various scenarios, but performance was extremely poor under all alternatives. Only the current operations scenario is shown in the ladder performance results (below in Table 16) with current ladders in place, and the results clearly demonstrate the problem with alewife restoration.

To include alternatives that could achieve fish passage goals, the Project Team with stakeholder input modeled new fish ladders as described in Section 3. As shown in Table 15 the model suggests that the addition of new ladders is likely to successfully and consistently allow upstream fish movement at both structures during the April-May migration period. The first metric, “percent of days achieving fish ladder flow target” analyzes how many days under each water management scenario have adequate flows in the fish ladder to permit fish passage during the upstream migration period. This metric looks across the whole period of record and takes the number of days with adequate flows divided by total days in April-May to get the percentage shown. The second metric, “frequency of years with effective fish ladder flows” allows an examination of how performance may differ across year types (e.g. dry year, wet years). The April-May period of each modeling year (1962-2000) was analyzed to determine how often the ladder flow target was met and, if so, whether over 80% of days (i.e. 50 or more out of 61 days) within the migration period were adequate for passage.

Table 16. Fish Ladder Assessment	**1. Percent of Days Achieving Fish Ladder Flow Target**	**2. Frequency of Years with Effective Fish Ladder Flows**
First Herring Brook WEAP Model Results – **Modeling Years 1962-2000**	% of days within April-May migration period that flows in ladder exceed passage flows across period of record	% of years within April-May migration period in which 50 or more days exceed passage flows
	>80%	>75%
	50-80%	60-75%
	<50%	< 60%
Scenario	Apr-May %	Apr-May %
Old Oaken Bucket Fish Ladder		
Natural	n/a	n/a
1. Current Ops + Current Ladders (1.77)	0	0
2. Current Ops (1.54)	95	90
3. Dredge Both (1.75)	93	85
4. Satuit 0.75 (2.18)	99	97
5. BioQ90 (1.2)	85	74
6. BioQ90 + Satuit 0.75 (1.82)	95	95
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	93	87
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	96	95
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	82	67
Reservoir Fish Ladder		
Natural	n/a	n/a
1. Current Ops + Current Ladders (1.77)	3	0
2. Current Ops (1.54)	80	59

3. Dredge Both (1.75)		84	69
4. Satuit 0.75 (2.18)		87	79
5. BioQ90 (1.2)		74	56
6. BioQ90 + Satuit 0.75 (1.82)		84	82
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)		85	77
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)		83	67
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)		89	82

Scenarios that include the improved Old Oaken Bucket fish ladder demonstrate extremely high success in moving fish past the dam (yet not all scenarios are able to meet water supply needs, as discussed above). There is not only a large number of days over the modeled time period when passage would be possible but also, in most cases, a high frequency of years in which passage would occur. Performance for Scenarios 5 and 9 is somewhat poorer. Scenario 5, Bioperiod Q90 Release, is releasing more water downstream without additional water system capacity thereby driving the levels of OOB down in the spring and allowing less water into the fish ladder. In Scenario 9, which combines a range of options, the dredging of Old Oaken Bucket pond for system capacity appears to create relatively lower water levels in the impoundment. These relatively lower water levels over the period of record appear to be negatively impacting fish ladder performance in dry spring seasons.

For the Reservoir fish ladder, extremely large improvements are seen for all scenarios relative to current operations and ladders, although less dramatically than for Old Oaken Bucket. As with Old Oaken Bucket, poorer performance is seen for the Bioperiod Q90 release scenario, likely for the same reasons stated above. The current operations scenario, due to the shuttling of water down to Old Oaken Bucket, shows less strong performance in both metrics of ladder effectiveness. As with below OOB, the scenarios that include dredging of the Reservoir also lead to poorer performance in dry years likely due to relatively low impoundment levels in dry years.

Overall, for the fish ladders at both OOB and the Reservoir, the level of performance is quite high with the improved ladders in place providing evidence that restoration of alewife upstream migration is achievable.

Downstream migration is also an important consideration in attempting to achieve the restoration of river herring to First Herring Brook. Currently, based on input from USFWS biologists, downstream juvenile fish passage performance is likely to be poor given the existing fish ladder design and relatively limited flows through the fish ladders and over the spillways in the downstream migration period (September-October). Thus, the stakeholder group recommended the Project Team model the inclusion and operation of weirs for downstream passage of alewife in September and October of each modeling year (more details on weirs in Section 3).

The results from the operations of the weirs are more mixed than for the ladders, as can be seen in Table 17. Both metrics used in the weir performance table are parallel metrics to those used for upstream migration. Note that for metric 2 the threshold of days required in each out-migration season for a year to be considered adequate is twenty or more out of 61 (i.e. 1/3 or more days in each September-October period). Also, since no weirs exist currently on either dam we can not compare results with current conditions.

Table 17. Weir Performance Assessment

First Herring Brook WEAP Model Results	**1. Percent of Days Equal or Exceeding Weir Flow Target Across Period of Record** % of days within Sept-Oct outmigration period that flows over weir exceed performance flows across period of record (1962-2000)	**2. Frequency of Adequate Years for Out-migration** % of years within Sept-Oct outmigration period in which more than 20 days exceed weir performance flows
September 2009 Results	>33%	>50%
	10 to 33%	20-50%
	<10%	< 20%
Old Oaken Bucket Weir		
Scenario (yield)	Sept-Oct %	Sept-Oct %
Natural	n/a	n/a
1. Current Ops + Current Ladders (1.77)	n/a	n/a
2. Current Ops (1.54)	31	38
3. Dredge Both (1.75)	28	33
4. Satuit 0.75 (2.18)	59	77
5. BioQ90 (1.2)	25	33
6. BioQ90 + Satuit 0.75 (1.82)	51	77
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	31	36
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	37	51
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	23	33
Reservoir Weir		
Natural	n/a	n/a
1. Current Ops + Current Ladders (1.77)	n/a	n/a
2. Current Ops (1.54)	10	10
3. Dredge Both (1.75)	11	10
4. Satuit 0.75 (2.18)	23	23
5. BioQ90 (1.2)	7	8

6. BioQ90 + Satuit 0.75 (1.82)	18	18
7. Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	14	15
8. Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	12	13
9. Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	24	31

The Old Oaken Bucket simulated weir performs relatively well for options that do not involve dredging of the impoundment (thereby lowering water elevations). Across all scenarios, whether looked at across the whole record or by year, generally a third or more of the time the Old Oaken Bucket weir is likely performing adequately for downstream passage which is promising. For the Reservoir weir, performance is adequate typically between one tenth and one third of the time which is less promising. This is largely the result that by fall the Reservoir has been drawn down to meet water supply demands and water levels are not above the weirs on as nearly a regular basis as they are in the spring when alewife are moving upstream. Results are relatively better for scenarios that include development of a water source in the Satuit Meadow, likely because Reservoir levels can remain higher in the fall when this source is available at some quantity.

Although the weir performance results are a concern for downstream migration of alewife, it is likely an issue that can be mitigated through three approaches. One approach is to lower the elevation of the bottom of the weir so that water may be released over the weir at lower water levels. The current model assumes that the weirs would be installed two feet below the spillway elevation, at 38 feet elevation. Water levels during summer and fall bioperiods are generally above elevations of 35-37 feet in the Reservoir and 18 feet in Old Oaken Bucket Pond for at least 75% of the period of record. If the weirs were installed six inches below these elevations, their performance could likely be improved significantly. This would require additional boards to be added and removed from the weir but would enable downstream releases to occur more frequently during out-migration. However, the release of additional water through the weirs would also affect the water supply yield and reservoir levels and a new WEAP model run should be conducted to determine the full extent of this impact.

The second approach is to provide only 4.5 inches of depth (2.2 cfs) over the weir structures during the outmigration period as opposed to six inches (3.39 cfs). This would reduce the amount of water released from the Reservoir and Old Oaken Bucket Pond during the late summer/early fall, when reservoir levels and the ability to make streamflow releases are most taxed.

Another approach is to release flow pulses rather than continuous flows throughout the out-migration period. According to biologists on the stakeholder group, because alewife wait for flow cues (i.e. high water pulses at particular water temperatures) (Kosa et al, 2001; Yako et al., 2002.) to move downstream it is possible that successful downstream migration can be facilitated using short pulses of water released from weirs or other structures. This approach, which would require more human effort than the weir design modeled in the scenarios, could also be substantially more efficient at maintaining water in OOB and the Reservoir. Continued work with state and federal fisheries biologists is needed to determine the appropriate volume and frequency of these downstream water pulses to meet project goals. Given that Old Oaken Bucket is much smaller and is kept at or near full for water supply needs we would expect that weir performance can be more easily improved for Old Oaken Bucket than for the Reservoir. Based on this analysis, providing reliable upstream and downstream passage from Old Oaken Bucket appears to be achievable while downstream passage from the Reservoir is still uncertain.

VII. Effects on Channel Depth for Fish Passage

In addition to allowing enough flow for the fish ladders and weirs to pass fish up and downstream, the depth of water in the stream channel itself must also allow for fish passage. A depth of 6 inches over the deepest point of riffles was recommended by fisheries experts as a benchmark for adequate depth for passage of adult herring up and down the river channel. Depths, velocities and channel slopes were measured at two riffles, one downstream of the Reservoir near Eisenhower Ln. and one downstream of Old Oaken Bucket Pond. These data were used to calculate the necessary flows to provide six inches of depth over the riffles and other associated parameters. Downstream of the Reservoir, 0.37 cfs provides a maximum of six inches of depth, with a wetted width of 8.6 ft and a wetted cross-sectional area of 1.8 square ft. Downstream of Old Oaken Bucket Pond 0.38 cfs provides a maximum depth of six inches, with a wetted width of 6.1 ft and a wetted cross-sectional area of 1.38 square ft.

Table 18 relates the natural occurrence of these conditions to the frequency for each modeled scenario. Under natural conditions, the channel downstream of the Reservoir is at least six inches deep 80-100% of the time and the channel downstream of Old Oaken Bucket Pond is at least six inches deep 90-100% of the time. Downstream of the Reservoir, all scenarios except BioQ90 + Satuit 0.75 reduce the occurrence of adequate depths somewhat in the September – November Bioperiod. This results is likely due to the relative lack of required releases from the reservoir during that period because of the reliance on heavy withdrawals from Satuit Meadow (0.75mgd). Other bioperiods do not experience significant changes. Downstream of Old Oaken Bucket Pond, the addition of BioQ90 requirements provides near-natural occurrence of adequate channel depth in all bioperiods, while scenarios without BioQ90 flow requirements have significantly reduced occurrence of adequate channel depths.

Table 18. Stream Depth Assessment	**Percent of Days of Adequate Channel Depth for Fish Passage**			
First Herring Brook WEAP Model Results	percent duration of flows >= 6 inches deep over period of record			
Legend:	> 75			
	50-75			
	< 50			
Streamflow Below Old Oaken Bucket Pond	Mar-May	Jun-Aug	Sep-Nov	Dec Feb
Number of days in bioperiod for period of record	3588	3588	3549	3510
Scenario (yield, mgd):				
Natural	100	90	92	100

Current Ops + Current Ladders (1.77)	100	29	46	94
Current Ops (1.54)	100	29	64	94
Dredge Both (1.75)	100	29	62	94
Satuit 0.75 (2.18)	94	25	59	93
BioQ90 (1.2)	100	95	94	100
BioQ90 + Satuit 0.75 (1.82)	100	89	97	100
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	100	89	91	100
Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	100	89	93	100
Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	100	89	90	100
Streamflow Below the Reservoir	Mar-May	Jun-Aug	Sep-Nov	Dec Feb
Number of days in bioperiod for period of record	3588	3588	3549	3510
Scenario (yield, mgd):				
Natural	100	83	87	100
Current Ops + Current Ladders (1.77)	99	98	71	92
Current Ops (1.54)	99	96	65	84
Dredge Both (1.75)	99	97	67	86
Satuit 0.75 (2.18)	98	75	58	98
BioQ90 (1.2)	100	89	66	97
BioQ90 + Satuit 0.75 (1.82)	85	89	89	86
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)	100	96	65	100
Bio Q90 + Satuit 0.35 + Drought Mgmt (1.65)	100	95	64	100
Bio Q90 + Satuit 0.35 + Dredge OOB + Drought Mgmt (1.68)	100	80	66	100

VIII. Conclusions

The First Herring Brook Project was designed to develop a water budget model for the First Herring Brook, including Tack Factory Pond, the Main Reservoir and Old Oaken Bucket Pond impoundments and the Scituate Water Supply system as it affects this stream system. The model developed successfully evaluates the feasibility of restoring flows downstream of Old Oaken Bucket and between the two impoundments to restore aquatic habitat for river herring and to improve the overall health of the aquatic system. In particular, the model is able to evaluate how various changes to the system – either to improve environmental conditions or increase system capacity – affect the ability to meet environmental and water supply goals.

Some general conclusions can be drawn from this project. The first is that the difficulty in meeting both the water supply and environmental goals is limited to certain months and weeks during the year. This is demonstrated in the streamflow results of this report, which illustrate the challenges in balancing water supply and habitat in summer and fall.

Though no single scenario modeled to date met all the goals defined by the group the results provide the pieces necessary to develop a system design and operations plan that is capable of meeting all of the various goals identified. Model results indicate that additional water sources are likely to be needed to restore herring and improve overall aquatic condition while maintaining drinking water supplies. The model remains available for the continued use by the Town, the Watershed Association or others to continue to develop scenarios and determine results that best balance water supply and environmental goals.

One key assumption to our modeling approach for restoring herring to this system was the use of improved fish ladders. This was a result of the low or no performance of the existing fish ladders and the greatly reduced water requirements of the new designs. In addition, the model assumed the use of new weirs in the dams to promote downstream passage of fish in the fall. Further work on weirs operations and design is also likely necessary – both on managing their use as “pulses” when fish are present (rather than continuous spills during the fall), reducing the minimum required depth of flow to 4.5 inches rather than 6 inches, and considering whether weirs could be built at lower elevations.

Another avenue of potential water to meet environmental objectives is to investigate and model the use of additional water conservation measures. The drought management scenarios modeled to date reflect the Town's existing water conservation policy and tend to result in higher Reservoir levels in summer as well as increased yields. CEI's 2003 report indicates that Scituate's peak water use is 2.05 times its average demand. Although the town’s annual per capita demand falls within state guidelines, the large increase in summertime water use, in excess of likely summer population increase, indicates the potential for additional summer water savings. A discussion of achievable water conservation goals may result in scenarios with greater demand reductions as well as higher summer Reservoir levels and yields.

Another area that might help achieve the water supply and environmental goals is to look at the prescribed reservoir releases as modeled. Two ideas are worth considering. First, the primary reservoir release modeled was based on the bioperiod Q90. Other releases amounts based either on other statistics or perhaps on the water needed to maintain certain depths of water in the channels could be considered. In addition, consideration should be given to reservoir release rules that cut back the required release amounts during drought periods. Significant gains in yield and environmental benefits can be made by this “share the pain” approach during drought periods. In such scenarios reservoir release reductions are implemented at the same time that water use restrictions are put into place.

The First Herring Brook Environmental Flows Project was a collaborative and informative effort among all stakeholders to examine water management & infrastructure changes. We hope our work will be successful in leading Town towards options that maintain water supplies and improve habitat.

IX. Appendix A: The WEAP Model Development

As mentioned in Section 6A, the development of any WEAP model applications follows a specific set of steps (see Figure 7). We used this same approach to develop the application for First Herring Brook. These general steps are outlined below.

Study Definition

Evaluating the implications of managing diversions and impoundments along a river requires the consideration of the entire land area that contributes to the flow within the river – the river basin. Within WEAP it is necessary to set the spatial scope of the analysis by defining the boundaries of the river basin. Within these boundaries there are smaller rivers and streams (or tributaries) that flow into the main river of interest. Because these tributaries determine the distribution of water throughout the whole basin, it is also necessary to divide the study area into sub-basins such that we can characterize this spatial variability of river flows. The description of the First Herring Brook watershed and its sub-basins is presented in Sections 9.2 through 9.3.2.

Current Accounts

The current accounts represent the basic definition of the water system as it currently exists. Establishing current accounts requires the user to "calibrate" the system data and assumptions to a point that accurately reflects the observed operation of the system. The current accounts include the specification of supply and demand data (including definitions of reservoirs, pipelines, treatment plants, pollution generation, etc.). A description of the operational characteristics of the town of Scituate's water management system and a calibration to historical observations is presented in Sections 9.3.3 through 9.4.

Scenarios

At the heart of WEAP is the concept of scenario analysis. Scenarios are self-consistent story-lines of how a future system might evolve over time. The scenarios can address a broad range of "what if" questions. This allows us to evaluate the implications of unintended changes in the system and then how these changes may be mitigated by policy and/or technical interventions. For example, WEAP may be used to evaluate the water supply and demand impacts of a range of future changes in demography, land use, and climate. The result of these analyses will be used to guide the development of response packages, which are combinations of management and/or infrastructural changes that enhance the productivity of the system. Details concerning water supply and streamflow augmentation strategies considered in this study are presented in Section 9.5.

Evaluation

Once the performance of a set of response packages has been simulated within the context of future scenarios, the packages can be compared relative to key metrics. Often these relate to water supply reliability, water allocation equity, ecosystem sustainability, and cost, but any number of performance metrics can be defined and quantified within WEAP. These results are presented in the main body of this report. Some additional results are included in Appendix B.

A. Water Allocation

Two user-defined priority systems are used to determine allocations of water supplies to demands (i.e. urban and agricultural), for instream flow requirements, and for filling reservoirs – demand priorities and supply preferences.

Demand priorities are used to allocate water to competing demand sites and catchments, flow requirements, and reservoir storages. The demand priority is attached to the demand site, catchment, reservoir, or flow requirement and range from 1 to 99, with 1 being the highest priority and 99 the lowest. Many demand sites can share the same priority, which is useful in representing a system of water rights, where water users are defined by their water usage and/or seniority. In cases of water shortage, higher priority users are satisfied as fully as possible before lower priority users are considered. If priorities are the same, shortage will be shared equally (as a percentage of their demands).

When demands sites or catchments are connected to more than one supply source, the order of withdrawal is determined by supply preferences. Similar to demand priorities, supply preferences are assigned a value between 1 and 99, with lower numbers indicating preferred water sources. The assignment of these preferences usually reflects some economic, environmental, historic, legal and/or political realities. In general, multiple water sources are present when the preferred water source is insufficient to satisfy all of an area's water demands. WEAP treats the additional sources as supplemental supplies and will draw from these sources only after it encounters a capacity constraint (expressed as either a maximum flow volume or a maximum percent of the demand) associated with the preferred water source.

WEAP's allocation routine uses demand priorities and supply preferences to balance water supplies and demands. To do this, WEAP must make an assessment of the available water supplies at any given timestep. While total supplies may be sufficient to meet all of the demands within the system, it is often the case that operational considerations prevent the release of water to do so. These regulations are usually intended to hold water back in times of shortage so that delivery reliability is maximized for the highest priority water users (often urban indoor demands). WEAP can represent this controlled release of stored water using its built-in reservoir object.

WEAP uses generic reservoir objects that divide storage into four zones, or pools (See Figure 8). These include, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone. The conservation and buffer pools together constitute the reservoir's active storage. WEAP will ensure that the flood-control zone is always vacant – i.e. the volume of water in the reservoir cannot exceed the top of the conservation pool. The size of each of these pools can change throughout the year according to regulatory guidelines, such as flood control rule curves.

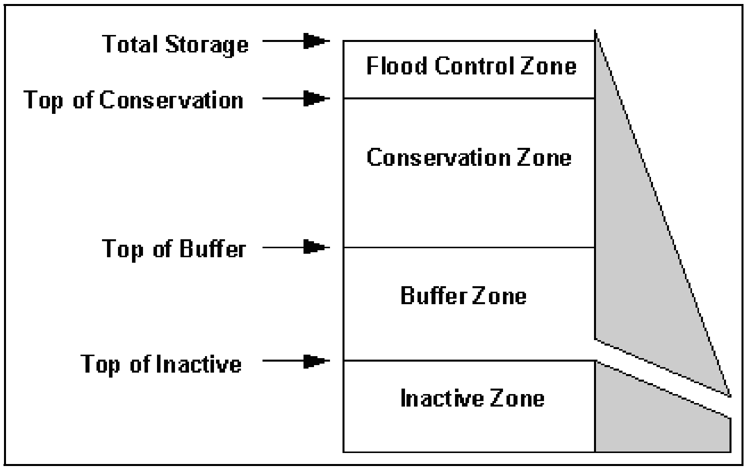

Figure 8. Reservoir zones

WEAP allows the reservoir to freely release water from the conservation pool to fully meet withdrawal and other downstream requirements. Once the storage level drops into the buffer pool, the release will be restricted according to the buffer coefficient, to conserve the reservoir's dwindling supplies. The buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully while rapidly emptying the buffer zone, while a coefficient close to 0 will leave demands unmet while preserving the storage in the buffer zone. Water in the inactive pool is not available for allocation, although under extreme conditions evaporation may draw the reservoir into the inactive pool.

B. Geographic scope

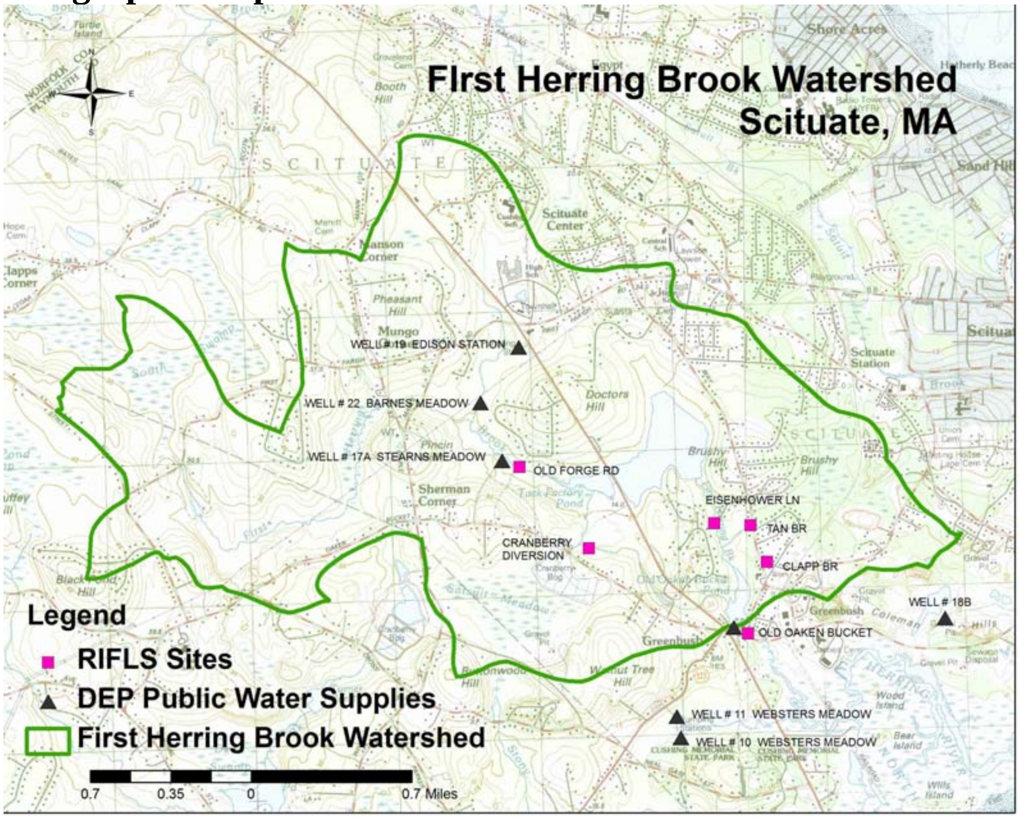

Figure 9. First Herring Brook watershed

The WEAP model encompasses the First Herring Brook watershed in Scituate, Massachusetts upstream of and including its confluence with the Satuit Meadow tributary, located just downstream of Old Oaken Bucket Pond (Figure 9). The watershed drains 5.24 square miles of mostly residential lands, bisected by a major state road, Route 3A. The upper portion of the watershed drains a very flat swampy area know as South Swamp. Surface flow in the upper portion of this area is reported to change flow direction occasionally, draining west into the Bound Brook watershed[*]. Additional wetlands, known as the Brushy Swamp, are located in the eastern portion of the watershed.

C. Data Inputs

1. Network Schematic

A stylistic schematic of the First Herring Brook WEAP application is presented in Figure 10. The model represents streamflows (blue lines) on the mainstem of First Herring Brook plus other significant inflows – Doctors Brook, Tan Brook, Clapp Brook, and the Cranberry Diversion. The main water storage facilities (green triangles) included in the model are Tack Factory Pond, The Reservoir, and Old Oaken Bucket Pond. The water demands (red circle) for the Town of Scituate are considered as one centralized demand within the model. Water supplies (green lines) for this demand are divided between existing groundwater (green squares) and surface water sources and proposed additional groundwater wells. In some cases, the model has been applied to consider the impact of managing water resources to meet in-stream flow standards (magenta crosses).

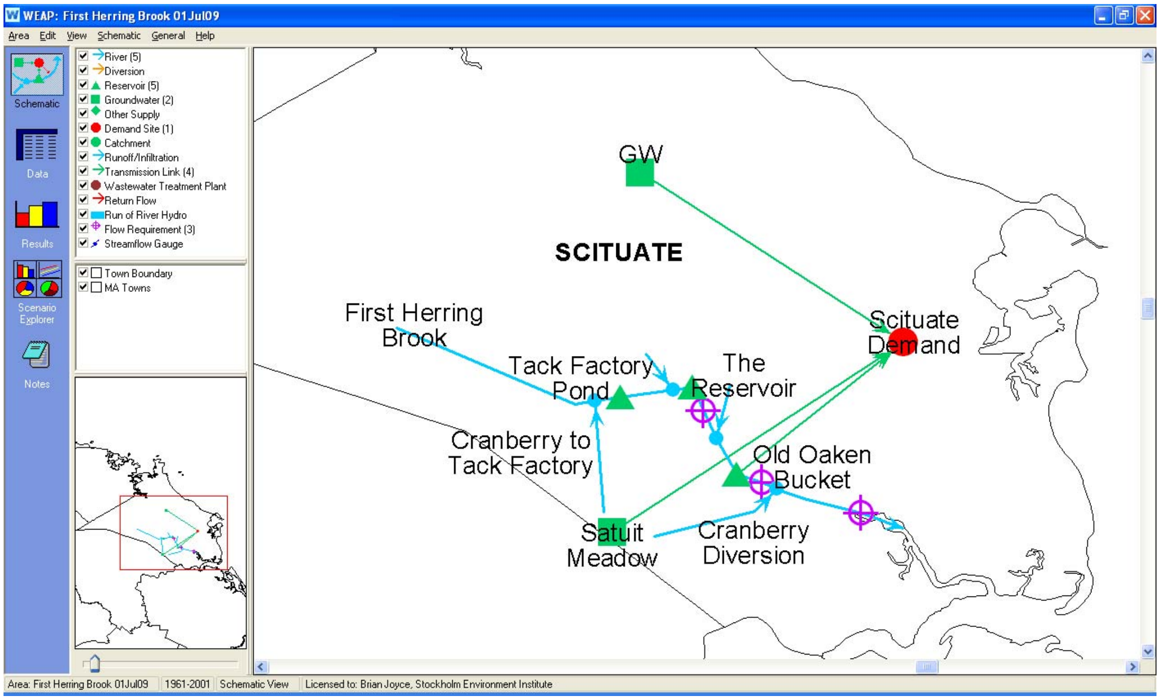

Figure 10. Schematic representation of First Herring Brook in WEAP

2. Inflows

Inflow files were generated to represent the amount of stream flow in First Herring Brook and its major tributaries given current land uses and soil types without reservoirs, water withdrawals or water

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[*] Scituate Water Study Committee. March 2004. Scituate Water Study Committee Report.

or wastewater returns over a climatic period representing conditions from 1961 to 2007. Flow duration curves were estimated for five subwatersheds (Fig. 11) using regression equations based on Fennessey (1994), which incorporate the effects of drainage area, basin elevation, geographic location, slope, soil retention factor, snowfall and precipitation. The 5.24 square mile drainage area and watershed boundaries were obtained from GIS using the National Hydrography Dataset with ArcHydro tools. The geographic location was obtained in GIS using the Massachusetts State Plane projection. Channel slope was calculated following Waldron and Archfield's (2006) method from USGS 15-minute topographic quadrangles. The soil retention factor was calculated using MassGIS 1999 Land Use data, hand-digitized Plymouth County Soil Survey data (Natural Resources Conservation Service, 2002) and runoff curve numbers from TR-55 (United States Department of Agriculture, 1986). Snowfall and precipitation values were obtained directly from USGS staff (Archfield, 2008) based on NOAA climate station data.

