Upper Nemasket River Enhancement Planning

From 2019 to 2022 several partners, working with the communities of Lakeville and Middleborough and other stakeholders of the Nemasket River, conducted two parallel planning efforts that assessed opportunities for improving river flow, flood mitigation, fish passage and recreational use along the Upper Nemasket River. Following are the results of both of these studies.

The *Upper Nemasket River Enhancement Plan Community Engagement Report* provides an overview of the stakeholder engagement process conducted by CommonPlace Landscape and Planning, in coordination with SRPEDD, Horsley Witten Group, The Nature Conservancy and Walberg Consulting. Through a series of public meetings, the project team explored the benefits and potential trade-offs of various management actions.

Concurrently, Horsley Witten conducted a Hydrology and Hydraulics (H&H) Modeling Study to assess current flow conditions and predicted conditions under potential management actions. The *Upper Nemasket River Hydrology and Hydraulics Modeling Study* report details the modeling process and results.

The H&H Study provides the technical foundation for assessing the impacts of the various management strategies on flow conditions. The results were interpreted for a public audience during the community engagement process to help the public understand and provide input on various management interventions under consideration.

Both of the attached reports should be considered side-by-side when planning for the future of the Upper Nemasket River. It is important management officials understand the impacts each action may have, both on riverine flow as well as the public's use of the river and its resources.

SRPEDD
Southeastern Regional Planning & Economic Development District

HORSLEY WITTEN GROUP
Sustainable Environmental Solutions

The Nature Conservancy

WALBERG CONSULTING

CommonPlace
Landscape and Planning

SNEP NETWORK

New England neefc
Environmental Finance Center

UPPER NEMASKET RIVER

ENHANCEMENT PLAN
COMMUNITY ENGAGEMENT REPORT

October 2022

CommonPlace Landscape and Planning's involvement in the Upper Nemasket River Enhancement Plan was made possible by a generous grant from the Taunton River Stewardship Council, stewards of the federally designated Wild & Scenic Taunton River.

Unless otherwise noted, all photographs are taken by Emily Vogler.

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SRPEDD
Southeastern Regional Planning & Economic Development District

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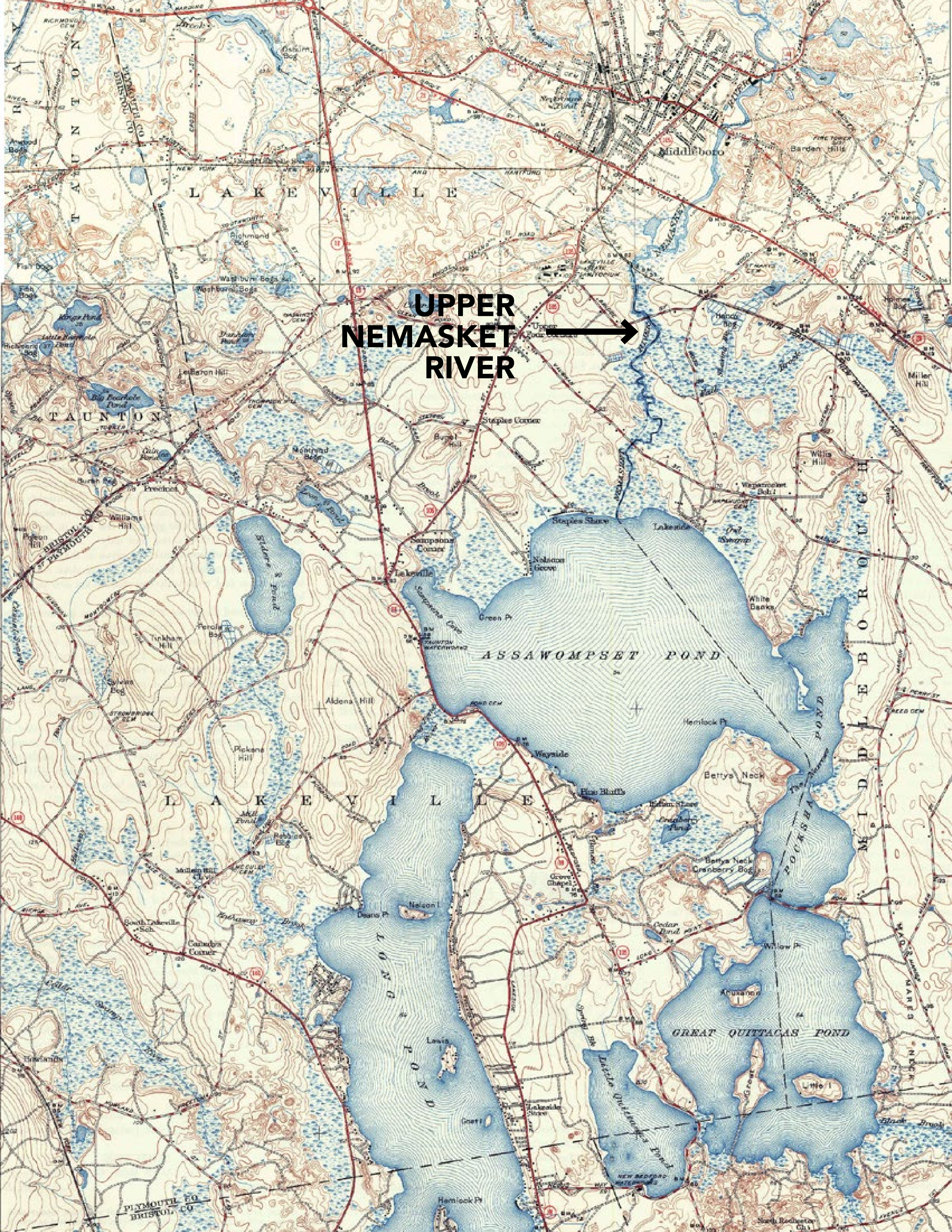
NEMASKET RIVER OVERVIEW


UPPER NEMASKET RIVER
LAKEVILLE
Middleboro
ASSAWOMPSET POND
LONG POND
GREAT QUITTACAS POND
POCKSHA POND
MIDDLEBOROUGH
TAUNTON
Elders Pond
Lakeville
Betty's Neck
Nelson I.
Lewis I.
Anuxanon
Little I.
Staples Shore
Green Pt
Hemlock Pt
Wayside
Pine Bluffs
Aldens Hill
Pickens Hill
Tinkham Hill
Williams Hill
Staples Corner
Sampsons Corner
White Banks
Lakeside
Willow Pt
Great Swamp
PLYMOUTH CO
BRISTOL CO

The Nemasket River is a small but important river in Southeast Massachusetts. It flows North 11.5 miles from the Assawompset Pond Complex through Middleborough to its confluence with the Taunton River. There are 3 dams between the confluence with the Taunton River and the Assawompset Pond Complex (APC); the Oliver Mill Dam at river mile 5.3 with an unknown owner, the Wareham St Dam at river mile 7.5 owned by the Town of Middleborough, and the Assawompset Pond Dam at river mile 11.5 owned by the City of New Bedford and Taunton. There are no dams on the Taunton River between the confluence of the Nemasket River and Narragansett Bay.

There currently are 4 main issues on the Nemasket River:

- **FISH PASSAGE** - The Assawompset Pond complex is the largest natural lake complex in Massachusetts and provides key spawning grounds for migratory fish. As a result, the Nemasket River supports one of the largest coastal river herring populations in Southeast New England. The Oliver Mill Dam has a bypass channel with a set of stream baffles, Wareham St. Dam has a large pool and weir ladder, and the Assawompset Pond Dam has a relatively small denil type fishway. However, fish can swim over the Assawompset Pond Dam during spring flows when the water level below the dam rises sufficiently to allow passage. When the pool level drops, the migrating herring use the fishway.
- **FLOW -** The flow of the Nemasket River has been altered by the construction of dams. The slowing of the river between the dams and the erosion and migration of sediment from the Assawompset Pond Complex has led to an increase in sedimentation along the Nemasket River. The sediment has collected in the river channel and the shallow bottom has in turn led to the growth of invasive aquatic weeds that have further restricted the flow of water. The shallow channel and excessive aquatic plants make it difficult for migratory fish to navigate the river. In addition, the low flow of the river in summer months limit the recreational opportunities on the river.
- **FLOODING** - Due to the relatively flat topography, altered hydrology and development near the Nemasket River, there are issues with flooding. In 2010 there was a 100-year flood that severely impacted the surrounding communities of Lakeville, Rochester, Freetown, and Middleborough. A storm event like that will happen again and it is important to address the flow issues in the river to reduce the future impact of flooding on residences and infrastructure.
- **WATER QUALITY -** Massachusetts Department of Environmental Protection (MASS DEP) recently added the Upper Nemasket River to the Impaired Water list for not supporting the Aquatic Life Use due to low dissolved oxygen, high temperatures, and aquatic toxicity. Dams, water temperature and excessive aquatic plant growth can lead to low oxygen conditions.

Historic photos and historical accounts of the river help us to understand these issues within the historical context. While things have gotten worse over time, the issues of aquatic plants, sediment, low flows, flooding, and fish passage are not new to the Nemasket River. On the following pages are historic photos of the river that highlight some of these persistent issues.

Swale grass being cut from the banks of the Nemasket River. The grass was used as animal fodder well into the late 19th century. In addition, to help the flow of the water to the water wheels, men would wade the river during August of each year and mow the weeds from the edge of the banks with scythes. (Town of Middleborough. Unknown photographer. https://www.southcoasttoday.com/story/news/local/the-gazette/2012/08/16/fickle-little-stream-Nemasket-river/49463293007/

Herring Harvest at Muttock (Oliver Mill Park), late 19th century. (Unknown photographer, Recollecting Nemasket Blogspot)

Despite the growing popularity, of the steam boat in the 1800's, steam boating on the Nemasket River was fraught with difficulty including rocks, small shoals, fluctuating water levels and a prodigious growth of grass which often made passage difficult. (Unknown photographer. Recollecting Nemasket Blogspot)

Photo from the 2010 flood. Tom Richardson rescues one of his cats from his home in Freetown near Long Pond (Peter Pereira from the Standard Times)

The Nemasket River at Wareham Street in Middleborough was once part of the industrial complex known as the Upper Factory that included a cotton mill, shovel works, grist and saw mills, and a forge. It was here at the Upper Factory that the last shovels manufactured in Middleborough were made in 1883. (Unknown Photographer)

In the years surrounding 1900, rowing and canoeing on the Nemasket River came into vogue. The popularity of the river resulted in the construction of a number of boathouses, especially near East Grove Street. Photographs of recreational use of the river on this and the following page. (Unknown Photographer)

UPPER NEMASKET RIVER ENHANCEMENT PLAN

COMMUNITY ENGAGEMENT

UPPER NEMASKET RIVER ENHANCEMENT PLAN

In 2018, the Southeastern Regional Planning and Economic Development District (SRPEDD) and its partners at Mass Audubon, Manomet Inc., Horsley Witten Group, and The Nature Conservancy received a grant from the Massachusetts Division of Ecological Restoration (MASS DER) to work with the long-standing, inter-municipal and inter-agency Assawompset Ponds Complex Management Team to design a flood water management program for the APC and Nemasket.

The purpose of the project was to examine all previous studies of this system, going back 40 years up to the present, to prioritize actions and set the stage for the implementation of priority actions that advance floodwater management in the APC and Nemasket River. SRPEDD sought a floodwater management framework that wove together the threads of previous recommendations with a program for prioritizing actions in order to achieve a basis for further funding and implementation of the highest priority mitigation actions. This work was grounded in concerns for future flooding impacts brought about by climate change, the goal to use the best knowledge garnered from past efforts paired with modern priorities to identify the key most effective and significant projects to pursue, and to take a holistic approach to floodwater management that combined the positive effects of both green and grey infrastructure approaches.

Coming out of that study, SRPEDD was able to secure additional funding for the *Upper Nemasket River Enhancement Plan*. The *Enhancement Plan* is made up of two parts- the Hydrologic and Hydraulic Study (H&H study) undertaken by Horsley Witten Group and the Community Outreach led by Commonplace Landscape and Planning in collaboration with SRPEDD staff.

COMMUNITY ENGAGEMENT APPROACH

Commonplace Landscape and Planning was brought into the process to lead the community outreach for the *Upper Nemasket River Enhancement Plan*. Given the underlying issues of flooding, flow, fish passage and water quality on the river, and the long history of the APC Management Team trying to address these issues, there was an opportunity to bring the community together to discuss possible ways to help strengthen the resilience of the local community to future floods, improve the ecological and hydrological connectivity along the river and improve recreational opportunities in the region. The goal of the outreach was to bring together the general public and state and local organizations, agencies and nonprofits to take a systematic and holistic approach to looking at all the issues along the Nemasket River and explore alternatives that could provide multiple benefits.

The following values and assumptions guided our involvement in the project:

- Environmental management decisions benefit from a meaningful and robust input from surrounding communities.
- Both scientific facts and individual and community values should be factored into the decision making process.
- The goal is to support and facilitate the discussion but not to advocate for any specific solution.

For this project, we used a method that brought together the community engagement work that is common in design charrettes with the methods used in Structured Decision Making (SDM). Structured Decision Making is founded on the idea that good decisions are grounded in an in-depth understanding of both values (what is important) and consequences (what is likely to happen if an alternative is implemented). It is based on the assumption that there are not "right decisions" so aims to help inform and make decisions transparent rather than prescribe a preferred solution. In our hybrid approach, we loosely structure our work around the Structured Decision Making framework and brought it together with the creative and visual work that is common at design charrettes for engaging a broader public audience.

	BENEFITS	**LIMITS**
STRUCTURED DECISION MAKING	• Clearly defined process for coming to a decision • Ability to evaluate alternatives based on performance measures	• Limited guidance on how to engage the public in decision making
CHARRETTES	• Geared toward groups of the general public • Use of visualizations to communicate about complex alternatives • Guidance on facilitation	• Often more open ended design process without clear guidance on how to make a final decision.

FIGURE 1: Benefits and limitations to the Structured Decision Making process and Charrettes that lend themselves to a hybrid approach

It is important to note, that between the initial planning of the community outreach strategy and the actual meetings, the COVID pandemic caused a major disruption in the world. The majority of our community engagement work had to shift to being online. This led to significant challenges but also some unforeseen benefits. The interactive methods originally proposed were much harder to do online so the project team had to come up with new and creative ways to engage the community during the online meetings. In addition, the casual conversations, relationship building and connections that normally take place during in person meetings were not possible. However one of the benefits of shifting the meetings to being online was that some people who might not have been able to participate, could join the meetings from home remotely.

Below is a list of traditional steps in the Structured Decision Making process: problem framing, determining objectives, identifying alternatives, estimating consequences, evaluating trade-offs, and deciding and taking actions. Below that is the way that the process aligned with the community outreach for the *Upper Nemasket River Enhancement Plan.*

STEPS IN PROCESS	UNDERLYING QUESTION
1. Problem Framing	What is the context for (scope and bounds of) the decision?
2. Determining Objectives	What objectives and performance measures will be used to identify and evaluate the alternatives?
3. Identifying Alternatives	What are the alternative actions or strategies under consideration?
4. Estimating Consequences	What are the expected consequences of these actions or strategies?
5. Evaluating Trade-offs	What are the key trade-offs among consequences?
6. Deciding And Taking Actions.	How can the decision be implemented in a way that promotes learning over time and provides opportunities to revise management actions based on what is learned?

FIGURE 2: Traditional steps in the Structured Decision Making process

STEPS IN THE UPPER NEMASKET RIVER ENHANCEMENT PLANNING PROCESS:

STEP 1: PROBLEM FRAMING (PROJECT TEAM AND STEERING COMMITTEE)

STEP 2: DETERMINING PROJECT OBJECTIVES (PUBLIC MEETING 1)

STEP 3: IDENTIFY ALTERNATIVES (PUBLIC MEETING 2)

STEP 4: ESTIMATE CONSEQUENCES (H&H MODEL)

STEP 5: EVALUATE TRADE-OFFS (PUBLIC MEETING 3)

STEP 6: DECIDING AND TAKING ACTION

FIGURE 3: Steps in the Structured Decision Making process adapted to the planning process for the Upper Nemasket River Enhancement Plan

COMMUNITY

There were 3 main groups that participated in this work. Their involvement informed one another at various stages of the process.

STEERING COMMITTEE - The Steering Committee was made up of members of the APC Management Team, community leaders, Town officials and others involved in the stewardship and management of the Nemasket River. There is a long history of community leadership in decisions about the management the APC. The APC Management Team is a long-standing body with representatives from each community, herring fishery stakeholders, state agencies, and water supply entities. For the Upper Nemasket River Enhancement Plan Steering Committee, we aimed to work with select members of the APC Management Team and bring in other community members with expertise on the river. Below is the list of the *Upper Nemasket River Enhancement Plan* Steering Committee Members:

- **Nancy Yeatts -** Town of Lakeville, Environmental Manager of the APC
- **Tom Barron -** Herring Commission
- **Trish Cassady -** Town of Middleborough, Cons. Agent
- **Lia Fabian -**Town of Lakeville, Selectman
- **Mike Arruda -** City of Taunton, Water Supervisor
- **Ymane Galotti -** NB water supply - director
- **Patti Kellogg -**MASS DEP
- **Chris Peck -** Middleborough, Director of Public Works
- **Martha Schroeder -** Lakeville Open Space Recreation Committee
- **Monica Bently-** TRWA, Wild and Scenic Taunton River Stewardship Council (NPS), Chair of the W & S Council's River Access Committee
- **James (Jim) Turek-** NOAA, Restoration Ecologist
- **Brad Chase -** MA DMF, Diadromous Fisheries Project Leader
- **Nathan Demers-** Representative from Middleborough BOS
- **Roger Desrosiers (Gray Fox) -** Dighton Intertribal Indian Council
- **Donna Desrosiers (Spirit Fox) -** Dighton Intertribal Indian Council

PROJECT TEAM - The project team was brought together by SRPEDD to provide the technical expertise needed for the project. The team met on a monthly basis throughout the planning process.

- **SRPEDD**- Project management and oversight and assisting with community engagement
- **Horsley Witten Group:** Hydrology and Hydraulic study that looked at the current and projected flow of various alternatives.
- **The Nature Conservancy -** Consulting on the ecological impact of alternatives on fish and other species
- **Manomet -** Climate Consultant
- **CommonPlace Landscape and Planning:** Community Outreach Consultant

COMMUNITY - The management of the Assawompset Pond Complex and Nemasket River impacts many people. The ponds provide water for approximately 250,000 people, the river is used as recreation by many from within the community and beyond, the river is a significant part of the communities' history and identity with the Herring Festival and public space surrounding the river, and the management of the ponds and river will affect flooding which will impact both residents that live along the river and ponds as well as the Town of Middleborough. The community was invited to participate at 3 key points in the planning process. The table on the following page explains the timing of the public involvement in the process and how it related to the Steering Committee and project team work.

STEERING COMMITTEE	PUBLIC MEETINGS	PROJECT TEAM
Steering Committee Meetings • Discuss the framing of the project • Outline and discuss the process • Identify objectives/and performance measures		• Research into the river system • Modeling of existing conditions
	1st Public Meeting: • Share what is currently known about the River • Explain the process and the "river scale" approach. • Use "Trade-off cards" to discuss what are the important issues for the community. • Get feedback on objectives and performance measures	
Steering Committee Meetings • Reflect on public meeting • Discuss alternatives to pursue in technical study		
	2nd Public Meeting: • Review project objectives • Discuss the alternative packages	
		• H&H Model of the alternatives
Steering Committee Meetings • Discuss modeling results • Develop consequence matrix for alternatives per technical reports		
	3rd Public Meeting: • Discuss the final selected alternatives • Evaluate the impact of the alternatives • Indicate preferred alternatives	
Steering Committee Meetings • Reflect on public meeting • Finalize preferred alternative • Discuss final report		
		• Develop Final reports
	SHARE FINAL REPORT	

FIGURE 4: Table explaining the relationship and interaction between different groups on the project

TIMELINE

The Upper Nemasket Enhancement Planning process took place between 2000 and 2022. Due to COVID and other factors, the process took longer than originally planned but the extended timeline allowed the time needed to get valuable feedback from the Steering Committee and the public and to run the full suite of alternatives through the H&H model.

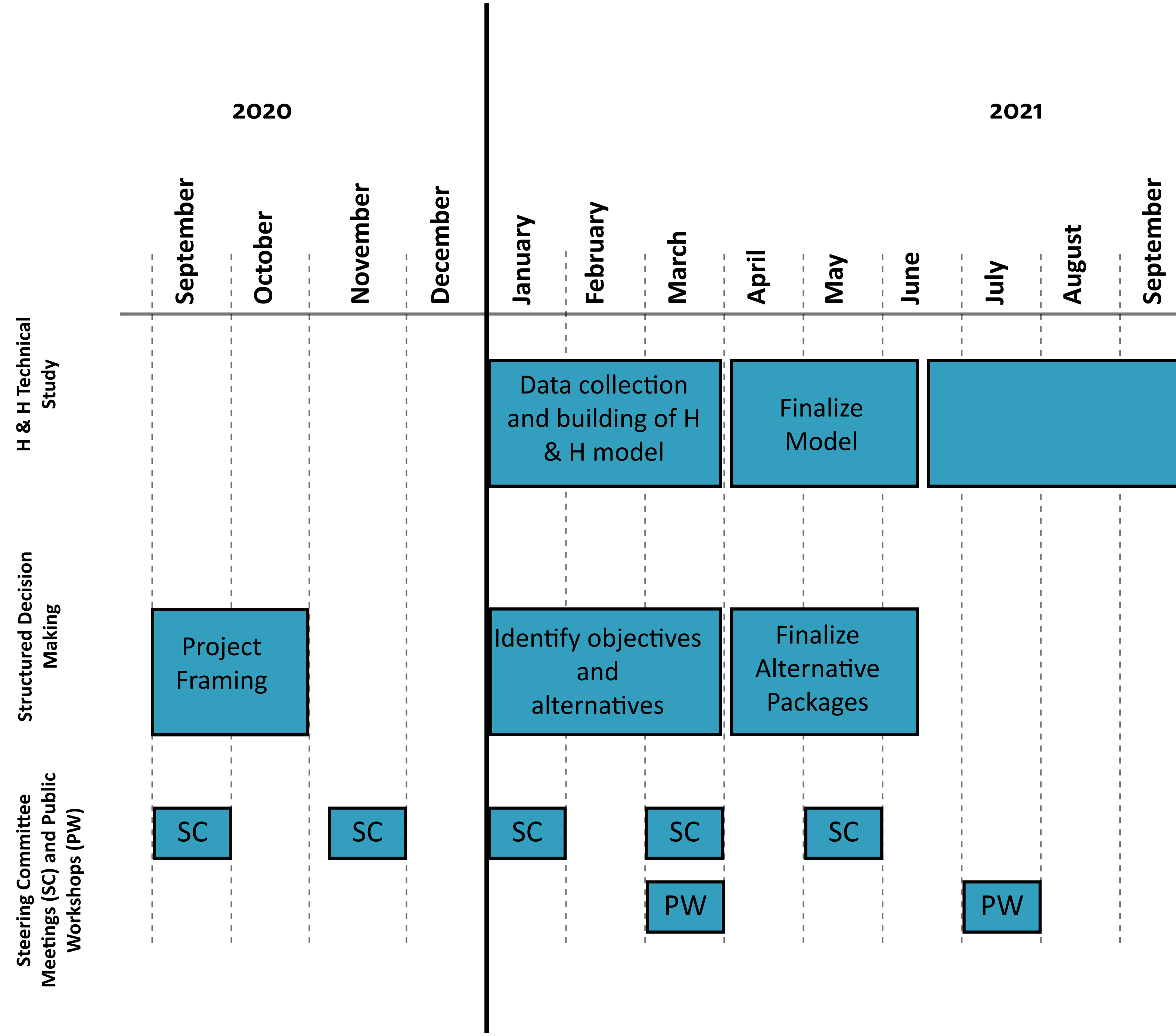
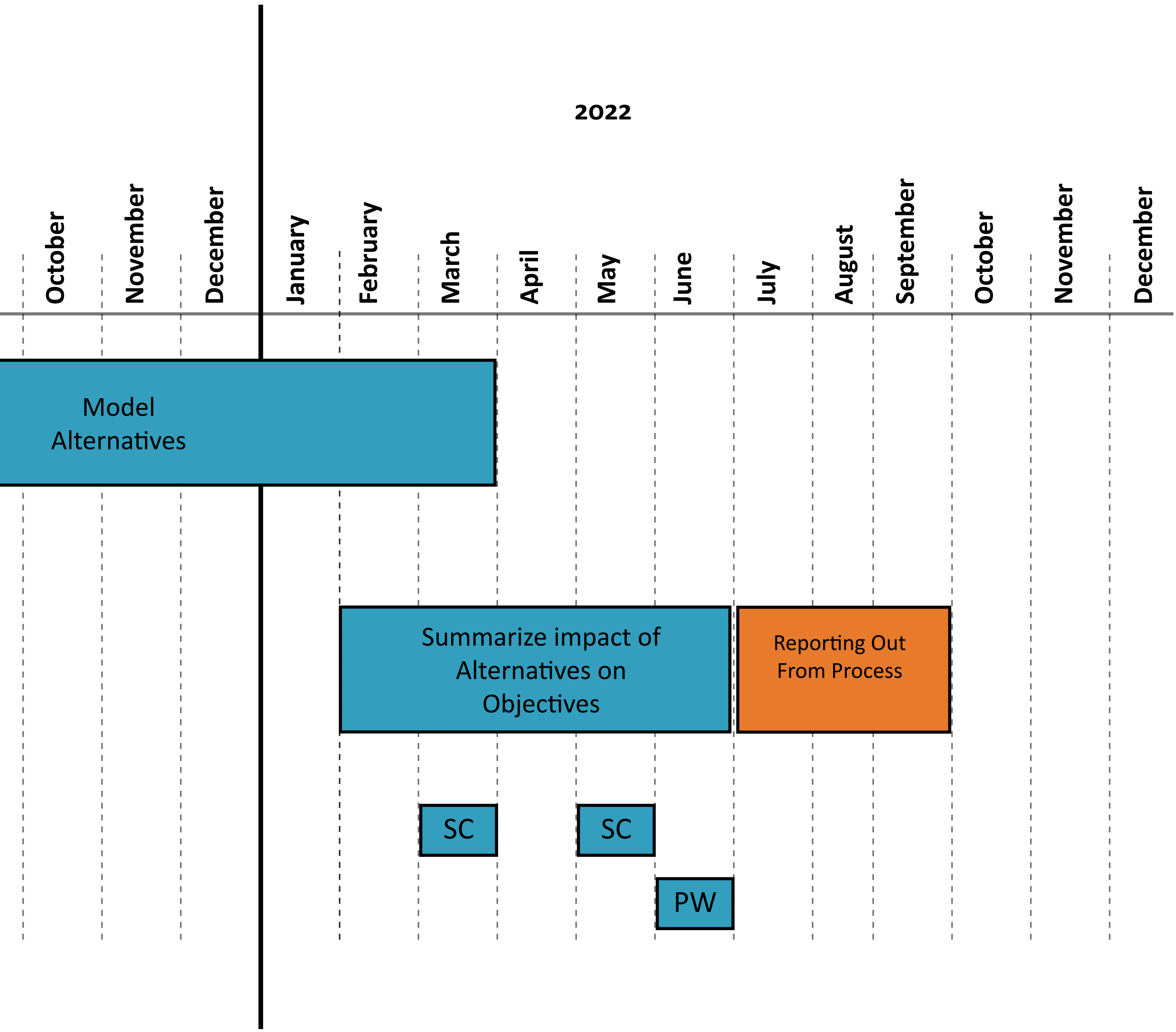


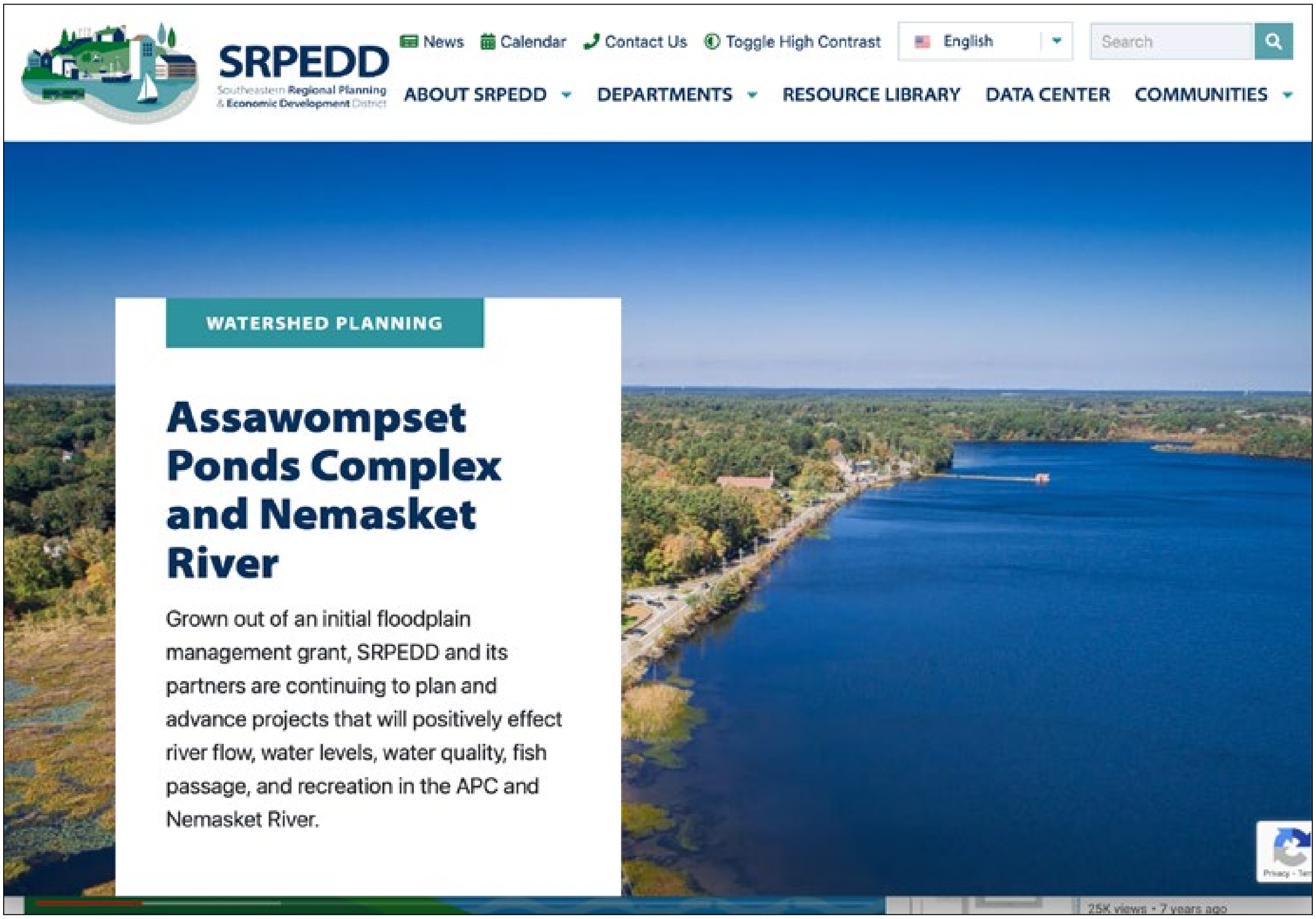
FIGURE 5: Project Timeline


2022
October
November
December
January
February
March
April
May
June
July
August
September
October
November
December
Model Alternatives
Summarize impact of Alternatives on Objectives
Reporting Out From Process
SC
SC
PW

ADDITIONAL OUTREACH

In addition to the public meetings, there were multiple other ways that the public could connect with the project. In June of 2021, Commonplace Landscape and Planning organized a paddle through the Upper Nemasket River. This allowed members of the project team, the steering committee and the public to see some of the issues on the river first hand.

The SRPEDD website is the clearinghouse for information about all the inter-related initiatives on the APC and Nemasket River. A survey was placed on the website to provide an additional way for people to provide feedback on the project. And lastly, the project team had a table set up at the Herring Festival to talk about the *Watershed and Climate Action Plan* and there was additional information about the third public meeting.



Nemasket River Enhancement

We're all working together to improve the Nemasket.

Give us your thoughts so that future actions in the River reflect your vision and priorities. Thank you!

1. When you imagine a healthy resilient Nemasket River, what does that look like to you? We suggest including at least three descriptive words or phrases if they readily come to mind.


Assawompset Pond Complex & Nemasket River
Watershed Management and Climate Action Plan
WATERSHED AREA = AREA COVERED IN THE PLAN
PARTICIPATING CITIES & TOWNS
Pondside Communities
Freetown
Lakeville
Middleborough
Rochester
Communities Drawing Water Supply
New Bedford
Taunton
GET INVOLVED!
PROJECT WEBSITE
www.srpedd.org/apc-nemasket-plan

Community Paddle on the Upper Nemasket River in June 2021.

STEP 1:
PROJECT FRAMING

PROBLEM FRAMING - DETERMINING SCOPE

One of the first steps was to frame the issues that we were trying to address through the planning process and determine the scope of work. Given the short length of the Nemasket River, the proximity and hydrological influence of the dams on one another, and the interconnectedness of the issues facing the river, it suggested that taking a holistic approach to addressing the issues along the whole upper river system would be beneficial. This broader systematic approach would lead to greater opportunities to find alternatives that create multiple social, ecological, and hydrological benefits rather than if the river is addressed in a piecemeal way (ex..looking at one dam at a time, dredging the river or removing the invasive aquatic plants without addressing the larger issues of flow).

The scope of work for the *Upper Nemasket River Enhancement Plan* is defined as extending from the Assawompset Pond Dam to Route 105 and includes the river channel and 8 bridge crossings within this 4 mile stretch of the river. While this study focused on the river due to what the H&H model could study, no river can be understood or studied without looking at the broader watershed context. In this case, a parallel and interrelated planning process for the *Assawompset Pond And Nemasket River Watershed Management And Climate Action Plan* covered these broader watershed scale issues.

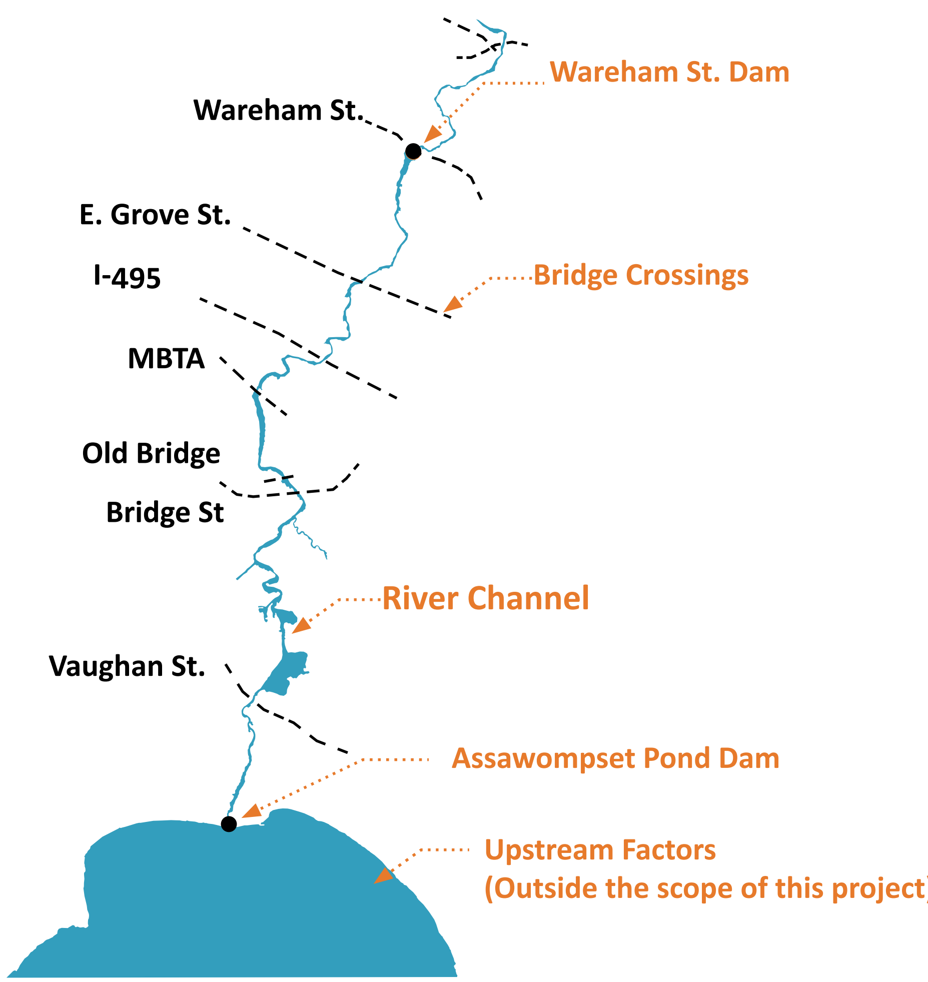
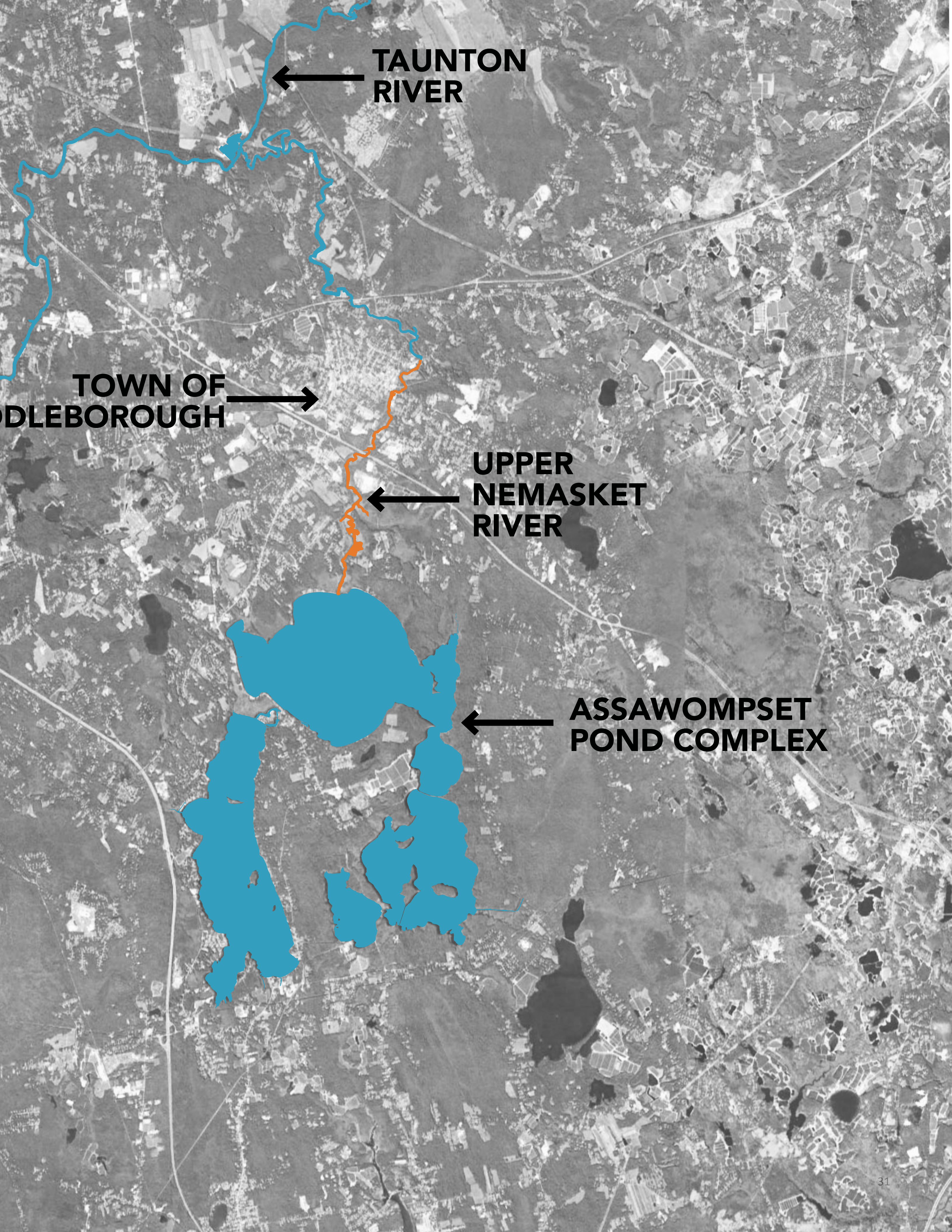


FIGURE 6: Scope of work


TOWN OF
TAUNTON
MID


TAUNTON
RIVER
TOWN OF
DDLEBOROUGH
UPPER
NEMASKET
RIVER
ASSAWOMPSET
POND COMPLEX

ASSAWOMPSET POND AND NEMASKET RIVER WATERSHED MANAGEMENT AND CLIMATE ACTION PLAN

Simultaneous to the development of the *Upper Nemasket River Enhancement Plan*, SRPEDD and other members of the project team were running a parallel community process surrounding the *Assawompset Pond And Nemasket River Watershed Management And Climate Action Plan*. The goal of the *APC and Nemasket River Watershed Management And Climate Action Plan* was to set priorities for improving the Assawompset Pond Complex and Nemasket River and extend these strategies to meet future conditions brought about by climate change. As part of the *Watershed Management And Climate Action Plan*, SRPEDD identified key strategies for balancing the essential functions of the APC and Nemasket River, especially in the areas of water supply maintenance, floodwater management, water quality, stormwater infiltration, habitat enhancement, land development, and recreational access. The plan recommendations included engineered and nature-based solutions for near-term and long-term floodwater mitigation, improved water quality, and consistent water supply in the APC as climate change occurs.

One of the first things that we needed to do as a project team for the *Upper Nemasket River Enhancement Plan* was to determine how the two concurrent planning processes related to each other and what was inside and outside of the scope of the *Upper Nemasket River Enhancement Plan.* We also had to be careful to consistently clarify this for the Steering Committee and the public. Since many members of the project team overlapped the two planning processes, there were significant opportunities for the concurrent planing processes to inform one another.

There were a couple of key issues that fell outside the scope of the *Upper Nemasket River Enhancement Plan:*

- Although development, land use, impervious surfaces and the management of stormwater throughout the watershed is one of the most important factors for addressing flooding, that issue fell within the *Watershed Management And Climate Action Plan* and not within the *Upper Nemasket River Enhancement Plan*.
- A second and important factor that fell outside of the scope of what we were addressing within the *Enhancement Plan* was water management permits and the operation and management of the dams. The Assawompset Pond Complex provides water for approximately 250,000 people in the cities of New Bedford, Taunton, and portions of other nearby towns. Sometimes there is tension between withdraws from water suppliers and the need to have water flowing in the Nemasket River. While this is an incredibly important issue, it also fell outside of this planning process because it came down to permitting and the operations of the dam. Our goal with the *Upper Nemasket River Enhancement Plan* was to determine the optimal configuration for the APC Dam to allow the maximum flexibility for releasing or holding back water.

On the following pages, the key components of the Upper Nemasket River are described in more detail.

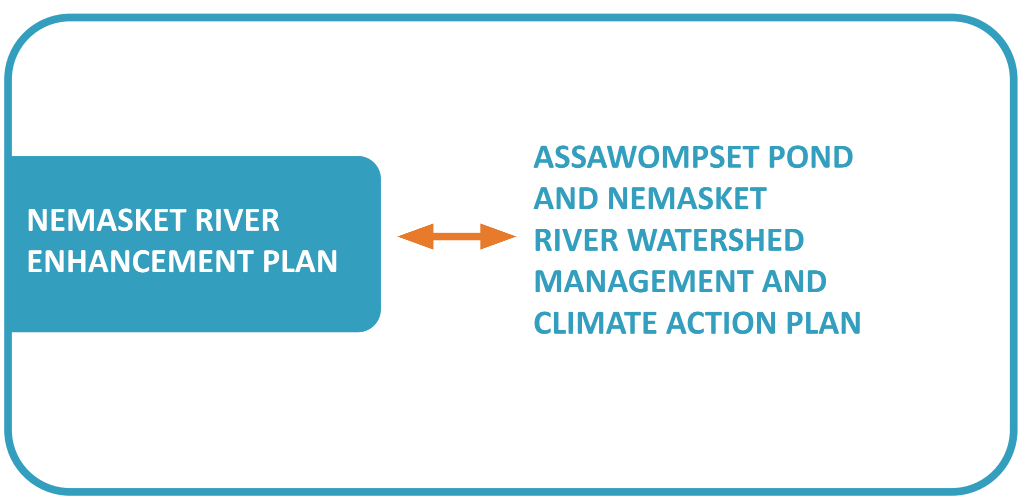
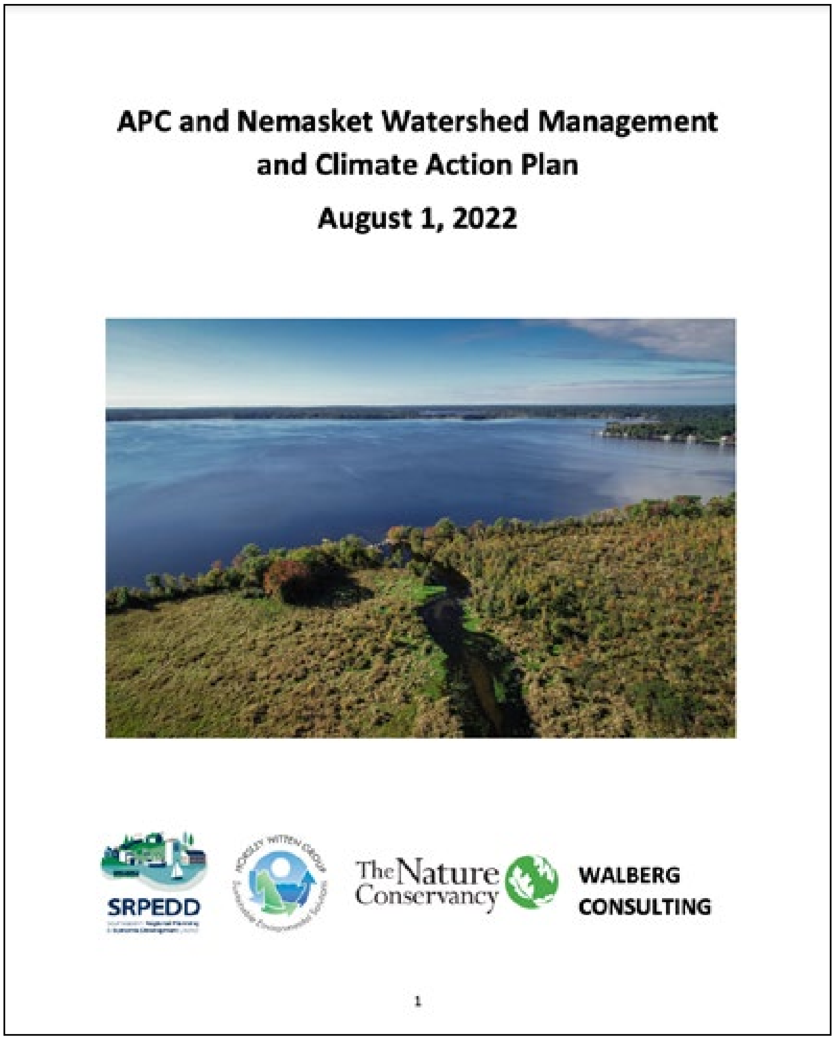


FIGURE 7: Diagram communicating the relationship between the two concurrent planning processes.


APC and Nemasket Watershed Management and Climate Action Plan

August 1, 2022

SRPEDD

The Nature Conservancy

WALBERG CONSULTING

1

FIGURE 8: The full APC And Nemasket River Watershed Management And Climate Action Plan was completed in August 2022 and can be viewed on the SRPEDD website.