The timing of flow magnitudes at an index USGS streamflow gage (Indian Head River at Hanover, MA, #01105730) was used in conjunction with the estimated flow duration curves to re-create 46 year records of streamflows representing past climatic conditions for each location (Waldron, M.C. and Archfield, S.A., 2006).

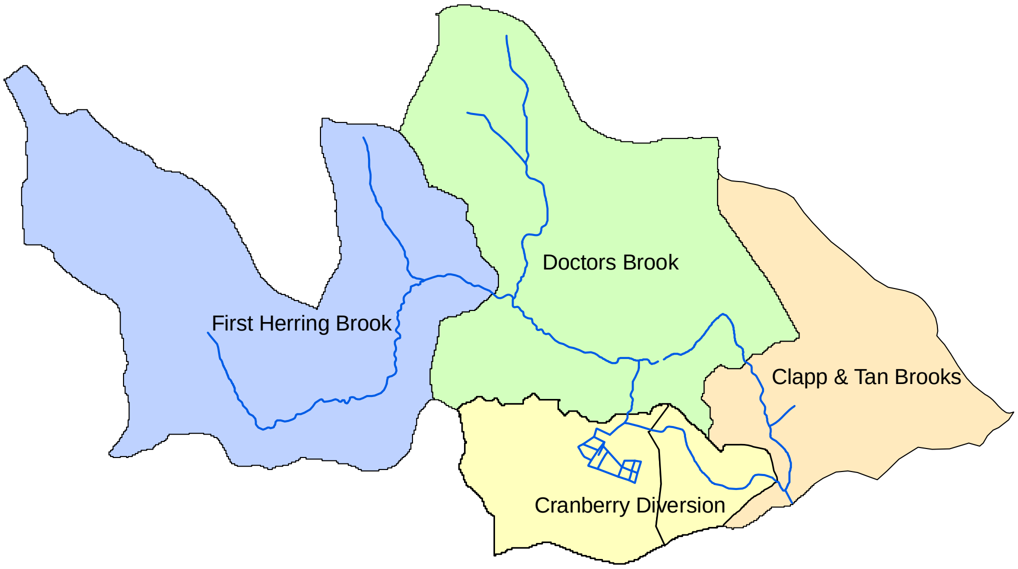


Fig. 11 Map of inflow watersheds

Watersheds and sub-watersheds for which inflow files were generated for the WEAP model. The Cranberry Diversion watershed was modeled as a single watershed for most scenarios, but broken into two sub-watersheds for a single scenario, called "Redivert Cranberry Brook".

3. Reservoirs/Dams

A storage-elevation curve taken from the "Town of Scituate Drinking Water Supply and Demand Analysis" (Comprehensive Environmental, Inc., (2003) was included for both reservoirs to relate the volume of water stored in the reservoirs to water surface elevations. The maximum depth of active storage for each reservoir was set to the elevation of the water supply intake pipes (27 ft elevation at the Reservoir and 15 feet at Old Oaken Bucket Pond.)

In order to enable reservoir water levels in the WEAP model to rise above the spillway elevation, outflows were limited by the structural and hydraulic constraints of the spillways, fish ladders and weirs. An elevation-outflow curve was created for each spillway, fish ladder and weir covering water levels up to one foot above the spillway elevation at the Reservoir and 0.25 feet above the Old Oaken Bucket Pond spillway elevation. The broad-crested weir equation (Brater and King, 1976) was used to estimate outflows for the two spillways and the sharp-crested weir equation was used for the two proposed weir structures (Chow, 1959). It was assumed that a set of three inch boards in each weir would be managed to maintain between six and nine inches of depth when water levels were below the spillway elevation for successful out-migration of herring. Outflows for the current fish ladders were based on the sharp-crested weir equation and it was assumed that boards were never manipulated, with no boards in the reservoir fish ladder and one six inch board always in the Old Oaken Bucket fish ladder. Outflows from the proposed new Alaska steeppass fish ladders were derived from observed flows for fully functioning similar ladders at a 1:6 slope (Alaska Department of Fish and Game, 1962).

4. Demands

The WEAP model was set up such that water management scenarios could be evaluated considering recent water use patterns. Total annual pumping and seasonal variation of pumping from surface water and groundwater sources for the years 1999 to 2007 were input into the model. These data are presented in Figure 12. The model was configured to allow the user to select the total annual pumping and the seasonal demand variation from any one of these nine years of record. For the purposes of our analysis, we used the average annual demand (611 Million Gallons) and the average seasonal variation.

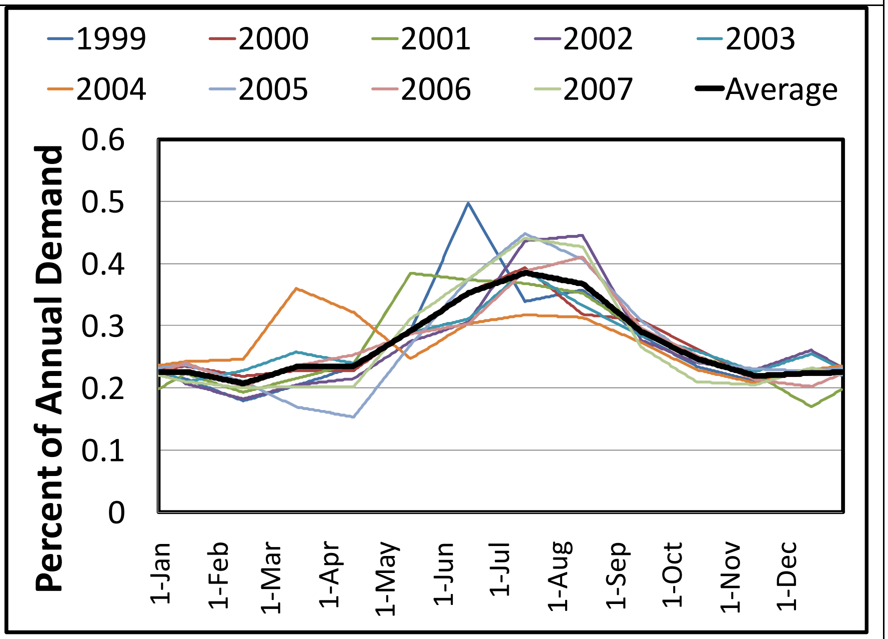
Year	Annual Demand (Million Gallons)	Daily Demand Variation (Percent)
1999	633	
2000	606	
2001	594	
2002	627	
2003	605	
2004	606	
2005	623	
2006	594	
2007	648	
Average	611	

Figure 12. Historical pumping, 1999-2007

5. Groundwater Pumping

The Town of Scituate uses both surface water and groundwater to meet the town's water demands. Surface water is withdrawn from Old Oaken Bucket reservoir and groundwater is pumped from six productions wells – wells 10, 11, 17A, 18B, 19, and 22.

Total monthly pumping is shown in Figure 13 for the period 1999-2007. These records show that, in most years, groundwater was used to meet the bulk of the town's water demands and that surface water was diverted primarily to augment supplies during the peak demand season. In fact, it appears that groundwater was pumped at a fairly constant rate throughout the years at a rate of about 1 MGD. For the purposes of this study, we assumed that all of the town's demands up to 1 MGD were met by pumping groundwater from the existing wells. Water demands above this level were met by diverting surface water from Old Oaken Bucket Pond or, in some cases, by increasing groundwater pumping capacity by adding another well within the First Herring Brook basin at Satuit Meadow.

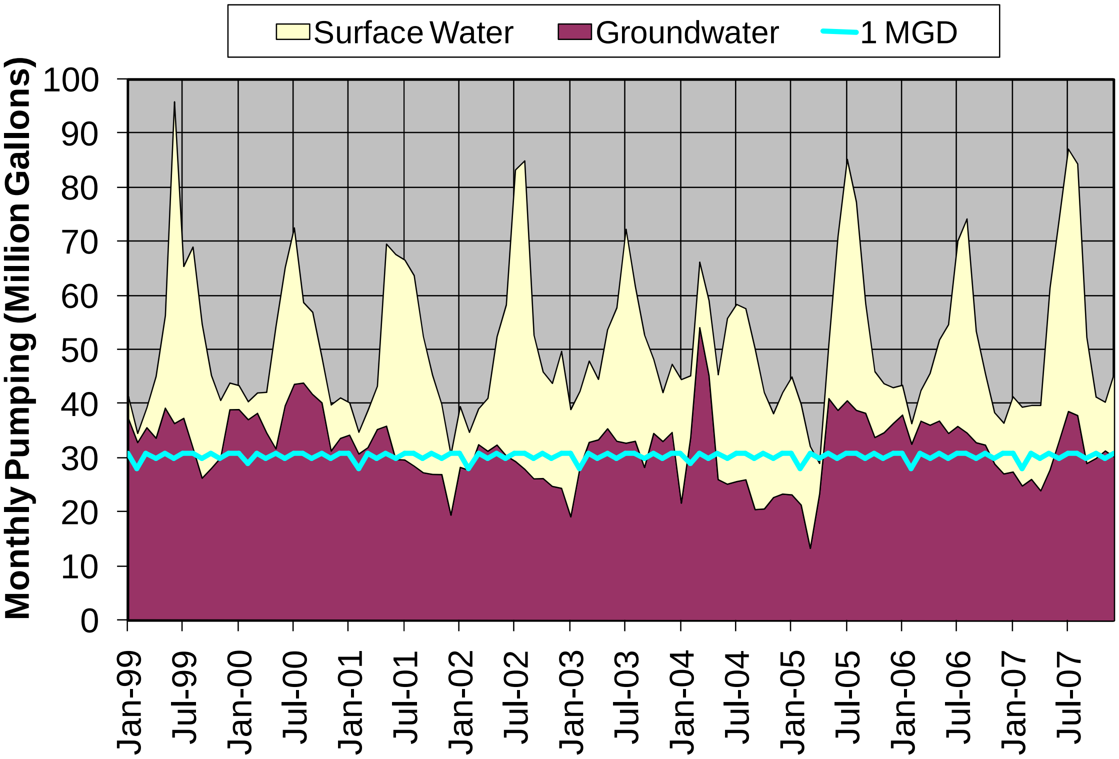


Figure 13. Total monthly surface water and groundwater pumping, 1999-2007

Only three of the existing groundwater pumping wells – 17A, 19, and 22 – lie within the First Herring Brook watershed. These wells are all located in the upper portion of the basin, above Tack Factory Pond. Each of these wells lies within close proximity to stream channels that flow into the pond. As such, it is reasonable to assume that pumping from these wells increases the hydraulic gradient such that water will flow from streams to recharge the local aquifer.

The Firm Yield Estimation methodolgy was used to generate naturalized streamflows throughout the basin (see section 2). This methodology accounts for climatic and geologic conditions, but it does not account for any changes in streamflow due to local groundwater management. Thus, these management effects needed to added into the WEAP model. To estimate recharge to the groundwater, we assumed a one-to-one relationship between streamflow loss and groundwater pumping from wells within the First Herring Brook watershed. A review of the pumping records (1999-2007) showed that pumping from these wells accounted for between 58 percent (in 2005) and 89 percent (in 2000) of the total annual groundwater pumping. For the purposes of this study, we assumed a constant rate of 75 percent of groundwater pumping from ‘in-basin’ wells. This translates to a 0.75 MGD streamflow loss to groundwater from First Herring Brook above Tack Factory Pond.

D. Model Calibration/Validation

6. Streamflows

Modeled flows from the historic demands scenario, representing actual water withdrawals, were compared to observed streamflows downstream of the Reservoir at Eisenhower Lane and downstream of Old Oaken Bucket Pond for a concurrent time period to test the validity of the model.

Observed stream flows were monitored by Riverways RIFLS program. Through this program, volunteers from the First Herring Brook Watershed Initiative recorded water depths at staff gauges and Riverways staff developed the rating curves to convert these depths to streamflow by making at least six sets of velocity and cross-sectional measurements over a range of flows.

Downstream of the reservoir, observed data were available from September, 2003 through December of 2007 on a near-daily basis. On average, these observed data compared favorably to the modeled data (Fig. 14). However, the observed data showed a greater range of daily variation than modeled data, particularly during summer months. It was assumed that this variability was caused by the active transport of water from the Reservoir down the river to Old Oaken Bucket Pond to meet water withdrawal demands there. The timing of these pulses is currently managed on an as needed basis, while in the model lake levels, fish ladders and demand for water drive the flows in this reach.

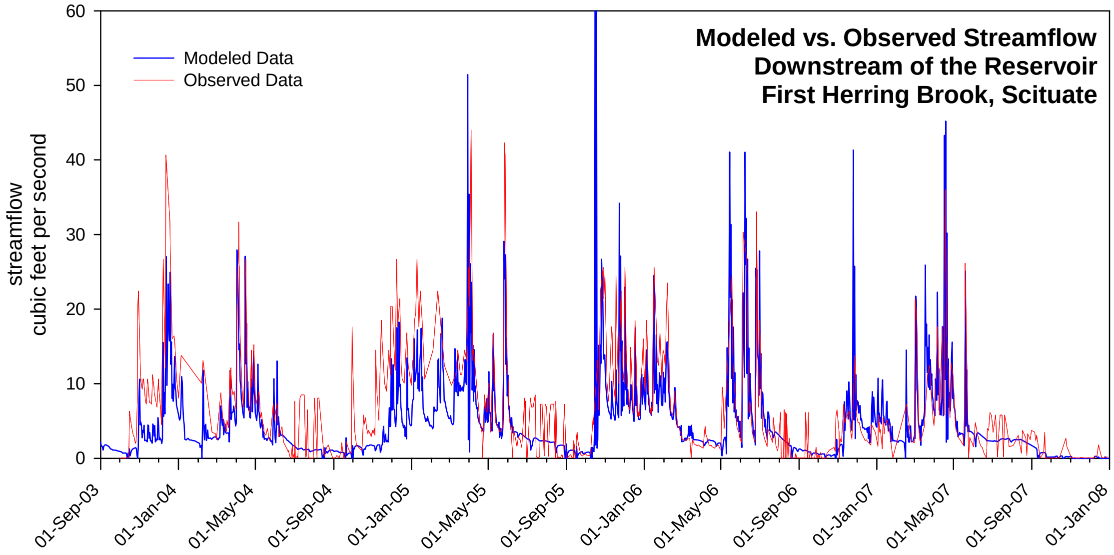


Figure 14. Modeled and observed stream flows in First Herring Brook downstream of the Reservoir.

Downstream of Old Oaken Bucket Pond a pressure transducer was deployed to record water depths at 30 minute intervals from July to December, 2007. Stream depths were converted into streamflow using a preliminary rating curve developed by the Riverways Program. Observed baseflows corresponded moderately well to modeled flows, though storm peaks were not apparent in the modeled data (Fig. 15).

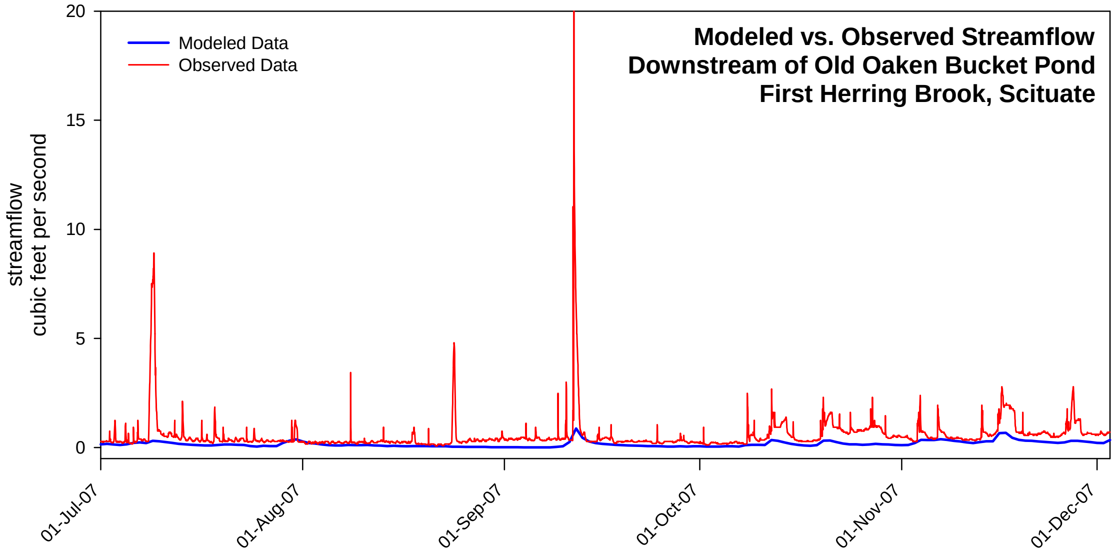


Figure 15. Modeled and observed stream flows in First Herring Brook downstream of Old Oaken Bucket Pond.

7. Reservoir Elevations

Lake level data was provided by the Scituate Water Division. Modeled lake levels from the historic demands scenario, representing actual water withdrawals, were compared to observed lake levels in the Reservoir and Old Oaken Bucket Pond for a concurrent time period to test the validity of the model.

Reservoir water surface elevations were available from July 2003 to May 2007. When the Reservoir was observed to be spilling, the model predicted water levels relatively well, though the observed daily variability was greater than the modeled daily variability. When the Reservoir level dropped below the spillway, the model often underestimated the water surface elevation by up to about one foot (Fig. 16). This was an improvement over the original attempt, in which the model underestimated water surface elevations by up to six feet. The improvement was made by including hydraulic controls on water spilling out of the reservoir and increasing the reservoir storage to allow the water surface to rise above the spillway elevation.

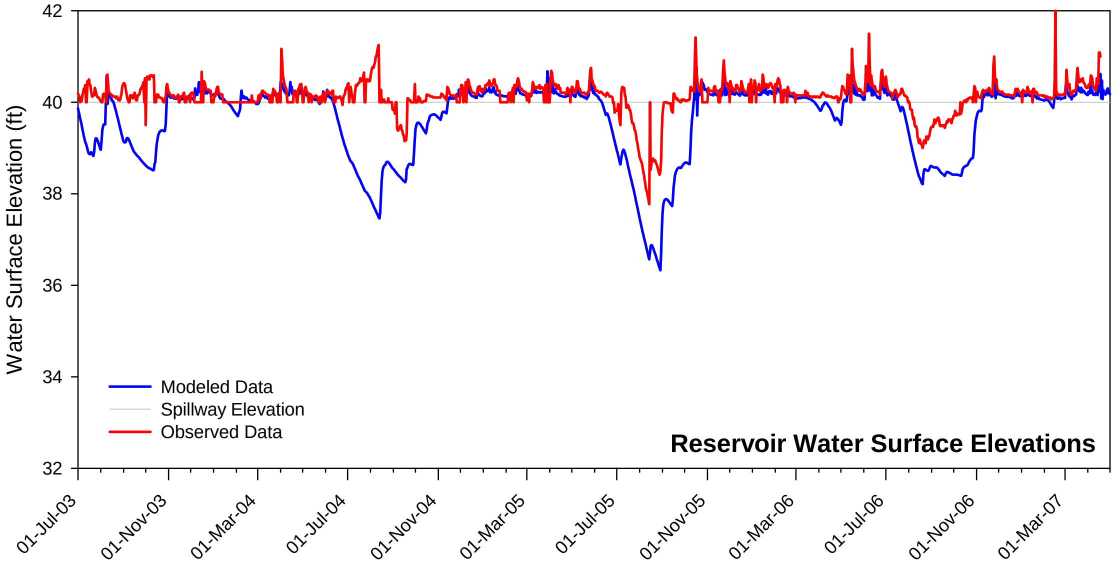


Figure 16. Modeled and observed water surface elevations in the Reservoir.

Old Oaken Bucket Pond water surface elevations were available from July 2003 to April 2007. The model predicted average water levels reasonably well, though the observed daily variability was greater than the modeled daily variability and storm events were not generally captured (Fig. 17). This was an improvement over the original attempt, in which the model water surface elevation never rose above the spillway and often underestimated water surface elevations by several inches. The improvement was made by including the hydraulic controls on water spilling out of the pond and increasing the pond's storage to allow the water surface to rise above the spillway elevation. The model is still limited to water levels up to 0.25 ft above the spillway elevation, a level which was observed to be exceeded during many high flow periods.

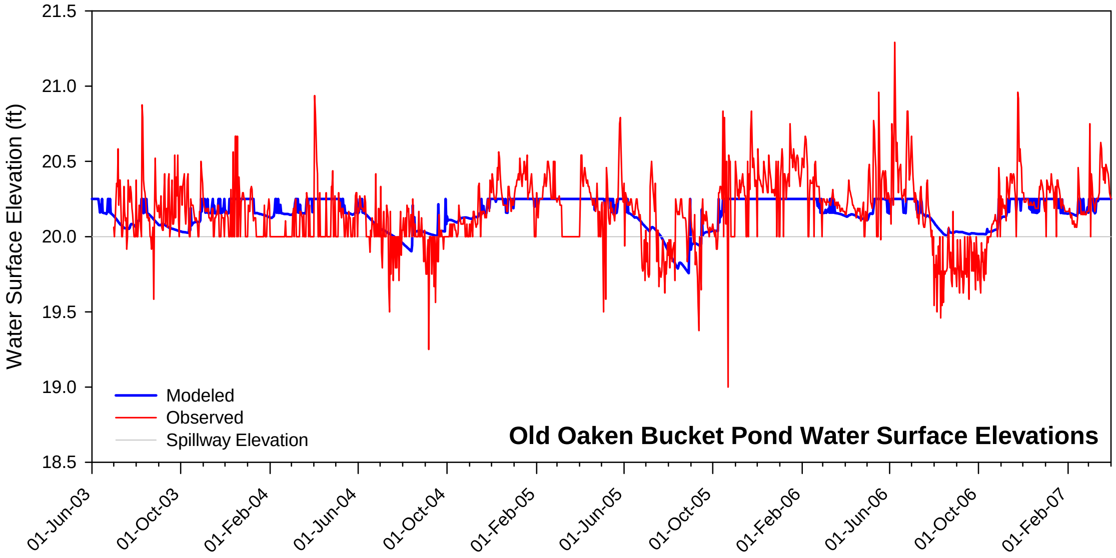


Figure 17. Modeled and observed water surface elevations in Old Oaken Bucket Pond.

8. System Yield

The amount of water available for use by the town is the sum of the water available from groundwater sources and the water available from the surface water system (the main Reservoir and Old Oaken Bucket). In general, the groundwater component of the current operations scenario was modeled as providing 1 mgd of the water demand. The reservoir yield was determined by defining the maximum yield that can be consistently met over the period of record of the inflow data used, which included the drought of record in the mid-1960s. The reservoir yield was defined using a two-part test: It evaluated the maximum allowable delivery over a study period (which included the drought of drought of record) and then checked that the reservoir completely refilled at least once after the reservoir(s) reached its lowest point. This second part of the test ensures that the system can fully recover after the period of greatest water scarcity.

E. Modeling the Proposed Management Options

9. New Fish Ladders and Weirs

To simulate new fish passage devices on both Old Oaken Bucket and the Reservoir, the Project Team put a set of design assumptions into the WEAP model. These design assumptions match the requirements of a future steeppass fish ladders and downstream passage weir, with specifications informed by discussions with USFWS.

The ladders were programmed to be of the same hypothetical design. They are each set with the top of the fins 1.66 feet (20 inches) below spillway and are designed to need a minimum of 2.2 cubic feet per second for in migration in spring, with additional flow being dependent on reservoir head. In the WEAP model, it is assumed that the ladder is blocked for non-migration months with stoplogs, and therefore no water spills into the ladder. The elevation of Old Oaken Bucket impoundment can not be less than 19.34 feet (0.66 ft (8 inches) below the spillway) during March and April to allow operation of the ladder. The elevation of the Reservoir can not be below 39.34 feet (1.66 ft (20 inches) below the spillway) to allow operation of the ladder.

The downstream passage weirs are modeled to be of the same hypothetical design, set 2 feet below spillway needing 3.39 cubic feet per second (6 in) of water for outmigration in Sept-Oct only. Weir flows are “managed” by 3 inch boards added/removed automatically by WEAP to keep 6 inch depth in out-migration months. This is modeled using a release from “active storage” that occurs during September and October when Old Oaken Bucket has water level up to at least 18.5 feet or the Reservoir has at least 38.5 feet.

10. Minimum Streamflow Releases

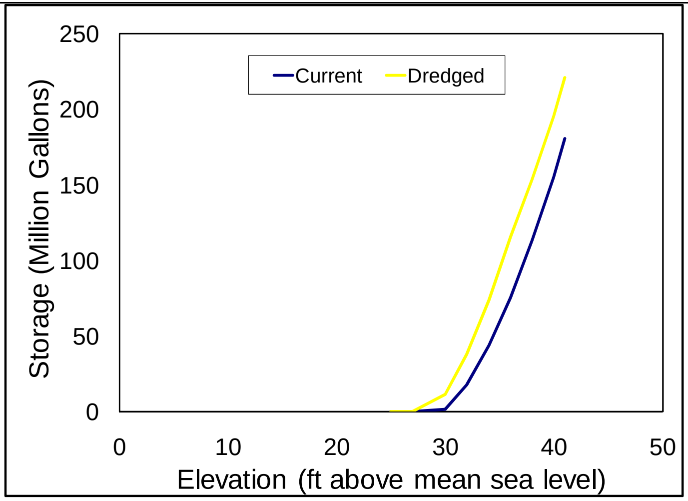
Improved streamflow releases were included in the WEAP model to improve habitat and water quality conditions in First Herring Brook by releasing water from the impoundments. The amount of the releases was defined based on simulating natural hydrology at those locations using the MA firm yield methodology. Bioperiod Q90 release was modeled in WEAP as a release that is equivalent to the lowest 10% of flows during the period of record for the bioperiod. If inflow to the Reservoir or OOB is naturally below this level, then only the amount equal to the inflow is released. A second stream flow release was also modeled using only the summer Q90 for all seasons. Specific values for these releases are listed below in Table 19.