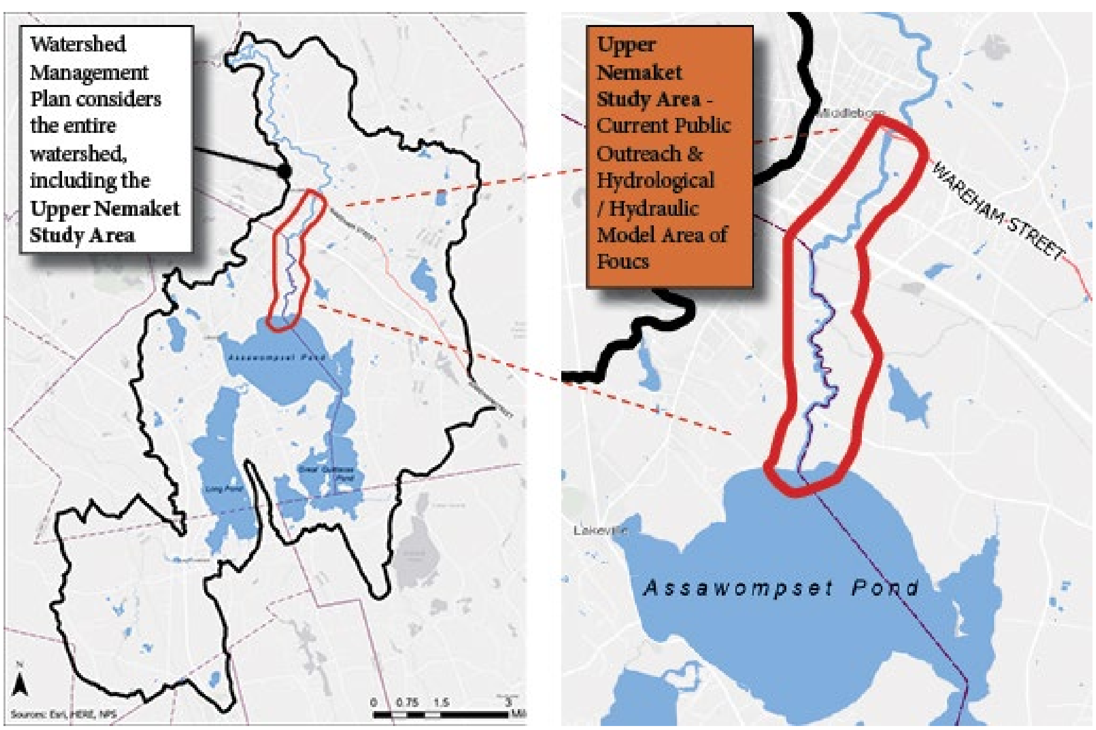


FIGURE 9: Map communicating the relationship between the two concurrent planning processes.


ASSAWOMPSET
POND DAM

ASSAWOMPSET POND DAM

The Assawompset Pond Dam was constructed in 1894. The spillway is constructed of stone piers with 5 bays that allow water to pass through (the photo on left is looking north at the dam and the photo on the following page is looking south). An earthen dyke continues along the northern edge of the Assawompset Pond. The water levels in the pond are controlled by wooden boards that are placed across the spillway bays. When all the boards are removed, the water can flow unrestricted from the ponds into the river (there is no drop in elevation). While the dam is used to manage lake elevations to balance the needs of the pond as a water supply as well as manage the amount of water flowing into Nemasket river, it wasn't built for this purpose. The dam is very crude and everything has to be done manually. This includes operators having to walk out onto the stone piers to insert boards which is dangerous during flood conditions. In addition, the knowledge of how the dam works is based entirely on the operators experience and knowledge. They know which boards fit together and which boards will achieve the desired height across all 5 bays. There is a fish ladder on the East side of the spillway however during low flow water does not flow over fish ladder

One of the primary tensions within the APC and the Nemasket River system is the operations of the APC Dam to balance the needs of the water suppliers, flood management and the ecology of the river.


SSAWOMPSET
POND DAM


WAREHAM
STREET DAM
Image credit: Horsley Witten

WAREHAM STREET DAM

There are two dams at Wareham Street. One that is directly below the Wareham Street Bridge (pictured to the left) and a small 3’ weir 200 ft downstream (pictured on next page). The main dam below the bridge can be adjusted to hold back or release water and also to control the amount of water going over the fish ladder.

There is a 300‘ pool and wier fish ladder that bypasses the two dam structures. While the bypass fish ladder does allow fish to pass upstream during the spring migration, it is a pinch point preventing a greater number of fish from going upstream. In addition, water doesn’t flow over the fish ladder during low flow conditions making the egress of small fry in the fall during low flow conditions challenging.

The Town of Middleborough has municipal wells upstream of the Wareham Street Dam. Any modifications to the dam would need to study the potential impact on the wells.


WAREHAM
STREET WEIR


VAUGHN
STREET
BRIDGE

BRIDGE CROSSINGS

There are seven bridge crossing between the Assawompset Pond Dam and the Wareham Street Dam (Photos of each of the bridges on the following pages from South to North). Many of the bridges were not built to current standards of flow (1.2 x bankfull width) and are pinch point on the river leading to increase in sedimentation and vegetation behind the bridge structures. Bankfull width means the width of the surface of the water at the point where water just begins to overflow into the active flood plain. The H&H study looked at each of the bridges to understand whether or not they are restricting the flow of the river.

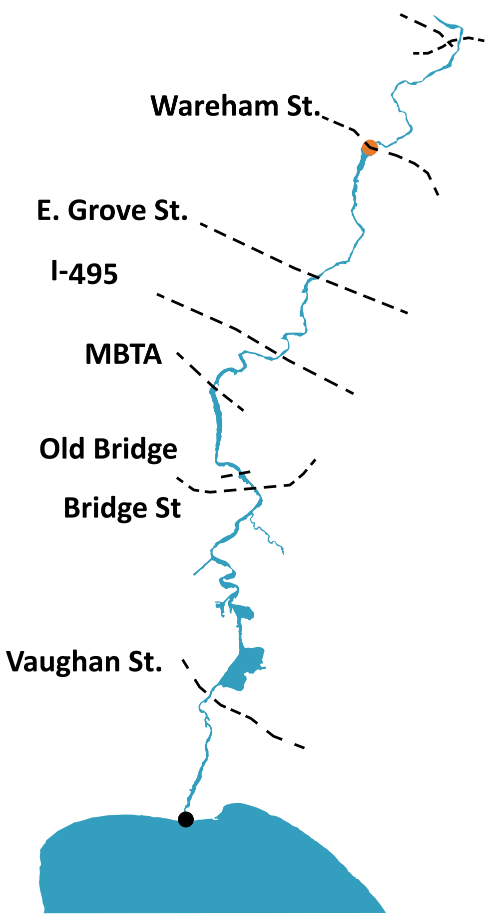


FIGURE 10: Bridge Crossings


BRIDGE
STREET
BRIDGE


OLD BRIDGE
STREET
BRIDGE
1910


MBTA
BRIDGE


495
BRIDGE


EAST GROVE ST/
RT 28
BRIDGE


WAREHAM
STREET
BRIDGE
CAUTION
DAM
AHEAD


UPPER NEMASKET
RIVER CHANNEL

UPPER NEMASKET RIVER CHANNEL

The Upper Nemasket River is a shallow low gradient river. The relatively flat topography combined with the construction of dams and restrictions from bridge crossings has led to the river collecting significant sediment over time. The shallow river and slow flowing water has led to the proliferation of excessive aquatic weed growth in sections of the river which further restrict flows. During many summer months, the river has very low flow. The combination of low flow, excessive aquatic plant growth and shallow conditions lead to decreased recreation and fish passage. The excessive aquatic weed growth also impairs water quality

Due to the low gradient of the river, the river can also experience flood conditions. Since there is not a lot of elevation change in the river, when there is a flood, the water spreads out rather than going downstream. While there are things that can be done to address the excess sediment and aquatic vegetation, this underlying topography of the region can not be altered.

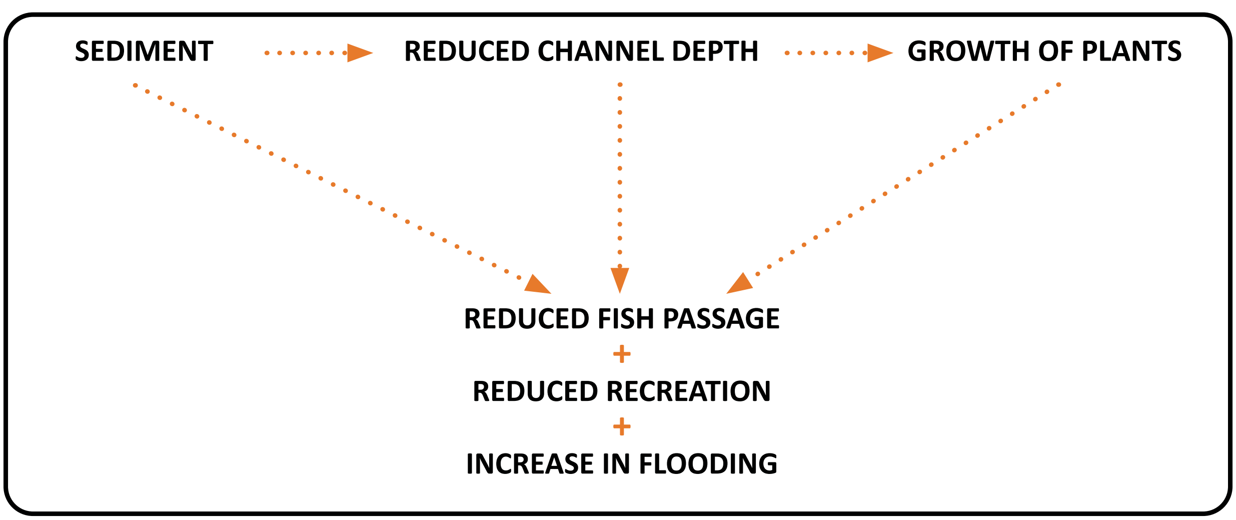


FIGURE 11: Diagram of some of the interconnected issues on the river.

IMPACT OF DAMS ON RIVER ECOLOGY

Due to the construction of dams, the ecology of the Nemasket River has been altered. When water collects in an impoundment behind a dam, the sediment drops out leading to an increase in siltation and turbidity. In addition, due to the open water and lack of canopy cover, impoundments have increased water temperatures which hold less dissolved oxygen leading to a decrease in the water quality. While impoundments are suitable for some common species, they eliminates the riffles, runs, and pools that are important for some habitat specialists. The diagrams and bullet points below summarize some the ecological impacts that dams have on river ecologies.

EXISTING CONDITIONS - DAMS + OBSTRUCTIONS

- Increases siltation and turbidity
- Increases water temperatures which hold less dissolved oxygen
- Suitable for some common species, such as mallards, sunfish, and painted and snapping turtles, and some invasive plants tolerant of more degraded conditions.
- Alters substrates, native vegetation, and eliminates riffles, runs, and pools important for some habitat specialists

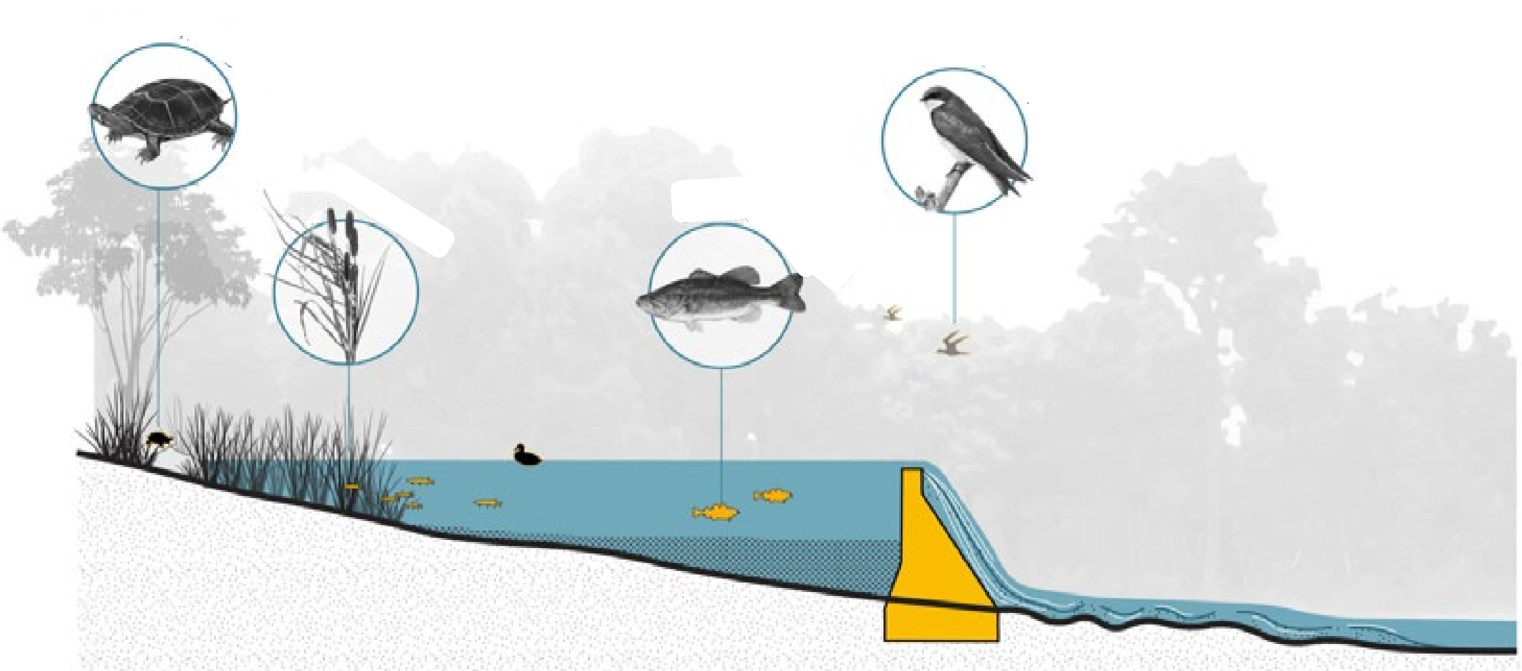


FIGURE 12: Ecology of a dammed river

FREE-FLOWING RIVER CONDITIONS

- Allows for unobstructed fish and wildlife passage
- Helps maintain adequate water quantity
- Maintains cooler water temperatures which increases dissolved oxygen levels
- Transports sediments downstream.
- Provides habitat for specialists, such as spawning blueback herring, bridle shiner, and invertebrates associated with good water quality, including freshwater mussels, caddisflies, mayflies, and stoneflies.

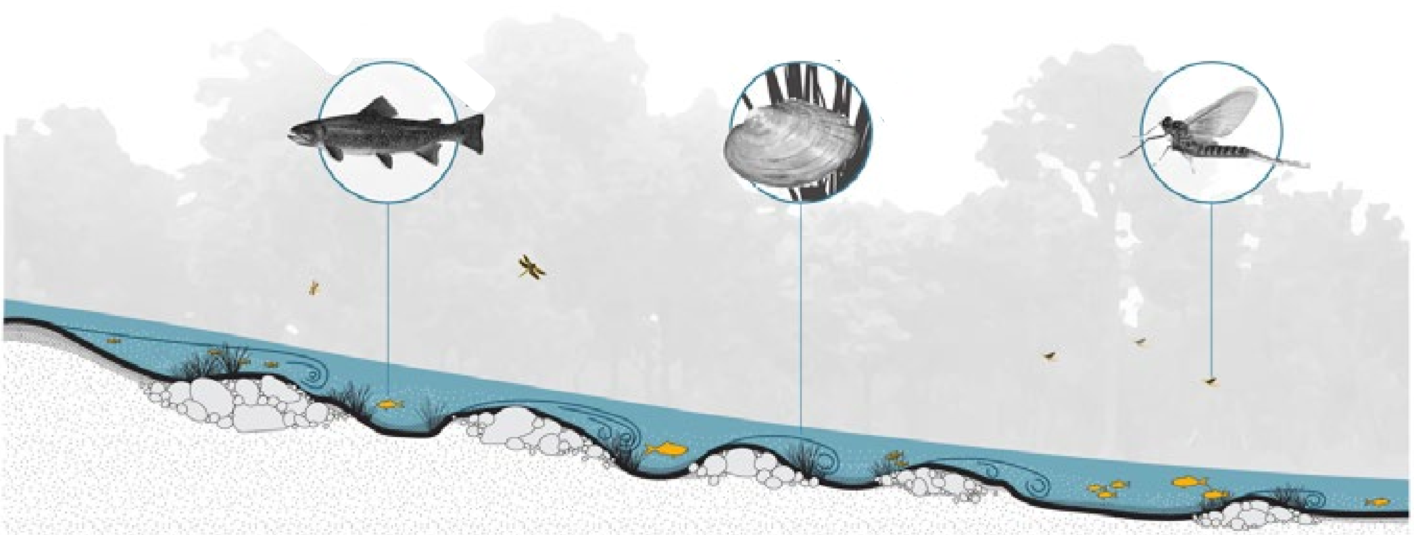


FIGURE 13: Ecology of a free-flowing river

WETLAND SPONGES

The Nemasket River is in a fairly rural area and there still remains a significant network of wetlands surrounding the river. The 1996 Fennessey Report stated, *"there is a tremendous volume of water stored in the wetlands, and the sand and gravel geology between the APC Dam and Wareham St as well as the surface water of the Nemasket River itself plus that of Fall Brook and other tributaries located within the subwatershed".* Currently a significant portion of the wetlands are filled with sediment, non native plants that "clog them up," and in some areas there is a subtle berm that disconnects the river from the wetlands. However there is an opportunity to restore the wetlands and reconnect the River to the wetlands so that they can serve as a "sponge" that can help to hold water during floods and release water during droughts. The extent of wetlands adjacent to the river can be seen in the GIS map to the right and the USGS Topo map on the following page.

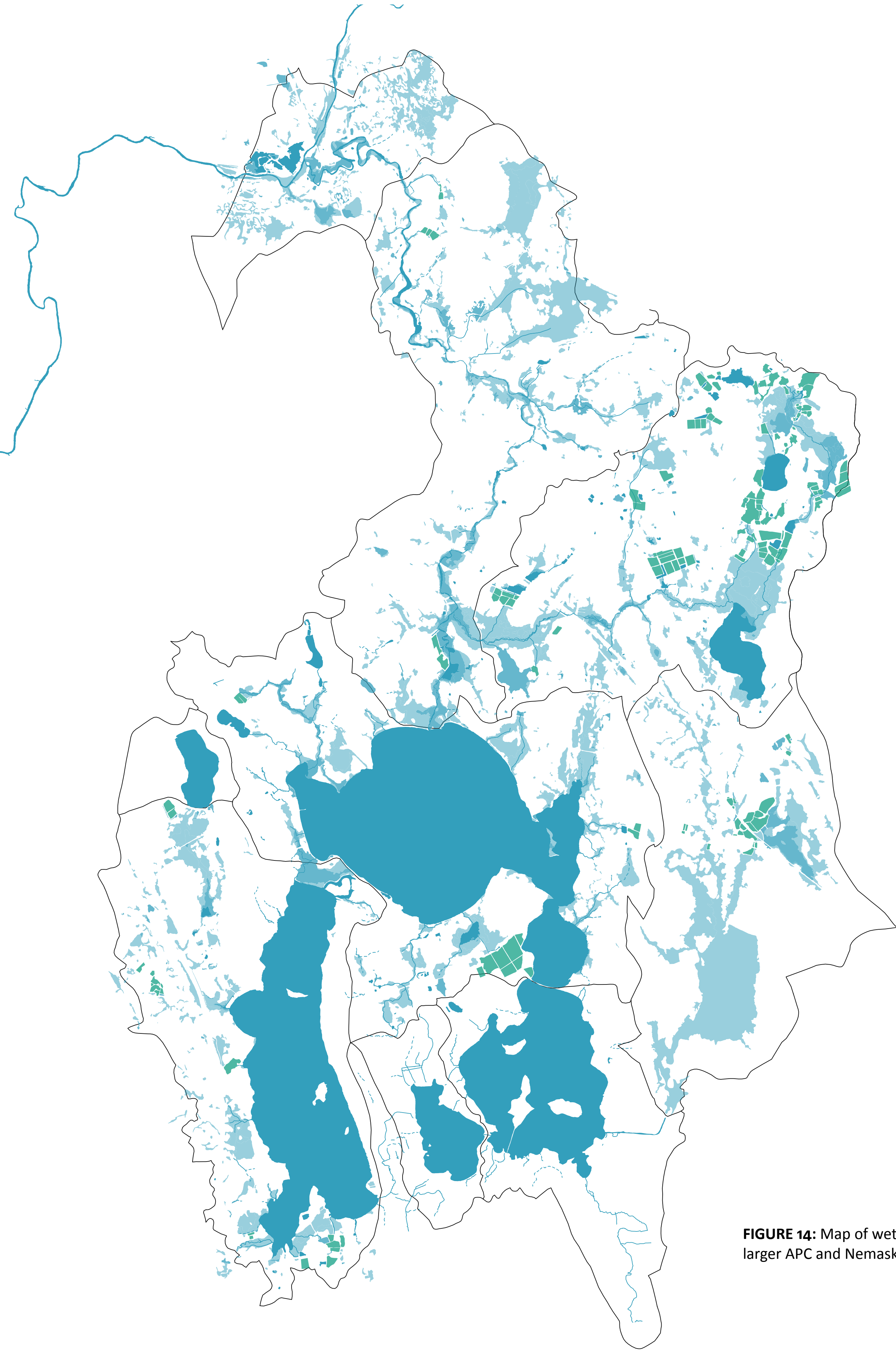
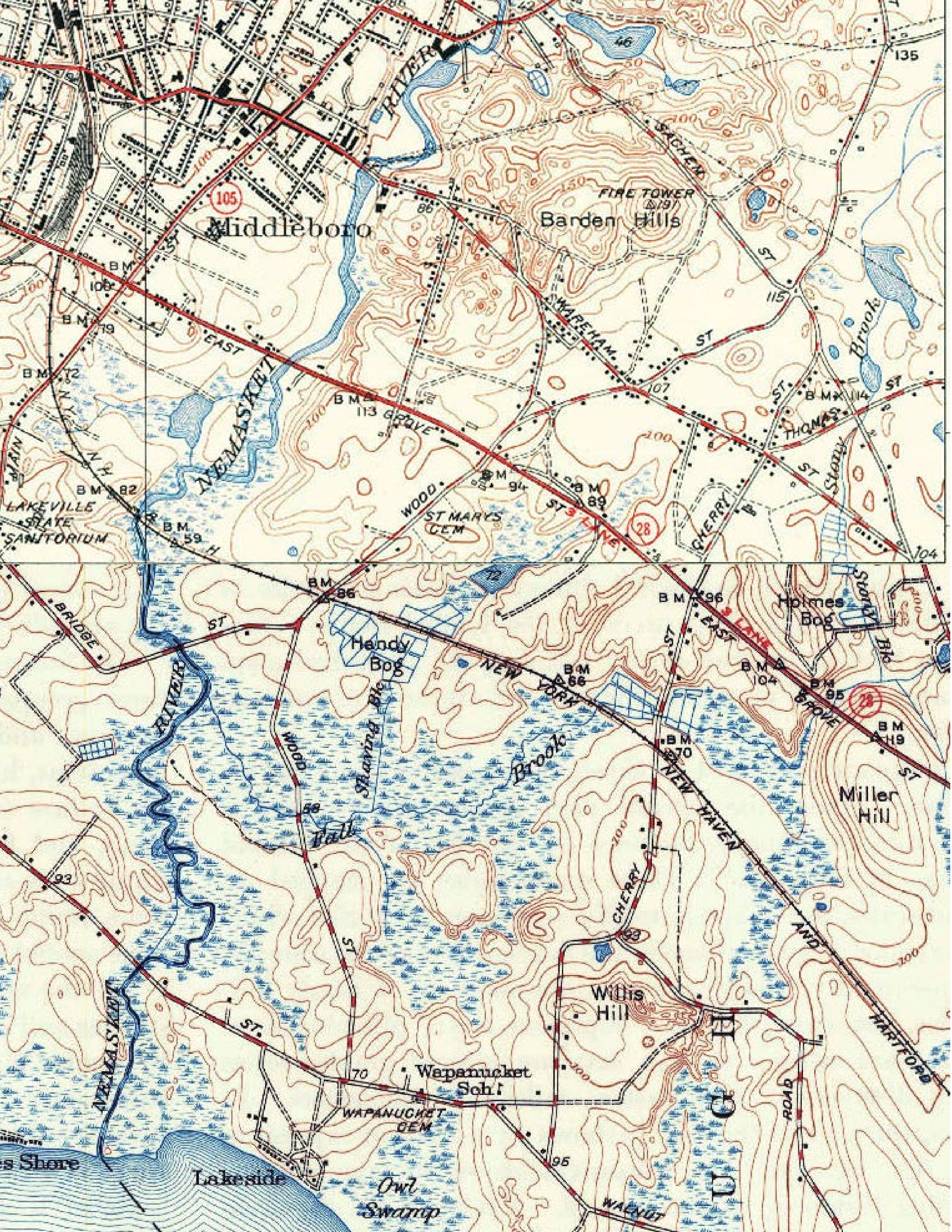


FIGURE 14: Map of wetlands within the larger APC and Nemasket Watershed

TAUNTON
GROVE
3 LANE
ST
28
44
CEM
Nevertown Pond
B M 56
B M 87
North Lakeville Sch
YORK
NEW HAVEN
AND
HARTFORD
B M 61
AKEVILLE
SOUTHWORTH
Richmond Bog
ST
18
3 LANE
B M 92
RHODE ISLAND ROAD
105
Washburn Bogs
Washburn Bogs
Clear Pond
CLEAR POND ROAD
HASKINS CEM
Dunham Pond
Upper Four Corners
VAUGHAN
B M 88
BEDFORD
ron Hill
CROOKED
B M 85
THOMPSON HILL CEM
ROAD
STETSON ST
Staples Corner
Bugel Hill
LANE
Thompson Bk
Montrond Bogs
Bates Brook
MAIN
Loon Pond
B M 99
105
Sampsons
Staple



Middleboro
Barden Hills
FIRE TOWER
NEMASKET
RIVER
LAKEVILLE
STATE
SANITORIUM
ST MARYS
CEM
Hendy
Bog
Holmes
Bog
Stony
Brook
Shaving Bk
Fall Brook
Miller
Hill
Willis
Hill
Wapanucket
Sch.
WAPANUCKET
CEM
Lakeside
Owl
Swamp
NEW YORK NEW HAVEN AND HARTFORD
WAREHAM
SACHEM
THOMAS
GROVE
WOOD
CHERRY
BRIDGE
WALNUT
ROAD
105
28

STEP 2:
DETERMINING PROJECT OBJECTIVES
FIRST PUBLIC MEETING
March 30, 2021

PROJECT OBJECTIVES

After defining the project scope, the next step in the process was to determine the project objectives. Project objectives are a way of envisioning and agreeing on what the goals of the project are. The diagram below was used to help explain the concept: "If this is where we are today.... where do we want to get to through this process?" The objectives were developed through a combination of research, discussion with the steering committee and the first public meeting. Working together to develop the project objectives allowed for us to come to agreements early on in the process before alternatives were being discussed.

Based on research into previous reports and meetings with the steering committee, an initial set of issues on the river had been identified. These issues were shared during the first public meeting to begin the discussion about project objectives. Some of these included:

- Sediment entering Nemasket from Assawompset Pond
- Low gradient of stream bed from Assawompset Pond Dam to Wareham St. Dam
- Sediment settles in channel leading to reduced channel depth
- Reduced channel depth leads to growth of aquatic plants
- Reduced channel depth and aquatic plants lead to reduced fish passage
- Reduced channel depth and aquatic plants lead to reduced recreation opportunities
- Reduced channel depth leads to increase in flooding
- Concern over water supply
- Concerns over habitat for aquatic and riparian species
- Tension between providing enough water for towns water supply vs water to Nemasket
- This area was very important for the Native American tribes that lived in this region

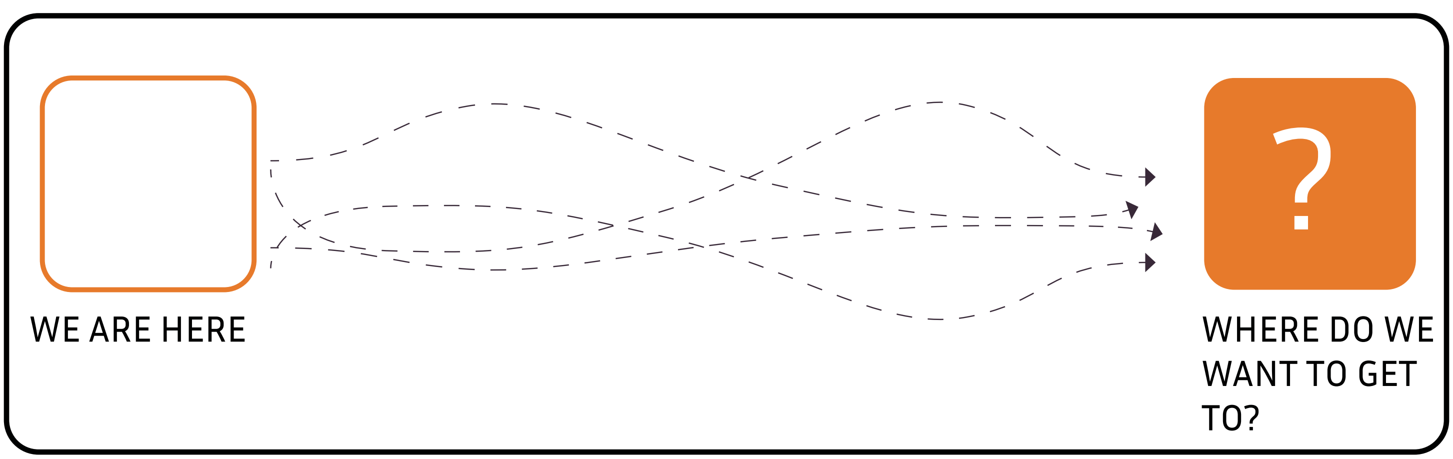


FIGURE 15: Explaining the project objectives

FIRST PUBLIC MEETING

Due to COVID, the first public meeting was held Online via ZOOM on March 30th 2021. The goal of the first meeting was to introduce the project, clarify the relationship between the *Upper Nemasket River Enhancement Plan* and other projects that are taking place in the watershed, cover some basics of river hydrology, and gain a better understanding of what issues were important to the community and ensure that they were reflected in the project objectives.

The meeting began with the whole group of attendees in the same "ZOOM Room". The project team gave an introduction presentation that included introductions of the team, clarifying the various concurrent planning processes that were taking place, and a general introduction to rivers. During the Rivers 101 introduction presentation, Neal, the engineer on the team, presented some key aspects of river hydrology:

- **Hydrology overview:** Described that rivers are made of runoff from rain and snow melt and baseflow from groundwater
- **Mass Balance:** Described the interaction between inflow, outflow, and storage
- **Impacts of urbanization on rivers:** Described that in more urbanized watersheds, infiltration decreases, and runoff increases. Leading to more frequent flooding, erosion and degradation of channel and lower flow between storms
- **Dynamic Equilibrium:** Described that the sediment balance in river systems is the dynamic equilibrium between sediment load and flow: When the flow power is greater than what is necessary to transport the sediment load, the channel degrades or erodes, becoming larger. When the flow power is less than what is necessary to transport the sediment load, the channel aggrades or fills in. Where rivers are well connected to floodplains, high flows are able to spread out across those floodplains thereby reducing the flow depth and power in the channel during high flow events.
- **Hydraulics:** Described the hydraulics of river and flow and the relationship between cross sectional area (the width of the channel) and the velocity of the water: wider rivers will be slower moving and narrow rivers will be faster moving.
- **River channels and floodplain:** Described how the majority of the time, rivers fluctuate within low-flow stages however every 1-2 years, rivers reach the bankfull stage and this is when the majority of river-forming activity takes place. Above the bankfull flow, rivers spill onto the flood plain
- **Sinuosity:** Explained the affect of meandering on channel slope- meandering rivers will have a more gradual slope vs channelized rivers

Following the presentation, there was a time for questions and answers and then the group was then divided into four break out groups and entered into separate zoom groups. Each break out group had a facilitator from the project team. Using a computer program called Jam Board, the facilitator asked the participants a series of questions and documented the comments with "post-it notes" on the Jam board. Below is a list of the break out questions:

- **What Do You Think Are The 5 Most Important Project Objectives?**
- **What Do We Want To Make Sure To Protect In This Process?**
- **What Are Some Of The Key Issues That You Want To Make Sure Are Addressed In This Planning Process?**
- **When You Imagine A Healthy Resilient Nemasket River, What Does That Look Like To You?**
- **How Can The Community Be Good Stewards Of The River?**

Following the breakout groups, the whole group came back together for a debrief. Some of the facilitators shared some of the highlights from their discussions. To close the meeting, the project team discussed the timeline for the *Upper Nemasket River Enhancement Plan* and opportunities for the public to be involved.

On the following pages are a summary of the topics that were discussed in each break out group and a couple of screen shots of the Jam Boards.

PUBLIC MEETING 1: Discuss the vision for river to help develop and refine project objectives.

PUBLIC MEETING 2: Discuss project objectives and alternative packages

PUBLIC MEETING 3: Evaluate how well the different alternative packages meet the project objectives

FIRST PUBLIC MEETING AGENDA

- INTRO PRESENTATION
  - Project team
  - Current planning processes
  - Rivers 101
- BREAKOUT GROUPS
  - Small group discussions about the future of the Nemasket River
- DISCUSS NEXT STEPS
  - Next steps in the process
  - Upcoming opportunities for you to be involved in the process

BREAK OUT GROUP # 1

Vision for the Nemasket:

- An unobstructed, wider, free flowing river with clean water, gravel bottom, free of invasive weeds with protected uplands/wetlands reducing runoff/pollution to system – to benefit herring, other wildlife/ plants, and the community (co-benefits)

Key Issues to Address:

- Safe/environmentally sensitive river access for general public
- Invasive species management plan
- Protect the floodplain and maintain open lands

Ensure Protection of:

- The regional/cultural history important for the community (herring important piece of this), as well as structural significance (bridges/stonework at Oliver Mill Park)

5 Important Project Goals:

- Larger watershed study, fund priority projects (inclusive of decades of previous work/ recommendations)
- Sand removal below APC Dam
- State DOT to remove sandbars they've caused in river
- Overall management plan including invasive weeds
- Enhanced recreational access.

How Community Can Be Good Stewards:

- Increase public information – need to get more than the usual people involved, foster a sense of ownership of river, publicity about river ecology, how individuals can help…

BREAK OUT GROUP # 2

- Wider, freer and faster flowing river. Some said things like “like it was 60 years ago”.
- Better balance between drinking water storage volume, and water release through dam to allow more flow for river functions.
- Weed/ invasives reduction for less overgrowth of channel.
- Less trash
- Increased recreational access, primarily for paddling.
- Longer recreational kayak season (meaning increased flow and channel depth to support boating for more of the summer).
- Sediment removal
- Flood protection
- Improved habitat for endangered species.
- Improved water quality
- Improved herring passage.

WHEN YOU IMAGINE A HEALTHY RESILIENT NEMASKET RIVER, WHAT DOES THAT LOOK LIKE TO YOU?

- wider free flowing river with gravel bottom, clean water, not much highway runoff/sediment
- an unobstructed river
- good water flow required for herring, unobstructed from sediment, also lot of other fish, birds, fur species that use the river require healthy free flowing river, will enhance those habitats too also - co-benefit
- free of pesticides/lawn care chemicals, these can work way into watershed, runoff from lawns/roads
- land protection/conservation

WHAT DO WE WANT TO MAKE SURE TO PROTECT IN THIS PROCESS?

- thee history of the region, the history of the herring are so important to the region/culture/communities
- structural elements/historical significance, particularly the bridges and stonework at Oliver Mill Park; Middleborough has town warrant to do some restoration here

HOW CAN THE COMMUNITY BE GOOD STEWARDS OF THE RIVER?

- recognize/identify the things a municipality could do that can cause problems in the river and work to stop doing them
- increased publicity about the river ecology and how individuals can help, e.g., lawn fertilizer run-off, improving septic system and flows
- residents/public already have higher level of involvement, they watch water levels posted by Lakeville, pay attention to dam board modification, flooding, people very concerned
- (community wide concern), if raises/drops 2" they scream (it's the talk at Dunkin Donuts)
- there is a strong awareness, acknowledgement of the importance of the river, tourism, herring festival - brings sense of community, awareness of preserving the species,
- draws people to the river that otherwise wouldn't go over there, creates great opportunities for citizens to learn more
- need to get lot of public info out there, but realize success is very limited, can get what looks like big public response with little results, e.g., Facebook tonight 800 views but not many people at mtg - prepare for failure
- awareness of the river both by townspeople and surrounding region, but need to foster more of a sense of ownership of the river - keep getting the publicity out there, need to get more than the usual people involved

BREAK OUT GROUP # 3

Vision for the Nemasket:

- FLOW: More water than in the picture! Flow has been reduced, summer and fall drought conditions, less sand deposit - siltation problems addressed at 495 crossing (brook source); headwater
- RECREATION: balance between recreation and natural community needs (down trees), clear canoe and kayak passage, easier to portage around Plymouth Street bridge (lower), Alleviate recreation safety issues - keep safe passageway? Many trees crossing.
- STEWARDSHIP: stewardship ethic develops because people can use the river, stewardship might vary by location along river - upper v. lower Nemasket, citizen science? No trash,
- INFRASTRUCTURE: no dams (except where necessary for drinking water), Continued cooperation between water suppliers and local DPW staff / herring commission, known and clarified permitting processes
- ECOLOGY: more fish and greater diversity of fish (both have diminished), monitors of fish and animals around river to keep track of numbers - (turtles up! fish down), less weeds

5 Important Project Goals:

- Weed clearance and removal
- Vaughn Street area gets chocked in bend of the river - have to take the canal through CB area
- Sand trap / sediment issues
- Cleanliness
- Recreational passage, more access to the river for recreational purposes - more put-ins and take-outs portage very difficult around bridges - sites with issues - poison ivy
- Keep small beaches and wading areas on upper
- Clarify permitting processes
- Trees - conservation department
- Upstream Superfund site - Plymouth Street RR Bridge - groundwater and surface water leaching - impacts on species
- Knowing chemistry of river water - safe to swim / snorkel use river?
- Build off TRWA testing


WHAT DO YOU THINK ARE THE 5 MOST IMPORTANT PROJECT OBJECTIVES/GOALS?
Please list in order of importance with 1 being most important
Weed clearance and removal
Vaughn Street area gets chocked in bend of the river - have to take the canal through CB area
sand trap / sediment issues
cleanliness
reacreational passage
more access to the river for recreational purposes - more put-ins and take-outs
portage very difficult around bridges - sites with issues - poison ivy
keep small beaches and wading areas on upper
Clarify permitting processes
Trees - conservation department (local)
knowing chemistry of river water - safe to swim / snorkel use river?
build off TRWA testing
upstream superfund site - Plymouth Street RR Bridge - groundwater and surface water leaching - impacts on species


WHEN YOU IMAGINE A HEALTHY RESILIENT NEMASKET RIVER, WHAT DOES THAT LOOK LIKE TO YOU?
more water than in the picture!
flow has been reduced
balance between recreators and natural community needs (down trees)
less weeds
summer and fall drought conditions
stewardship ethic develops because people can use the river
no trash
no dams (except where necessary for drinking water)
known and clarified permitting processes
stewardship might vary by location along river - upper v. lower Nemasket
continued cooperation between water suppliers and local DPW staff / herring commission
less sand deposit - siltation problems addressed at 495 crossing (brook source); headwater
more fish and greater diversity of fish (both have diminished)
monitors of fish and animals around river to keep track of numbers - (turtles up! fish down)
citizen science?
clear canoe and kayak passage
easier to portage around Plymouth Street bridge (lower)
Alleviate recreation safety issues - keep safe passageway? Many trees crossing.

BREAK OUT GROUP # 4

Vision for the Nemasket:

- Healthy flow- Invasive plants prevent the water from flowing downstream, biological diversity - plants and animals, restore adjacent wetland as flood storage, concerns over low flow in river and the impact on recreation

Key Issues to Address:

- Water quality - pH/etc to sustain life
- Understanding the impact of the dams on fish passage

What do we want to make sure to protect?

- Herring
- Other animals too: turtles, frogs and toad at risk
- Land protection along the river - open space / stream buffers
- Making sure that it is easily accessible for recreation

5 Important Project Goals:

- Flow / integrity of river
- Herring
- Recreation
- Invasive Aquatic Plants
- Planning for extremes - climate
- Retrofitting APC Dam
- Addressing sediment
- Removing the dam
- DPW site.

How Community Can Be Good Stewards:

- Education- school system - opportunity for education and connecting youth to river - curriculum and field trips
- Events - herring festival / recreation

WHEN YOU IMAGINE A HEALTHY RESILIENT NEMASKET RIVER, WHAT DOES THAT LOOK LIKE TO YOU?

- healthy flow- Invasive plants prevent the water from flowing downstream
- concerns over low flow in river and the impact on recreation
- biological diversity - plants and animals
- restore adjacent wetland as flood storage

WHAT ARE SOME OF THE KEY ISSUES THAT YOU WANT TO MAKE SURE ARE ADDRESSED IN THIS PROCESS?

- water quality - ph/etc to sustain life
- understanding the impact of the dams on fish passage

WHAT DO WE WANT TO MAKE SURE TO PROTECT IN THIS PROCESS?

- turtles, frogs and toad at risk
- Making sure that it is easily accessible for recreation
- land protection along the river - open space / stream buffers
- herring

SUMMARY

The first public meeting was a great opportunity to introduce the *Upper Nemasket River Enhancement Plan* to the public and to discuss the project objectives. Many of the issues that were identified from previous reports and from the Steering Committee were also echoed by the community, helping to reinforce some of the key objectives of the project. Due to the fact that the previous years had been drought years and the river had significantly reduced flow, issues of water flow came up often among the groups. Fish passage was of course important to many as was recreation and water quality.

In some cases there was a contradiction between what the community said they wanted and what is possible given the physical geography and hydrology of the river and the region. For example, multiple groups stated their vision was a "*Wider, freer and faster flowing river."* However, the engineer on the team was able to refer back to his River 101 presentation where he discussed the relationship between width/ cross sectional area and flow velocity- a wider river will be slower moving- a narrow river will be quicker moving. This was a helpful clarification for the group.

While outside the scope of this project, the question *"How can the community could be good stewards of the river*" led to some very interesting responses. Many groups mentioned the need for education- and the opportunity for the local school system to educate and connect the youth to river. Groups brainstormed about the possibility for curriculum and field trips to the river. Some groups also mentioned the importance of events such as the Herring Festival to connect people to the river. And lastly recreation was mentioned as a key part of building a community of stewards- people who spend time on the river care for the river.

Following the first public meeting, the project team met with the steering committee and a draft list of project objectives were reviewed. The objectives fell into three general categories; ecological objectives, infrastructural and operational objectives, and social objectives.

FINAL LIST OF PROJECT OBJECTIVES:

ECOLOGICAL OBJECTIVES:

- Improve passage of adult and juvenile herring and other migratory fish
- Enhance water quality for drinking water and ecosystem health
- Improve riparian and aquatic habitat
- Minimize conditions that could result in the spread of undesirable invasive species and manage existing invasive populations
- Improve low-flow aquatic connectivity

INFRASTRUCTURAL AND OPERATIONAL OBJECTIVES:

- Minimize flood damage to infrastructure and property upstream of APC Dam
- Minimize flood damage to infrastructure and property downstream of APC Dam
- Improve ability to manage water levels in pond to help ensure water supplies
- Reduce ongoing maintenance by working with river morphology

SOCIAL OBJECTIVES:

- Enhance quality and quantity of recreation on river
- Minimize construction costs within the context of other project objectives.
- Minimize long term costs for ongoing operations and maintenance within the context of other project objectives.

STEP 3:
IDENTIFYING ALTERNATIVES:
SECOND PUBLIC MEETING
July 8, 2021

IDENTIFYING ALTERNATIVES

Within the project scope, we were looking at two dams, seven bridges and 4 miles of river channel. Therefore we needed to explore the alternatives for each of these elements individually as well and the interaction between different combinations of the alternatives. A total of 20 "alternative packages" were included in the discussion and then modeled as part of the H&H study. A Hydrologic and Hydraulic (H&H) Study is the study of movement of water, including the volume and rate of flow as it moves through a watershed, basin, channel, or man-made structure.

Based on previous meetings with the Steering Committee and research from the project team, the following alternatives were developed prior to the second public meeting:

ASSAWOMPSET POND DAM

1. Do nothing
2. Replace/Modify dam
4. Restore hydrological connection to wetlands through berm
5. Sediment trap

RIVER CHANNEL

1. Do nothing
2. Dredge channel
3. Reconnect river to adjacent wetlands and floodplain
4. Redesign river channel - Narrower and deeper

BRIDGE CROSSINGS

1. Do nothing
2. Evaluate replacement/removal of bridge structures

WAREHAM STREET DAM

1. Do nothing
2. Remove dam

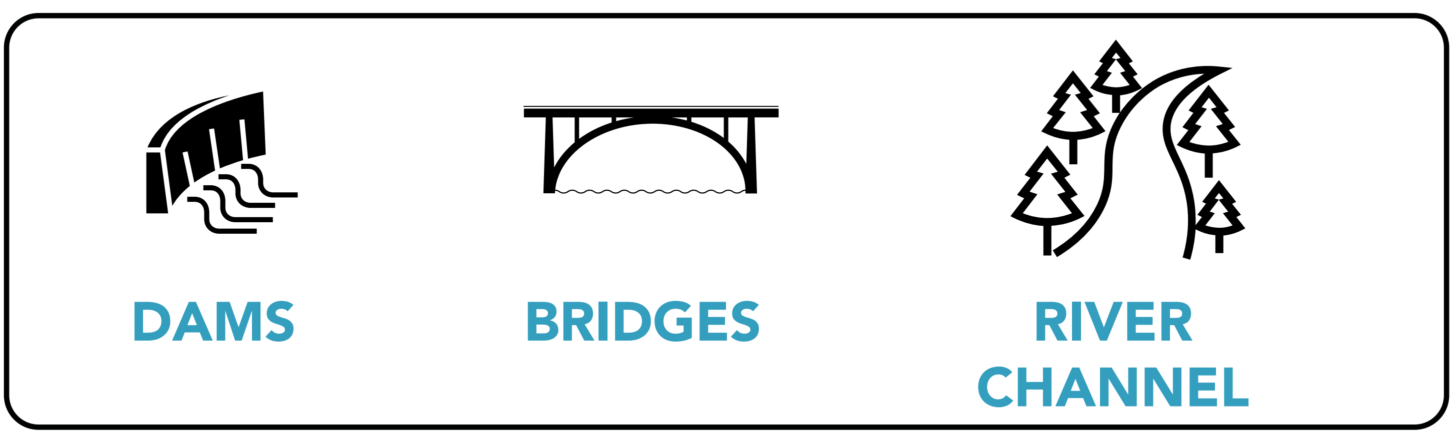


FIGURE 16: Different elements being considered as part of the alternative packages

SECOND PUBLIC MEETING

Prior to running the H&H Model on the alternatives, we wanted to have a public meeting to make sure that we were looking at the right alternatives and to make sure that no alternatives were being overlooked.

The goal of the second public meeting was to discuss the alternative packages with the community. Due to COVID, the second public meeting was also held Online via ZOOM on July 8th, 2021.

The meeting began with the whole group of attendees in the same “Zoom Room”. The Project Team started with a debrief from the first public meeting and reviewed the list of project objectives. Neal from Horsley Witten then gave an overview of the Hydrology and Hydraulics Model to explain what the model is and what we would be able to be learn from the modeling process:

- **Upper Nemasket River model:** Explained there would be two models used to study the alternative packages - the HydroCAD would be used to model the APC dam alternatives and the H&H model would be used to model the river alternatives.
- **FEMA HEC-RAS:** Described how they were adapting FEMA’s Hec-Ras model
- **Updating Transects and dams:** Described that the more cross sections used, the more accurate the estimates of the model. And for that reason, the original FEMA transects were updated with more recent LiDAR data, transects surveyed by Outback Engineering, and the topography outside of river channel was imported using LiDAR data.

Following the presentation on the H&H Model, the project team then walked through the alternative packages. Given the complexity of the issues- we walked through the packages one by one. The group of participants was then divided into smaller break out groups to discuss the project objectives and alternative packages. Below is a list of the breakout group questions:

- **Do the project objectives capture the issues that you think are important when considering the future of the Upper Nemasket River?**
- **Are there any questions about the alternative packages? Are there any alternatives or packages that we are missing?**

At the end of the meeting, the breakout groups came back together for a debrief. Some of the facilitators shared some of the highlights from their discussions. To conclude the meeting, the project team described the next steps of running the model and that there would be a third and final meeting to review the results of the H&H Model.

PUBLIC MEETING 1: Discuss the vision for river to help develop and refine project objectives.

PUBLIC MEETING 2: Discuss project objectives and alternative packages

PUBLIC MEETING 3: Evaluate how well the different alternative packages meet the project objectives

SECOND PUBLIC MEETING AGENDA

- Debrief from first public meeting
- Review project objectives
- Overview of H&H model
- Alternative Package presentation
- Small group discussion of project objectives and alternative packages
- Wrap up/next steps

ALTERNATIVE PACKAGES

The alternative packages discussed during the second public meeting included alternatives for the Assawompset Pond Dam, the Upper Nemasket River Channel, bridge crossings and the Wareham St Dam. A total of 20 alternative packages were discussed during the second public meeting.