Table 19: Biopheriod Q90 Low Flows (cfs), based on 1962 - 2000

Bioperiod	**Below OOB**	**Below Reservoir**
Mar-May	3.78	2.56
Jun-Aug	0.39	0.22
Sep-Nov	0.45	0.25
Dec-Feb	3.15	2.13

11. Reservoir Dredging

Based on the CEI Report (June 2003), the storage capacity of Old Oaken Bucket Pond could be expanded by 8 million gallons and the Reservoir's storage capacity could be expanded by 40 million gallons. This report, however, did not describe how the geometry of the reservoirs would be altered. As such, we developed new storage-elevation curves that apportioned most of the additional storage at lower elevations in each reservoir, based upon the assumption that the additional storage would be created by removing accumulated sediment within the reservoirs. These storage-elevation curves are shown below:

Elevation (ft)	Storage (Million Gallons)		
	Current	Dredged	
25	0	0	
27	0	5.73	
30	1.46	11.46	
32	17.77	37.77	
34	43.76	73.76	
36	75.55	115.55	
38	113.58	153.58	
40	155.30	195.30	
41	181.00	221.00	

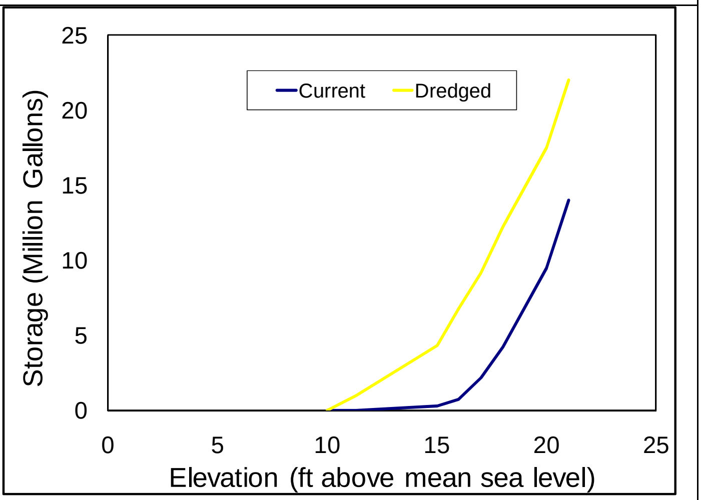
Elevation (ft)	Storage (Million Gallons)		
	Current	Dredged	
10	0	0	
11.3	0	1	
15	0.31	4.31	
16	0.76	6.76	
17	2.14	9.14	
18	4.22	12.22	
20	9.50	17.50	
21	14.00	22.00	

Figure 18. Storage-elevation curves used in WEAP based on simulated dredging

12. Satuit Meadow Groundwater Pumping

The Satuit Meadow watershed was originally modeled as a single watershed because one tributary was historically diverted into another due to concerns about pesticides in the cranberry bogs contaminating the town's water supply reservoirs. Originally, the stream running through the cranberry bog flowed into Tack Factory Pond and the smaller stream flowed directly into Old Oaken Bucket Pond.

In most of the WEAP scenarios, Satuit Meadow is modeled as a single watershed, with the outflow joining First Herring Brook just downstream of Old Oaken Bucket Pond. In the Satuit Meadow Groundwater Pumping scenarios, a groundwater well withdrawing 0.35 or 0.75 mgd from the single Satuit Meadow watershed was modeled.

13. Redivert Cranberry Brook

Inflows to the WEAP model were changed to allow this scenario to examine the impact of rediverting the Cranberry Diversion Tributary back into Tack Factory Pond. Inflows were generated separately for the larger drainage area of the cranberry bog, which drains into Tack Factory Pond, and for the smaller drainage area southeast of the bog which was a historically separate tributary that flowed into Old Oaken Bucket Pond. For the purposes of this scenario, only the cranberry bog tributary was redirected into Tack Factory Pond. The smaller tributary continued to drain into First Herring Brook just downstream of Old Oaken Bucket Pond, as it exists now.

The intent of this scenario was to provide additional recharge to the Reservoir storage. However, because natural flow from the bog is quite low during the critical summer and fall periods, it did not significantly increase the yield of the system nor did it offer the ability to improve flows in First Herring Brook and thus was not included in results of this report. Removing the artificial diversion structure may provide local benefits to macroinvertebrate, fish and other aquatic species expected to be found within these habitat types, however.

X. Appendix B: Additional Streamflow Results

The streamflow results below were evaluated by reviewing flow duration curves and boxplots of daily data over the model period in comparison to flow duration curves and boxplots of natural streamflow for the same locations. These scenarios examined below include some of those described in the body of the text, but also include some modifications. Two additional alternatives below include a summer 90% exceedence flow release (rather than a bioperiod based releases) and the reactivation of "Well #20" in the upper watershed. Flow duration curves depict the percent of time that a given flow was equaled or exceeded over the model period. Boxplots present similar data, with the center of the boxes representing the 50th percentile of daily flow data and the edges representing the 25th and 75th percentiles. The ends of the "whiskers" represent the 10th and 90th percentiles of data. Outliers are shown as stars.

Legend

Scenarios

Natural	—	Estimated natural stream flow
Managed	—	Current managed stream flow
Scenario 1	—	Fish ladder upgrades & Satuit Meadow well (0.75 MGD (summer bioperiod median)
Scenario 2	—	Fish ladder upgrades & Old Oaken Bucket Pond dredging (8 MG)
Scenario 3	—	Fish ladder upgrades, Satuit Meadow well & Old Oaken Bucket Pond dredging
Scenario 4	—	Fish ladder upgrades & Reservoir dredging (40 MG)
Scenario 5	—	Old Oaken Bucket fish ladder upgrade, Satuit Meadow well, Well #20 reactivation (0.20 mgd) & Old Oaken Bucket Pond dredging
Scenario 6	—	Scenario 3 & 0.43 cfs minimum flow (summer 90% exceedance) below Old Oaken Bucket Pond

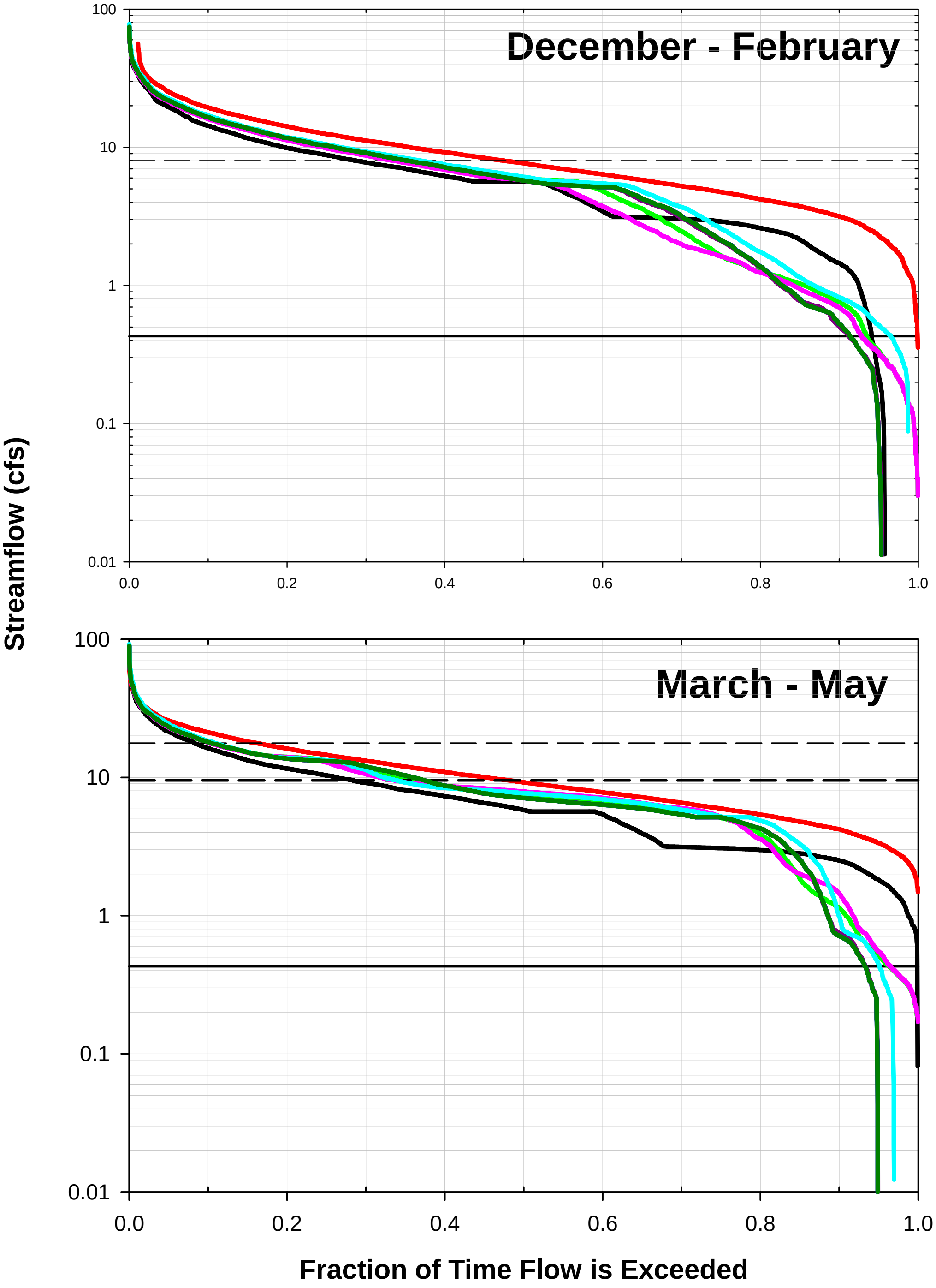
Reference Lines

Bioperiod Flow Goal(s)	— —
90th percentile of summer natural flow	—

First Herring Brook below Cranberry Diversion

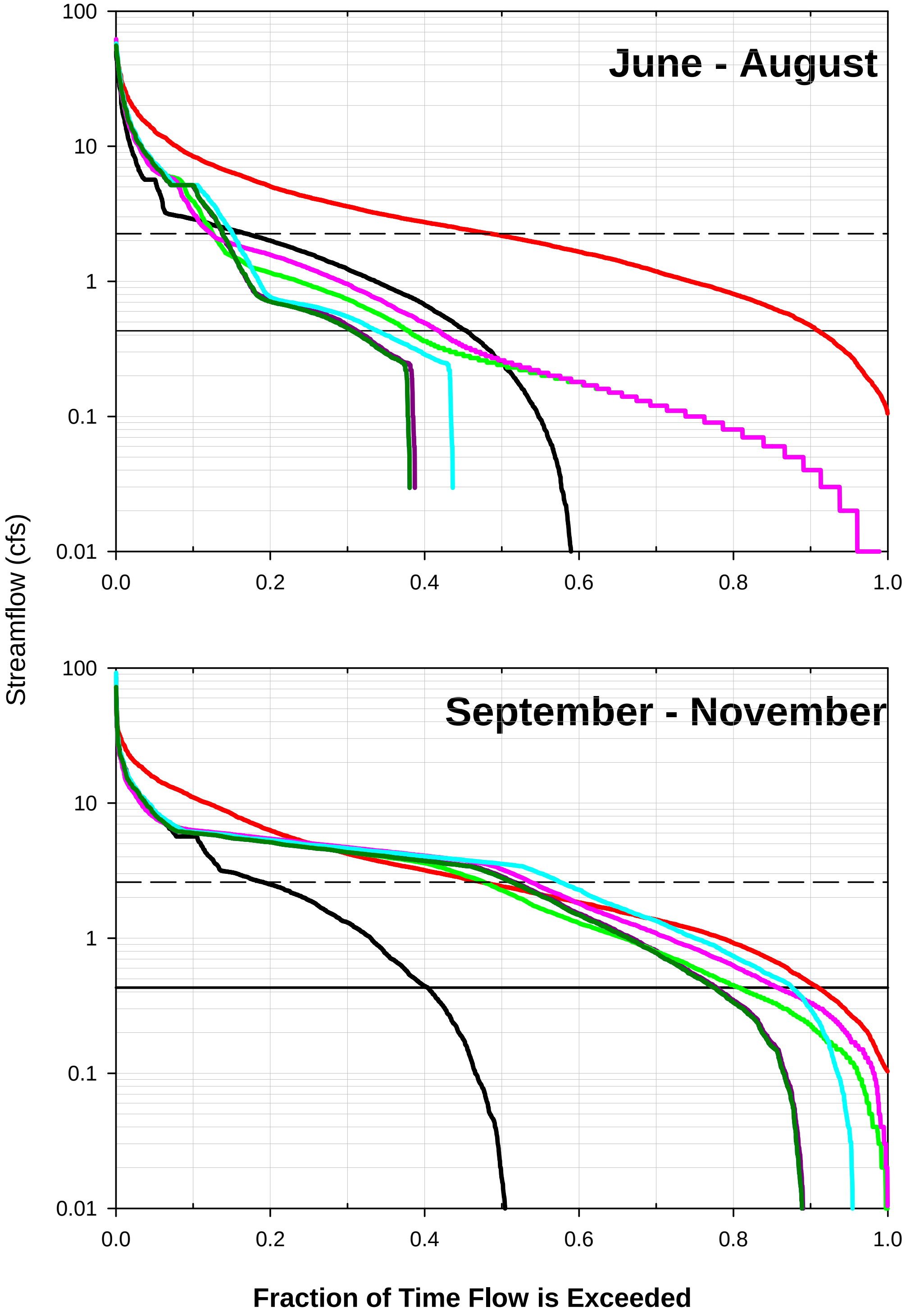
Bioperiod Flow Duration Curves for All Scenarios

With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



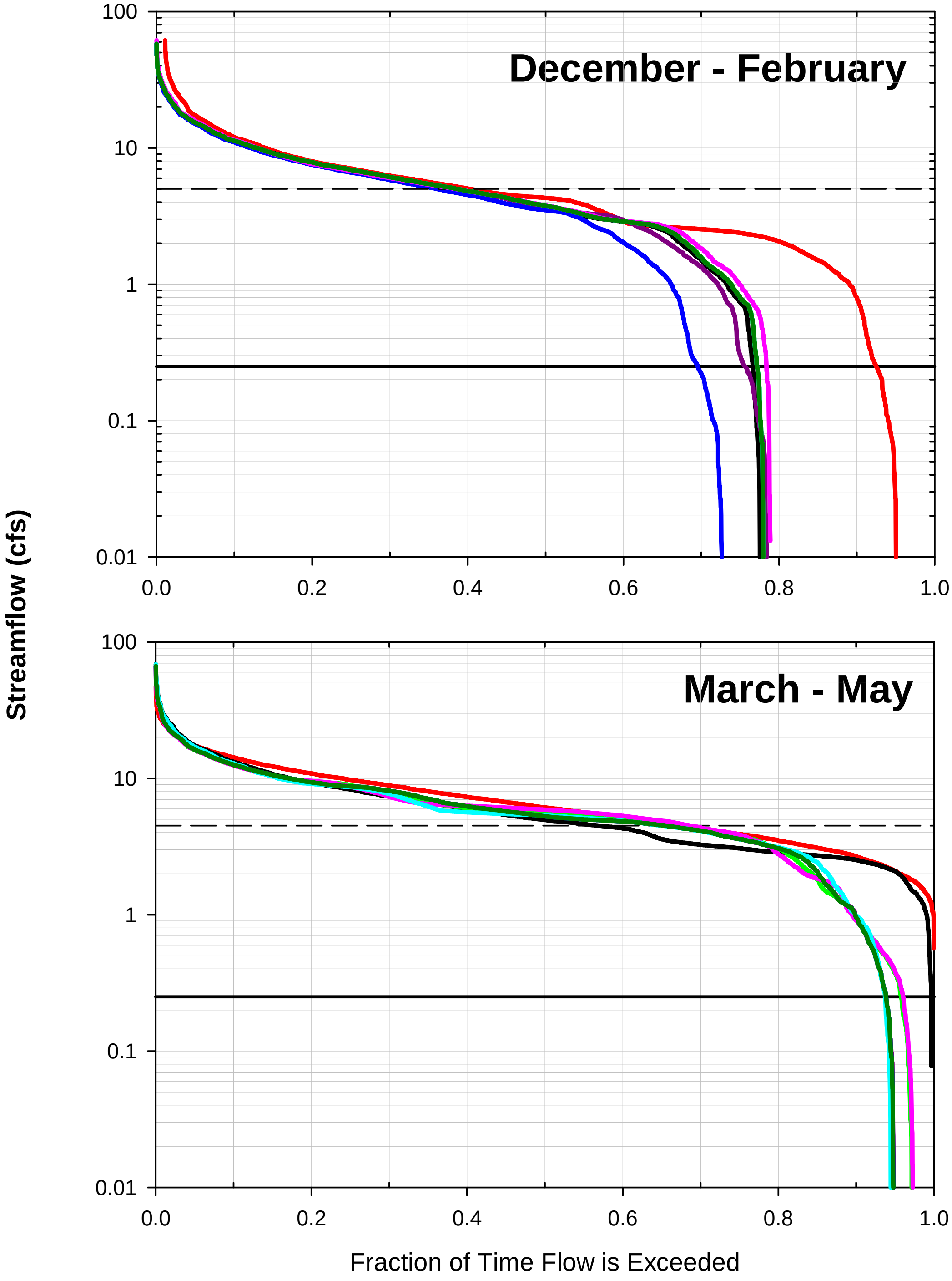
First Herring Brook below Cranberry Diversion

Bioperiod Flow Duration Curves for All Scenarios
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



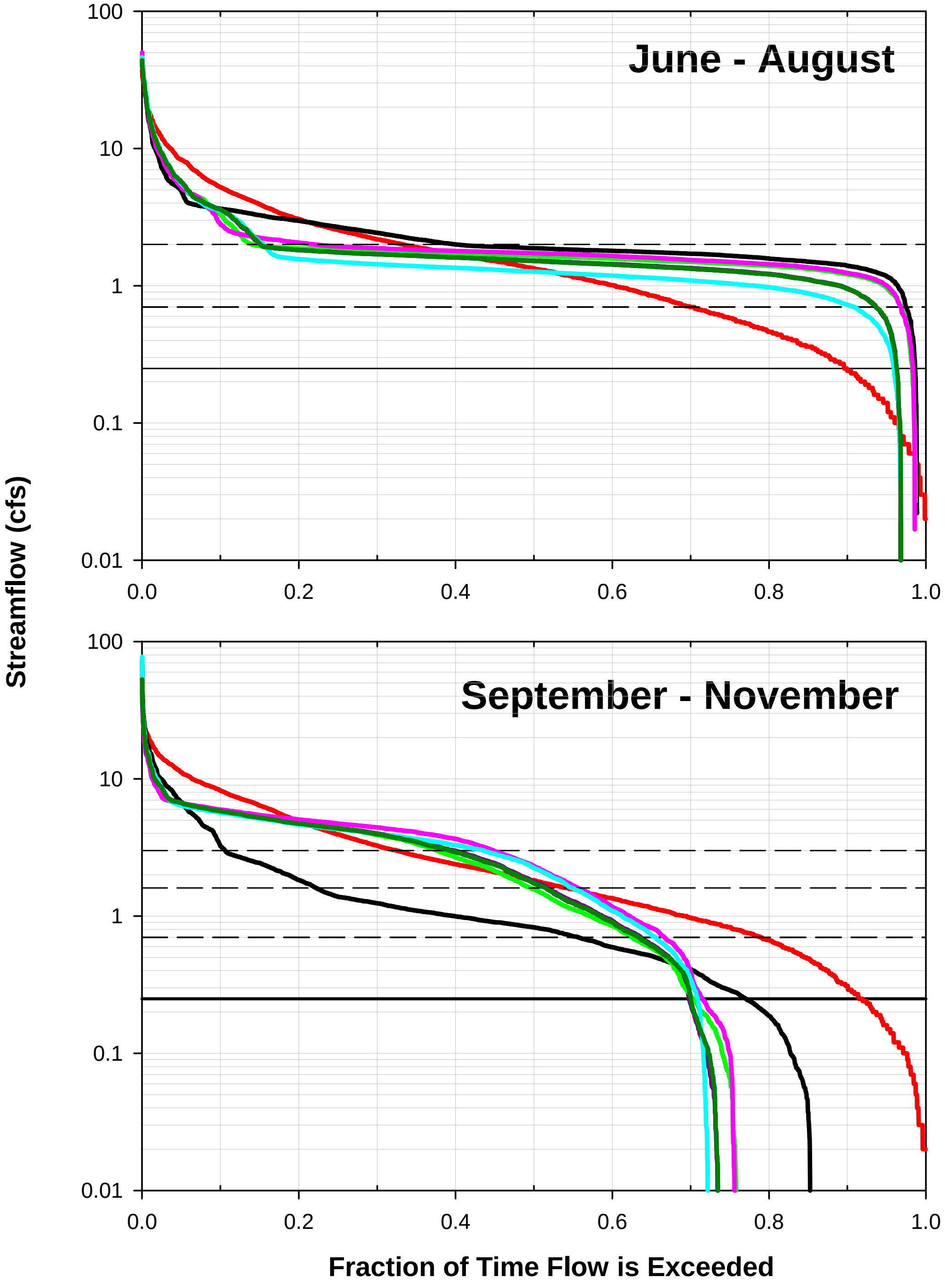
Eisenhower Ln (downstrream of Reservoir)

Bioperiod Flow Duration Curves for All Scenarios
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



Eisenhower Ln (downstrream of Reservoir)

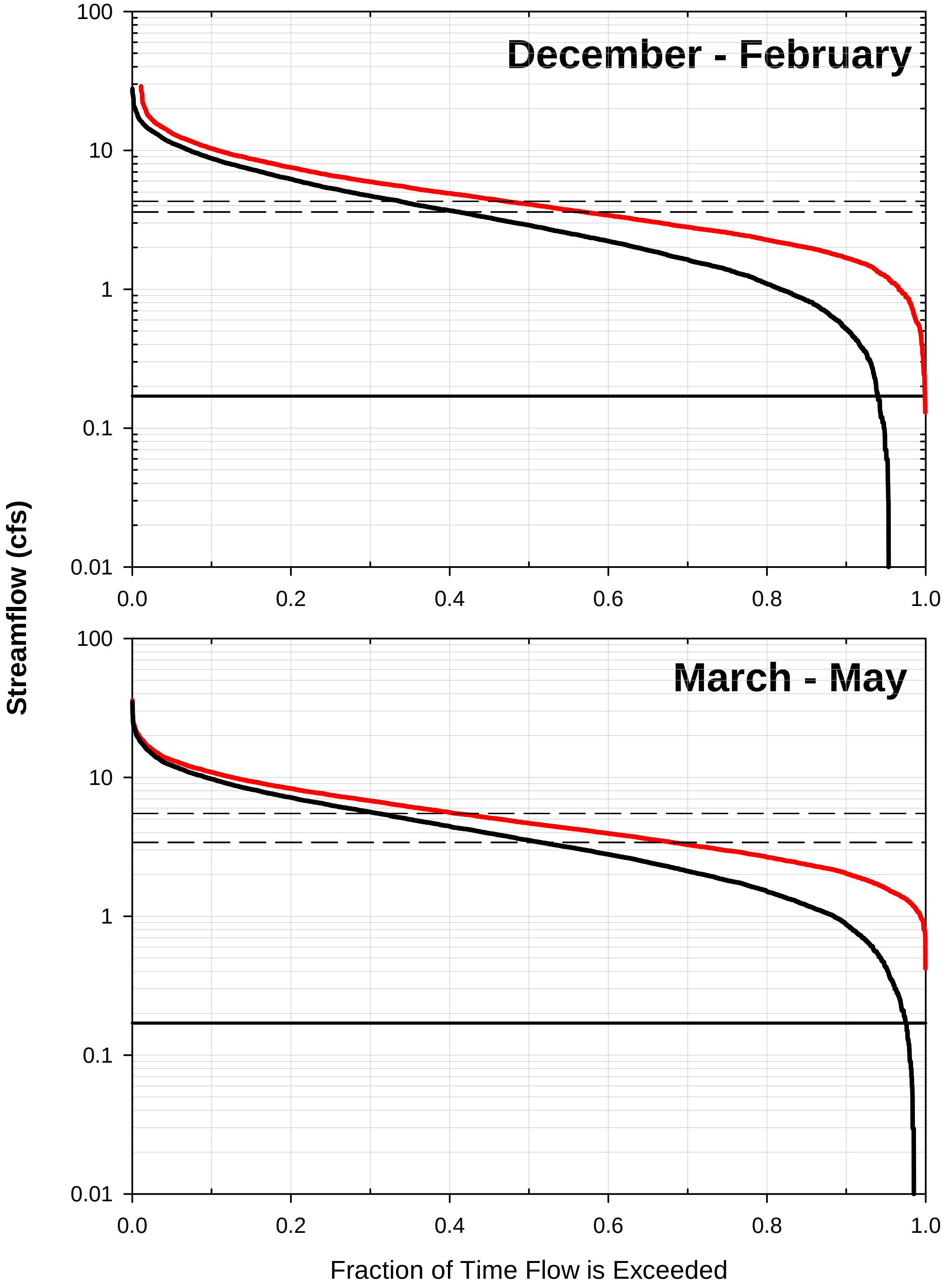
Bioperiod Flow Duration Curves for All Scenarios
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



Old Forge Rd

Bioperiod Flow Duration Curves

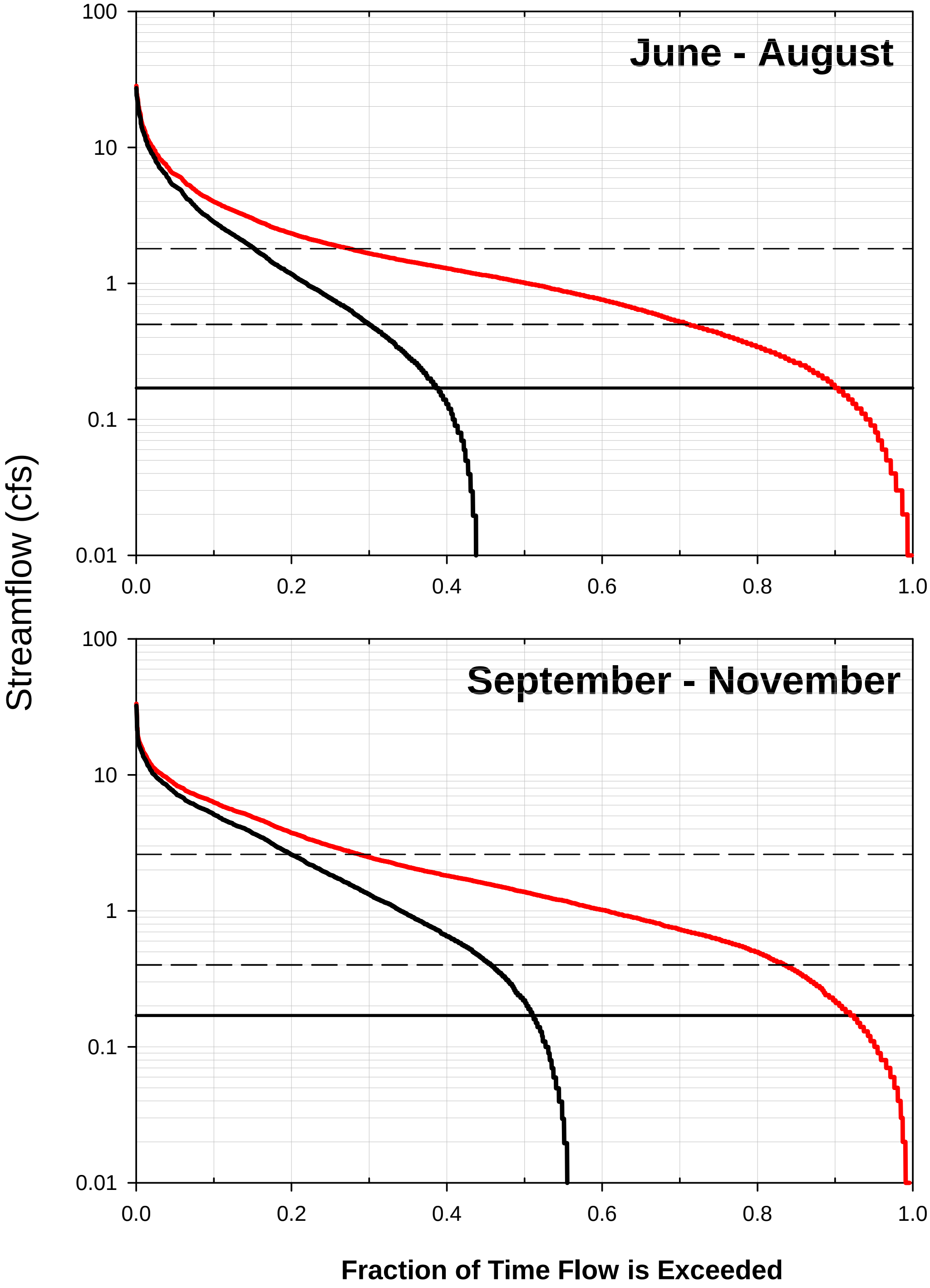
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



Old Forge Rd

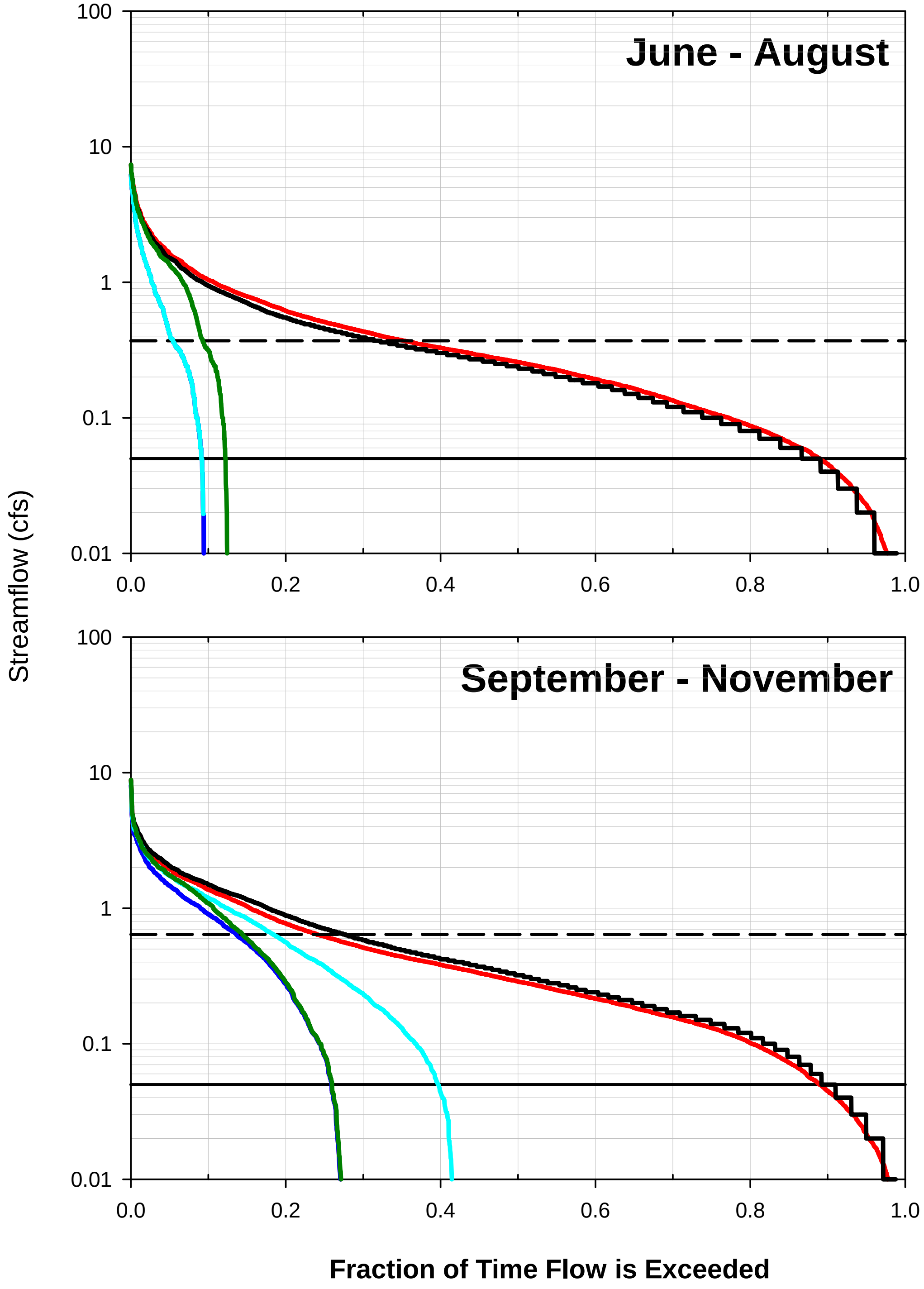
Bioperiod Flow Duration Curves

With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



Cranberry Diversion

Bioperiod Flow Duration Curves for Scenarios 1/3, 5 & 6
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference



Cranberry Diversion

Bioperiod Flow Duration Curves for Scenarios 1/3, 5 & 6
With Bioperiod Flow Goals and Summer 90th Percentile Exceedance Reference

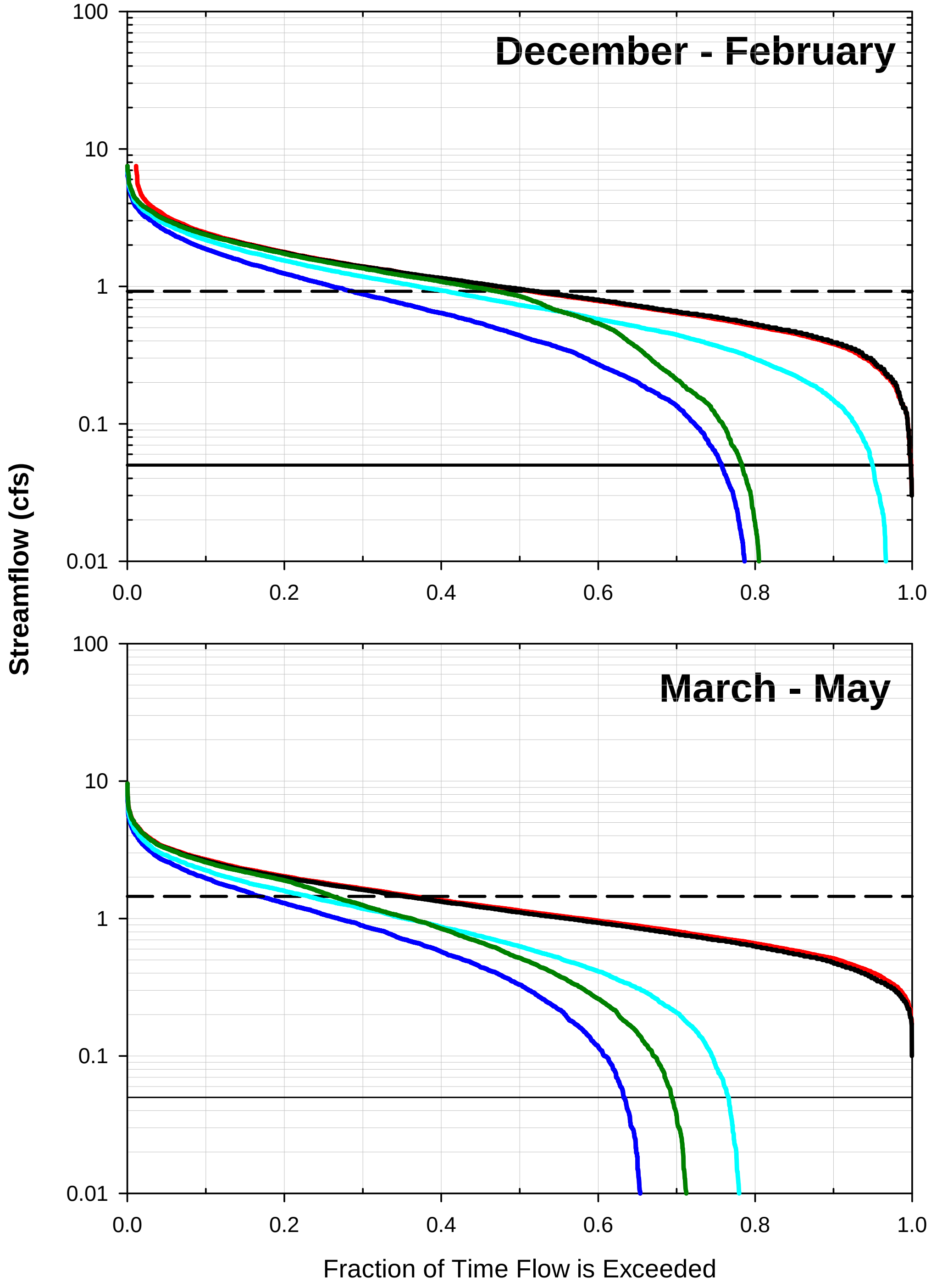
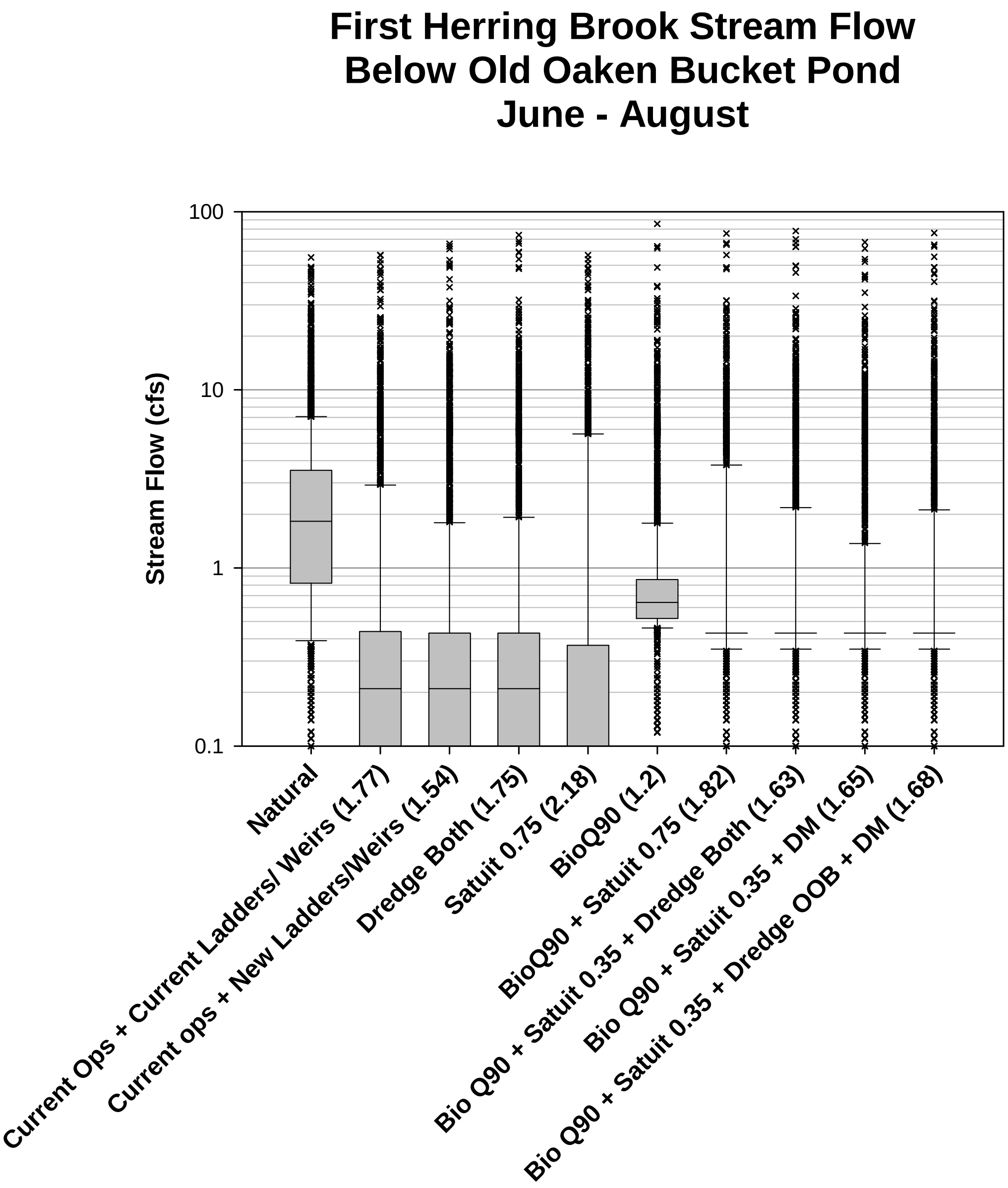
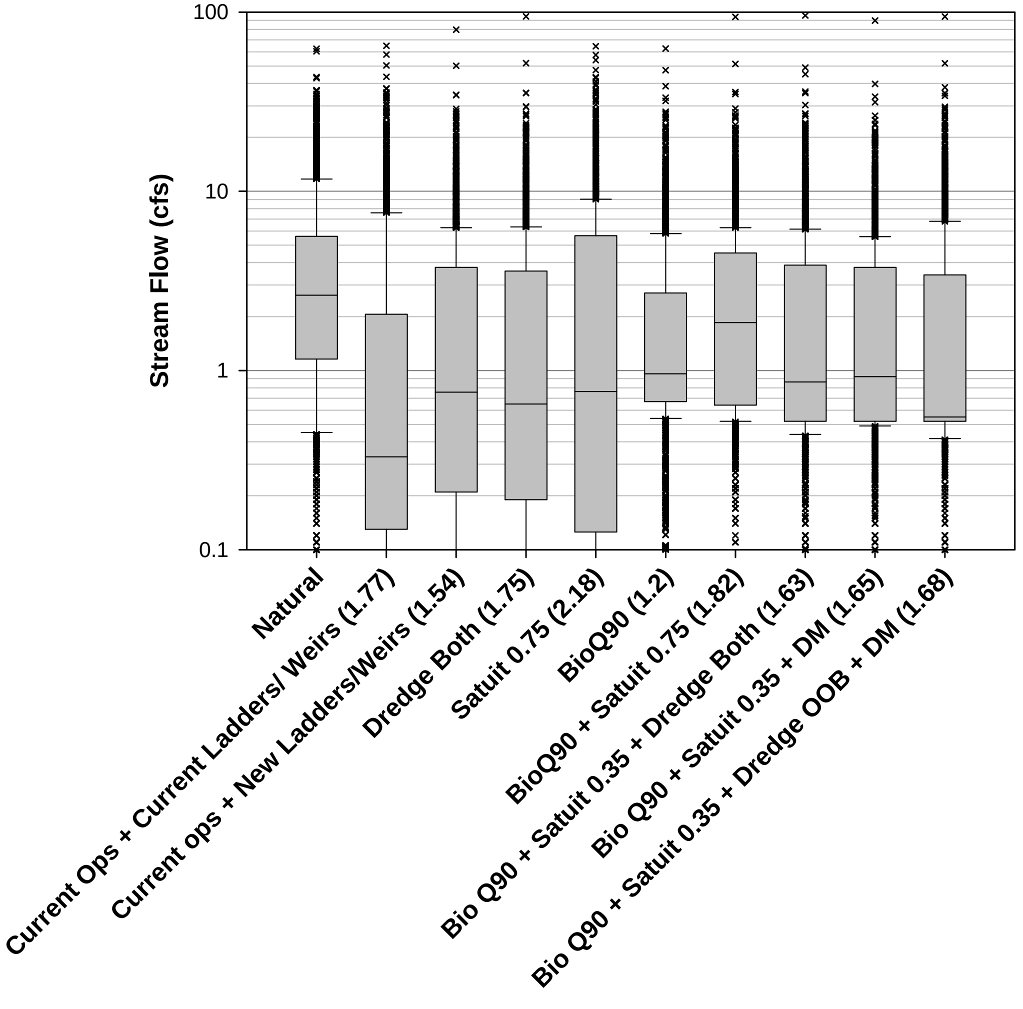
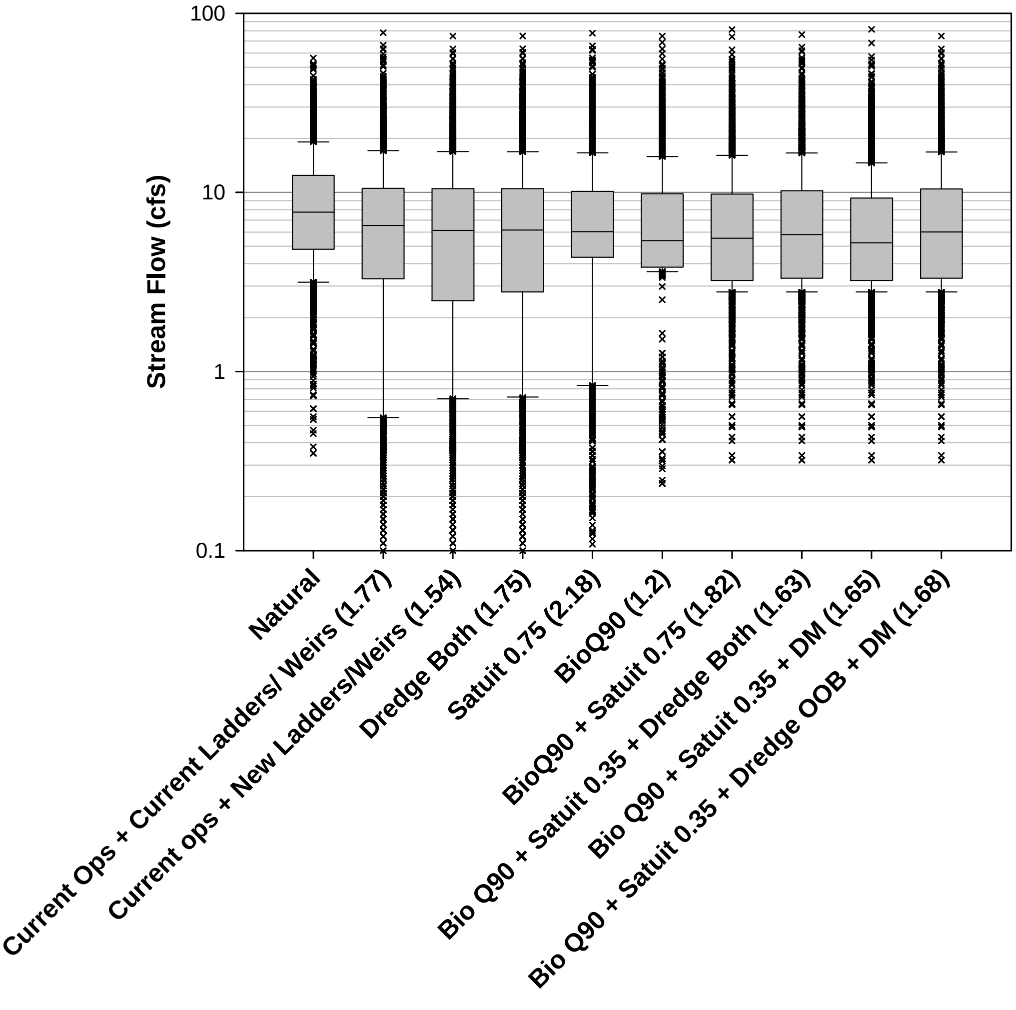


Figure 18. Boxplots of streamflow and elevation results for selected WEAP model scenarios. Yields (mgd) are shown in parentheses after scenario name.



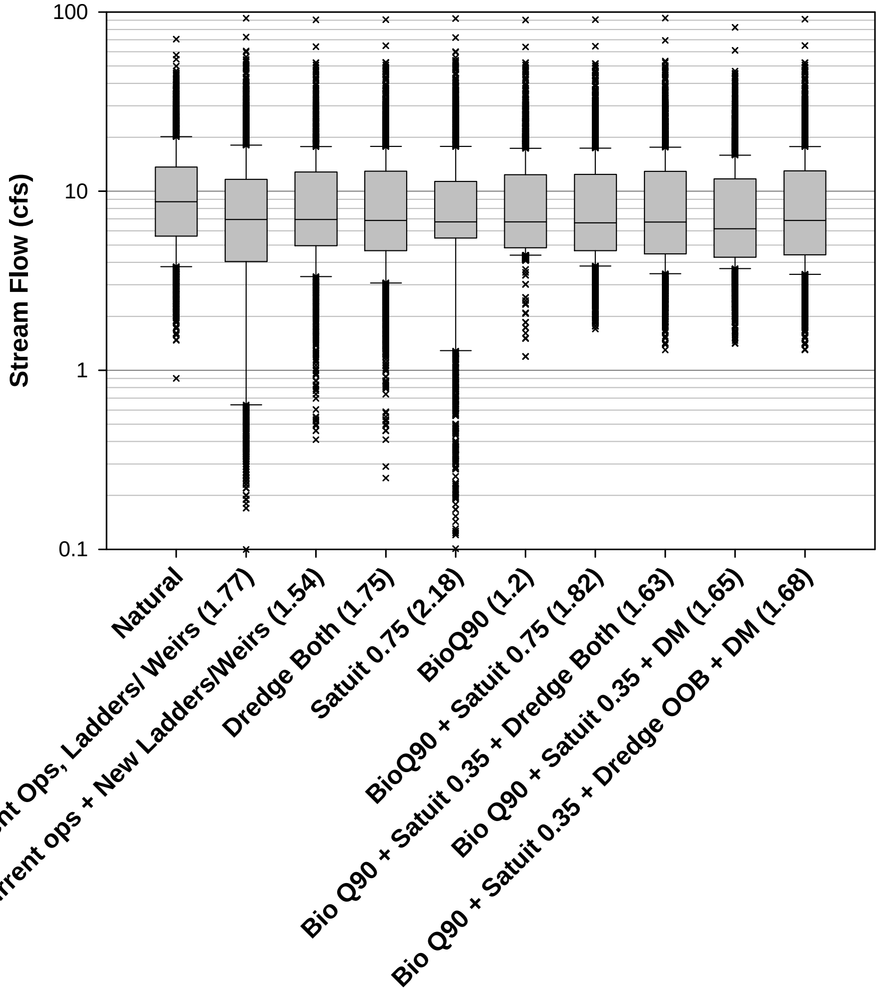
First Herring Brook Stream Flow
Below Old Oaken Bucket Pond
September - November

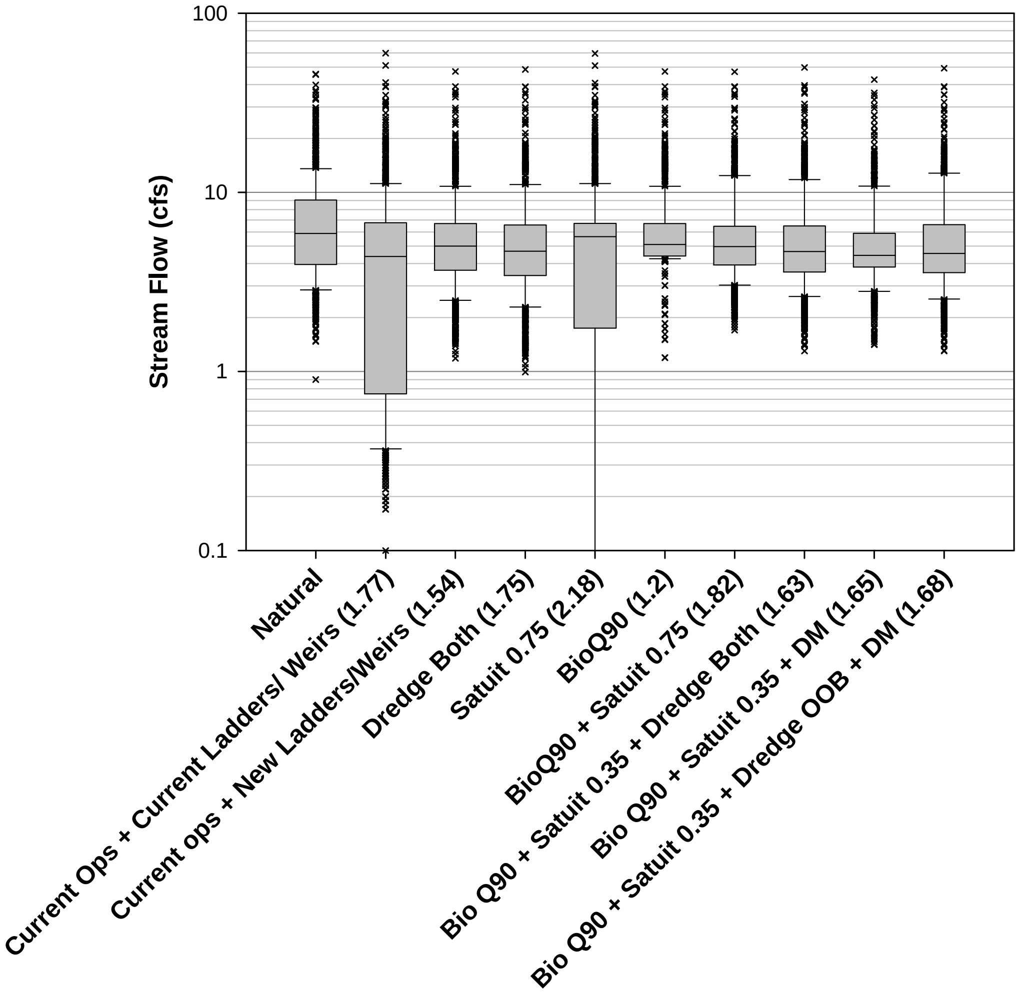




First Herring Brook Stream Flow
Below Old Oaken Bucket Pond
December - February

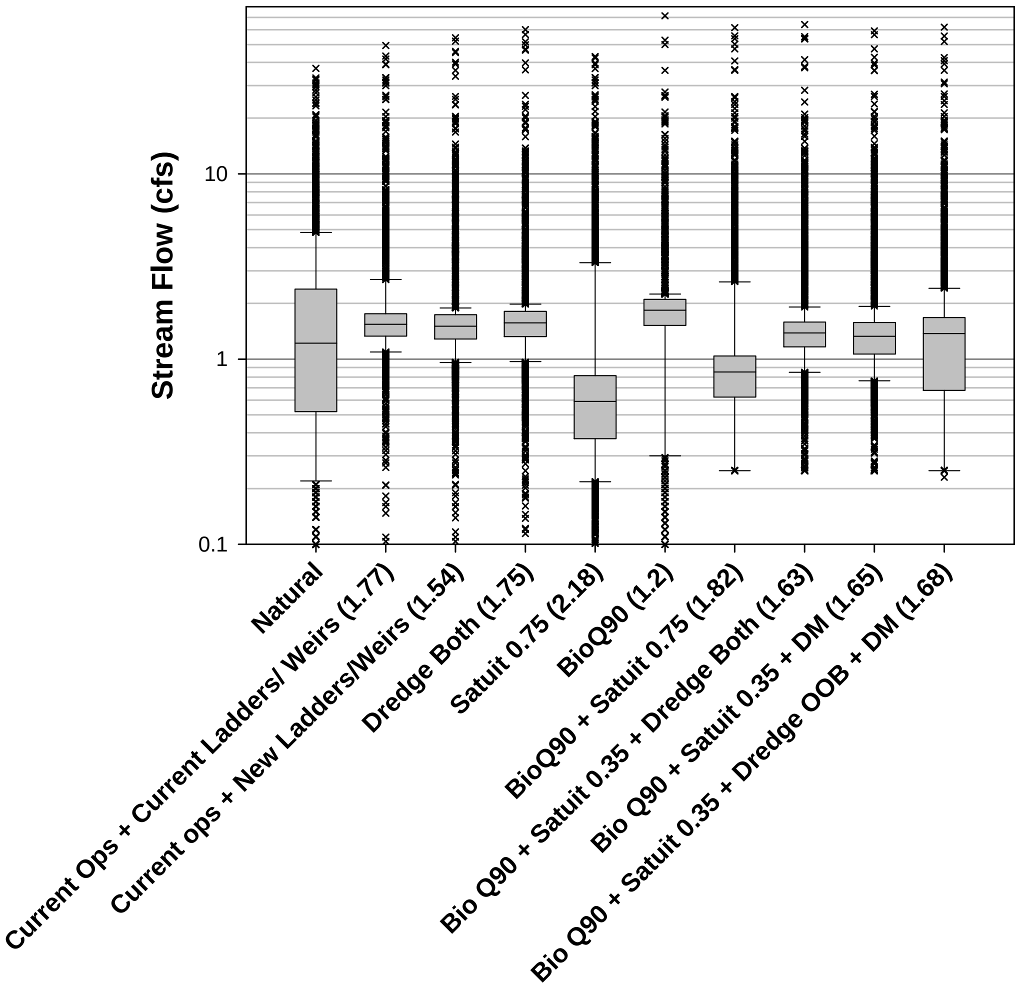
First Herring Brook Stream Flow
Below Old Oaken Bucket Pond
March - May