To the right are all 20 alternative packages. The logic of the alternative packages was to first run the H&H model to find the ideal alternative for each individual component and then to run different combinations of the individual components. The first 4 alternatives included looking at 4 options for the APC Dam to optimize flow. Alternatives 5-7 would choose the optimal result from the study of the APC Dam and then run that scenario with three options for the channel configuration. Alternative 8 looked at installing a silt trap below the dam and dredging the channel. Alternatives 9-13 looked at the impact of modifying the bridges. Alternative 14 looked at the impact of removing the Wareham St. Dam. The remaining alternatives looked at combinations of the optimal configurations from the previous studies. Alternative 15 included the optimal APC Dam alternative, the optimal river channel alternative and the removal of the Wareham St. Dam. Alternative 16 and 17 included the optimal APC Dam alternative and the optimal river channel alternative and ran those with two ideal bridge configurations. Alternative 18-19 did nothing to the APC Dam or the river channel and just modeled 2 bridge configurations and the removal of the Wareham St. Dam. And lastly, Alternative 20 included everything: the optimal APC Dam alternative, the optimal river channel alternative, the optimal bridge configuration and the removal of the Wareham St. Dam.

On the following page is an example of how the alternative packages were presented to the public during the second public meeting.

APC Dam Alternatives Package (1-4)

Assawompset Dam
4 Alternatives to optimizes flow
Upper Nemasket River Channel
Do Nothing
Bridge Crossings
Do Nothing
Wareham St. Dam
Do Nothing

Bridges Alternatives Package (9-13)

Assawompset Dam
Do Nothing
Upper Nemasket River Channel
Do Nothing
Bridge Crossings
Remove Old Bridge St bridge on its own, Selected modification of MBTA bridge, Pick three other bridges to modify on their own
Wareham St. Dam
Do Nothing

APC Dam + Upper River Channel + Select Bridge Alternatives Package (16-17)

Assawompset Dam
Selected APC Dam Alternative
Upper Nemasket River Channel
Selected River Channel Alternative
Bridge Crossings
2 configurations
Wareham St. Dam
Do Nothing

APC Dam + Upper River Channel Alternatives Package (5-7)

Assawompset Dam
Selected APC Dam Alternative
Upper Nemasket River Channel
3 channel configurations
Bridge Crossings
Do Nothing
Wareham St. Dam
Do Nothing

Silt Trap + Dredge Alternative Package (8)

Assawompset Dam
Silt Trap Below dam
Upper Nemasket River Channel
Dredge Channel
Bridge Crossings
Do Nothing
Wareham St. Dam
Do Nothing

Wareham St. Dam Alternative Package (14)

Assawompset Dam
Do Nothing
Upper Nemasket River Channel
Do Nothing
Bridge Crossings
Do Nothing
Wareham St. Dam
Remove

Both Dams + Upper River Channel Alternative Package (15)

Assawompset Dam
Selected APC Dam Alternative
Upper Nemasket River Channel
Selected River Channel Alternative
Bridge Crossings
Do Nothing
Wareham St. Dam
Remove

Wareham St Dam + Select Bridge Alternatives Package (18-19)

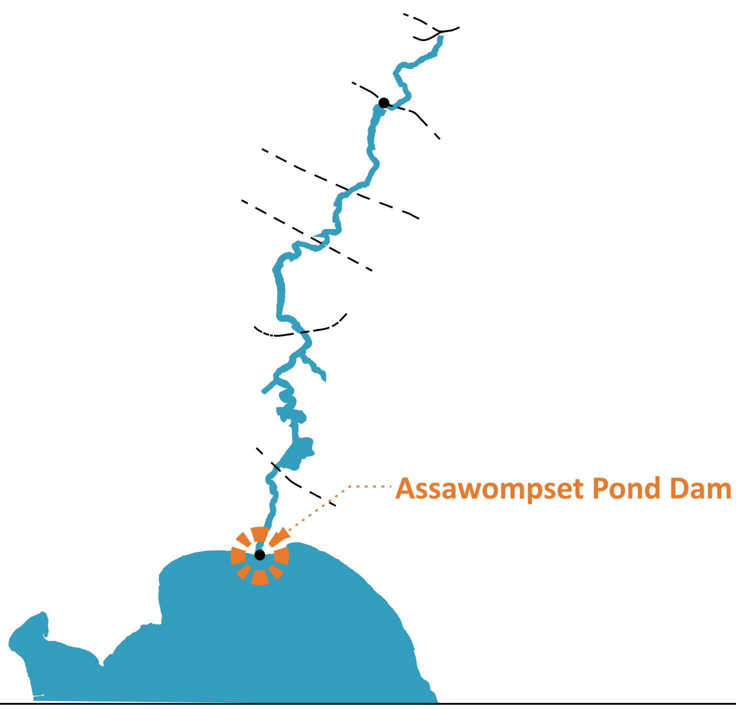
Assawompset Dam
Do Nothing
Upper Nemasket River Channel
Do Nothing
Bridge Crossings
2 configurations
Wareham St. Dam
Removal

Both Dams + Upper River Channel + Select Bridge Alternative Package (20)

Assawompset Dam
Selected APC Dam Alternative
Upper Nemasket River Channel
Selected River Channel Alternative
Bridge Crossings
2 configurations
Wareham St. Dam
Removal

APC Dam Alternatives Package

Calculate average annual flow out of Assawompset Pond Complex for up to 4 dam and berm configurations. Pick one that optimizes flow out at high water while maintaining pond levels at minimum desired level during low water.



Scenarios 1-4

Assawompset Dam
4 Alternatives to optimizes flow out at high water while maintaining pond levels during low water.

Upper Nemasket River Channel
Do Nothing

Bridge Crossings
Do Nothing

Wareham St. Dam
Do Nothing

FIGURE 17: Slides from the second public meeting explaining alternatives 1-4

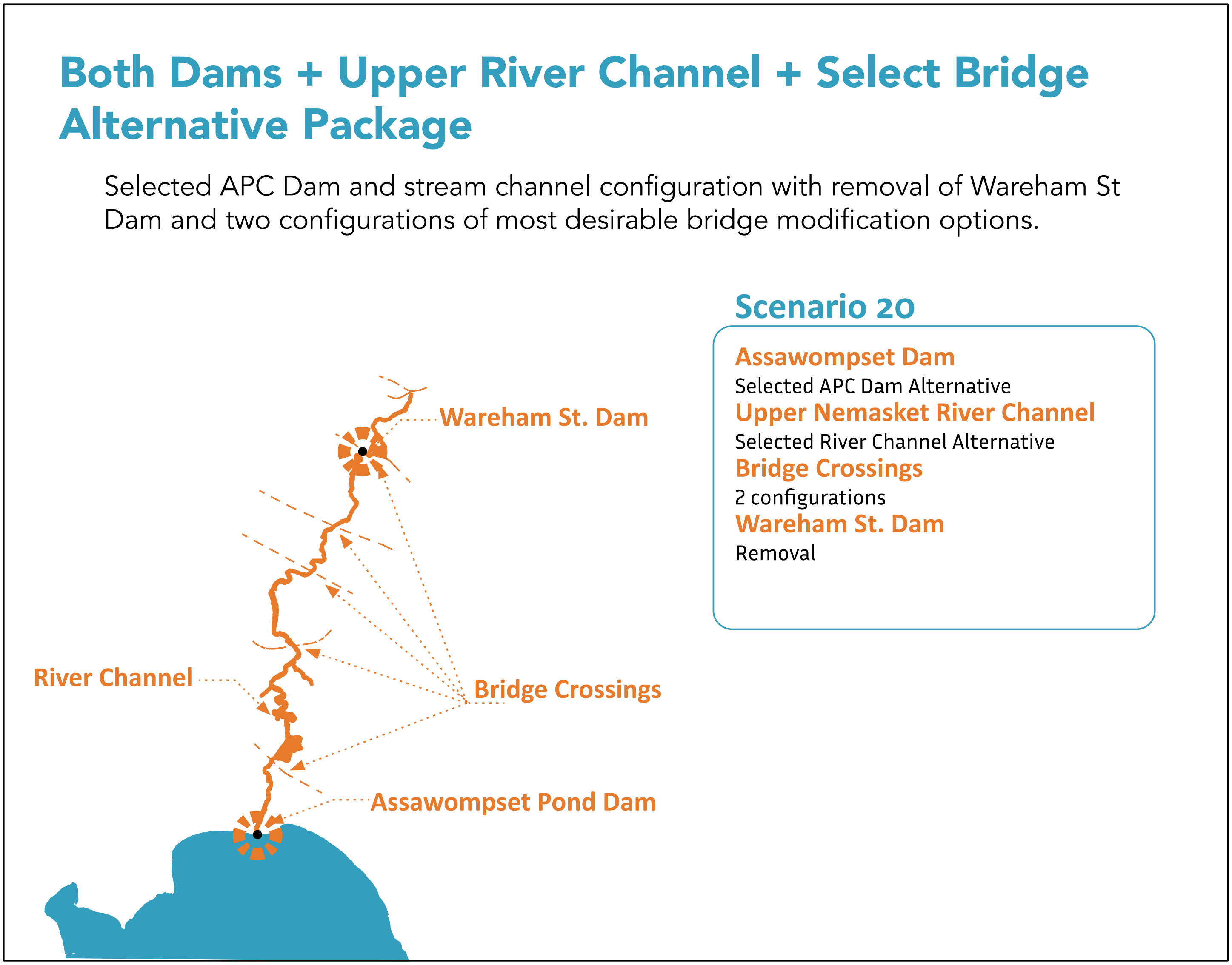


FIGURE 18: Slides from the second public meeting explaining alternative 20

SUMMARY

A lot of complex information was presented at the second public meeting. It was challenging to communicate the H&H model and the 20 alternative packages in a clear way to the general public. However, despite the complexity, by the end of the meeting there seemed to be a clear understanding of the alternative packages and an agreement on the packages that would be modeled.

During the two breakout groups, half of the time was spent reviewing and discussing the objectives and the second half discussing the alternatives. The discussion around the objectives allowed for participants that were not at the first meeting to weigh in on the objectives, a time for clarifying questions, and also and opportunity to ensure that all the key issues were being covered.

The second part of the discussion allowed the public to ask questions about the alternatives. Some interesting questions were raised:

- There were questions related to the bridge structures. Some participants wanted to know more about the history of the bridges, whether it would be possible to get DOT to replace the bridges if they were structurally sound, and the need to take recreation into consideration if the bridges are to be redone. There was a desire to better understand how significant the bridges are in altering the flow of the river.
- There was a more specific conversation about the Old Bridge St bridge that is no longer used as a vehicle bridge but fisherman use it for fishing. There was a suggestion that maybe there is an opportunity to leave historic bridge in place, but widen berth on Middleborough side.
- Since the Wareham St. Dam is used to adjust the water levels to modify how much water flows over the fish ladder, there was concern about potential impact of removing the Wareham St. Dam on fish passage. The project team and members of the herring commission explained that removing the dam would improve fish passage since all the water would flow into one channel and there would no longer be the pinch point at the ladder.
- There was also an issue raised about the feasibility of getting funds to pay for the upgrade of the APC Dam if it is doing a sufficient job as it is. The project team explained that different configurations would be modeled as part of the H&H model and then additional studies would look into cost and possible funding.
- There was a discussion that the different components of the alternatives packages may fit into different phases of the project.
- There was a discussion about the alternative to reconnect to river to the wetlands. One participate that lives close to the river commented that the wetlands are more grassland, and you can walk through them because of how dry it was.

In general the second meeting ended up being mostly informational and allowed the project team time to clarify questions about the alternative packages. During the meeting, there were no strong objections to any of the alternative being proposed and it seemed that all the alternatives were accounted for.

Following the second public meeting, there was a Steering Committee meeting in which some committee members advocated for a slight shift in the modeling process. Horsley Witten had originally planned to start with the HydroCAD model of the APC Dam (Scenarios 1-4) and then select the optimal configuration for the APC Dam and use the results from that model in the H&H model to study other downstream alternative packages. Based on feedback from the Steering Committee, the decision was made to reverse this order and first evaluate the river channel alternatives through the H&H model and then to use the river restoration scenarios to inform the “tailwater” conditions at the dam. This was not a significant shift in the process and the team agreed to this approach. This revised approach allowed the APC Dam alternatives to the “decoupled” from the river restoration scenarios and allow for multiple APC Dam configurations to be considered.

FINAL LIST OF PROJECT ALTERNATIVES:

ASSAWOMPSET POND DAM

1. Do nothing
2. Replace/Modify dam
4. Restore hydrological connection to wetlands through berm
5. Sediment trap

RIVER CHANNEL

1. Do nothing
2. Dredge channel
3. Reconnect river to adjacent wetlands and floodplain
4. Redesign river channel - Narrower and deeper

BRIDGE CROSSINGS

1. Do nothing
2. Evaluate replacement/removal of bridge structures

WAREHAM ST. DAM

1. Do nothing
2. Remove dam

STEP 4 + 5:

ESTIMATING CONSEQUENCES AND EVALUATING TRADE-OFFS

H&H STUDY AND THIRD PUBLIC MEETING

June 28, 2022

ESTIMATING CONSEQUENCES - MODELING ALTERNATIVES

Once the decision was made to first evaluate the river channel alternatives and then to use the river restoration scenarios to inform the “tailwater” conditions at the dam, Horsley Witten ran the models to understand the impact of the various alternatives. The HydroCAD model for the APC Dam was used to study the impact of the APC Dam configurations on the upstream APC pond levels. The H&H Model was used to study the impact of the Nemasket River alternatives (channel modification, bridge crossings, Wareham St Dam removal) on the river flow and flooding downstream of the APC Dam. And finally the three selected APC Dam scenarios were evaluated with the Full River Restoration Package (Alternative 4) to see if it had any impact on flooding in the ponds.

NEMASKET RIVER ALTERNATIVES

Following the modeling process, the team at Horsley Witten determined that of the 20 alternative combinations that were studied for the river channel, that 4 were worth moving forward with for the final discussion at the third public meeting. The rational for this is that when Horsely Witten ran the H&H model, they found that the removal of the Wareham St. Dam had by far the most significant impact on the river- it reduced flood area, increased the energy gradient, led to less sediment settling in the river bed and improved fish passage. In addition to the removal of the Wareham St. Dam, other effective scenarios included modifications to E. Grove St. bridge, and the MBTA bridge and the removal of the Old Bridge St. bridge. Based on the results of the model, the decision was made to present the following alternatives during the 3rd public meeting:

RIVER ALTERNATIVE 1. No Action Alternative/ Do nothing
RIVER ALTERNATIVE 2. Sediment Trap
RIVER ALTERNATIVE 3. Removal of Wareham St. Dam
RIVER ALTERNATIVE 4. Full River Restoration Package -Removal of Wareham St. Dam, channel restoration, removal of the Old Bridge St. Bridge and modification of the MBTA and E. Grove St. Bridge.

APC DAM ALTERNATIVES

There were multiple alternatives studied for the APC Dam to understand the impact of modifying the dam on the upstream pond levels. The alternatives looked at different widths for the main and emergency spillway openings. Three of the APC Dam alternatives were selected to present at the public meeting. They were presented individually and in combination with the Full River Restoration Package (Alternative 4).

APC DAM ALTERNATIVE 1: Do Nothing
APC DAM ALTERNATIVE 2: 75’ Main spillway + 100’ Emergency spillway (no changes to river channel)
APC DAM ALTERNATIVE 2 + Full River Restoration
APC DAM ALTERNATIVE 3: 100’ Main spillway + 200’ Emergency spillway (no changes to river channel)
APC DAM ALTERNATIVE 3 + Full River Restoration

THIRD PUBLIC MEETING - EVALUATING TRADE-OFFS

The third public meeting was held in person at the Lakeville Public Library on June 28th, 2022. Similar to previous meetings, the team started with an introduction to the project team, reviewed the project objectives, and went over the H&H model. Following that, Neal from Horsley Witten, described the river channel alternatives and the result of the modeling process on flooding, fish passage, and the river ecosystem. Neil then described the APC Dam alternatives and the impact of the alternatives on the ponds flood elevation.

Following the presentation, the group was divided into smaller groups to discuss the alternatives and the use the summary matrix table to evaluate the trade-offs. Given the nature of the two groups of alternatives being studied, there were two separate alternative matrices- one for the river restoration alternatives and one for the APC Dam alternatives. Following the discussion, the participants were given red, green, and yellow stickers; with green indicating preferred alternative, yellow indicating acceptable alternative, and red indicating opposition to an alternative. Participants were asked to use at least one green and at least one yellow sticker. The yellow "acceptable alternative" sticker was intended to help participants find a space of negotiation. After ranking the alternatives, the participants discussed their selection with the group.

The group was then briefly brought back together to talk about next steps in the process and the initiatives that were already underway to address some of the issues discussed during the meeting.

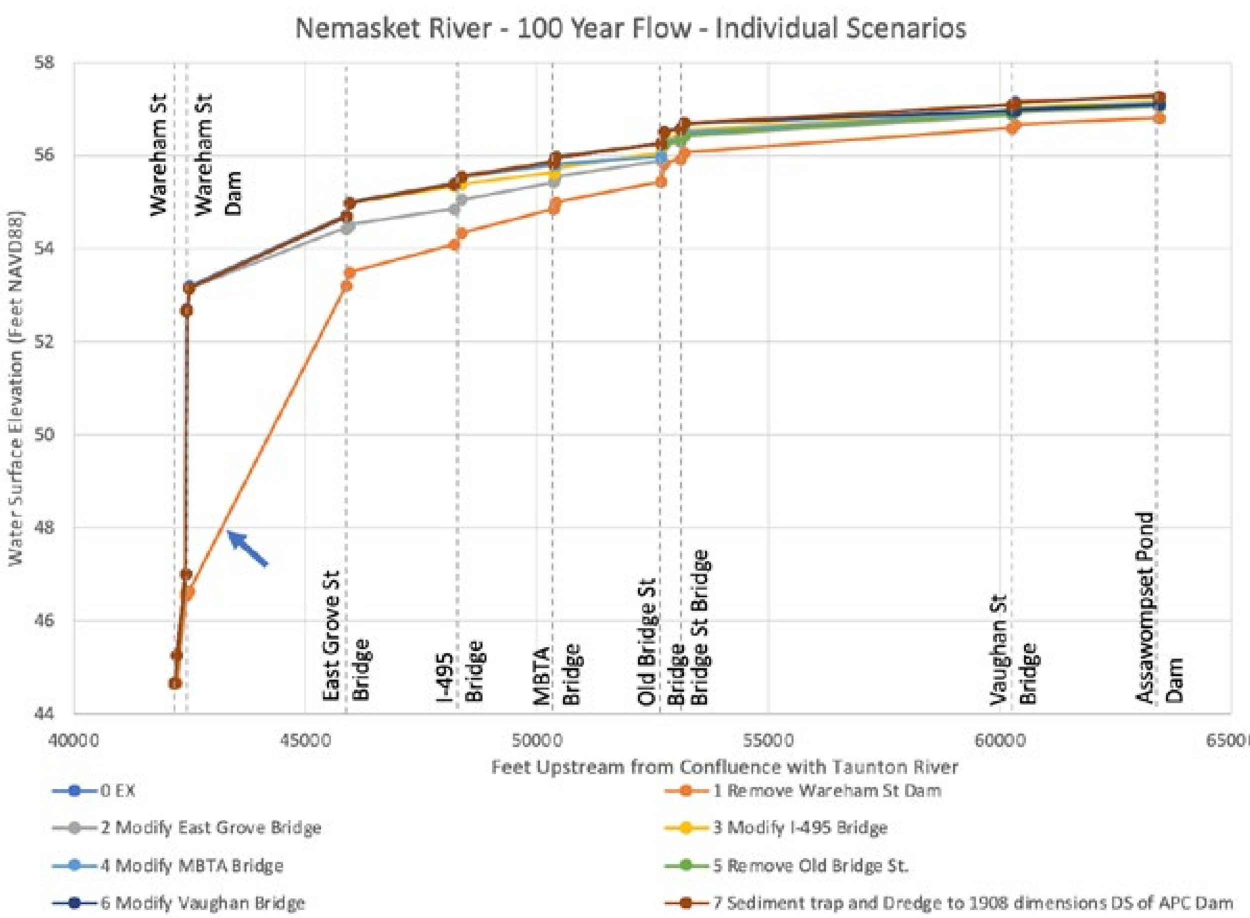


FIGURE 19: Results from the H&H Model showing the impact of the individual alternatives on flooding (Horsley Witten)

PUBLIC MEETING 1: Discuss the vision for river to help develop and refine project objectives.

PUBLIC MEETING 2: Discuss project objectives and alternative packages

PUBLIC MEETING 3: Evaluate how well the different alternative packages meet the project objectives

THIRD PUBLIC MEETING AGENDA

- Introduction Presentation - (40 minutes)
- Break out groups:
  - Introductions (5 min)
  - Discussion of alternative packages + summary table (30 min)
- Report out (10 min)
- Wrap up/next steps (5 min)

RIVER CHANNEL SCENARIOS

There are four river alternatives that were discussed during the public meeting.

DO NOTHING: The No Action Alternative would keep things as they currently are and does nothing to address current issues of flooding, low flows, fish passage and water quality.

SEDIMENT TRAP: The second alternative was included as one of the alternatives because it is an alternative that has been discussed as a possible solution for the river in the past. The sediment trap would be expected to capture suspended sand that is carried in the river during modeled flow events. It was simulated to produce flow velocities suitable for settling of silt and fine sand which meant that it was more effective at lower flow rates. The sediment input supply is uncertain and therefore the time required to fill trap is also uncertain.

WAREHAM ST. DAM REMOVAL: The Wareham St. Dam removal included the removal of the Wareham St. Dam and weir and the widening of the Wareham Street bridge to 1.2x bankfull width. This alternative was the individual alternative that had the greatest impact so it was kept as a separate alternative.

FULL RIVER RESTORATION PACKAGE: The Full River Restoration Package included the removal of the Wareham St. Dam, modifying E. Grove St. bridge, modifying the MBTA bridge, removing old bridge, and restoring the river channel. For this alternative, both the E. Grove St. bridge and the MBTA bridge would be modified from their current width to 80.' This dimension was chosen because it is 1.2 x bankfull width. Widening the bridges would remove these pinch point from river.

	Current Span (ft)	Proposed Span (ft)
E. Grove St.	22'	80'
MBTA	40'	80'
Old Bridge	35'	Remove

FIGURE 20: Bridge modifications (1.2x bankfull width)

In the Full River Restoration Package, the channel would be narrowed from current approximately 100' width down to 54' bankfull width which would lead to an increase of the water velocity in the channel, reducing sediment buildup. The channel restoration would also include reconnection of channel downstream of APC Dam to the adjacent floodplain.

FLOODING

The model results found with only the Wareham St. Dam Removed there would be a 6% reduction in flooded area and 4 buildings would no longer be in flooded area. Under the Full River Restoration Scenario, there would be a 10% reduction in flooded area with 8 buildings no longer in the flooded area.