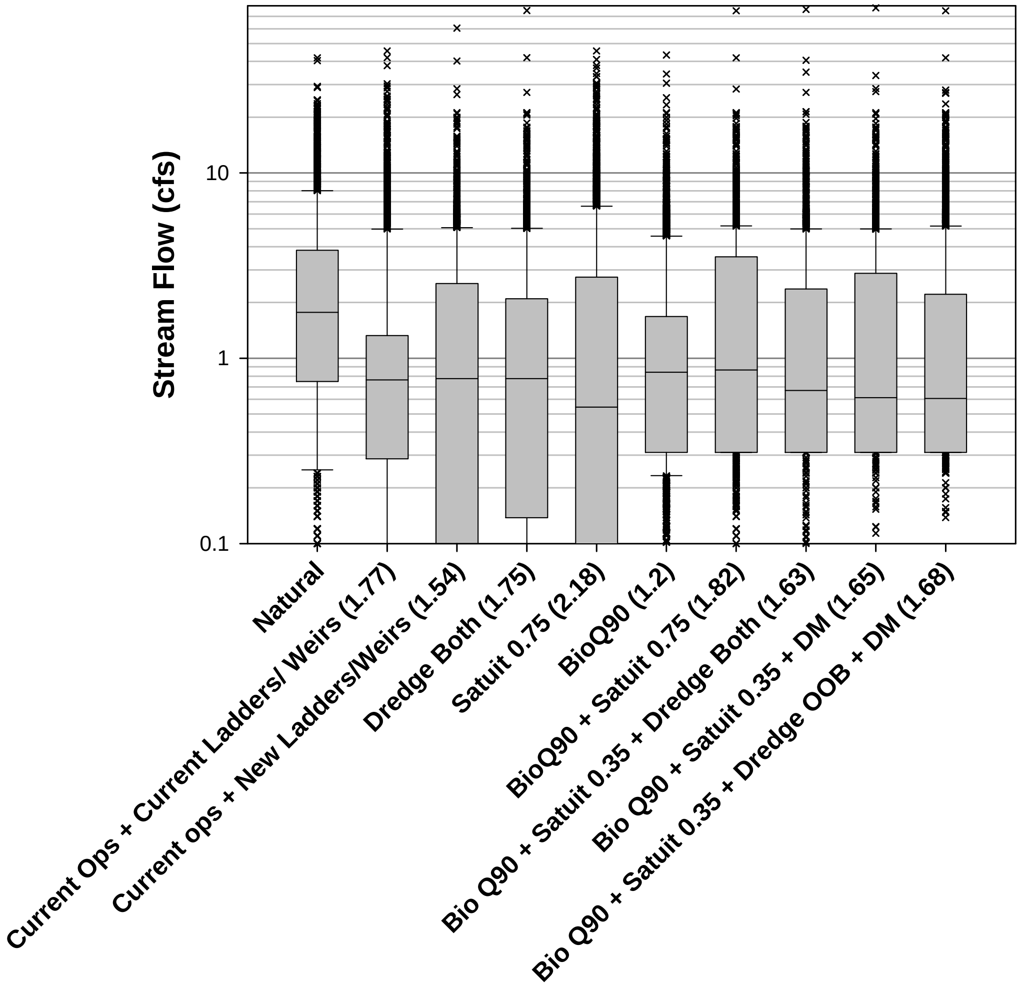


First Herring Brook Stream Flow
Below Old Oaken Bucket Pond
May

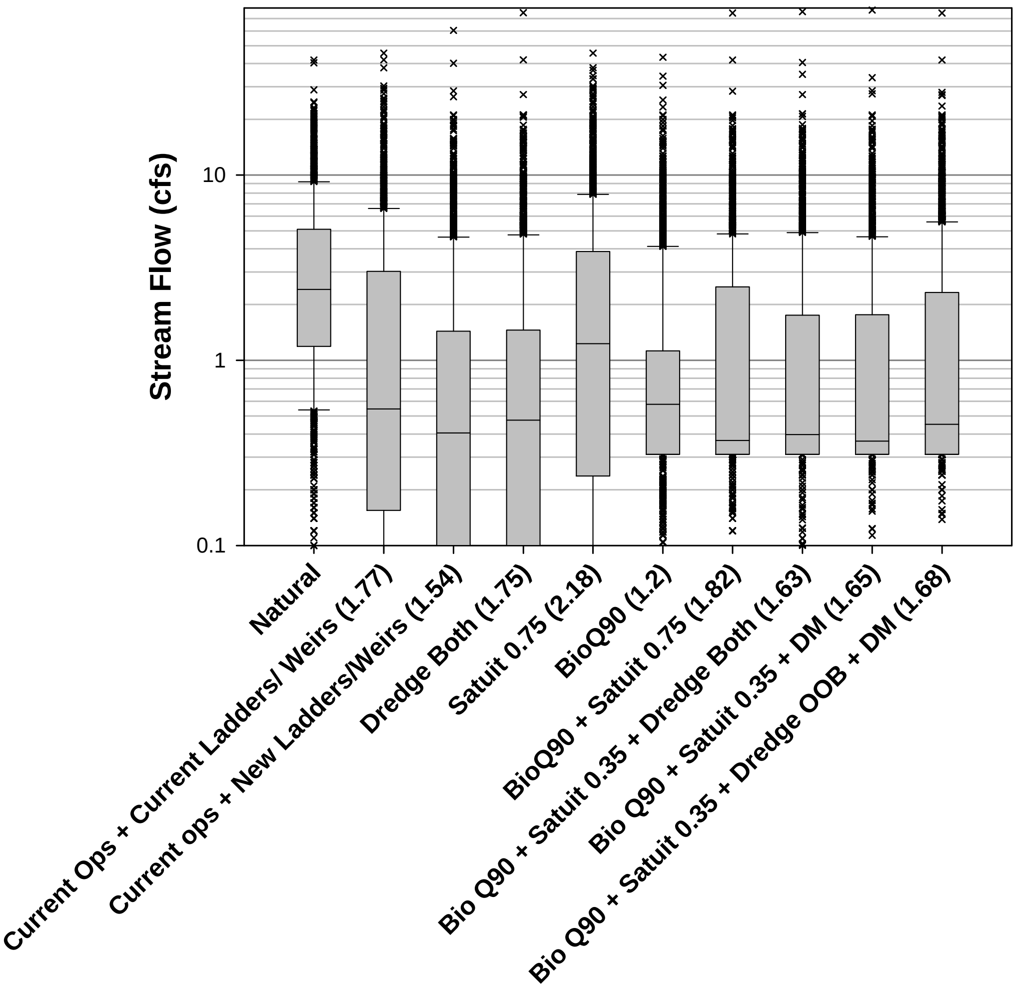
First Herring Brook Stream Flow
Below the Reservoir
June - August

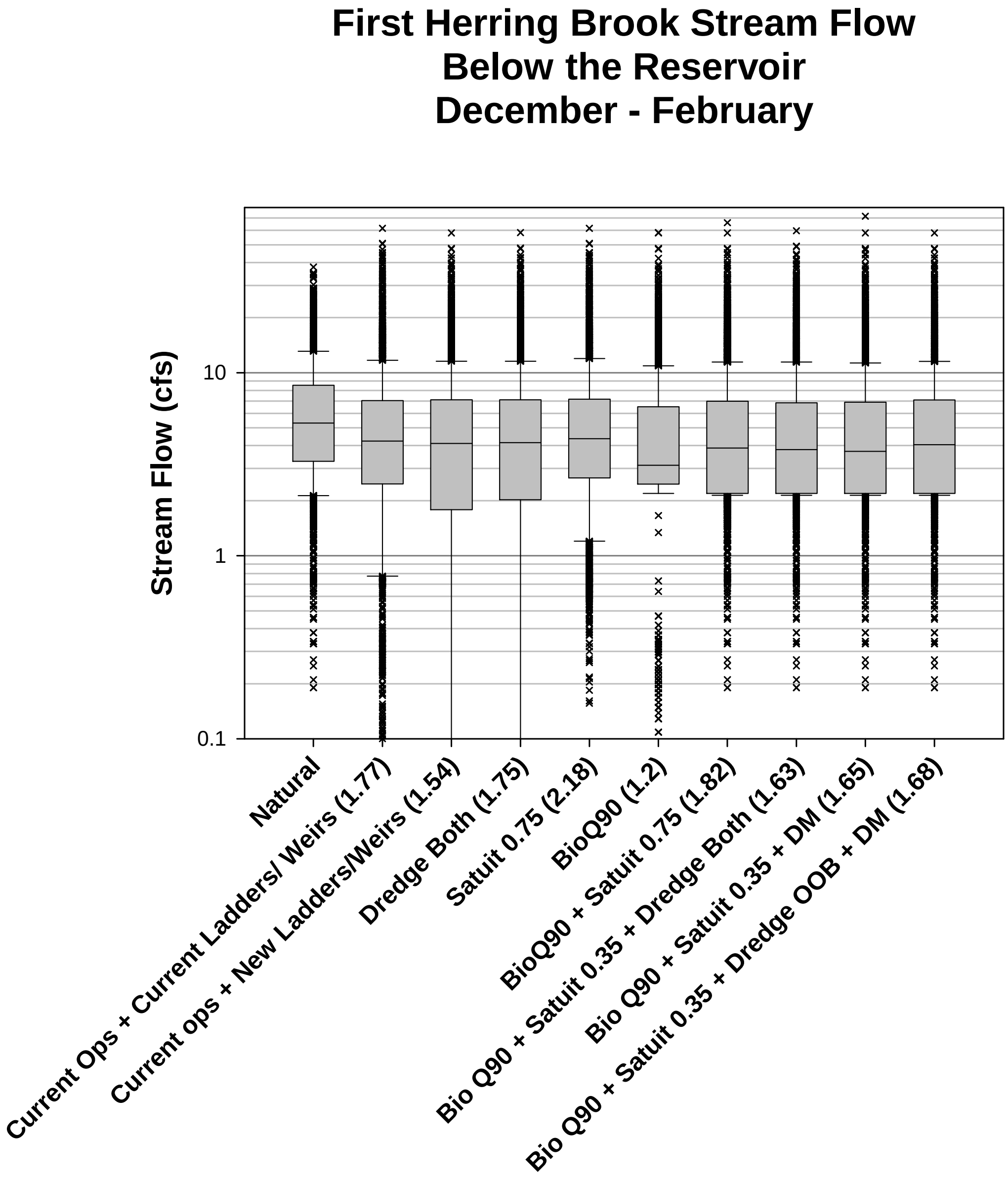


First Herring Brook Stream Flow
Below the Reservoir
September - November

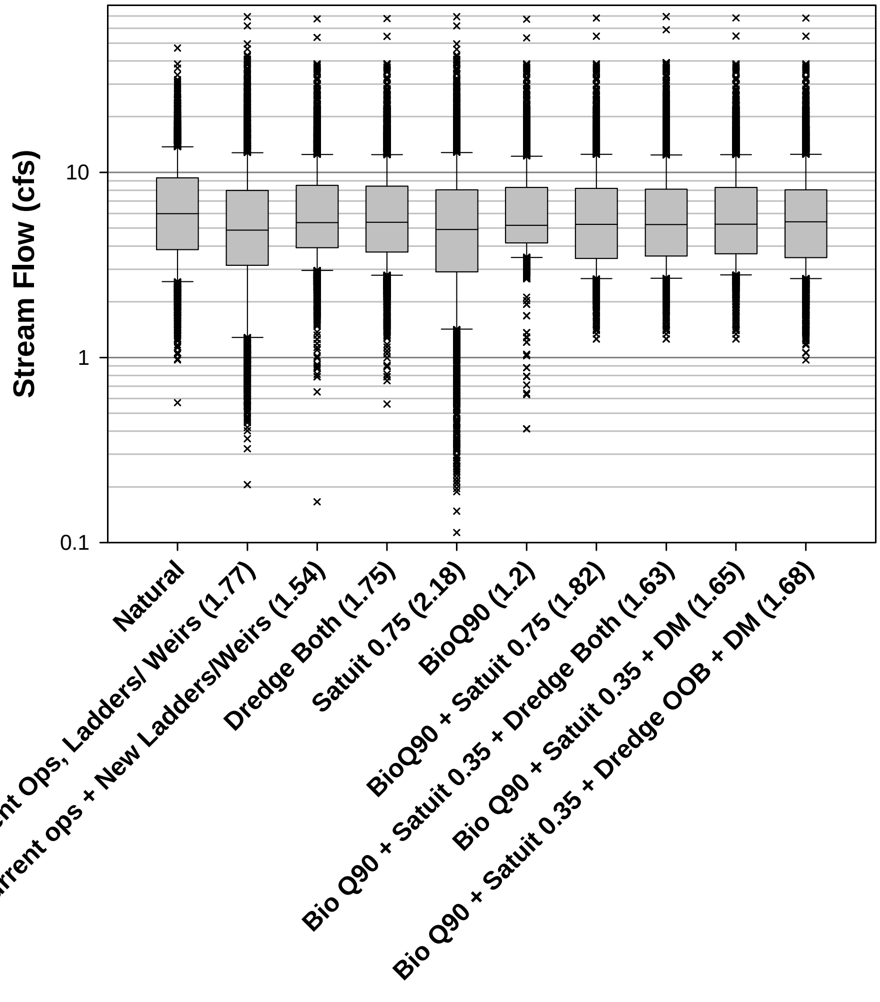


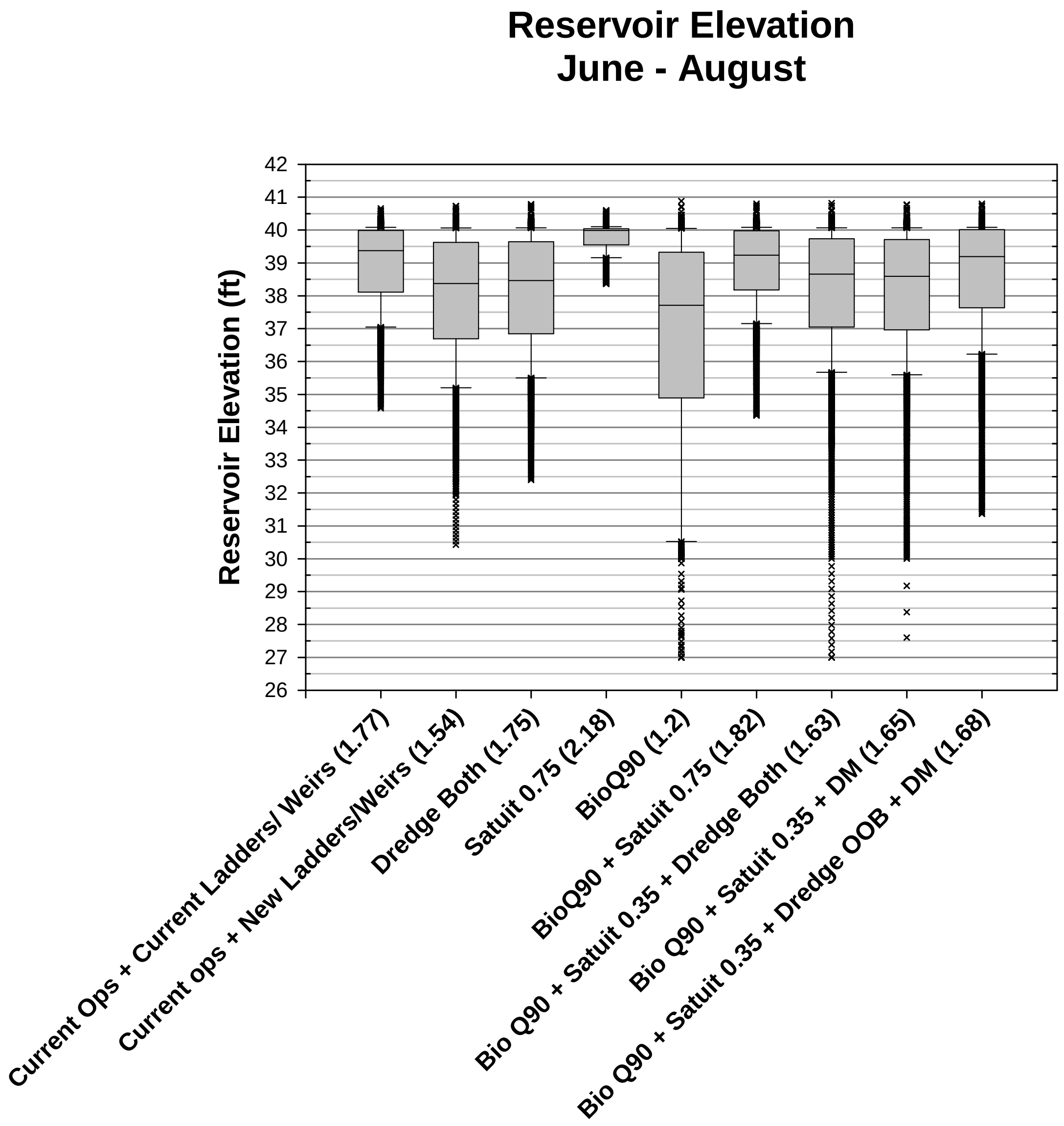
First Herring Brook Stream Flow
Below the Reservoir
October - November

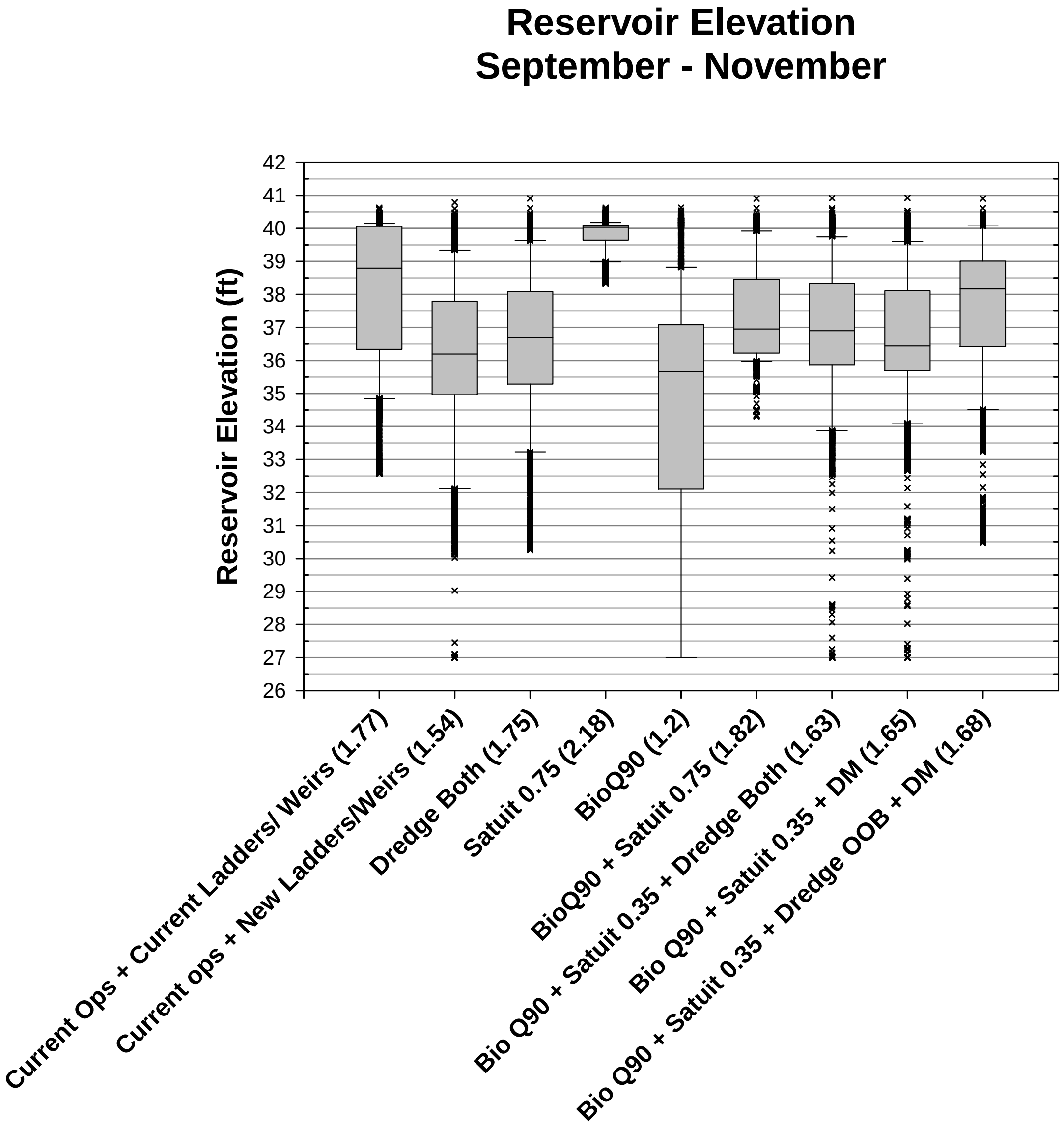


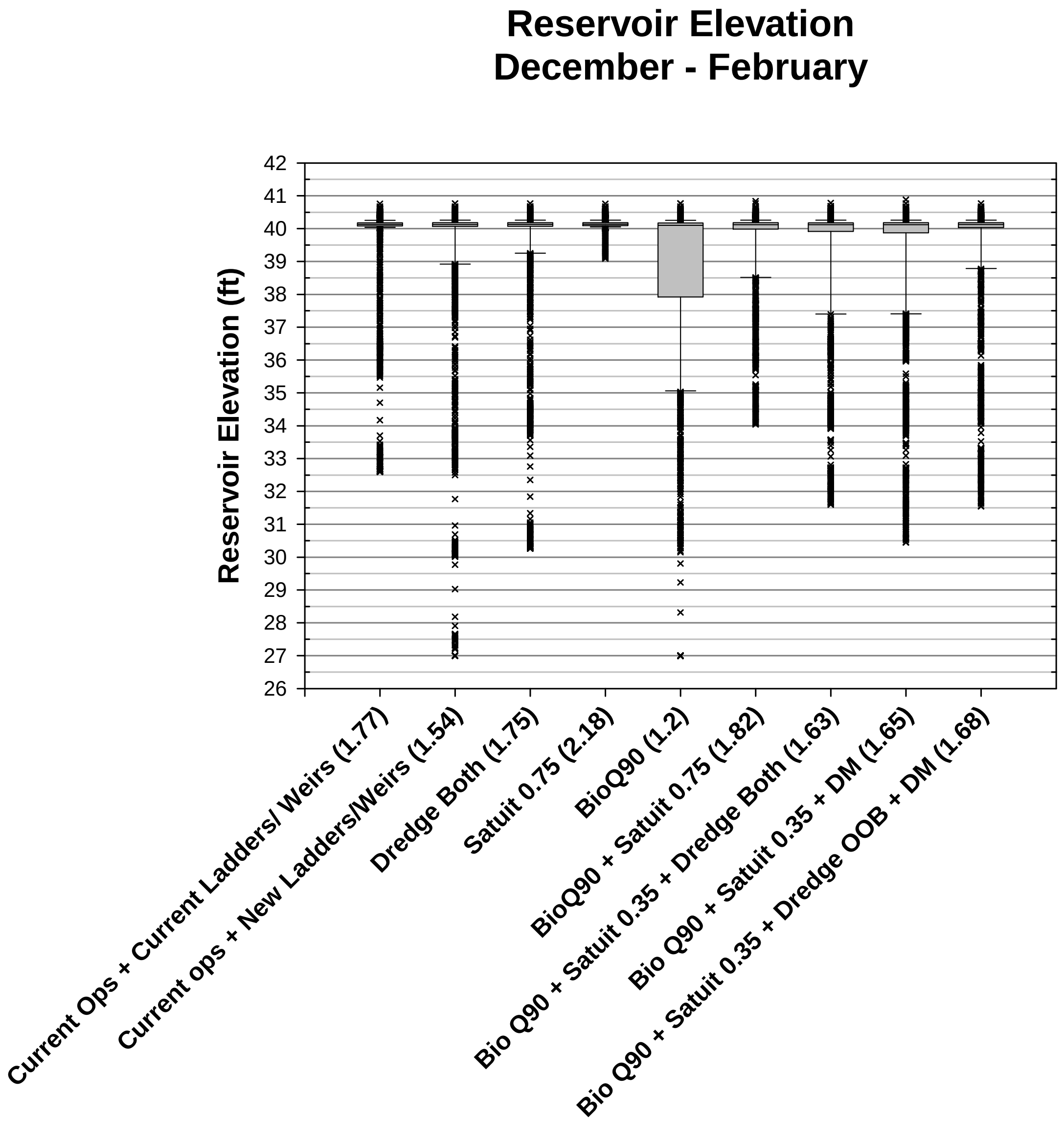

First Herring Brook Stream Flow
Below the Reservoir
December - February
Stream Flow (cfs)
10
1
0.1
Natural
Current Ops + Current Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

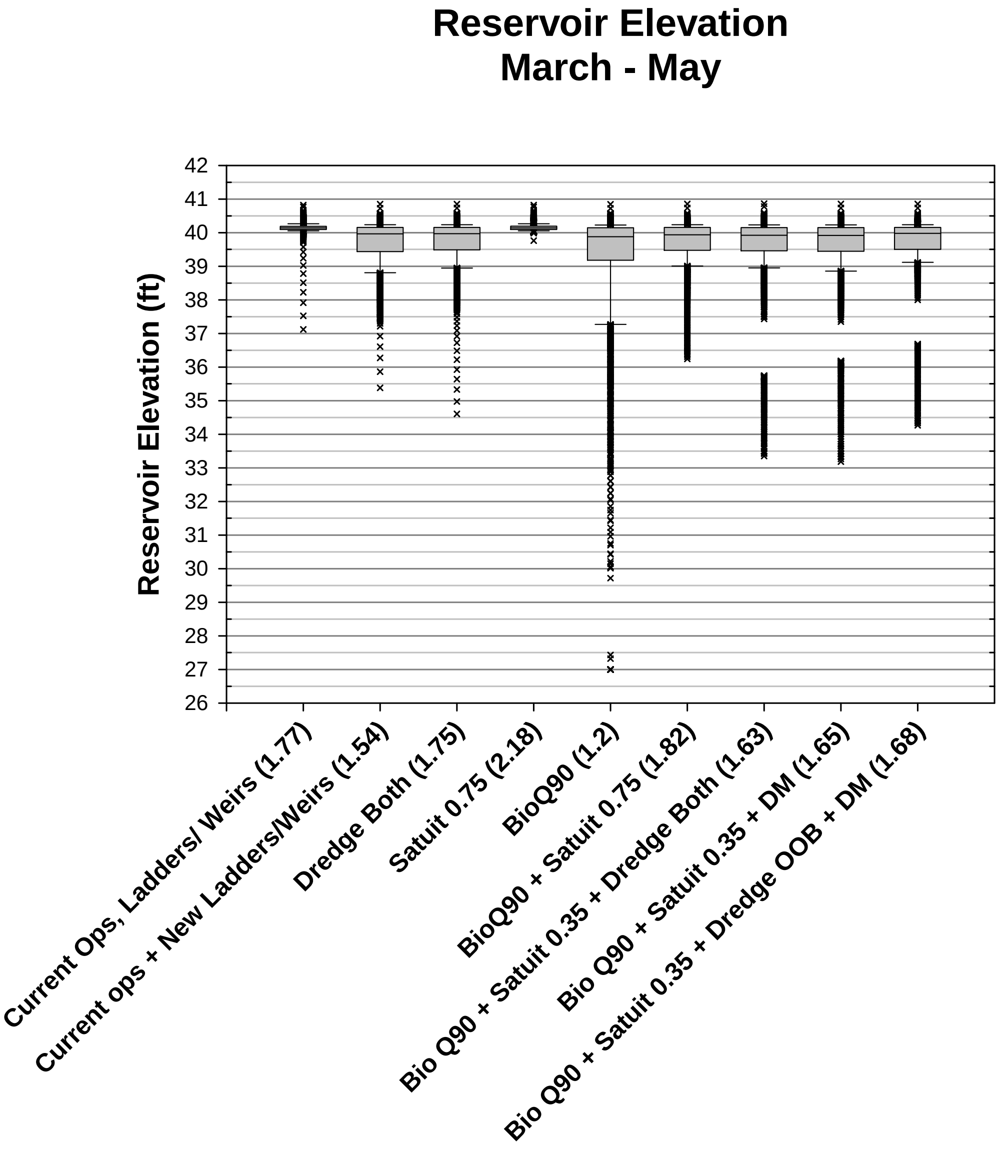
First Herring Brook Stream Flow
Below the Reservoir
March - May

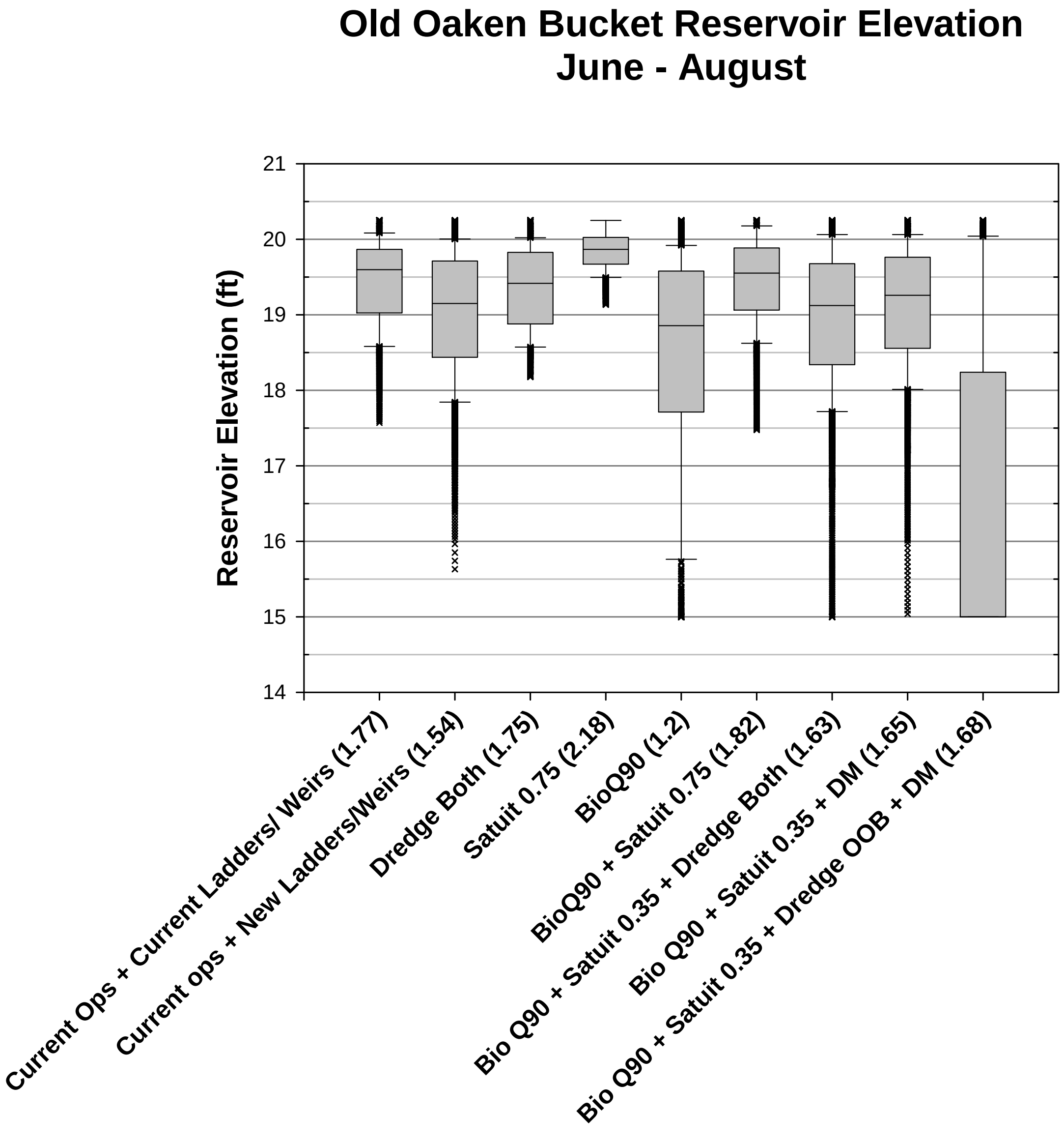



Reservoir Elevation
June - August
Reservoir Elevation (ft)
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
Current Ops + Current Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

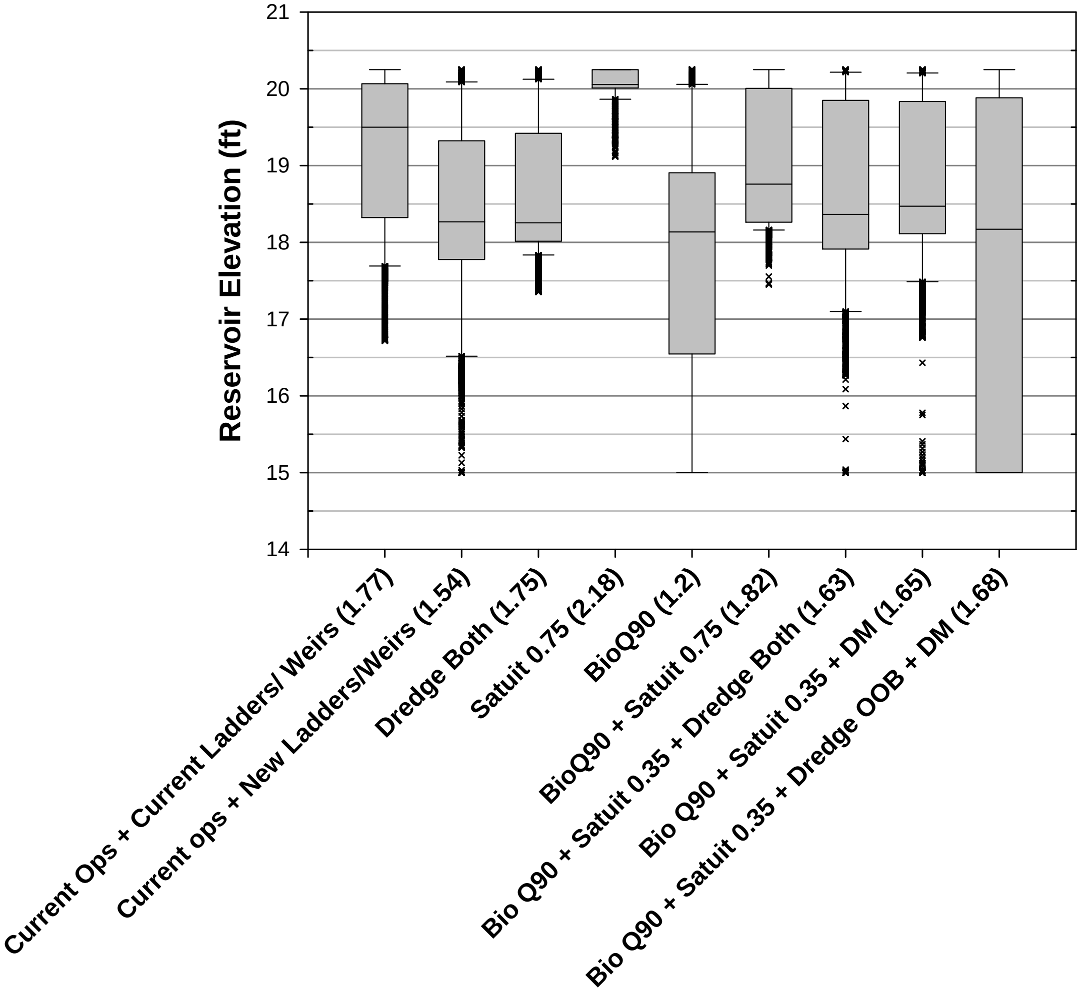

Reservoir Elevation
September - November
Reservoir Elevation (ft)
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
Current Ops + Current Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

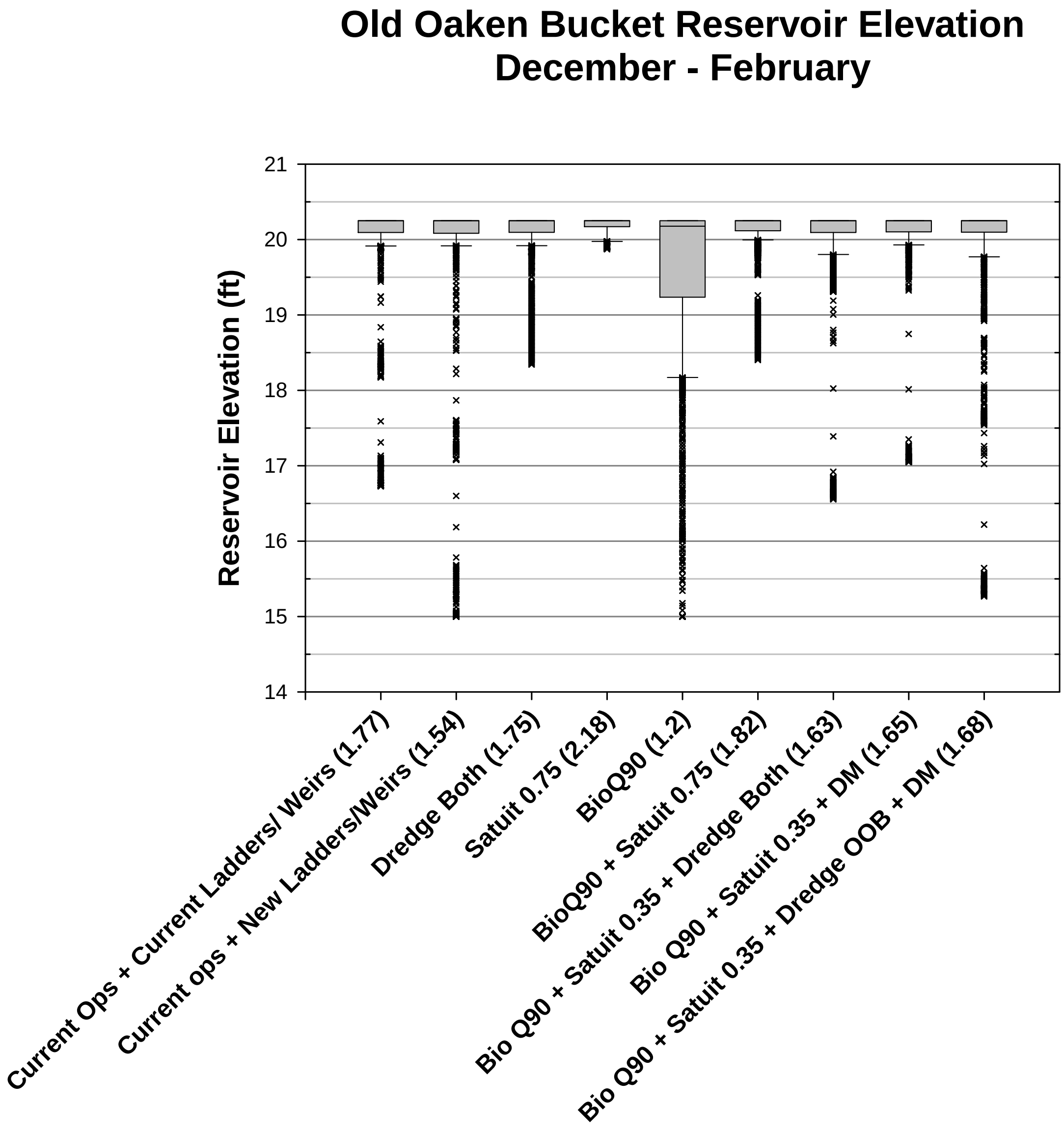

Reservoir Elevation
December - February
Reservoir Elevation (ft)
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
Current Ops + Current Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)


Reservoir Elevation
March - May
Reservoir Elevation (ft)
42
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
Current Ops, Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

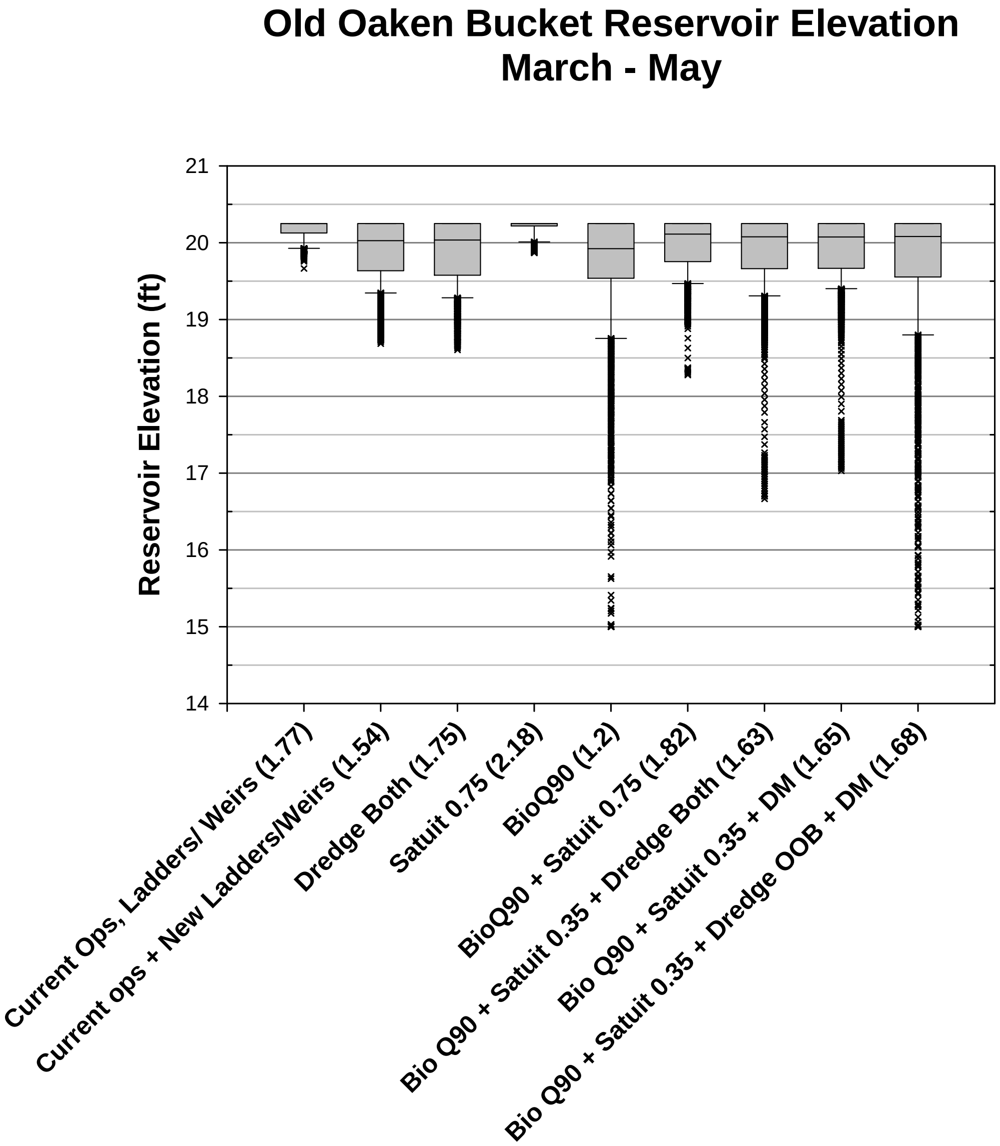

Old Oaken Bucket Reservoir Elevation
June - August
Reservoir Elevation (ft)
21
20
19
18
17
16
15
14
Current Ops + Current Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

Old Oaken Bucket Reservoir Elevation
September - November



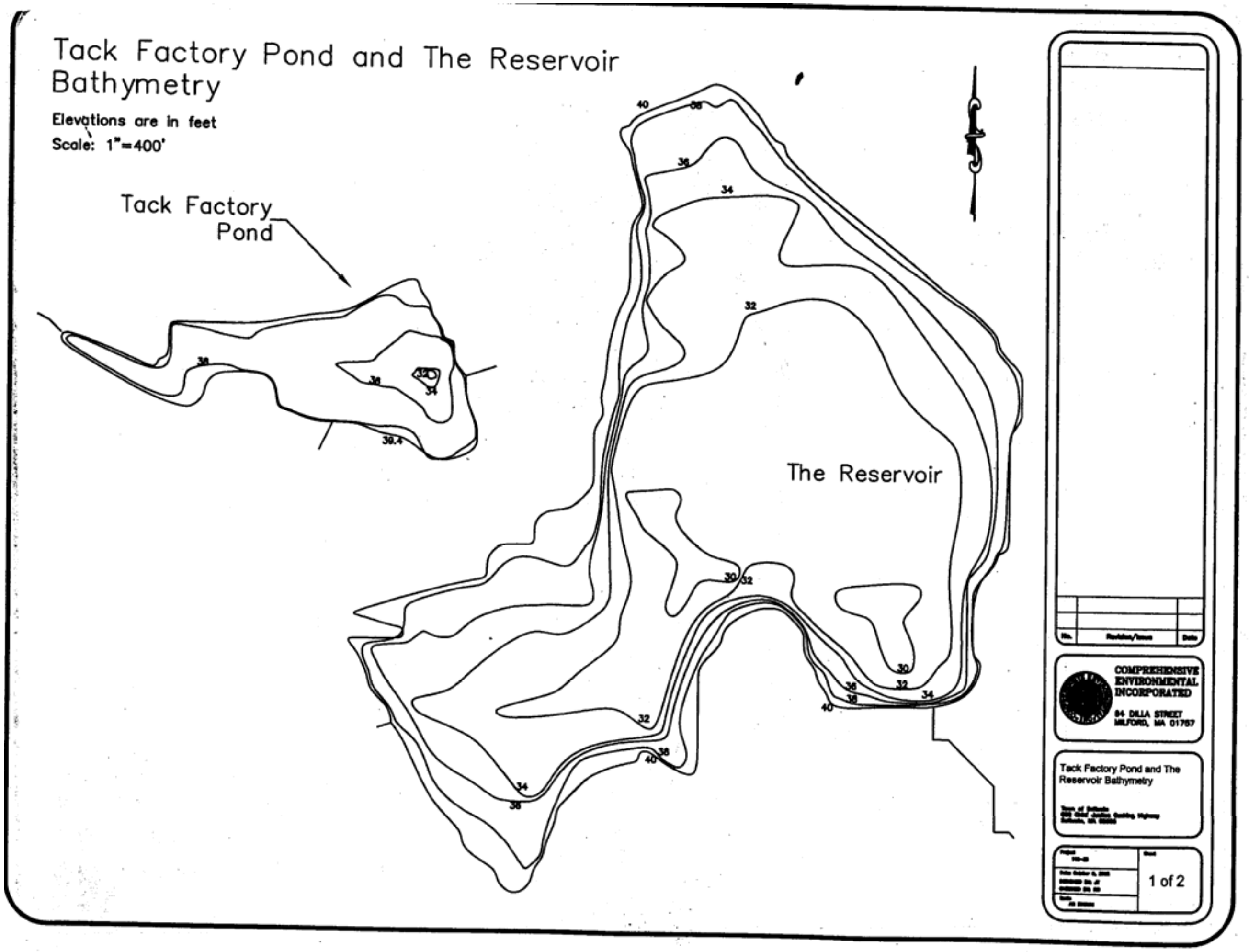


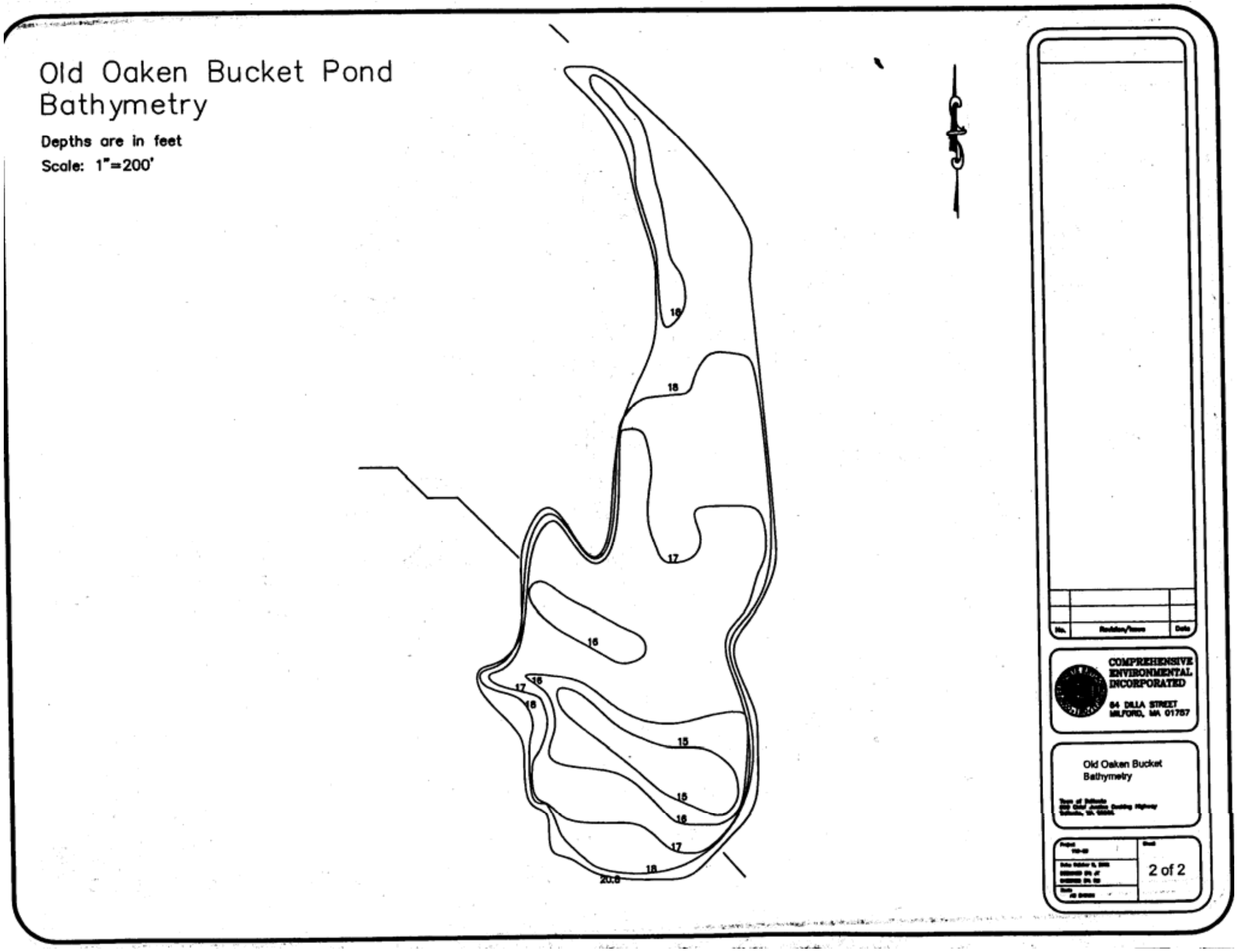
Old Oaken Bucket Reservoir Elevation
December - February


Old Oaken Bucket Reservoir Elevation
March - May
Reservoir Elevation (ft)
21
20
19
18
17
16
15
14
Current Ops, Ladders/ Weirs (1.77)
Current ops + New Ladders/Weirs (1.54)
Dredge Both (1.75)
Satuit 0.75 (2.18)
BioQ90 (1.2)
BioQ90 + Satuit 0.75 (1.82)
Bio Q90 + Satuit 0.35 + Dredge Both (1.63)
Bio Q90 + Satuit 0.35 + DM (1.65)
Bio Q90 + Satuit 0.35 + Dredge OOB + DM (1.68)

XI. Appendix C: Bathymetric Maps Reservoir and Old Oaken Bucket Pond

Images scanned from: Comprehensive Environmental, Inc., 2003.




Old Oaken Bucket Pond
Bathymetry
Depths are in feet
Scale: 1"=200'
18
18
17
16
16
17
18
15
15
16
17
18
20.8
No.
Revision/Issue
Date
COMPREHENSIVE
ENVIRONMENTAL
INCORPORATED
64 DILLA STREET
MILFORD, MA 01757
Old Oaken Bucket
Bathymetry
2 of 2

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Yako L.A., M.E. Mather, and F. Juanes. 2002. Mechanisms for migration of anadromous herring: an ecological basis for effective conservation. Ecological Applications 12(2): 521-534.

MassDEP

Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

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Charles D. Baker
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Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

September 16, 2016

Board of Selectmen
Town Hall
600 Chief Justice Cushing Way
Scituate, MA 02066

SCITUATE – BRP/WMA
Scituate Water Division
PWS ID #4264000
Water Management Act Permit #9P4421264.02

Dear Sirs,

Attached please find:

- Findings of Fact in support of the renewal of Permit #9P4421264.02, and
- WMA Permit #9P4421264.02 for the Scituate Water Division.

If you have any questions regarding this information, please contact Elizabeth McCann at (617) 292-5901 or via e-mail at elizabeth.mccann@state.ma.us.

Sincerely,

Rebecca Weidman
Director, Division of Watershed Management
Bureau of Resource Protection

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Ecc: Sean Anderson, Town of Scituate
Kevin Cafferty, Town of Scituate
Duane LeVangie, MassDEP
Patti Kellogg, MassDEP SERO
Michele Drury, DCR OWR
Michelle Craddock, DFW
Jen Pederson, MWWA

Cc: Samantha Woods, NSRWA, PO Box 43, Norwell, MA 02061
Dorrie Stolley, WAA, 2173 Washington Str., Canton, MA 02021
John Clarkeson, Scituate Water Resources Comm., 600 Chief Justice Cushing Hwy., Scituate MA 02066

Communication For Non-English Speaking Parties - **310 CMR 1.03(5)(a)**
Contact Michelle Waters-Ekanem, Diversity Director/Civil Rights: 617-292-5751 TTY#
MassRelay Service 1-800-439-2370.
http://www.mass.gov/eea/agencies/massdep/service/justice/ (Version 3.30.15)

1 English:
This document is important and should be translated immediately. If you need this document translated, please contact MassDEP's Diversity Director at the telephone numbers listed below.

2 Español (Spanish):
Este documento es importante y debe ser traducido inmediatamente. Si necesita este documento traducido, por favor póngase en contacto con el Director de Diversidad MassDEP a los números de teléfono que aparecen más abajo.

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4(a) 中國（傳統）(Chinese (Traditional):
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4(b) 中国（简体中文）(Chinese (Simplified):
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5 Ayisyen (franse kreyòl) (Haitian) (French Creole):
Dokiman sa-a se yon bagay enpòtan epi yo ta dwe tradui imedyatman. Si ou bezwen dokiman sa a tradui, tanpri kontakte Divèsite Direktè MassDEP a nan nimewo telefòn ki nan lis pi ba a.

6 Việt (Vietnamese):
Tài liệu này là rất quan trọng và cần được dịch ngay lập tức. Nếu bạn cần dịch tài liệu này, xin vui lòng liên hệ với Giám đốc MassDEP đa dạng tại các số điện thoại được liệt kê dưới đây.