Restoration Scenario	Flooded Area (100-Year)	Building Impacted
EXISTING CONDITIONS	723 Acres	27
WAREHAM ST. DAM REMOVED	680 Acres	23
FULL RIVER RESTORATION	653 Acres	19

FIGURE 21: Change in flood conditions with river alternatives

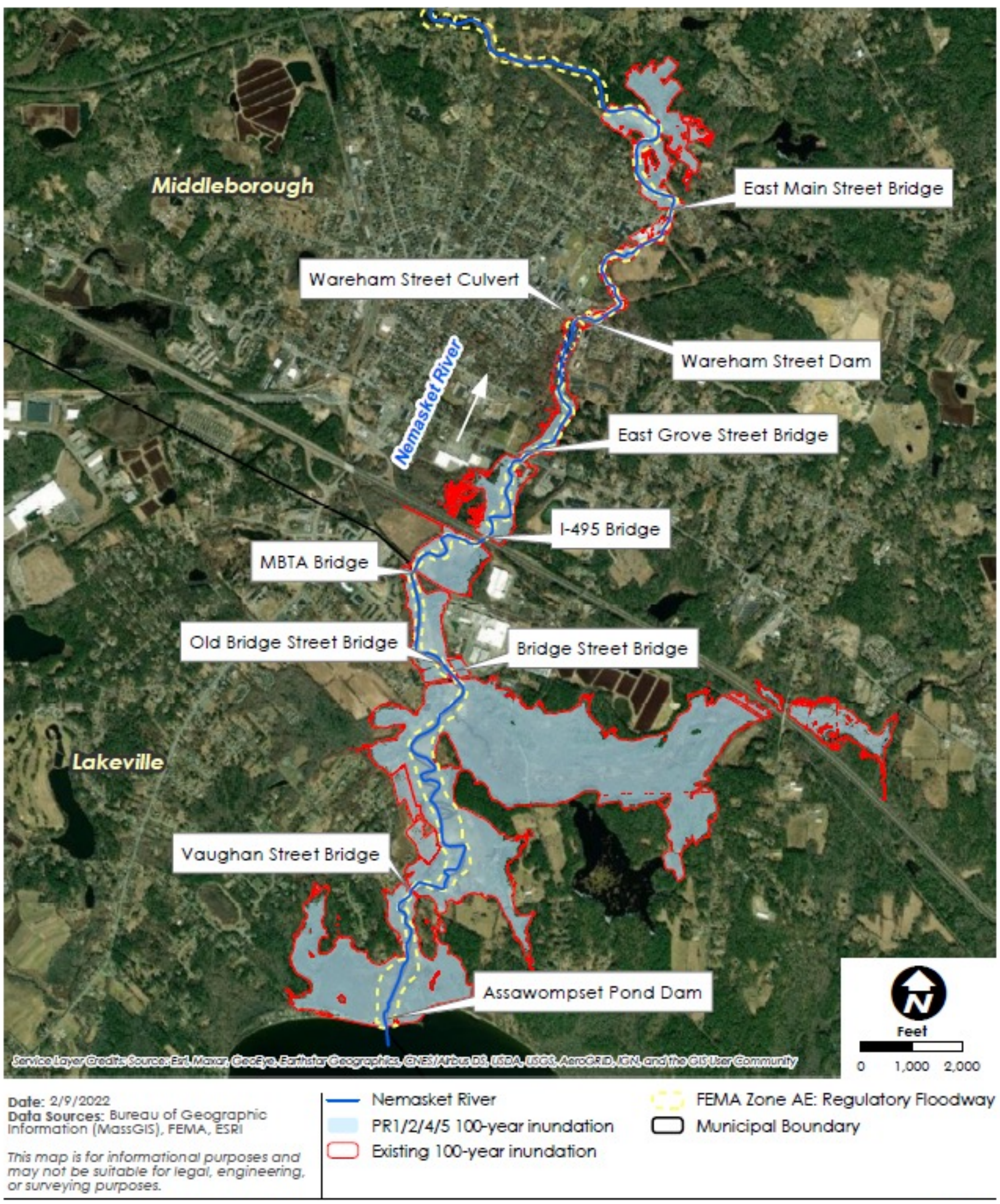


FIGURE 22: 100-year flood inundation area for existing vs proposed conditions for Full River Restoration Package (Horsley Witten)

FISH PASSAGE

Fish passage was evaluated in terms of two criteria: Are water depths deep enough for fish passage during low flow conditions and are water velocities low enough for fish swimming upstream during high flow conditions? Fish species of concern evaluated were blueback and alewife herring that require a minimum water depth of 0.5 feet (USFW) and a maximum burst speed of 3.5 fps (NRCS).

Given these criteria, the river alternatives were evaluated to see the impact on passage. Under current conditions, water depths are too shallow for herring during low flow at 7 locations circled below and water velocity is not too fast for herring during high flow at any location.

If the Wareham St. Dam is removed, the East Grove Street (blue) shallow location is removed and there is greatly improved passage at Wareham Street.

Under the Full River Restoration scenario, in addition to the above two locations being removed, the impediment of the shallow point up-stream of Bridge Street (Orange) is also removed.

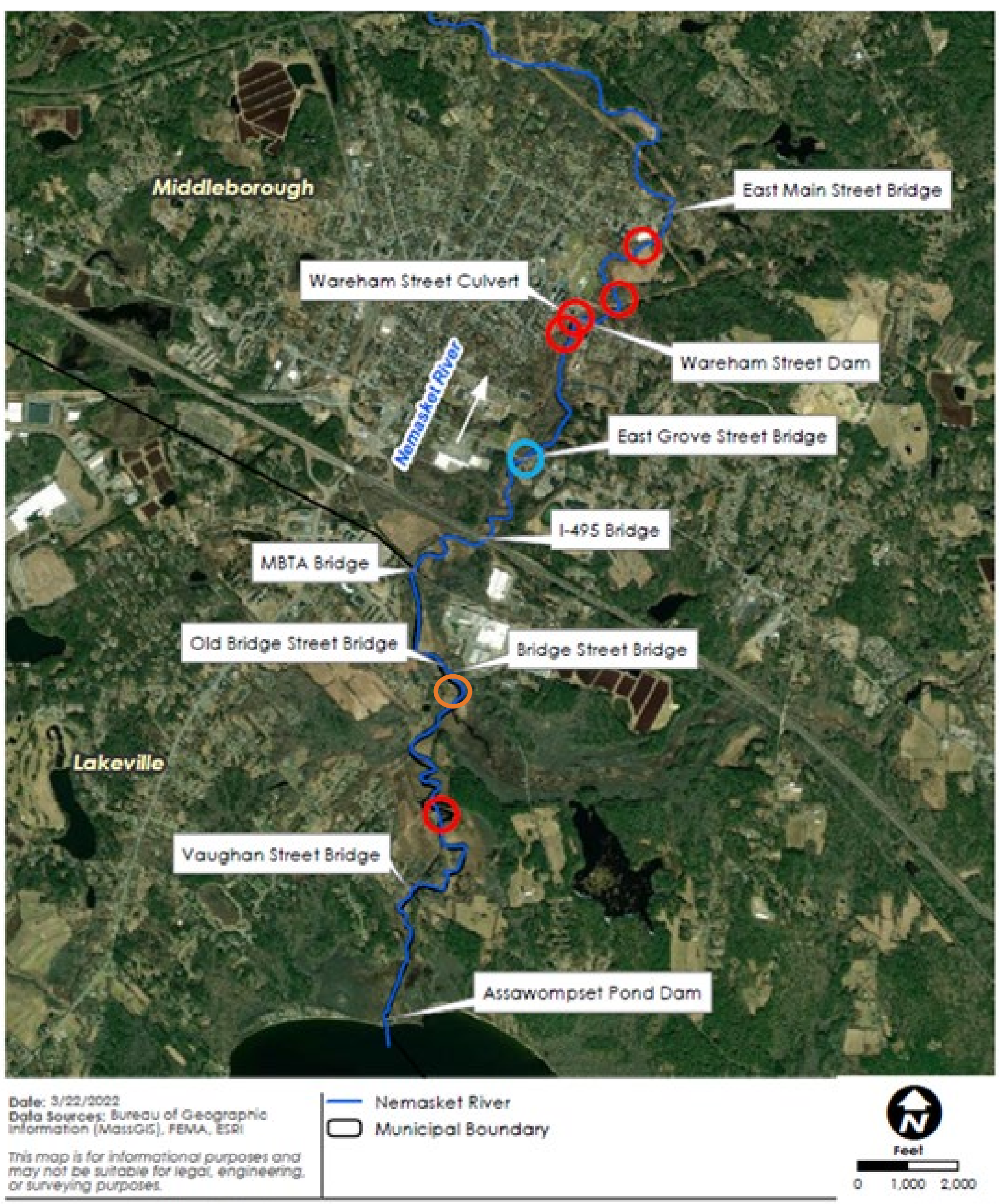
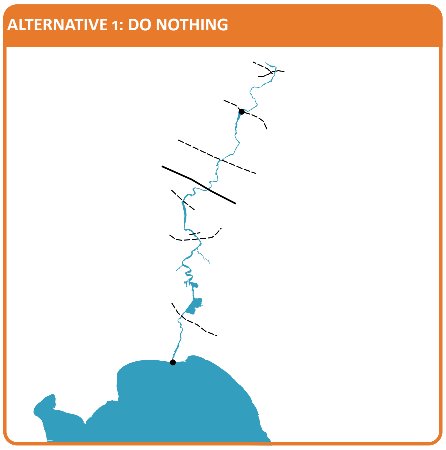


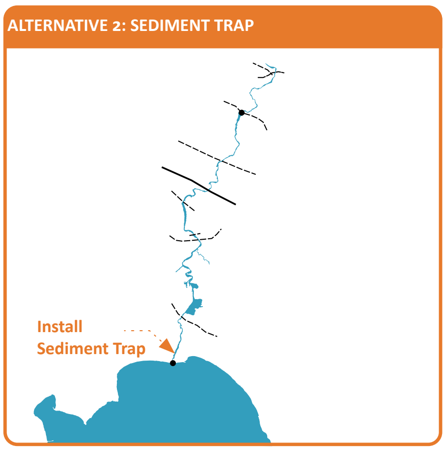
FIGURE 23: Locations where water depths are too shallow for herring (Horsley Witten)

SUMMARY OF IMPACTS OF 4 RIVER ALTERNATIVES



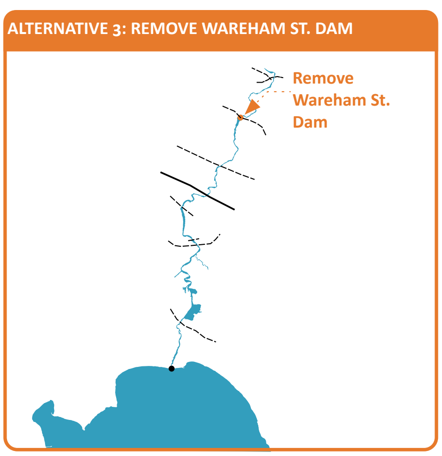
DO NOTHING

- No impact on flood control/water levels
- No changes to current fish passage issues
- Does not work with river morphology
- Does not improve water quality and habitat



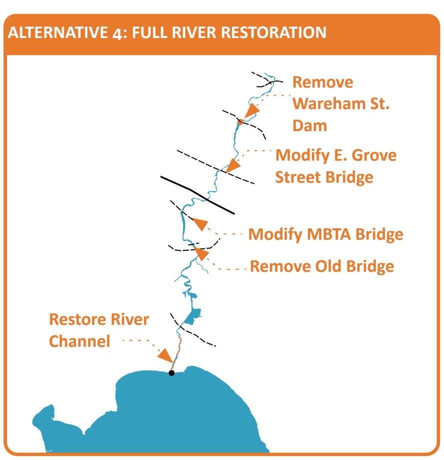
SEDIMENT TRAP

- Little impact on flood control/water levels
- Likely difficult to permit
- Impacts on fish passage unclear
- Does not work with river morphology- will require ongoing maintenance



WAREHAM ST. DAM REMOVAL

- Reduces flood area
- Increases energy gradient which will lead to less sediment
- Improves fish passage
- Improves water quality and habitat
- Works with river morphology



FULL RIVER RESTORATION PACKAGE

- Greatest impact on flood reduction
- Greatest increase in energy gradient + reduction in sediment
- Greatest improvement of fish passage
- Greatest improvement of water quality and habitat
- Greatest alignment with river morphology reducing ongoing maintenance

ALTERNATIVES MATRIX

All of the information about the river alternatives was summarized in the summary table to the right. The matrix listed out the alternatives along the top of the sheet and along the left side it listed out trade-offs. The impact of the alternatives was included within the matrix. This table allowed for the public to easily compare across the alternatives.

RIVER ALTERNATIVES SUMMARY TABLE		
ECOLOGICAL OBJECTIVES	**Fish Passage up and downstream**	
	Improve Water quality + Habitat	
	Improve low-flow aquatic connectivity	Points along river challenging for He pass
INFRASTRUCTURAL AND OPERATIONAL OBJECTIVES	**Minimize flood damage to infrastructure and property downstream of APC.**	Flooded Are (100 Year stor
		Impacted build
	Reduce ongoing maintenance by working with river morphology	
	Permitting	
RECREATIONAL OBJECTIVES	**Maximize quality and quantity of recreation on the river**	Boating Opportu
		Expanding fishery diversity
ECONOMIC OBJECTIVES		Cost
		Availability of Fu
	GREEN = Preferred YELLOW = Acceptable RED = Oppose You must use at least one green and one yellow sticker	

FIGURE 24: Alternatives matrix used at the third public meeting showing impact of river restoration alternatives.

	No Action Alternative	Sediment Trap	Remove Wareham St Dam	Full River Restoration Remove Wareham St Dam Naturalized channel Widen 3 bridges
	NO CHANGE	MINOR IMPROVEMENT	IMPROVED	GREATLY IMPROVED
	— Disolved Oxygen — Water Temperature — Sediment Transport	— Disolved Oxygen — Water Temperature ↓ Sediment Transport	↑ Disolved Oxygen ↓ Water Temperature ↓ Sediment Transport	↑ Disolved Oxygen ↓ Water Temperature ↓ Sediment Transport
where rring to	7 potential low points	7 potential low points	5 potential low points	4 potential low points
ea rm)	723 Acres	723 Acres NO Reduction	680 Acres 6% Reduction	653 Acres 10% Reduction
lings	27 Buildings	27 Buildings	23 Buildings	19 Buildings
	Works against river morphology	Works against river morphology. Requires ongoing maintenance	Works with river morphology	Works with river morphology
	N/A	VERY CHALLENGING	CHALLENGING	CHALLENGING
unities habitat	FLAT WATER RIVER RECREATION Maintains Existing "flat water" recreation on river + ease of round trips	FLAT WATER RIVER RECREATION Maintains Existing "flat water" recreation on river + ease of round trips	FREE FLOWING RIVER RECREATION No portage at Wareham st and fewer low flow areas	FREE FLOWING RIVER RECREATION No portage at Wareham st and fewer low flow areas
	N/A	$	$$	$$$
nding	N/A	UNLIKELY	LIKELY	LIKELY

APC DAM ALTERNATIVES

The objectives specific to the APC Dam were to minimize flood damage to infrastructure and property upstream of APC, improve the ability to manage water levels in the pond to help ensure water supplies during drought conditions and minimize safety risk to workers. The ultimate design of the dam will allow for water levels to be raised and lowered in the ponds - similar to how the boards are used now. Therefore, the operation of the dam will determine how much water is kept in the pond vs released downstream. The HydroCAD model ran these alternatives "wide open" during flood conditions to study the potential impact the spillway dimensions would have on alleviating flooding in the ponds upstream of the APC Dam. But during a flood, the APC Management team would make the decision about how much water to allow through the dam.

Following discussions with the steering committee, three APC Dam alternatives were chosen to be presented at the final meeting. Similar to the "Do Nothing" alternative for the river channel, there was a "Do Nothing" alternative for the APC Dam. There was a second alternative that proposed a 75' spillway with a 100' emergency spillway and a third alternative with the 150' main spillway and a 200' emergency spillway. These three alternatives are presented on the facing page.

The table below summarizes the results from the model. The modeling results found that pond levels can be curbed up to 0.64 feet by widest dam (From 57.27 to 56.63 with Alternative 3). The wider dams can decrease flooded times in the APC from 13 days down to as low as 2.5 days. And the widest dams can hold water above lowest target level for 3-4 weeks (assuming no rain fall during that time).

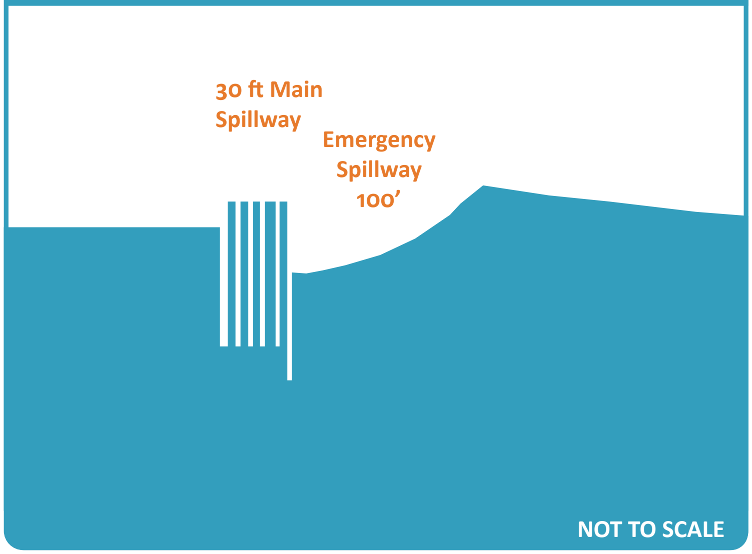
	Peak APC Elevation (NAVD88, ft)		Time to drop from 100-year El to 52.82' (Days)	Time to drop from 52.82' to 51.32' (Days) **
	2- Year	100- Year		
Do Nothing: 30' Main 100'Emergency	54.76	57.27*	12.9	85.3
APC Alternative 2: 75' Main 100'Emergency	54.73	56.93	4.9	30.5
APC Alternative 3: 150' Main 200'Emergency	54.67	56.63	2.4	22.2

*Blue asterisk indicates water level above FEMA 100-year flood elevation

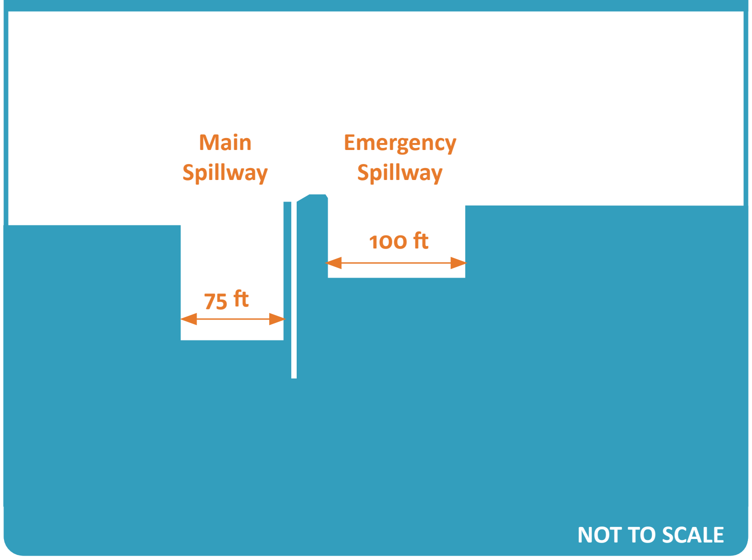
** In the 52.82 to 51.32 drop time analysis, the main spillway was set at elevation 51.32

FIGURE 25: Impact of APC Dam Alternatives on flooding

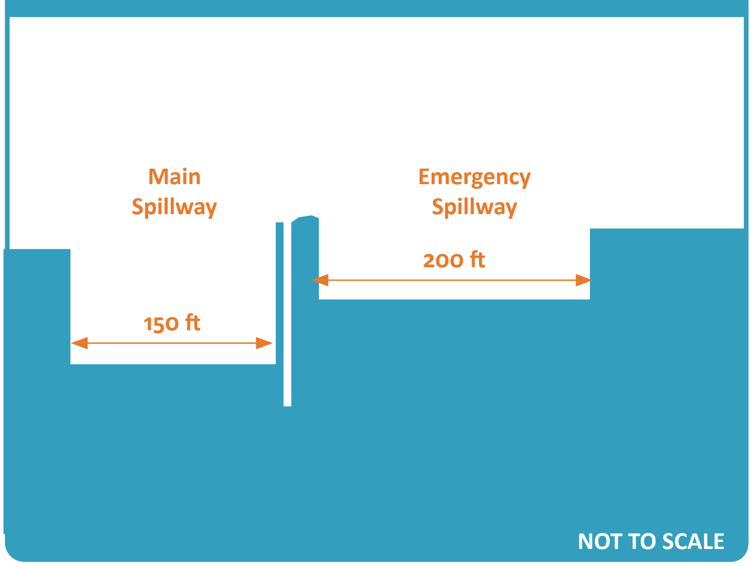
APC ALTERNATIVE 1: DO NOTHING - 30’ Main Spillway



APC ALTERNATIVE 2: 75’ Main Spillway + 100’ Emergency Spillway



APC ALTERNATIVE 3: 150’ Main Spillway + 200’ Emergency Spillway



APC DAM ALTERNATIVES + FULL RIVER RESTORATION

The final set of alternatives studied the impact of the three APC Dam scenarios in combination with the Full River Restoration Package.

The table below summarizes the results from the model. With the Full River Restoration Package, there is a 0.9’ flood reduction in the ponds even if the APC Dam remains unchanged (the elevation is lowered from 57.27’ to 56.39’). With the Full River Restoration Package combined with the widest spillway for the APC Dam alternative, there is a 1.38’ flood reduction in the ponds (the elevation is lowered from 57.27’ to 55.89). The modeling results found that river restoration had minimal impact on the amount of time it took to drop from peak flood levels or down to minimum target levels.

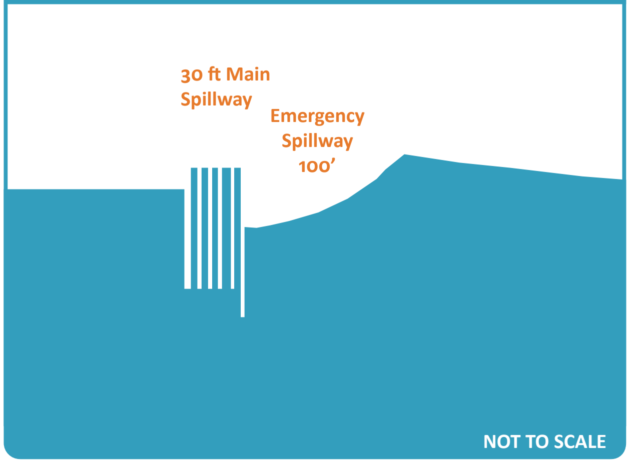
	Peak APC Elevation (NAVD88, ft)		Time to drop from 100-year El to 52.82’ (Days)	Time to drop from 52.82’ to 51.32’ (Days) **
	2- Year	100- Year		
Do Nothing: 30’ Main 100’Emergency	54.47 54.76	56.39 57.27*	11.9 12.9	85.3 ← With River Restoration 85.3 ← W/out River Restoration
APC Alternative 2: 75’ Main 100’Emergency	54.43 54.73	56.19 56.93	4.5 4.9	29.8 30.5
APC Alternative 3: 150’ Main 200’Emergency	54.38 54.67	55.89 56.63	2.2 2.4	21.7 22.2

*Asterisk indicates water level above FEMA 100-year flood elevation

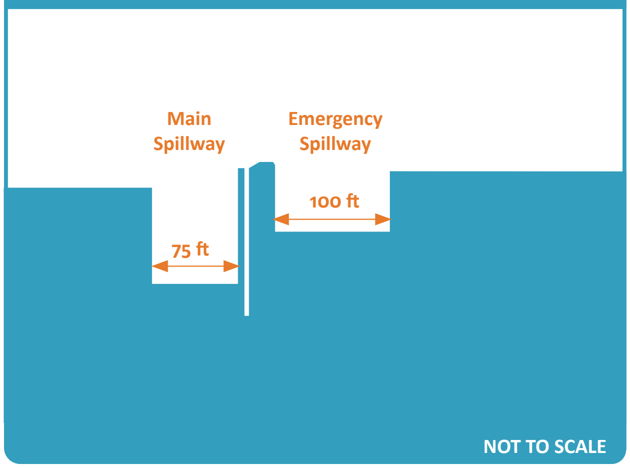
** In the 52.82 to 51.32 drop time analysis, the main spillway was set at elevation 51.32

FIGURE 26: Impact of APC Dam Alternatives with Full River Restoration Package on flooding

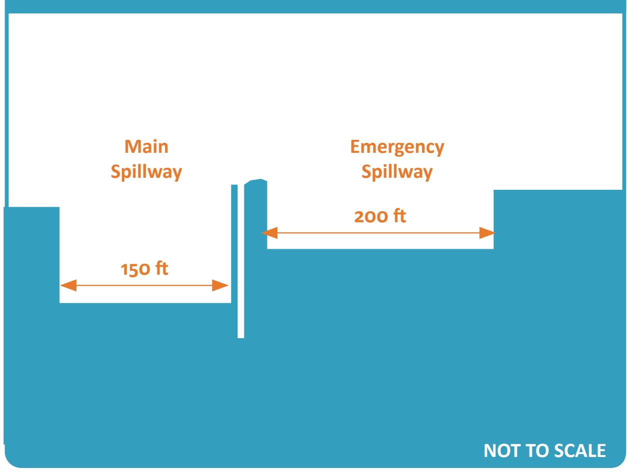
APC ALTERNATIVE 1: DO NOTHING - 30’ Main Spillway



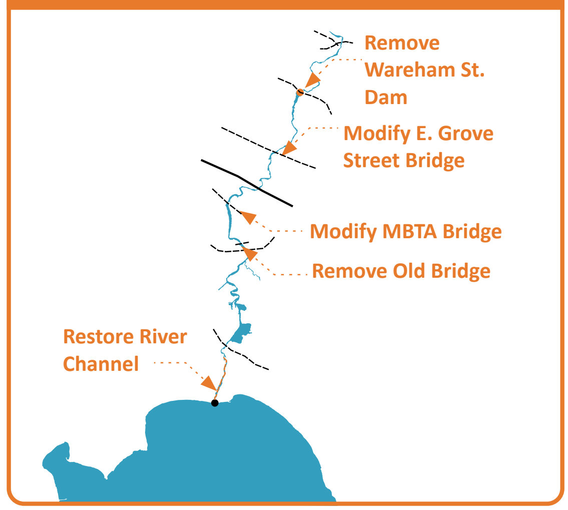
APC ALTERNATIVE 2: 75’ Main Spillway + 100’ Emergency Spillway



APC ALTERNATIVE 3: 150’ Main Spillway + 200’ Emergency Spillway



ALTERNATIVE 4: FULL RIVER RESTORATION



APC DAM ALTERNATIVES SUMMARY TABLE			NO ACTION ALTERNATIVE
ECOLOGICAL OBJECTIVES	**Fish Passage up and downstream**		
INFRASTRUCTURAL AND OPERATIONAL OBJECTIVES	**Minimize flood damage to infrastructure and property upstream of APC**	Peak APC elevation (100 Year flood)	57.27
		Time for water levels to drop from 100-year elevation to 52.82′	13 Days
		Time for water levels to drop from 52.82′ to 51.32	85 Days
	Improve ability to manage water levels in pond to help ensure water supplies during drought conditions and minimize safety risk to workers		NO
	GREEN = Preferred YELLOW = Acceptable RED = Oppose You must use at least one green and one yellow sticker		

FIGURE 27: Alternatives matrix used at third public meeting showing impact of APC Dam alternatives.