7 ប្រទេសកម្ពុជា (Kmer (Cambodian):
ឯកសារនេះគឺមានសារៈសំខាន់និងគួរត្រូវបានបកប្រែភ្លាមៗ ប្រសិនបើអ្នកត្រូវបានបកប្រែឯកសារនេះសូមទំនាក់ទំនងឆ្នោតជានាយក MassDEP នៅលេខទូរស័ព្ទដែលបានរាយខាងក្រោម។

8 Kriolu Kabuverdianu (Cape Verdean):
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Communication For Non-English Speaking Parties - 310 CMR 1.03(5)(a)
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هذه الوثيقة الهامة وينبغي أن تترجم على الفور. اذا كنت بحاجة الى هذه الوثيقة المترجمة، يرجى الاتصال مدير التنوع في MassDEPعلى أرقام الهواتف المدرجة أدناه.

11 한국어 (Korean):
이 문서는 중요하고 즉시 번역해야합니다. 당신이 번역이 문서가 필요하면 아래의 전화 번호로 MassDEP의 다양성 감독에 문의하시기 바랍니다.

12 հայերեն (Armenian):
Այս փաստաթուղթը շատ կարեւոր է եւ պետք է թարգմանել անմիջապես. Եթե Ձեզ անհրաժեշտ է այս փաստաթուղթը թարգմանվել դիմել MassDEP բազմազանությունը տնօրեն է հեռախոսահամարների թվարկված են ստորեւ.

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این سند مهم است و باید فورا ترجمه شده است.
اگر شما نیاز به این سند ترجمه شده، لطفا با ما تماس تنوع مدیر MassDEP در شماره تلفن های ذکر شده در زیر.

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यह दस्तावेज महत्वपूर्ण है और तुरंत अनुवाद किया जाना चाहिए. आप अनुवाद इस दस्तावेज़ की जरूरत है, नीचे सूचीबद्ध फोन नंबरों पर MassDEP की विविधता निदेशक से संपर्क करें.

MassDEP
Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

Charles D. Baker
Governor

Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

Findings of Fact in Support of
Water Management Permit #9P4421264.02
Town of Scituate

The Department of Environmental Protection (the Department) makes the following Findings of Fact in support of the attached Water Management Permit #9P4421264.02, and includes herewith its reasons for issuing the Permit and for conditions of approval imposed, as required by M.G.L. c. 21G, § 11. The issuance of this permit is in response to a water withdrawal permit renewal application by the Town of Scituate Department of Public Works, Water Division, (Scituate) for the purpose of public water supply.

The Department adopted revised Water Management Regulations at 310 CMR 36.00 on November 7, 2014, (described in greater detail below). Since that time, the Department has been working closely with each Water Management Act (WMA) permittee to fully consider all aspects of their individual situations and ensure thoughtful and implementable permits.

The Department met with Scituate's representatives on three occasions regarding the conditions in this permit and, in particular, the streamflow augmentation and restoration of the herring run in the Old Oaken Bucket Pond system. Consequently, the permit continues to incorporate Scituate's ongoing First Herring Brook Interim Operational Plan. This plan is an example of forward-looking environmental stewardship undertaken in conjunction with providing reliable water supply for public health and safety and ensuring water supplies for future economic growth.

The Department has included Scituate's independently developed Scituate Water Resources Committee Conservation Plan, adopted in March 2016, as one aspect of Scituate's minimization plan (Condition 11) of this permit. Scituate has been proactive in promoting conservation practices that recognize water as a limited and precious resource needed for the community's health and safety and economic development, while also protecting the ecological health of local resources.

The Permit Extensions

WMA permits issued during the first 20-year permitting cycle for the South Coastal Basin expired on August 31, 2010. All permittees seeking to renew their Water Management permit were required to file a renewal application on or before May 31, 2010. Scituate filed a timely renewal application and received a one-year Interim Permit, to August 31, 2011, to continue operations while the permit renewal review was ongoing. The Department published notice of the permit renewal application in the Environmental Monitor on June 23, 2010. One comment was received from North & South Rivers Watershed Association which is addressed in the Response to Comments section below.

Subsequently, the expiration dates for all Water Management permits were extended for four years by Chapter 240 of the Acts of 2010 as amended by Chapter 238 of the Acts of 2012, collectively known as the Permit Extension Act. In addition, in a letter of September 25, 2015, the Department informed Scituate that the Department would need additional time before making a determination on the application in order to ensure that all permit renewal applicants in the South Coastal Basin fully understood the new Water Management Regulations (discussed below), and to give proper consideration to all permit renewal applications within the basin. Pursuant to M.G.L. c. 30A, § 13, and 310 CMR 36.18(7), Scituate's permit continues in force and effect until the Department issues a final decision on the permit renewal application.

The expiration date for all permits going forward in the South Coastal Basin will be August 31, 2030, in order to restore the staggered permitting schedule set forth in the regulations.

The Water Management Act (M.G.L. c. 21G)

The Water Management Act (Act) requires the Department to issue permits that balance a variety of factors including without limitation:

- Impact of the withdrawal on other water sources;
- Water available within the safe yield of the water source;
- Reasonable protection of existing water uses, land values, investments and enterprises;
- Proposed use of the water and other existing or projected uses of water from the water source;
- Municipal and Massachusetts Water Resources Commission (WRC) water resource management plans;
- Reasonable conservation consistent with efficient water use;
- Reasonable protection of public drinking water supplies, water quality, wastewater treatment capacity, waste assimilation capacity, groundwater recharge areas, navigation, hydropower resources, water-based recreation, wetland habitat, fish and wildlife, agriculture, flood plains; and
- Reasonable economic development and job creation.

Water Management Regulation Revisions

In 2010 the Executive Office of Energy and Environmental Affairs (EEA) convened the Sustainable Water Management Initiative (SWMI) for the purpose of incorporating the best available science into the management of the Commonwealth's water resources. SWMI was a multi-year process that included a wide range of stakeholders and support from the Departments of Environmental Protection, Fish and Game, and Conservation and Recreation. In November 2012 the *Massachusetts Sustainable Water Management Initiative Framework Summary* (http://www.mass.gov/eea/docs/eea/water/swmi-framework-nov-2012.pdf) was released.

On November 7, 2014, the Department adopted revised Water Management Regulations at 310 CMR 36.00 that incorporate elements of the SWMI framework and the Water Conservation Standards adopted by the Massachusetts WRC. The regulations reflect a carefully developed balance to protect the health of Massachusetts' water bodies while meeting the needs of businesses and communities for water.

Without limitation, the Department has incorporated the following into Water Management permitting:

- Safe yield determinations for the major river basins based on a new methodology developed through SWMI (see the Safe Yield in the South Coastal Basin section of this document);
- Water needs forecasts for public water suppliers developed by the Department of Conservation and Recreation, Office of Water Resources (DCR), using a methodology reviewed and approved by the Massachusetts WRC;
- Water supply protection measures for public water supplies including Zone II delineations for groundwater sources, and wellhead and surface water protection measures as required by Massachusetts Drinking Water Regulations (310 CMR 22.00);

- Water conservation and performance standards reviewed and approved by the WRC in July 2006 and revised in June 2012 (http://www.mass.gov/eea/docs/eea/wrc/water-conservation-standards-rev-june-2012.pdf), including without limitation;
    - performance standard of 65 residential gallons per capita day or less;
    - performance standard of 10% or less unaccounted-for-water;
    - seasonal limits on nonessential outdoor water use;
    - a water conservation program that includes leak detection and repair, full metering of the system and proper maintenance of the meters, periodic review of pricing, and education and outreach to residents and industrial and commercial water users; and
- Environmental protections developed through SWMI, including without limitation;
    - protection for coldwater fish resources;
    - minimization of withdrawal impacts in areas stressed by groundwater use;
    - mitigation of the impacts of increasing withdrawals.

Safe Yield in the South Coastal Basin

This permit is being issued under the safe yield methodology adopted by the Department on November 7, 2014, and described in the regulations at 310 CMR 36.13. As of the date of issuance of this permit, the safe yield for the South Coastal Basin is 70.1 million gallons per day (MGD), and total registered and permitted withdrawals are 47.4 MGD, leaving 22.70 MGD potentially available. The maximum withdrawals that will be authorized in this permit, and all other permits currently under review by the Department within the South Coastal Basin, will be within the safe yield and may be further conditioned as outlined in the regulations.

Findings of Fact for Permit Conditions in Scituate's Water Management Act Permit

The following Findings of Fact for the special conditions included in the permit generally describe the rationale and background for each special condition in the permit. This summary of permit special conditions is not intended to, and should not be construed as, modifying any of the permit special conditions. In the event of any ambiguity between this summary and the actual permit conditions, the permit language shall control.

Water for the Humarock section of Scituate is currently purchased from the Town of Marshfield. Scituate might connect Humarock to the water distribution system in the future. Should Scituate decide to connect Humarock, Scituate is required to file BRP WS 32 Permit, Distribution Modifications for Systems That Serve More Than 3,300 People, and receive approval from the Department prior to connecting Humarock to the water supply distribution system.

Special Condition 1, Maximum Authorized Annual Average Withdrawal for this renewed permit cannot exceed Scituate's 1.80 MGD baseline withdrawal rate without a permit amendment (BRPWM02) to incorporate a mitigation plan (see Special Condition 12).

Thereafter withdrawals cannot exceed the lesser of either:

a) the maximum withdrawal volume authorized in the expiring permit, or
b) the water needs forecasts developed for Scituate by DCR.

The table below compares the maximum withdrawal volumes authorized by Scituate's expiring permit and the maximum water needs forecasts for Scituate. The maximum withdrawal volumes to be authorized in this permit are highlighted in bold print.

	Maximum Authorized in Scituate's Expiring Permit	DCR 2030 Water Needs Projection + Five Percent Buffer
Without Humarock on the Supply System	**1.85 MGD**	1.78 MGD + 0.09 = 1.87 MGD
With Humarock on the Supply System	2.01 MGD	1.88 MGD + 0.09 = **1.97 MGD**

Special Condition 1 authorizes Scituate to withdraw water in five-year increments (permit periods) up to the maximum authorized, 1.85 MGD without supplying Humarock, or 1.97 if Humarock is connected to the system. If Scituate's water demand increases more quickly than anticipated in the DCR water needs forecasts, Scituate may withdraw volumes authorized for later permit periods provided that all other conditions of this permit are met.

If water needs are expected to exceed the maximum authorized in this permit, Scituate may apply for additional volume at any time by submitting a new Water Management Permit application BRPWM03.

Please note that the Department has recalculated Scituate's net raw water withdrawals for water supply distribution that were reported on Scituate's Annual Statistical Reports. The recalculation was done because Scituate currently withdraws water from Well #17A and pumps it directly into Old Oaken Bucket Pond to maintain water levels in the pond and to provide dilution for elevated manganese levels in the well. In order to avoid double counting water withdrawn from Well #17A, the Department recalculated the net raw water withdrawals by totaling water withdrawals from all permitted sources as reported on Scituate's Annual Statistical Reports, and subtracting withdrawals from Well #17A. The recalculation shows that net raw water withdrawals for water supply distribution were 1.54 MGD for 2014 and 1.43 MGD for 2013. Raw water withdrawals for 2015 were 1.46 MGD and were reported without double counting Well #17A.

Special Condition 2, Maximum Daily Withdrawals from Groundwater Withdrawal Points, reflects the MassDEP-approved Zone II maximum daily pumping rate for each of Scituate's permitted wells based on prolonged pumping tests. Withdrawals in excess of these maximum daily rates require approval from the Department.

Special Condition 3, Maximum Withdrawals from Old Oaken Bucket Pond, reflects the Mass-DEP approved maximum withdrawal rates from Scituate's reservoir system.

- The maximum daily withdrawal rate reflects the capacity of the intake structure at Old Oaken Bucket Pond.
- The annual daily average withdrawal rate and total annual withdrawal volume for Old Oaken Bucket Pond are based on the Old Oaken Bucket Pond Firm Yield, dated June 2003, and approved by the Department on May 13, 2004, which determined the firm yield to be 0.79 MGD under the drought of record (1960's drought) for Massachusetts with no downstream releases.
- MassDEP notes that the USGS Refinement and Evaluation of the Massachusetts Firm-Yield Estimator Model Version 2.0 (SIR 2011-5125) shows significant reductions in firm yield for Scituate's Main Reservoir in scenarios that include downstream releases similar to the release included in the First Herring Brook Interim Operational Plan, Version 2. Scituate's Water Conservation Plan and Drought Management Plan include shut-off of downstream releases when the reservoir reaches specified levels that are expected to provide sufficient protection for water supply purposes with a Firm Yield of 0.79 MGD.

Special Condition 4, Zone II Delineation requirements have been met and no further delineations are required as a condition of this permit.

Special Condition 5, Wellhead and Surface Water Protection requirements have been met and are up to date as of the issuance of this permit.

Special Condition 6, Development of Minimum Streamflow Targets for Fish Passage at First Herring Brook updates this condition to require Scituate's continuing work to refine and implement the First Herring Brook Interim Operational Plan.

Special Condition 7, Performance Standard for Residential Gallons Per Capita Day Water has changed from 80 RGPCD required in Scituate's permit of June 12, 2007. The RGPCD required for all PWS permittees is now 65 gallons. Permittees that cannot comply within the timeframe in the permit must meet Functional Equivalence requirements outlined in Attachment A. Scituate's 2015 RGPCD was 58 as reported in the 2015 ASR.

Special Condition 8, Performance Standard for Unaccounted for Water has changed from 15% UAW required annually in Scituate's permit of June 12, 2007. The UAW required for all PWS permittees is now 10% for 2 out of every 3 years. MassDEP has found that most PWS's year-to-year reported UAW varies by several percentage points. MassDEP's review of UAW values reported over the last ten years has shown that a rolling three-year average is a better indicator of a PWS's long-term compliance with the standard, and assessing compliance based on the rolling three-year average avoids most instances of a PWS falling out of compliance because of an anomalous year. Permittees that cannot comply within the timeframe in the permit must meet Functional Equivalence requirements based on the AWWA/IWA Water Audits and Loss Control Programs, Manual of Water Supply Practices M36, as outlined in Attachment B. Scituate's UAW for the most recent three years has been:

2015	2014	2013
19%	17%	14%

Special Condition 9, Seasonal Limits on Nonessential Outdoor Water Use for Scituate is based upon the Town's independently developed nonessential outdoor water use restrictions. Scituate analyzed water use data and determined that the top 5% of water users increased their water usage an average of 25% during the summer months, accounting for over 300,000 additional gallons per day. Based on that analysis, the use of inground irrigation systems was restricted to one day per week between Memorial Day and Labor Day. In 2015 Scituate expanded the timeframe for its outdoor water use restrictions to May 1st through September 30th and adopted the authority to implement a total ban on nonessential outdoor water use when Scituate's Reservoir falls to a level of 36 feet (49% full). Since implementation of the nonessential water use restrictions, summer water use has fallen by approximately 30%.

The Department has determined that Scituate's limits are at least as restrictive as the Department's standard seasonal limits on nonessential outdoor water use. Scituate's limits are also uniquely suited to the water supply system which includes both surface and groundwater supplies, and are an integral part of Scituate's First Herring Brook Interim Operational Plan, which is incorporated into this permit in **Special Condition 6, Development of Minimum Streamflow Targets for Fish Passage at First Herring Brook.**

Special Condition 10, Water Conservation Requirements, incorporates the Water Conservation Standards for the Commonwealth of Massachusetts reviewed and approved by the WRC in July 2006 and revised in June 2012. (http://www.mass.gov/eea/docs/eea/wrc/water-conservation-standards-rev-june-2012.pdf). The Department recognizes that the Town of Scituate is currently implementing a conservation program that incorporates these requirements as documented in the Scituate Water Resources Committee Conservation Plan, adopted in March, 2016.

Special Condition 11, Minimization of Groundwater Withdrawal Impacts in Stressed Subbasins, requires permittees with permitted groundwater sources in subbasins[1] with net groundwater depletion of 25% or more during August to minimize their withdrawal impacts on those subbasins to the greatest extent feasible through

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[1] Subbasins used for WMA permitting are the 1,395 subbasins delineated by the U.S. Geological Survey in *Indicators of Streamflow Alteration, Habitat Fragmentation, Impervious Cover, and Water Quality for Massachusetts Stream Basins* (Weiskel *et al.*, 2010, USGS SIR 2009-5272).

optimization of groundwater sources, surface water releases to improve streamflows, outdoor water use restrictions and conservation programs that go beyond standard Water Management permit requirements.

The Department reviewed Scituate's performance relative to these requirements based on Department records and information submitted by Scituate and finds that minimization requirements will be met as follows:

- Scituate's groundwater sources 4264000-01G, 02G, 03G, 05G and 11G are located in Subbasin 22132, which is 94.3% August net groundwater depleted. Scituate has one groundwater source, Well #18B (4264000-12G), in Subbasin 22091 which is near the coast where August net groundwater depletion cannot be readily determined. Department review of Scituate's pumping records show that Scituate has consistently pumped Well #18B at between 70% and 80% of its Department-approved maximum daily capacity throughout the past 5 years. This permit does not require that Scituate shift additional pumping to Well #18B because prolonged pumping at a higher rate could risk degradation of the source.
- Scituate is required to work with the Scituate Water Study Committee and First Herring Brook Watershed Initiative to refine and implement the First Herring Brook Interim Operational Plan in **Special Condition 6**.
- Scituate is required to continue implementation of nonessential outdoor water use restrictions in **Special Condition 8** that go beyond MassDEP's standard permit requirement.
- Scituate has developed a progressive water conservation program as outlined in the Scituate Water Resources Committee Conservation Plan, adopted in March 2016. Continued implementation of the plan, and of specific elements of the plan that go beyond the standard permit requirements is required in **Special Condition 11**.

Special Condition 12, Mitigation of Impacts for Withdrawals that Exceed Baseline Withdrawals requires mitigation of the impacts of withdrawals above the permittee's 2003-2005 baseline withdrawal rate. Mitigating the impacts of increasing withdrawals can be through direct mitigation including surface water releases, stormwater recharge, and projects to remove infiltration/inflow removal from the wastewater collection system. If additional mitigation is required after direct mitigation measures have been put in place, indirect mitigation activities that will result in streamflow and habitat improvements may be required.

Scituate's baseline withdrawal rate is 1.80 MGD, based on Scituate's 2005 withdrawals plus 5%. **Prior to making average annual withdrawals greater than the 1.80 MGD baseline, Scituate is required to develop a mitigation plan for review and approval by MassDEP, incorporate the approved mitigation plan into this permit through a permit amendment (BRPWM02), and implement required mitigation activities.** MassDEP's Water Management Act Permit Guidance Document provides additional information on mitigation planning. In addition, Water Management Program staff is available for consultation as a mitigation plan is prepared.

The summary below outlines Scituate's mitigation requirement. The summary assumes that Scituate's future withdrawals will be discharged to on-site septic systems at the same rate (60%) as current water withdrawals.

Scituate's Mitigation without Supplying Humarock = 0.0245 MGD or 24,500 gpd
Permitted amount above Baseline = 0.05 MGD • Permitted amount above Baseline: 1.85 – 1.80 = 0.05 MGD
Adjustment for Wastewater Discharge to Local Groundwater = 0.0255 MGD • 60% of increased withdrawals are delivered to areas with on-site septic systems: 0.05 MGD x 0.6 (60%) = 0.03 MGD • 85% of water delivered to areas with on-site septic systems returns to groundwater: 0.03 MGD x 0.85 (85%) = 0.0255 MGD
Amount to be Mitigated after Adjustment for Wastewater Discharge to Local Groundwater = 0.0245 MGD

• Permitted amount above baseline (0.05 MGD) – adjustment for wastewater discharge to local groundwater (0.0255 MGD) = 0.0245 MGD
Scituate's Mitigation if Humarock is Added to the Distribution System = 0.0833 MGD or 83,300 gpd
Permitted amount above Baseline = 0.17 MGD • Permitted amount above Baseline: 1.97 – 1.80 = 0.17 MGD
Adjustment for Wastewater Discharge to Local Groundwater = 0.0867 MGD • 60% of increased withdrawals are delivered to areas with on-site septic systems: 0.17 MGD x 0.6 (60%) = 0.102 MGD • 85% of water delivered to areas with on-site septic systems returns to groundwater: 0.102 MGD x 0.85 (85%) = 0.0867MGD
Amount to be Mitigated after Adjustment for Wastewater Discharge to Local Groundwater = 0.0833 • Permitted amount above baseline (0.17 MGD) – adjustment for wastewater discharge to local groundwater (0.0867 MGD) = 0.0833 MGD

Special Condition 13, Reporting Requirements, ensures that the information necessary to evaluate compliance with the conditions included herein is accurately reported.

Coldwater Fish Resource Protection was incorporated into the Water Management Regulations in November 2014. Coldwater Fish Resource Protection is not a condition of this permit because Scituate's withdrawals do not impact any waters that MA Division of Fisheries and Wildlife has identified as supporting coldwater fish.

Response to Comments

One comment on Scituate's permit renewal application was received from the North & South Rivers Watershed Association, dated February 13, 2010, urging the Department to review the work of the team of stakeholders working on the First Herring Brook Watershed Initiative and incorporate that work into the renewed permit. The Department has reviewed all studies cited in the letter, and has reviewed the subsequent work of the Initiative. The First Herring Brook Interim Operation Plan continues to be incorporated into this renewed permit in **Special Condition 6, Development of Minimum Streamflow Targets for Fish Passage at First Herring Brook,** and related seasonal limits on nonessential outdoor water use are incorporated into **Special Condition 9, Seasonal Limits on Nonessential Outdoor Water Use.**

Two comments on Scituate's June 1, 2016, draft permit were received from the North & South Rivers Watershed Association (July 8, 2016) and the Massachusetts Rivers Alliance (July 8, 2016). Comments that related directly to this permit are outlined below.

Comments on Target Releases at First Herring Brook and Mitigation Requirements in the Draft Permit

The draft permit released for public comment on June 8, 2016, included a requirement that Scituate mitigate the impacts of its withdrawals above its 1.80 MGD baseline withdrawal rate (based on 2003-2005 withdrawal rates) by:

- Continuing to participate in the work of First Herring Brook Watershed Initiative to explore the development of minimum flow targets for fish passage at Old Oaken Bucket Pond and Tack Factory Pond;
- Implementing the First Herring Brook Operation Plan, prepared in conjunction with the North & South Rivers Watershed Association and the MA Division of Ecological Restoration, to improve streamflow and fisheries habitat; and
- Submitting a detailed annual report of actions taken during the previous year.

Comments received on the draft permit's mitigation requirements included:

- Scituate may have trouble meeting release requirements at current withdrawals rates, and may be unable to meet the permit target releases as withdrawals increase over the life of the permit.
- If Scituate cannot make the target releases due to low water levels in the reservoir, then mitigation credit should be reduced.
- The target releases to First Herring Brook exceed the gallon amount that Scituate is required to mitigate. Scituate should not be able to "bank" extra mitigation credit.
- Mitigation activities, such as stormwater remediation projects, that return water upgradient of Scituate's water sources could be more environmentally beneficial than surface water releases to First Herring Brook downstream of Scituate's wells and reservoir.
- Additional mitigation activities should be required in the permit because the subbasin is 94.3% August net groundwater depleted.

Upon consideration of the issues raised by the commenters, and in light of the 2016 drought when releases at Old Oaken Bucket Pond were curtailed on August 1st due to low reservoir levels, MassDEP has reassessed the feasibility of including stream flow releases from Old Oaken Bucket Pond as Scituate's mitigation plan.

- o The permit now requires that Scituate, prior to making average annual withdrawals greater than the 1.80 MGD baseline, develop a mitigation plan for review and approval by MassDEP, incorporate the approved mitigation plan into this permit through a permit amendment (BRPWM02), and implement required mitigation activities.
- o Development of water release targets for fish passage at First Herring Brook, which was included in the expiring permit, is now included as Special Condition 6 in the permit. The permit continues to require that Scituate work to refine and implement the First Herring Brook Interim Operational Plan, but does not require specific downstream releases.
- o More detailed requirements for reporting refinements to the flow targets, plan implementation, and measured flows vs. target flows at First Herring Brook have been incorporated into Special Condition 6.
- o August net groundwater depletion is addressed through minimization requirements in Water Management permitting (310 CMR 36.22(5)).

Comments on Minimization Requirements in the Draft Permit
Comments received on the draft permit's mitigation requirements included (with MassDEP's response immediately below):

- Scituate did not submit a plan to minimize impacts to the greatest extent feasible per 310 CMR 36.22(5) (a)-(d) with the renewal application.
    - o MassDEP's Water Management Act Permit Guidance (November 7, 2014) outlines 4 required elements of a Minimization Plan. MassDEP reviewed Scituate's performance relative to those requirements based on information submitted by the Town.
- Scituate's nonessential outdoor water use limits are not more protective than MassDEP standard.
    - o Suppliers with surface water supplies may submit a plan that ties outdoor watering restrictions to reservoir elevation and environmental considerations, which Scituate's does.
    - o MassDEP allows permittees to present locally adopted outdoor water use restrictions that are at least as restrictive as the standard restrictions outlined in the Water Management Act Permit Guidance. After review of Scituate's outdoor water use restrictions and the water use reductions seen when the restrictions were implemented, MassDEP determined that, in Scituate's case, locally adopted outdoor water use restrictions were more effective.
- Scituate's permit should require specific conservation measures rather than reference the Scituate *Board of Water Commissioners and Water Committee Draft Water Conservation Plan, March 2014* (updated March 2016).

  - The Minimization requirement in the permit (Special Condition 11) has been revised to incorporate Scituate's final Water Resources Committee Conservation Plan, adopted in March, 2016, and specifies certain water conservation measures in the Scituate plan that go beyond the standard conservation measures required in all public water supply permits.
- It is unclear whether Scituate is meeting the standard conservation requirement to retrofit municipally owned public buildings with water saving devices.
  - Retrofitting public buildings is expensive with relatively little return in water savings for the investment. MassDEP allows communities with public buildings slated for renovation to defer retrofitting. Scituate's plans for a new Middle School, new Public Safety Complex and renovated Library will meet the conservation requirements in the permit.
- It appears that Scituate is not meeting the standard conservation requirement to review the water use records of industrial, commercial and institutional water users, inventory the largest water users and develop an outreach program to reduce water use.
  - Scituate's water conservation plan notes the industrial and commercial sector uses only 6.9% of municipal water annually and so this has not been a focus of the Town's conservation program.
  - Each community's circumstances are different and, in Scituate's case, MassDEP concurs that using limited resources to concentrate on seasonal water use and capital investments in infrastructure to address high UAW will better meet the requirements of the permit.
  - The Industrial and Commercial Water Conservation in Special Condition 9 has been updated to better reflect Scituate's circumstances.

Comment on the Draft Finding of Fact

- The Findings of Fact in the permit should identify Scituate's Permit Tier, and the Biological Category and Groundwater Category of each subbasin where Scituate's supply sources are located, and should identify the location of Coldwater Fish Resources.
  - MassDEP notes that WMA permits are very long. The Findings of Fact for each permit are drafted to include information that explains the requirements of the permit and will help the permittee understand what is required and how to meet those requirements. Including background information on GWC and BC in the permit will lengthen the permit document without adding to the Town's understanding of the permit requirements.
  - MassDEP, as part of its review of the permit renewal application, examined the impact of Scituate's proposed withdrawals and found no change to the Biological Category or Groundwater Category in any subbasin. There are no Coldwater Fish Resources that could be impacted by Scituate's withdrawals.

MassDEP

Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

Charles D. Baker
Governor

Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

WATER WITHDRAWAL PERMIT RENEWAL
#9P4421264.02
Town of Scituate

This renewal of Permit #9P4421264.02 is approved pursuant to the Massachusetts Water Management Act (WMA) for the sole purpose of authorizing the withdrawal of a volume of water as stated below and subject to the following special and general conditions. This permit conveys no right in or to any property.