NO CHANGES TO RIVER REPLACE APC DAM 75′ Main Spillway 100′ Emergency Spillway	FULL RIVER RESTORATION + REPLACE APC DAM 75′ Main Spillway 100′ Emergency Spillway	NO CHANGES TO RIVER REPLACE APC DAM 150′ Main Spillway 200′ Emergency Spillway	FULL RIVER RESTORATION + REPLACE APC DAM 150′ Main Spillway 200′ Emergency Spillway
SLIGHTLY IMPROVED	GREATLY IMPROVED	SLIGHTLY IMPROVED	GREATLY IMPROVED
56.93	56.19	56.63	55.89
5 Days	5 Days	2 Days	2 Days
31 Days	30 Days	22 Days	22 Days
YES	YES	YES	YES

SUMMARY

Below is a summary of the discussions during the break out groups at the third public meeting. The Summary Matrix was very helpful during the discussions- participants often referred to the sheets to clarify a question, to compare across alternatives, or to make a point- however, not everyone used the matrix to document their preferred alternatives. Therefore, the discussion notes are very helpful for understand the preferred alternatives of the people who attended the meeting.

RIVER ALTERNATIVES DISCUSSION

RIVER ALTERNATIVE 1- DO NOTHING: Many groups indicated that the "Do nothing" alternative was unacceptable. Of the participants that used the Matrix, eight marked it with a red dot (opposed) and one person marked it with a yellow dot (acceptable).

RIVER ALTERNATIVE 2- SEDIMENT TRAP: Sediment reduction was important to many groups but there was an expanded conversation about sediment removal in general and not just the sediment trap alternative. Some groups discussed that while the sediment trap could address sedimentation, it would require regular maintenance and provide only minor improvement for fish passage and habitat. There was discussion about whether sediment removal would be part of the other alternatives and this was confirmed by the project team and will be taking place as one of the short term action items. The sediment trap was not a preferred alternative to many participants because it did not achieve the other restoration goals. Of the participants that used the Matrix, three marked the sediment trap with red dots (oppose), one marked it with a yellow dot (acceptable), and one marked it with a green dot (preferred).

RIVER ALTERNATIVE 3 AND 4: Some participants felt that River Alternative 4 (full river restoration) would be ideal since it would have the most ecological benefits. One participate said "This is the best option for restoration - why would we not go all the way?" But some voiced concern that it would be more challenging given the cost and that it might be hard to get full public support. Some participants suggested that the Full River Restoration Package would probably be implemented over time vs it all happening at once. In line with that comment, many participants agreed that Alternative 3 seemed to have the most impact and would be more doable in the near term- other parts of Alternative 4 could be additive over time.

In some groups, there was a clear preference for River Alternative 3 (Wareham St. Dam Removal). They did not feel like the benefits of River Alternative 4 (Full River Restoration) would merit the extra costs. However, similar to the other groups, they proposed starting with removing Wareham St. Dam and then if funds become available other parts of the full river restoration alternative could be considered.

Of the participants that used the matrix, thirteen marked River Alternative 3 (Wareham St. Dam Removal) with a green dot (preferred) and one marked it with a yellow dot (acceptable). No one indicted they were opposed to this alternative. Of the participants that used the matrix, six marked River Alternative 4 (Full River Restoration) with a green dot (preferred alternative) and eight people marked it with a yellow dot (acceptable), and one person marked it with a red dot (oppose).

There were some concerns about the impact of removing the Wareham St. Dam on paddling since many people do round trips. There was concern that increased flow due to the removal of Wareham St. Dam would make canoe/kayak upstream difficult.

Multiple groups mentioned that Old Bridge Street is historical and a community landmark and that they hope that some part of the structure could remain. There were also concerns because many people currently use one side for fishing and want to preserve that access. There were questions about whether the opposite side could be widened and leave the structure for fishing or if fishing access be incorporated in new designs.

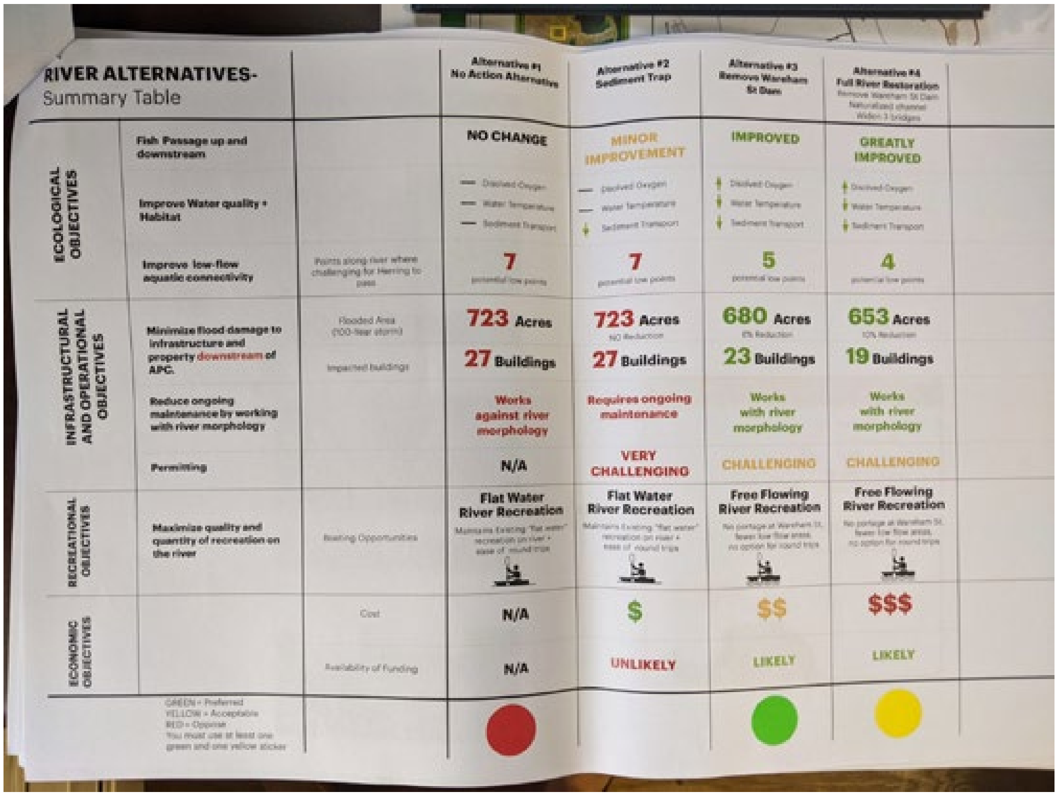
APC DAM ALTERNATIVES DISCUSSION

DO NOTHING: Similar to the sentiments about the river alternatives, many people felt the "Do nothing" alternative for the APC Dam was unacceptable. Of the participants that used the Matrix, seven marked it with a red dot (opposed).

APC DAM ALTERNATIVE 2: In some groups, APC Dam Alternative 2 w/ full river restoration was preferred because it greatly improved fish passage and significantly reduced the number of days for water levels to drop. It was also preferred because it required a narrower spillway modification and which participants assumed would mean lower costs. Alternative 2 did seem to emerge as a compromise option between current conditions and APC Dam Alternative 3. Since the removal of the Wareham St. Dam was the preferred option for some groups, they wanted to see the APC Dam scenarios modeled with just the Wareham St. Dam removal. Of the participants that used the Matrix, two people marked the APC Alternative 2 + no changes to River with a yellow dot and one person marked with a green dot. Six people marked the APC Alternative 2 + Full River Restoration with a green dot and one marked it with a yellow dot. Two additional people modified the matrix and put a green dot next to text that indicated APC Alternative 2 + Wareham St. Dam removal (but not the full restoration package). There were no red dots (opposed) marked for the APC Alternative 2 or the APC Alternative 2 with Full River Restoration.

APC DAM ALTERNATIVE 3: Some participants felt that if the dam was being modified that the APC Dam Alternative 3 was preferred because it would make the greatest improvements and provide the greatest flexibility. However, there were some that said this may not be the best option for all interests - particularly water suppliers that may feel this would lead to less control over water levels for water suppliers. Also there was concern that a larger spill way might be more disruptive (more land would need to be disturbed to expand spillway - trees removed and other potential environmental impacts) and that the minimal decrease to drainage time may not be worth it. No one used the matrix to indicate a preference for APC Alternative 3 and four people marked the APC Alternative 3 + Full River Restoration with a yellow dot (Acceptable) and four people marked it with a green dot (preferred).

One group was surprised and disappointed that the Full River Restoration Alternatives did not have a greater impact on flooding in the ponds. Someone in the group mentioned that during flood events that water flows over the earthen portion of the dam that extends along the north side of the pond…so why do the apertures of the dam even matter? They wanted to know how to get all the water moving better through the whole system. The project team reminded everyone that while there are things that we can modify in the APC/Nemasket system- dams, river channel, bridges- that there are some things that can't be modified such as the relatively flat topography that results in the water not draining more quickly trough the whole system.



RIVER ALTERNATIVES-
Summary Table

			Alternative #1 No Action Alternative	Alternative #2 Sediment Trap	Alternative #3 Remove Wareham St Dam	Alternative #4 Full River Restoration Remove Wareham St Dam Naturalized channel Widen 3 bridges
ECOLOGICAL OBJECTIVES	Fish Passage up and downstream		NO CHANGE	MINOR IMPROVEMENT	IMPROVED	GREATLY IMPROVED
	Improve Water quality + Habitat		— Dissolved Oxygen — Water Temperature — Sediment Transport	— Dissolved Oxygen — Water Temperature ↓ Sediment Transport	↑ Dissolved Oxygen ↓ Water Temperature ↓ Sediment Transport	↑ Dissolved Oxygen ↓ Water Temperature ↓ Sediment Transport
	Improve low-flow aquatic connectivity	Points along river where challenging for Herring to pass	7 potential low points	7 potential low points	5 potential low points	4 potential low points
INFRASTRUCTURAL AND OPERATIONAL OBJECTIVES	Minimize flood damage to infrastructure and property downstream of APC.	Flooded Area (100-Year storm)	723 Acres	723 Acres NO Reduction	680 Acres 6% Reduction	653 Acres 10% Reduction
		Impacted buildings	27 Buildings	27 Buildings	23 Buildings	19 Buildings
	Reduce ongoing maintenance by working with river morphology		Works against river morphology	Requires ongoing maintenance	Works with river morphology	Works with river morphology
	Permitting		N/A	VERY CHALLENGING	CHALLENGING	CHALLENGING
RECREATIONAL OBJECTIVES	Maximize quality and quantity of recreation on the river	Boating Opportunities	Flat Water River Recreation Maintains Existing "flat water" recreation on river + ease of round trips	Flat Water River Recreation Maintains Existing "flat water" recreation on river + ease of round trips	Free Flowing River Recreation No portage at Wareham St, fewer low flow areas, no option for round trips	Free Flowing River Recreation No portage at Wareham St, fewer low flow areas, no option for round trips
ECONOMIC OBJECTIVES		Cost	N/A	$	$$	$$$
		Availability of Funding	N/A	UNLIKELY	LIKELY	LIKELY
	GREEN = Preferred YELLOW = Acceptable RED = Oppose You must use at least one green and one yellow sticker					

MATRIX TABLE SUMMARY

Not everyone at the meeting used the stickers to document their preferences. However, some did and those results are tallied below. These results are supported by the overall notes from each group.

RIVER ALTERNATIVES

1 Do Nothing: I I I I I I I I I
2 Sediment Trap : I I I I I
3 Wareham Street Dam Removal : I I I I I I I I I I I I I
4 Full Restoration: I I I I I I I I I I I I I I I

APC DAM ALTERNATIVES

1 Do Nothing: I I I I I I I
2: APC Alternative 2 + no changes to River: I I I
3: APC Alternative 2 + Full River Restoration: I I I I I I I
4: APC Alternative 3 + no changes to River
5: APC Alternative 3 + Full River Restoration: I I I I I I I I

STEP 6:
TAKING ACTION

TAKING ACTION

There have been discussions about flooding, fish passage, flow and water quality on the Upper Nemasket River for decades. There is a clear need to take action. The methodical planning process that SRPEDD and its partners are undertaking ensures that the needed studies are being completed to understand the impact of priority actions and that the community and stakeholders are involved in the process.

The public process for the *Upper Nemasket River Enhancement Plan* was a great way to get community input at key points in the planning process. There are some key take aways that were learned from the process that can inform the next steps of action:

- **TAKE A PHASED APPROACH:** Based on the feedback we received, there seems to be community support for taking a phased approach to the river alternatives.
- **START WITH REMOVING THE WAREHAM STREET DAM:** Everyone seemed to be in agreement that removing the Wareham St. Dam should be the first priority and then other aspects of the Full River Restoration Package can be undertaken if and when funds become available. At this time, asides for concerns about the Middleborough Wells, there was no opposition voiced by the community about removing the Wareham St. Dam.
- **CONSIDER THE USES AND AESTHETICS OF OLD BRIDGE ST. BRIDGE:** If there is any future discussion of removing the Old Bridge Street Bridge there should be outreach to explore how the visual landmark and fishing uses of the bridge can be preserved or incorporated into the redesign of the site.
- **NEED MORE INFORMATION ON COST AND IMPACTS TO ACCESS THE APC DAM ALTERNATIVES:** There was a desire to move forward with modifying the APC Dam but there was not a clear preference for the exact dimensions of the spillway. Many participants felt they needed more information about cost to make an informed decision about the alternatives.

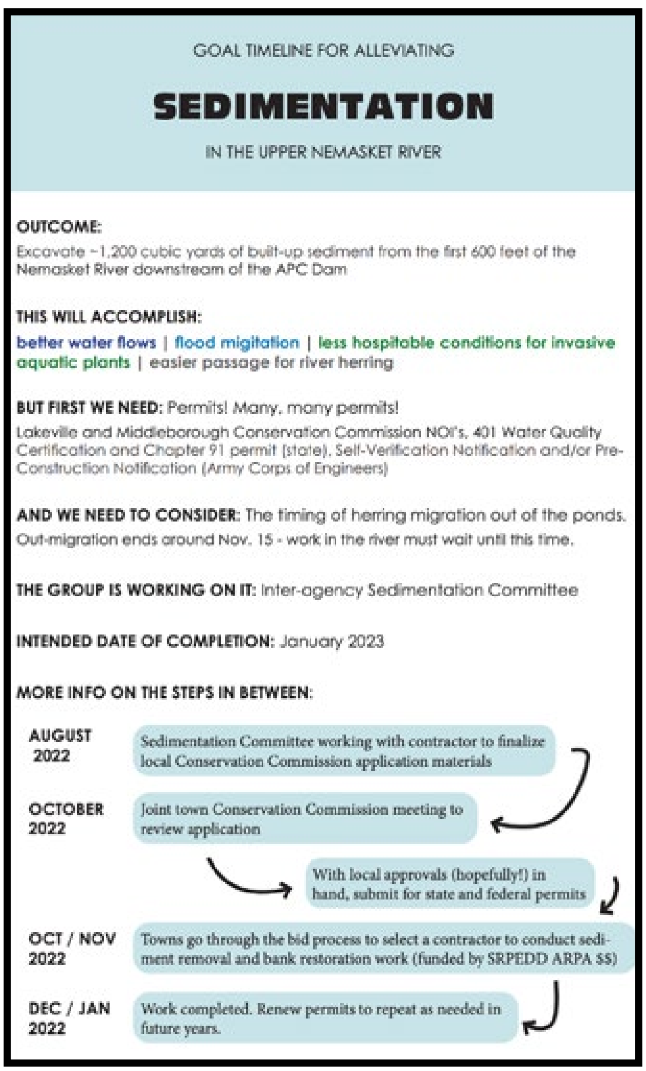
As this planning process is wrapping up, SRPEDD was able to acquire additional funding and the project team from the *Upper Nemasket River Enhancement Plan* is directly transitioning into the next phase of work to conduct additional studies, design and community outreach to explore the removal of the Wareham St. Dam. This next phase of work will include design studies of the Wareham St. Dam removal and a groundwater study to understand the potential impact of removal on the Middleborough Wells. Commonplace Landscape and Planning will continue to work on the community outreach through this next phase of work.

PHASING

Many community members are eager to see action in addressing the longstanding issues on the river. The *Assawompset Pond And Nemasket River Watershed Management And Climate Action Plan* together with the *Upper Nemasket River Enhancement Plan* provide a foundation from which to take further action.

In the *Watershed Management And Climate Action Plan,* SRPEDD developed a 12 point plan for priority APC-Nemasket Project Phasing (See diagram on following page). The first two items on the project phasing list are already underway. In the summer of 2022 and 2023, weeds are being removed from the Long Pond and the Nemasket River. In addition, SRPEDD is working on acquiring permits for a 5 year emergency permit to address sedimentation in the river. Priorities Number 3 and 4 do not directly relate to the Upper Nemasket River. Priority 5, Wareham Street Dam removal is moving forward with the next phase of work into the feasibility, design and engineering studies mentioned on the previous page. Priorities 6-10 do not directly relate to the Upper Nemasket River. As can be seen on the diagram, modifications to the APC Dam is number 11 on the priority list. Due to the complexity of water permits and operations, this action item still needs additional study and consideration.

This is an exciting time for the Assawompset Pond Complex and the Upper Nemasket River. As we conclude this phase of work, there are both immediate improvements taking place on the ground and long term planning that will support a more holistic approach to addressing these interconnected issues on the river. Most importantly, there is a passionate and dedicated community of people that have participated in the steering committee meetings, attended public meetings, and are committed to seeing this work move forward.



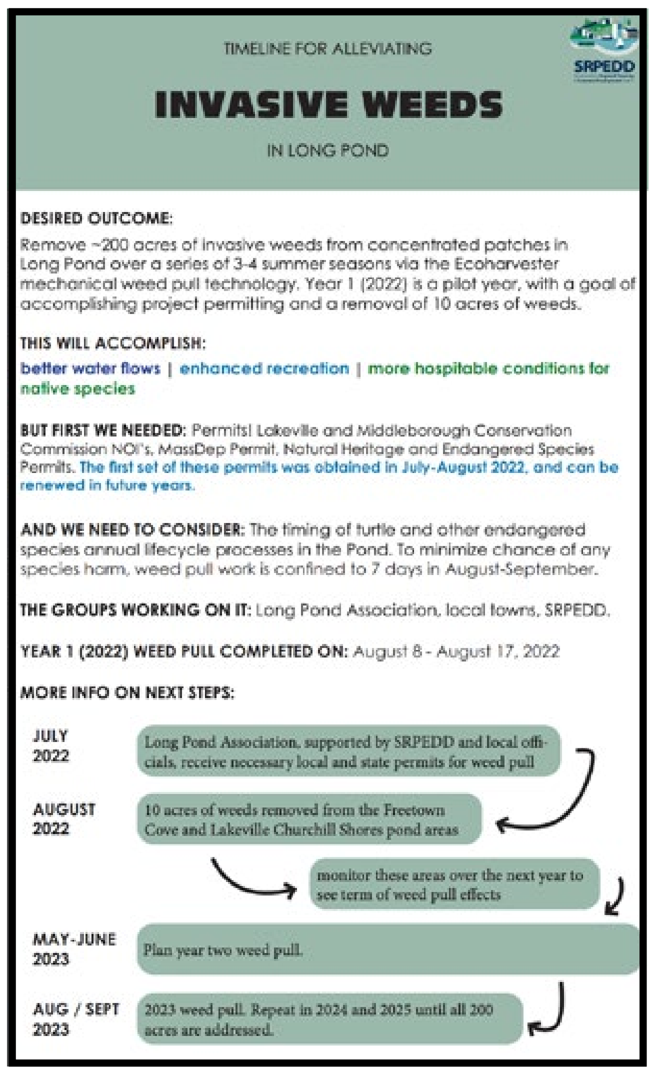


FIGURE 28: Informational sheets developed by SRPEDD to communicate about next steps on the project (SRPEDD)

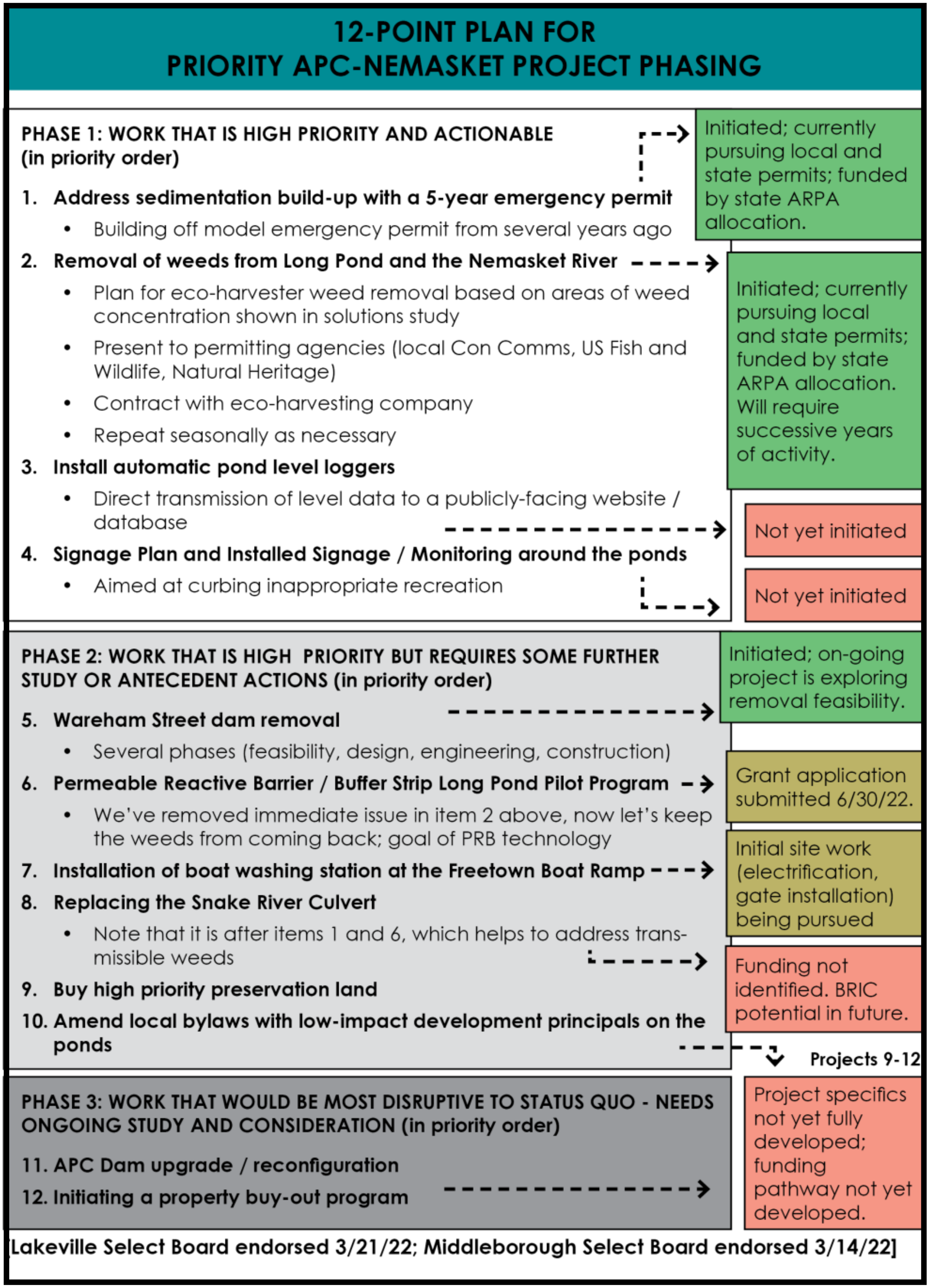


FIGURE 29: 12-Point Plan for Priority APC-Nemasket Project Planning (SRPEDD)

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United States Geological Survey. Assawompset Pond Quadrangle. 7.5-minute quadrangle. Reston, Va: U.S. Department of the Interior. 1941

United States Geological Survey. Bridgewater Quadrangle. 7.5-minute quadrangle. Reston, Va: U.S. Department of the Interior. 1941

United States Geological Survey. Middleborough Quadrangle. 7.5-minute quadrangle. Reston, Va: U.S. Department of the Interior. 1941

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SNEP NETWORK

Upper Nemasket River Hydrology and Hydraulics Modeling Study

Middleborough and Lakeville, MA

October 2022

Prepared for:
New England Environmental Finance Center
Southeast New England (SNEP) Network
34 Bedford Street
Portland, ME 04104

Prepared by:
Horsley Witten Group, Inc.