PERMIT NUMBER: 9P4421264.02 **RIVER BASIN:** South Coastal

PERMITTEE:
Town of Scituate
Board of Selectmen
Town Hall, 600 Chief Justice Cushing Way
Scituate, MA 02066

EFFECTIVE DATE: September 16, 2016

EXPIRATION DATE: August 31, 2030

TYPE AND NUMBER OF WITHDRAWAL POINTS: Groundwater: 6 Surface Water: 1

USE: Public Water Supply

DAYS OF OPERATION: 365

AUTHORIZED WITHDRAWAL POINTS:

Table 1: Withdrawal Point Identification

Source	Source Code
Old Oaken Bucket Pond	4264000-01S
Well #10, Websters Meadow	4264000-01G
Well #11, Websters Meadow	4264000-02G
Well #17A, Stearns Meadow	4264000-03G
Well #19, Edison Station	4264000-05G
Well #22, Barnes Meadow	4264000-11G
Well #18B, Boston Sand	4264000-12G

SPECIAL CONDITIONS – PERMIT #9P4421264.02

1. Maximum Authorized Annual Average Withdrawal

This permit authorizes the Town of Scituate to withdraw water from the South Coastal Basin at the rate described in Tables 2A and 2B below. The volume reflected by this rate is in addition to the 1.49 MGD previously authorized to Scituate under WMA Registration #421264.01. The permitted volume is expressed both as an average daily withdrawal rate (million gallons per day or MGD), and as a total annual withdrawal volume (million gallons per year or MGY) for each five-year period of the permit term.

Prior to making average annual withdrawals greater than the 1.80 MGD baseline, Scituate is required to develop a mitigation plan for review and approval by MassDEP, incorporate the approved mitigation plan into this permit through a permit amendment (BRPWM02), and implement required mitigation activities (see Special Condition 12).

Table 2A: Authorized Withdrawals - Without Humarock

Permit Periods	**Total Raw Water Withdrawal Volumes**			
	Permit		**Registration + Permit**	
	Daily Average (MGD)	Total Annual (MGY)	Daily Average (MGD)	Total Annual (MGY)
9/16 /2016 to 8/31/2020	0.26	94.90	1.49 + 0.26 = 1.75	638.75
9/1/2020 to 8/31/2025	0.28	102.20	1.49 + 0.28 = 1.77	646.05
9/1/2025 to 8/31/2030	0.27 + 0.04 buffer = 0.31	113.15	1.49 + 0.31 =1.80	657.00
Prior to making withdrawals greater than Scituate's baseline of 1.80 MGD, a mitigation plan must be incorporated into this permit through a permit amendment (BRPWM02), and required mitigation activities must be implemented.				
9/1/2025 to 8/31/2030	0.27 + 0.09 buffer = 0.36	131.4	1.49 + 0.36 =1.85	675.25

Should Scituate connect the Humarock area of town to the water system, the following withdrawal volume is authorized by this permit. Until such time as Humarock is connected to the water system, Scituate is limited to the withdrawal volumes listed in Table 2A above.

Table 2B: Authorized Withdrawals - With Humarock

Scituate will be required to file an application for a BRP WS 32 Permit, Distribution Modifications for Systems that serve more than 3,300 people, and receive approval from the Department prior to connecting Humarock to the current distribution system.

Permit Periods	**Total Raw Water Withdrawal Volumes**			
	Permit		**Registration + Permit**	
	Daily Average (MGD)	Total Annual (MGY)	Daily Average (MGD)	Total Annual (MGY)
9/16/2016 to 8/31/2020	0.31	113.15	1.49 + 0.31 =1.80	657.00
Prior to making withdrawals greater than Scituate's baseline of 1.80 MGD, a mitigation plan must be incorporated into this permit through a permit amendment (BRPWM02), and required mitigation activities must be implemented.				
9/16/2016 to 8/31/2020	0.36	131.40	1.49 + 0.36 = 1.85	675.25
9/1/2020 to 8/31/2025	0.38	138.70	1.49 + 0.38 = 1.87	682.55
9/1/2025 to 8/31/2030	0.39 + 0.09 buffer = 0.48	175.20	1.49 + 0.48 = 1.97	719.05

Should Scituate's water demand increase more quickly than anticipated by the withdrawal rates authorized in the Permit Periods in Tables 2A and 2B above, Scituate may withdraw volumes authorized for later Permit Periods, up to Scituate's baseline of 1.80 MGD, provided that all other conditions of this permit are met.

2. **Maximum Daily Withdrawals from Groundwater Withdrawal Points**
   Withdrawals from permitted groundwater sources are not to exceed the approved maximum daily rates listed in Table 3 below without advance approval from the Department.

Table 3: Maximum Daily Withdrawal Rates from the Authorized Groundwater Withdrawal Points

Source	Maximum Daily Rate
Well #10, Websters Meadow, 4264000-01G	0.20 MGD (138 gpm)
Well #11, Websters Meadow, 4264000-02G	0.12 MGD (81 gpm)
Well #17A, Stearns Meadow, 4264000-03G	0.39 MGD (270 gpm)
Well #19, Edison Station, 4264000-05G	0.41 MGD (288 gpm)
Well #22, Barnes Meadow, 4264000-11G	0.50 MGD (350 gpm)
Well #18B, Boston Sand, 4264000-12G	0.22 MGD (153 gpm)

3. **Maximum Withdrawals from Old Oaken Bucket Pond**
   Withdrawals are not to exceed the approved maximum withdrawals listed in Table 4 below without advance approval from the Department.

Table 4: Maximum Withdrawals from Old Oaken Bucket Pond

Maximum Daily Withdrawal	Maximum Annual Average Daily Withdrawal	Maximum Annual Withdrawal
3.0 MGD	0.79 MGD	288.35 million gallons

4. **Zone II Delineation**
   Department records show that all of the Town of Scituate's sources have approved Zone II delineations, therefore, no further Zone II work is required.

5. **Wellhead and Surface Water Protection**
   Department records show that Scituate has implemented municipal controls that comply with Wellhead Protection Regulations at 310 CMR 22.21(2), has an approved Surface Water Supply Protection Plan that complies with Surface Water Supply Protection Regulations at 310 CMR 22.20B, and, in August 2014, passed an updated Surface Water Supply Protection bylaw which is in compliance with 310 CMR 22.20C.

6. **Development of Minimum Streamflow Targets for Fish Passage at First Herring Brook**
   Scituate shall continue to participate in the work of the Scituate Water Study Committee and First Herring Brook Watershed Initiative to refine and implement the minimum flow targets in First Herring Brook Interim Operational Plan, Version 2, and as amended during the term of this permit.

   Each year Scituate shall submit with its Annual Statistical Report (ASR) a detailed report of actions taken during the previous year. The report shall contain, at a minimum, a detailed description of any refinements made to the minimum flow targets, a description of any infrastructure improvements made to facilitate plan implementation and graphic representations of measured average daily flows and measured median monthly flows compared to target flows at the Reservoir (Eisenhower Lane) and Old Oaken Bucket Pond (Country Way).

7. **Performance Standard for Residential Gallons Per Capita Day Water Use**
   Scituate's performance standard for residential gallons per capita day (RGPCD) is 65 gallons or less. Scituate shall be in compliance with this performance standard by December 31, 2018, or, if Scituate does not meet the standard, shall be in compliance with the functional equivalence requirements (Appendix A).

8. Performance Standard for Unaccounted for Water

Scituate's Performance Standard for Unaccounted for Water (UAW) is 10% or less of overall water withdrawal for 2 of the most recent years 3 throughout the permit period. Scituate shall be in compliance with this performance standard by December 31, 2019 or, if Scituate does not meet the standard, shall be in compliance with the functional equivalence requirements (Appendix B).

Nothing in the permit shall prevent a permittee who meets the 10% performance standard from demonstrating compliance with the UAW performance standard by developing and implementing a water loss control program following the *AWWA M36 Water Audits and Loss Control Programs*.

Permittees meeting the Performance Standard for Unaccounted for Water through implementation of a water loss control program based on AWWA M36 annual water audits and guidance shall continue to report UAW annually as required in the Annual Statistical Report for public water suppliers.

9. Seasonal Limits on Nonessential Outdoor Water Use

Between May 1st and September 30th all nonessential outdoor water use must occur before 9 am and after 5 pm. Between May 1st and September 30th, **automatic irrigation systems** may be used **one day per week,** before 9 am and after 5 pm. When Scituate's Reservoir falls to or below a level of 36 feet (49% full), Scituate shall implement a total ban on all nonessential outdoor water use.

Scituate shall continue to implement and enforce its limits on nonessential outdoor water use through Section 30660 of the Town of Scituate General Bylaws.

Restricted Nonessential Outdoor Water Uses

Nonessential outdoor water uses that are subject to mandatory restrictions include:
- irrigation of lawns via automatic irrigation systems;
- filling swimming pools;
- washing vehicles, except in a commercial car wash or as necessary for operator safety; and
- washing exterior building surfaces, parking lots, driveways or sidewalks, except as necessary to apply surface treatments such as paint, preservatives, stucco, pavement or cement.

The following uses may be allowed when mandatory restrictions are in place:
- irrigation to establish a new lawn and new plantings during the months of May and September;
- irrigation of public parks and recreational fields before 9 am and after 5 pm;
- irrigation of gardens, flowers and ornamental plants by means of a hand-held hose or drip irrigation system; and
- irrigation of lawns by means of a hand-held hose.

Water uses NOT subject to mandatory restrictions are those required:
- for health or safety reasons;
- by regulation;
- for the production of food and fiber;
- for the maintenance of livestock; or
- to meet the core functions of a business (for example, irrigation by golf courses as necessary to maintain tees, greens, and minimal fairway watering, or irrigation by plant nurseries as necessary to maintain stock).

Public Notice of Seasonal Nonessential Outdoor Water Use Restrictions

Scituate shall notify its customers of the restrictions, including a detailed description of the restrictions and penalties for violating the restrictions, by April 15th each year.

Notice that restrictions have been put in place shall be filed each year with the Department within 14 days of the restriction's effective date. Filing shall be in writing on the form "Notification of Water Use Restrictions" available on MassDEP's website.

Nothing in the permit shall prevent Permittee from implementing water use restrictions that are more stringent than those set forth in this permit.

10. Water Conservation Requirements

At a minimum, Scituate shall implement the following conservation measures forthwith and shall be in compliance with these measures on or before September 1, 2018. Compliance with the water conservation requirements shall be reported to the Department upon request, unless otherwise noted below.

Table 5: Minimum Water Conservation Requirements
Leak Detection
1. At a minimum, conduct a full leak detection survey every three years. See also Special Condition 7.
2. Conduct leak detection of the entire distribution system within one year whenever the percentage of UAW increases by 5% or more (for example an increase from 3% to 8%) over the percentage reported on the ASR for the prior calendar year. Within 60 days of completing the leak detection survey, submit to the Department a report detailing the survey, any leaks uncovered as a result of the survey or otherwise, dates of repair and the estimated water savings as a result of the repairs.
3. Conduct field surveys for leaks and repair programs in accordance with the <u>AWWA Manual 36</u>.
4. Scituate shall have repair reports available for inspection by the Department. Scituate shall establish a schedule for repairing leaks that is at least as stringent as the following: o Leaks of 3 gallons per minute or more shall be repaired within 3 months of detection. o Leaks of less than 3 gallons per minute at hydrants and appurtenances shall be repaired as soon as possible. o Leaks of less than 3 gallons per minute shall be repaired in a timely manner, but in no event more than 6 months from detection, except that leaks in freeway, arterial or collector roadways shall be repaired when other roadwork is being performed on the roadway. Leaks shall be repaired in accordance with Scituate's priority schedule including leaks up to the property line, curb stop or service meter, as applicable. Scituate shall have water use regulations in place that require property owners to expeditiously repair leaks on their property.
Metering
1. Calibrate all source and finished water meters at least annually and report date of calibration on the ASR.
2. Scituate reports its system is 100% metered. All water distribution system users shall have properly sized service lines and meters that meet AWWA calibration and accuracy performance standards as set forth in <u>AWWA Manual M6 – Water Meters</u>.
3. Scituate shall have an ongoing program to inspect individual service meters to ensure that all service meters accurately measure the volume of water used by its customers. The metering program shall include regular meter maintenance, including testing, calibration, repair, replacement and checks for tampering to identify and correct illegal connections. The plan shall continue to include placement of sufficient funds in the annual budget to calibrate, repair, or replace meters as necessary.
Pricing
1. Scituate shall maintain a water pricing structure that includes the full cost of operating the water supply system. Scituate shall evaluate rates at a minimum every three to five years and adjust costs as needed. Full cost pricing factors all costs - operations, maintenance, capital, and indirect costs (environmental impacts,

Table 5: Minimum Water Conservation Requirements
watershed protection) - into prices.
2. Scituate shall not use decreasing block rates. Decreasing block rates which charge lower prices as water use increases during the billing period, are not allowed by M.G.L. Chapter 40 Section 39L.
Residential and Public Sector Conservation
1. Scituate shall meet the standards set forth in the Federal Energy Policy Act, 1992 and the Massachusetts Plumbing Code.
2. Meter or estimate water used by contractors using fire hydrants for pipe flushing and construction.
3. Scituate shall continue to ensure that water savings devices are installed in all municipal buildings as they are renovated, and shall ensure water conserving fixtures and landscaping practices are incorporating into the design of new municipal capital projects.
Industrial and Commercial Water Conservation
1. Scituate shall ensure water conservation practices in all development proposals, particularly low flow devices and water-wise landscaping practices.
Public Education and Outreach
1. Scituate shall continue to implement its water conservation and education efforts designed to educate the Town's water customers on ways to conserve water. Without limitation, Scituate's plan may include the following actions: o Include in bill stuffers and/or bills, a work sheet to enable customers to track water use and conservation efforts and estimate the dollar savings; o Public space advertising/media stories on successes (and failures); o Conservation information centers perhaps run jointly with electric or gas company; o Speakers for community organizations; o Public service announcements; radio/T.V./audio-visual presentations; o Joint advertising with hardware stores to promote conservation devices; o Use of civic and professional organization resources; o Special events such as Conservation Fairs; o Develop materials that are targeted to schools with media that appeals to children, including materials on water resource projects and field trips; and o Provide multilingual materials as needed.
2. Upon request of the Department, the Town of Scituate shall report on its public education and outreach effort, including a summary of activities developed for specific target audiences, any events or activities sponsored to promote water conservation and copies of written materials.

11. Minimization of Groundwater Withdrawal Impacts in Stressed Subbasins

Scituate shall minimize the impacts of its groundwater withdrawals from sources 4264000-01G, 02G, 03G, 05G and 011G, located in Subbasin 22132 as follows:

- Withdraw water from Well #18B, (4264000-12G), located in Subbasin 22091, to the extent practicable while still protecting the capacity and water quality of the source. Scituate has consistently pumped Well #18B at between 70% and 80% of its Department-approved maximum daily capacity throughout the 5 years prior to this permit renewal. This permit does not require that Scituate shift additional pumping to Well #18B because prolonged pumping at a higher rate could risk degradation of the source;
- Continue to participate in the work of the Scituate Water Study Committee and First Herring Brook Watershed Initiative to refine and implement the First Herring Brook Interim Operational Plan as outlined in **Special Condition 6**;
- Implement seasonal limits on nonessential outdoor water use as outlined in **Special Condition 9**;

- Implement the conservation program outlined in the Scituate Water Resources Committee Conservation Plan, adopted in March 2016, including but not limited to:
    - Installation and maintenance of radio-read meters;
    - Quarterly billing based on actual meter readings and comparing water use from year to year;
    - Continued use of an increasing block rate for residential water use explicitly designed to target increased summer outdoor water use;
    - Implementation of the pipe replacement program funded through a $22 million 2014 capital spending authorization.

12. Mitigation of Impacts for Withdrawals that Exceed Baseline

Scituate's Baseline Withdrawal is 1.80 MGD, based on Scituate's 2005 withdrawals plus 5%. **Prior to making average annual withdrawals greater than the 1.80 MGD baseline, Scituate is required to develop a mitigation plan for review and approval by MassDEP, incorporate the approved mitigation plan into this permit through a permit amendment (BRPWM02), and implement required mitigation activities.**

Thereafter, this renewed permit authorizes Scituate to withdraw up to 1.85 MGD without supplying Humarock, or 1.97 if Humarock is connected to the system. After calculating the adjustment for authorized withdrawals over baseline that will be returned to groundwater through septic system discharge, Scituate's total mitigation requirement will be up to 0.0245 MGD (24,500 gallons per day) without supplying Humarock, or 0.0833 MGD (83,300 gallons per day) if Humarock is connected to the system.

13. Reporting Requirements

Scituate shall report annually as required by completing the electronic Annual Statistical Report (eASR) for public water suppliers, and shall provide other reporting as specified in the Special Conditions above.

General Permit Conditions (applicable to all Permittees)

No withdrawal in excess of 100,000 gallons per day over the registered volume (if any) shall be made following the expiration of this permit, unless before that date the Department has received a renewal permit application pursuant to and in compliance with 310 CMR 36.00.

1. **Duty to Comply** The Permittee shall comply at all times with the terms and conditions of this permit, the Act and all applicable State and Federal statutes and regulations.

2. **Operation and Maintenance** The Permittee shall at all times properly operate and maintain all facilities and equipment installed or used to withdraw water so as not to impair the purposes and interests of the Act.

3. **Entry and Inspections** The Permittee or the Permittee's agent shall allow personnel or authorized agents or employees of the Department to enter and examine any property over which Permittee has authority, title or control, for the purpose of determining compliance with this permit, the Act or the regulations published pursuant thereto, upon presentation of proper identification and an oral statement of purpose.

4. **Water Emergency** Withdrawal volumes authorized by this permit are subject to restriction in any water emergency declared by the Department pursuant to M.G.L. c. 21G, §§ 15-17, M.G.L. c. 111, § 160, or any other enabling authority.

5. **Transfer of Permits** This permit shall not be transferred in whole or in part unless and until the Department approves such transfer in writing, pursuant to a transfer application on forms provided by the Department requesting such approval and received by the Department at least thirty (30) days before the

effective date of the proposed transfer. No transfer application shall be deemed filed unless it is accompanied by the applicable transfer fee established by 310 CMR 36.33.

6. **Duty to Report** The Permittee shall submit annually, on a form provided by the Department, a certified statement of the withdrawal. Such report is to be received by the Department by the date specified by the Department. Such report must be submitted as specified on the report form.

7. **Duty to Maintain Records** The Permittee shall be responsible for maintaining withdrawal and all other records as specified by this permit.

8. **Metering** Withdrawal points shall be metered. Meters shall be calibrated annually. Meters shall be maintained and replaced as necessary to ensure the accuracy of the withdrawal records.

9. **Right to Amend, Suspend or Terminate** The Department may amend, suspend or terminate the permit in accordance with M.G.L. c. 21G and 310 CMR 36.29.

APPEAL RIGHTS AND TIME LIMITS

This permit is a decision of the Department. Any person aggrieved by this decision may request an adjudicatory hearing as described herein and in accordance with the procedures described at 310 CMR 36.37. Any such request must be made in writing, by certified mail or hand delivered and received by the Department within twenty-one (21) days of the date of receipt of this permit. The hearing request, including proof of payment of the filing fee, must be mailed to:

Case Administrator
MassDEP Office of Appeals and Dispute Resolution
One Winter Street
Boston, MA 02108

No request for an appeal of this permit shall be validly filed unless a copy of the request is sent by certified mail, or delivered by hand to the local water resources management official in the community in which the withdrawal point is located; and for any person appealing this decision, who is not the applicant, unless such person notifies the permit applicant of the appeal in writing by certified mail or by hand within five (5) days of mailing the appeal to the Department.

CONTENTS OF HEARING REQUEST

310 CMR 1.01(6)(b) requires the request to include a clear and concise statement of the facts which are the grounds for the request and the relief sought. In addition, the request must include a statement of the reasons why the decision of the Department is not consistent with applicable rules and regulations, and for any person appealing this decision who is not the applicant, a clear and concise statement of how that person is aggrieved by the issuance of his permit.

FILING FEE AND ADDRESS

The Department's fee transmittal form, together with a valid check, payable to the Commonwealth of Massachusetts in the amount of $100 must be mailed to:

Commonwealth of Massachusetts
Department of Environmental Protection
P.O. Box 4062
Boston, MA 02211

The request shall be dismissed if the filing fee is not paid, unless the appellant is exempt or granted a waiver as described below.

EXEMPTIONS

The filing fee is not required if the appellant is a municipality (or municipal agency), county, district of the Commonwealth of Massachusetts, or a municipal housing authority.

WAIVER

The Department may waive the adjudicatory hearing filing fee for any person who demonstrates to the satisfaction of the Department that the fee will create an undue financial hardship. A person seeking a waiver must file, together with the hearing request, an affidavit setting forth the facts which support the claim of undue hardship.

Rebecca Weidman

Rebecca Weidman
Director, Division of Watershed Management
Bureau of Resource Protection

9/16/16
Date

Appendix A – Functional Equivalence with the 65 Residential Gallons Per Capita Day Performance Standard

MassDEP will consider PWS permittees who cannot meet the 65 RGPCD performance standard to be functionally equivalent, and in compliance with their permit, if they have an on-going program in place that ensures "best practices" for controlling residential water use as described below.

If the permittee fails to document compliance with the RGPCD performance standard in its 2018 Annual Statistical Report (ASR), or in any ASR thereafter, then the permittee must file with that ASR a Residential Gallons Per Capita Day Compliance Plan (RGPCD Plan) which shall include, at a minimum:

1. A description of the actions taken during the prior calendar year to meet the performance standard;
2. An analysis of the cause of the failure to meet the performance standard;
3. A description of the actions that will be taken to meet the performance standard which must include, at a minimum, at least one of the following:
   a) a program that provides water saving devices such as faucet aerators and low flow shower heads at cost;
   b) a program that provides rebates or other incentives for the purchase of low water use appliances (washing machines, dishwashers, and toilets), or
   c) the adoption and enforcement of an ordinance, by-law or regulation to require the installation of moisture sensors or similar climate related control technology on all automatic irrigation systems;

   and may include, without limitation, the following:
   d) the use of an increasing block water rate or a seasonal water rate structure as a tool to encourage water conservation;
   e) a program that provides rebates or other incentives for the installation of moisture sensors or similar climate related control technology on automatic irrigation systems;
   f) the adoption and enforcement of an ordinance, by-law or regulation to require that all new construction include water saving devices and low water use appliances;
   g) the adoption and enforcement of an ordinance, by-law or regulation to require that all new construction minimize lawn area and/or irrigated lawn area, maximize the use of drought resistant landscaping, and maximize the use of top soil with a high water retention rate;
   h) the implementation of a program to encourage the use of cisterns or rain barrels for outside watering;
   i) the implementation of monthly or quarterly billing.
4. A schedule for implementation; and
5. An analysis of how the planned actions will address the specific circumstances that resulted in the failure to meet the performance standard.

If the permittee is already implementing one or more of these programs, it must include in its RGPCD plan the continued implementation of such program(s), as well as implementation of at least one additional program. All programs must include a public information component designed to inform customers of the program and to encourage participation in the program.

RGPCD plans may be amended to revise the actions that will be taken to meet the performance standard. Amended RGPCD plans must include the information set forth above.

If a RGPCD plan is required, the permittee must:

1. submit information and supporting documentation sufficient to demonstrate compliance with its RGPCD plan annually at the time it files its ASR, and
2. continue to implement the RGPCD plan until it complies with the performance standard and such compliance is documented in the permittee's ASR for the calendar year in which the standard is met.

Appendix B – Functional Equivalence with the 10% Unaccounted for Water Performance Standard

MassDEP will consider PWS permittees who cannot meet the 10% UAW performance standard to be functionally equivalent, and in compliance with their permit, if they have an on-going program in place that ensures "best practices" for controlling water loss. The water loss control program will be based on annual water audits and guidance as described in the AWWA/IWA *Manual of Water Supply Practices – M36, Water Audits and Loss Control Programs* (AWWA M36).

If, as of December 31, 2019, the permittee fails to document compliance with the Unaccounted for Water performance standard (UAW of 10% or less for 2 of the 3 most recent years throughout the permit period), then the permittee shall develop and implement a water loss control program following the *AWWA M36 Water Audits and Loss Control Programs* within 5 full calendar years.

1. Conduct an annual "top down" Level 1 water audit, calculate the data validity level/score using AWWA Water Loss Control Committee's Free Water Audit Software, and submit the AWWA WLCC Free Water Audit Software: Reporting Worksheet and data validity score annually with its Annual Statistical Report (ASR).
    - If a PWS's data validity level/score is less than Level III (51-70), steps recommended through the audit(s) shall be taken to improve the reliability of the data prior to developing a long-term program to reduce real and apparent water losses.
    - Data with a validity score of 50 or less are considered too weak to be used to develop a component analysis or for infrastructure planning and maintenance.
    - Developing data with an acceptably strong validity score can be a multi-year process.
2. When the data validity score meets the Level III (51-70) requirement, the permittee shall conduct a component analysis to identify causes of real and apparent water loss and develop a program to control losses based on the results of the component analysis. The Permittee shall submit the component analysis and water loss control program with a proposed implementation schedule to the Department.
3. Continued implementation will be a condition of the permit in place of meeting the 10% UAW performance standard.
4. Upon request of the Department, the permittee shall report on its implementation of the water loss control program.

A PWS permittee may choose to discontinue the water loss program implementation if UAW, as reported on the ASR and approved by MassDEP, is below 10% for four consecutive years, and the water audit data validity scores are at least Level III (51-70) for the same four years.

> **NOTE FOR SMALL SYSTEMS**: For small systems with less than 3,000 service connections or a service connection density of less than 16 connections per mile of pipeline, the Unavoidable Annual Real Loss (UARL) calculation and the Infrastructure Leak Index (ILI) developed as the final steps of the top down water audit may not result in valid performance indicators, and may not be comparable to the UARL and ILI calculations for larger systems.
>
> However, these small systems can benefit from developing reliable data and conducting an annual top down water audit. Small systems can rely on the real losses (gallons per mile of main per day) performance indicator developed in the water audit as a measure of real water loss when developing a water loss control program. The M36 Manual discusses the audit process for small systems, and includes a chapter to guide small systems in understanding the results of their audits and in developing a water loss control program (*Manual of Water Supply Practices – M36, Fourth Edition, Chapter 9: Considerations for Small Systems*, pp. 293-305).

MassDEP UAW Water Loss Control Measures: Permittees who do not have MassDEP approved Water Loss Control Programs in place by 6th calendar year after 2019 will be required to implement the MassDEP UAW Water Loss Control Measures outlined below:

- An annual water audit and leak detection survey, as described in the AWWA M36 Manual, of the entire system.
    - Within one year, repair 75% (by water volume) of all leaks detected in the survey that are under the control of the public water system;
    - Thereafter, repair leaks as necessary to reduce permittee's UAW to 10% or the minimum level possible.
- Meter inspection and, as appropriate, repair, replace and calibrate water meters:
    - Large Meters (2" or greater) – within one year
    - Medium Meters (1" or greater and less than 2") – within 2 years
    - Small Meters (less than 1") - within three years
    - Thereafter, calibrate and or replace all meters according to type and specification.
- Bill at least quarterly within three years.
- Water pricing structure sufficient to pay the full cost of operating the system.

Hardship - A permittee may present an analysis of the cost effectiveness of implementing certain conservation measures included in the MassDEP UAW Water Loss Control Measures and offer alternative measures. Any analysis must explicitly consider environmental impacts and must produce equal or greater environmental benefits. Suppliers will be able to present:

- Reasons why specific measures are not cost effective because the cost would exceed the costs of alternative methods of achieving the appropriate standard;
- Alternative specific conservation measures that would result in equal or greater system-wide water savings or equal or greater environmental benefits than the conservation measures included in the MassDEP UAW Functional Equivalence Plan; and
- When applicable, an analysis demonstrating that implementation of specific measures will cause or exacerbate significant economic hardship.