The SNEP Network is administered by: New England Environmental Finance Center at the University of Southern Maine, UMaine System.

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The Southeast New England Program (SNEP) Network brings together local environmental organizations, academic institutions, regional planners, and consultants who collaborate to provide municipalities, tribes and organizations in Rhode Island and Southeast Massachusetts access to free training and technical assistance to advance stormwater management, ecological restoration, and sustainable financing goals across the region. The SNEP Network is administered through EPA's partnership with the New England Environmental Finance Center, a non-profit technical assistance provider for EPA Region 1.

This report has been developed for SNEP Network Partners MassAudubon, The Nature Conservancy and SRPEDD by a consulting team at Horsley Witten Group in partnership with the communities of Lakeville, Middleborough, Rochester, Freetown, Taunton and New Bedford through the Assawompset Pond Complex Management Team, as well as Commonplace Landscape and Planning. Financial support was provided by NEEFC. In some projects, the SNEP Network provides free services from its pre-approved consultant pool. *The consultant on this project (Horsley Witten Group) was selected from the SNEP Network's pre-approved consultant pool by the project team (excluding SRPEDD, which was not yet a SNEP Partner when this project was initiated). Consultants in the pre-approved consultant pool were evaluated on their qualifications, track record, and performance of their selected service areas.*

The SNEP Network supports this report as a key resource for improving Southeast New England's water resources, regional ecology, and community resilience. Find out more about the SNEP Network at www.snepnetwork.org.

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Attachments

Appendices

1 INTRODUCTION

The Horsley Witten Group, Inc. (HW) is pleased to provide Project Partners with this report summarizing our hydrologic and hydraulic (H&H) study of the Upper Nemasket River in Middleborough and Lakeville, MA. Project Partners include the Southeastern Regional Planning & Economic Development District (SRPEDD), the Nature Conservancy (TNC), the Manomet Center for Conservation Sciences (Manomet), Commonplace Landscape and Planning (Commonplace), and the Massachusetts Audubon Society (Mass Audubon), with funding provided by the U.S. Environmental Protection Agency's (EPA) Southeast New England Program (SNEP).

The Nemasket River is located in Middleborough and Lakeville, MA, and is a tributary to the Taunton River. The project area is generally the run of the river from its headwater at Assawompset Pond to just downstream of the Wareham Street Dam and fish ladder. A figure showing the project area including key points of interest is shown below as **Figure 1**. In total, the Nemasket River is approximately 12.0 miles in length. The Nemasket River supports the largest river herring run in Massachusetts; an estimated 739,000 herring were recorded migrating in the river in 2021[1], and the Assawompset Pond and Nemasket River watersheds provide a total of over 5,000 acres of spawning habitat[2].

This analysis was completed to provide an improved understanding of how the Assawompset Pond Dam, Wareham Street Dam, bridges and other river crossings, and river channel morphology affect water levels, flow velocities, sediment transport, fish passage, habitat, and related conditions along the riparian corridor within the project area. Specifically, this analysis assessed the potential future impacts of alterations to the dams and bridges along the Nemasket River, as well as alterations of the river channel morphology. Study input data, methods, assumptions, and results are presented herein, along with recommendations for the most effective river restoration scenarios and potential future project steps to further advance project goals.

Key features are discussed at greater length below. In this report, all left and right directional references are relative to the direction of the river flow looking downstream; river left refers to the river's left (generally west) bank and river right refers to the river's right (generally east) bank River channel stationing is relative to the confluence of the Nemasket River with the Taunton River, with the confluence serving as STN 0+00 and stations increasing in an upward direction. All elevation data given in this report are relative to the NAVD88 vertical datum in units of feet.

[1] Massachusetts Division of Marine Fisheries, "Diadromous Fish Program Update," January 11, 2022, retrieved from https://www.mass.gov/news/diadromous-fish-program-update

[2] Massachusetts Division of Marine Fisheries, "A Guide to Viewing River Herring in Coastal Massachusetts," July 2017, retrieved from https://www.mass.gov/files/2017-07/river-herring-viewing-guide.pdf

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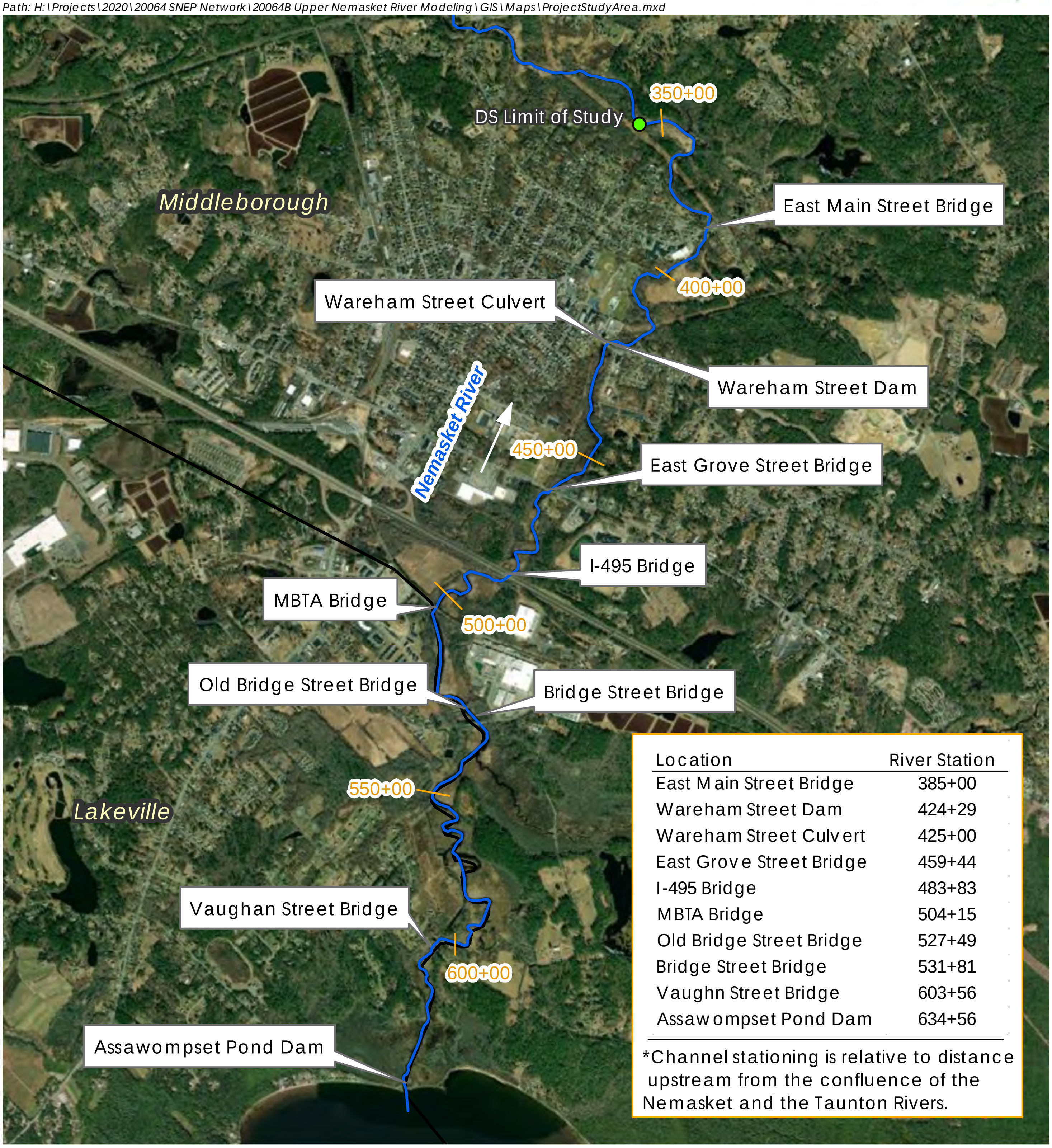

Location	River Station
East Main Street Bridge	385+00
Wareham Street Dam	424+29
Wareham Street Culvert	425+00
East Grove Street Bridge	459+44
I-495 Bridge	483+83
MBTA Bridge	504+15
Old Bridge Street Bridge	527+49
Bridge Street Bridge	531+81
Vaughn Street Bridge	603+56
Assawompset Pond Dam	634+56

*Channel stationing is relative to distance upstream from the confluence of the Nemasket and the Taunton Rivers.

Date: 3/29/2023
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Nemasket River
Municipal Boundary

N
Feet
0 1,000 2,000

Upper Nemasket River Hydrology and Hydraulics Study

Figure 1
Project Study Area

The primary tool utilized by HW to complete the hydraulic assessments at the heart of this project is the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center (HEC) River Analysis System (RAS) model. The HEC-RAS model is a powerful software program that has been used for decades by governmental and industry entities to assess flood risk and design bridges, dams, levees, and other structures within river corridors. The HEC-RAS model includes hydrologic inputs – the quantity of water available to flow through a river corridor under different statistical return frequencies[3] (e.g., 2-year flow), and geometric inputs (the cross-sectional shape of the river and its flood plain at many locations along the river) through which any given return interval hydrology must flow to estimate the spatially variable hydraulic characteristics of the river under that given return interval hydrology. In other words, the model can estimate the elevation and velocity of the river at any location within the model domain for any given hydrologic event (i.e., precipitation event) or return interval based on the geometric constraints of the river corridor input to the model. This allows for the evaluation of scenarios (e.g., replace a bridge of span X with another of span Y by altering the geometry of that specific cross section) to assess the hydraulic impacts (water height, velocity, and sediment transport capacity) of that scenario.

The H&H modeling conducted during this study was informed by an extensive review of existing information as well as extensive collection of new field data. Most significantly, additional topographic and bathymetric survey was conducted to inform the cross-sectional geometric inputs to the model. The results of the modeling were then used to assess various options for restoring more naturalized flow conditions in the river and the potential impacts from each option relative to water levels, flood risk, fish passage, sediment transport, and recreation. Restoration scenarios that were modeled were informed by substantial stakeholder input. The Assawompset Pond Complex Management Team served as the core stakeholder advisory group, with additional members from state and local entities[4].

2 PROJECT AREA

2.1 Nemasket River

Information on the project reach of the Nemasket River is based on a series of on the ground topographic and bathymetric surveys conducted by HW on April 20 and 23, 2021; on the ground surveys conducted by Outback Engineering, Inc. (OE) between June 11-18, 2020 and between April 27-28, 2020; a hydraulic analysis of the Nemasket River conducted by the Federal Emergency Management Agency (FEMA) in May, 2013; and other readily available data such as aerial imagery and historical documents referenced herein.

The project reach of the Nemasket River is located within Lakeville and Middleborough, Massachusetts. The oldest available map of the river dates to 1831 (**Figure 2**), at which time bridges or culverts were already in place at Wareham Street, East Grove Street, Old Bridge Street,

[3] The statistical return frequency of a river's flowrate refers to the likelihood of a given magnitude flowrate to occur in a single year. For example, the 2-year flow has a 1-in-2 (or 50%) chance of occurring any year, while the 100-year flow has a 1-in-100 (or 1%) chance of occurring.

[4] More information on the stakeholder and public engagement process surrounding this project is available in the companion report entitled "Upper Nemasket River Enhancement Plan Community Engagement Report," prepared by Commonplace Landscape and Planning, October 2022.

and Vaughan Street. Two impoundments upstream and downstream of Wareham Street indicate the location of what were once the "Upper Factory" and "Lower Factory" dams.

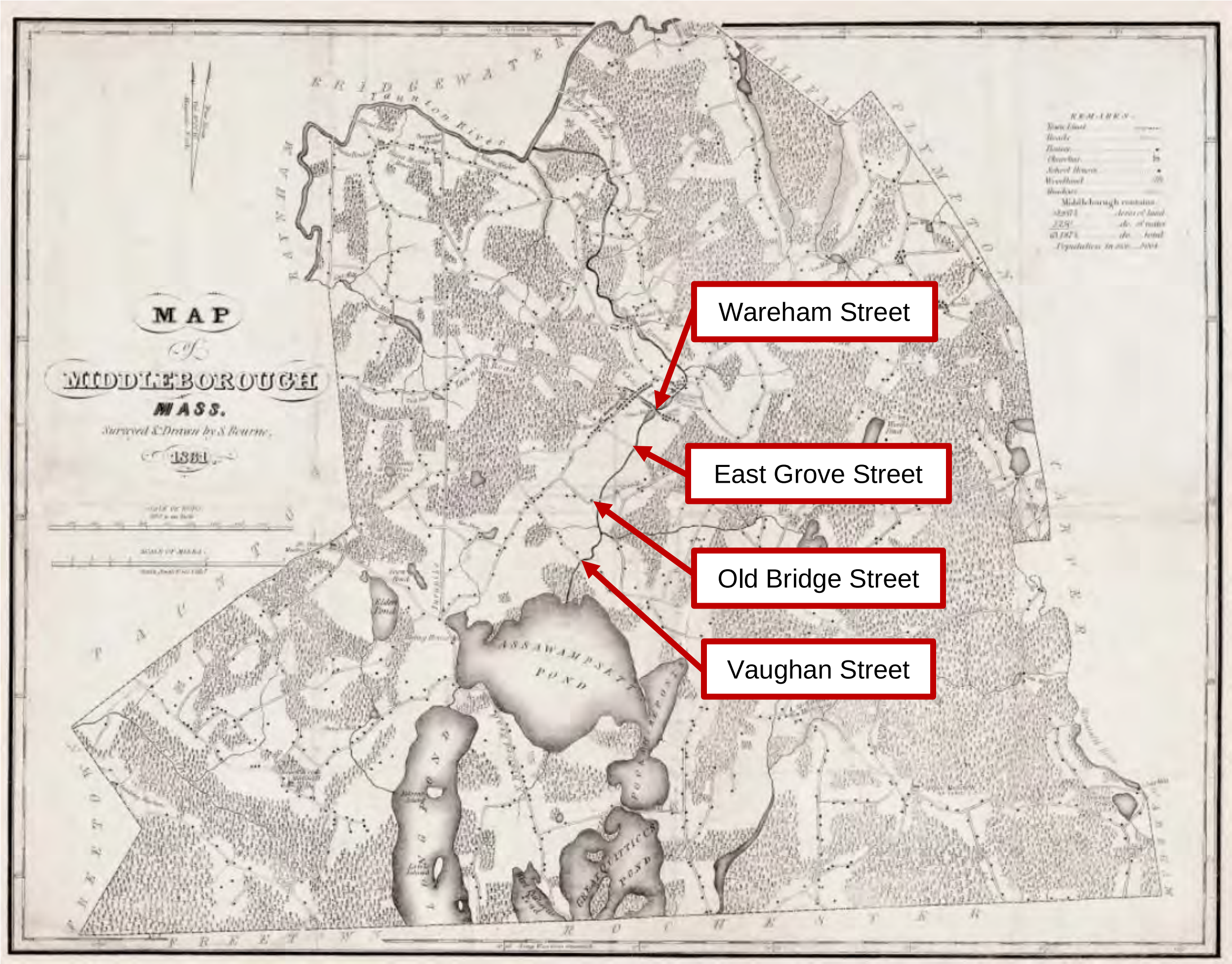

Figure 2. Map of Middleborough, Massachusetts (S. Bourne, 1831)

In pre-colonial times, the Nemasket River served as an important source of food for the indigenous Wampanoag people in the form of river herring; "Nemasket" means "place where the fish are" or "place of fish" in Wampanoag[5]. The two species of herring found in the Nemasket River are alewife herring (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). Upstream migration of alewife typically begins in mid-March and ends in mid-May, although the season can begin as early as February and extend through June on occasion. Blueback migration typically lags alewife migration by 3 weeks[6]. Other aquatic species supported by the Nemasket River include rainbow smelt, American eel, American shad, and striped bass.

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[5] Massachusetts Division of Marine Fisheries and Middleborough-Lakeville Herring Fishery Commission, "Nemasket River Sustainable Fishery Plan for River Herring," August 2016, retrieved from http://www.asmfc.org/files/RiverHerringSFMPs/MA_NemasketRiver_RiverHerringSFMP_Oct2016.pdf

[6] Ibid.

Commercial herring fishing on the Nemasket River occurred from the Colonial Era until 1965, when commercial fishing was banned[7]. Other commercial activities supported by the river included steamboat shipping and tours, which were conducted from 1877-1895[8]; and mill activity, which began at least as early was 1734 when the Muttock (now Oliver Mill) Dam was constructed[9]. At least three locations have supported dams and mills along the Nemasket River, not including the Assawompset Pond Dam at the headwaters of the Nemasket (which was constructed for water supply purposes).

2.2 Reach Characteristics

The Nemasket River is a low gradient river, with average slopes of 0.06% and 0.05% over its entire run and over the project reach, respectively. Two run-of-river dams, the Oliver Mill and Wareham Street dams, are located along the course of the Nemasket. The Oliver Mill Dam is located downstream of this project's study area and the Wareham Street Dam is located near the downstream end of the study area. A third dam, the Assawompset Pond Dam, is used to control water levels in the pond at the headwater of the river and controls flow into the headwaters of the river. The river is crossed by a total of 14 bridges or culverted roads, 7 of which are within the project reach.

Typical flow in the Nemasket River is characterized as slow, with only one section of more rapid flow downstream of the Wareham Street Weir[10]. The low river slope and channel velocity are both factors that contribute to sedimentation and growth of aquatic vegetation along the river[11].

2.3 River Crossings and Dams

The following key river crossings and dams are discussed at depth in this report and are arranged here in order from downstream to upstream.

2.3.1 Wareham Street Dam and Weir

The Wareham Street Dam (**Figure 3**) is located 4.0 miles downstream of the Assawompset Pond Dam, and 40 feet downstream of the Wareham Street culvert. Wareham Street has been the site of a dam since 1762, when the Upper Factory Dam was built[12]. The dam supported operations of various industries including a forge, cotton factory, grist mill, shovel mill, sawmill, and electric light plant. In 1964, the dam was most recently reconstructed based on a design by Rawley Engineering of Wareham, Massachusetts[13].

The current Wareham Street Dam is approximately 15 feet tall and 25 feet wide, with a hydraulic height of 23 feet[14]. The dam is of the Bascule design type, meaning that it features an adjustable

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7 Ibid.

8 Maddigan, M, "Nemasket Steamboats, 1877-95," April 23, 2010, retrieved from http://nemasket.blogspot.com/2010/04/nemasket-steamboats-1877-95.html

9 Thayer, D., "History, Town of Middleborough, Massachusetts," 1984, retrieved from https://web.archive.org/web/20160507060731/http://www.middleborough.com/about_history.html

10 MA DMF and Middleborough-Lakeville HFC, "Sustainable Fishery Plan"

11 Ibid.

12 Thayer, D., "History"

13 Pare Corporation, "Nemasket Park Dam: Phase I Inspection/Evaluation Report," October 27, 2020

14 Ibid.

gate at the top of the stone and mortar portion of the structure that can be raised or lowered to regulate water flow over the dam. The bascule gate is raised and lowered using a counterweight lever located by the control house. The height of the crest of the gate can range between 15-20 feet above the channel bottom downstream of the dam from fully lowered to fully raised. The Wareham Street Dam is often referred to as the Bascule Dam. In this report we refer to the dam as the Wareham Street dam referencing its location rather than the design type.

An additional 200 feet downstream of the Wareham Street Dam is the Wareham Street Weir (**Figure 4**). The weir is approximately 50 feet wide and 3.5 feet high relative to the downstream thalweg[15]. The weir height is not adjustable. The weir is located perpendicular to the downstream outlet of the fish ladder and serves to prevent herring from swimming beyond the fish ladder to the Wareham Street Dam.

HW surveyed the Wareham Street Dam and Weir on April 20, 2021. HW collected 3 river transects between the dam and the weir, as well as 4 transects downstream of the weir. Additionally, HW measured dam and weir geometry and observed channel substrate. Downstream of the weir, bankfull width was measured at multiple locations and ranged between 30-45 feet. Flow velocity is noticeably greater downstream than upstream of Wareham Street. Immediately downstream of the dam, the substrate in the channel was comprised of cobble with gravel and some sand. Slightly farther downstream, a sediment sample collected by OE approximately 40 feet downstream of the dam identified substrate as medium sand with trace gravel (**Appendix A**).

[15] The “thalweg” of a river is the lowest point in a river section (perpendicular to the river’s flow), continuous with other low points upstream and downstream along the river. The thalweg generally has the fastest flow velocities within a river section.

Figure 3. Wareham Street Dam

Figure 4. Wareham Street Weir

2.3.2 Wareham Street Culvert

The Wareham Street Culvert is comprised of two side by side barrels, each measuring 12 feet wide and 10.5 feet tall (**Figure 5**). The culvert is located 4.0 miles downstream of the Assawompset Pond Dam and 40 feet upstream from the Wareham Street Dam. Southeast of the culvert, a concrete fish ladder also runs underneath Wareham Street. The fish ladder is culverted under Wareham Street as two barrels, each 1.4 feet wide and 4.5 feet tall (**Figure 6**). Outside of the culvert, the fish ladder is 6 feet wide between the concrete walls that comprise the structure of the ladder. Wooden gates spaced every 20 feet along the ladder restrict the flow width to 4 feet. The culvert and fish ladder were originally constructed in 1964 when the Wareham Street Dam was reconstructed. That fish ladder was extended in length in 1969 and then removed and replaced in 1996 with the fish ladder currently in place at the site[16].

[16] Pare Corporation, "Nemasket Park Dam"

HW surveyed the Wareham Street Culvert on April 20, 2021, collecting 2 river transects upstream of Wareham Street in addition to measurements of culvert geometry. Upstream of the culvert, the impounded bankfull width was measured to be approximately 260 feet. Sediment sampling conducted by OE indicates that channel substrate upstream of the culvert was primarily medium to fine sand and silt (**Appendix A**). Sandy Silt was measured to be up to 7 feet deep above the underlying coarse substrate. Shallow areas within the river channel exhibited dense growth of aquatic plants. The extent of hydraulic influence from the Wareham Street Culvert cannot be isolated from that of the dam. Combined the dam and culvert represent a significant hydraulic restriction along the Nemasket River.

Figure 5. Wareham Street Culvert Viewed from Upstream

Figure 6. Wareham Street Fish Ladder Viewed from Downstream

2.3.3 East Grove Street Bridge

The East Grove Street Bridge (**Figure 7**) spans 22 feet and is located 17,500 feet (3.3 miles) downstream of the Assawompset Pond Dam. It is the narrowest bridge span on the Nemasket River within the project area, excluding culverts. Based on the existing HEC-RAS model produced by FEMA, the bottom of the bridge is only 6.5 feet above the channel thalweg. Sediment appears to have aggraded inside and upstream of the East Grove Street Bridge (**Figure 8**). Upstream of the bridge, the bankfull width of the Nemasket River was measured at 52 feet; downstream of the bridge, the bankfull width was measured at 44 feet. This is indicative of somewhat impounded conditions created upstream of the East Grove Street Bridge.

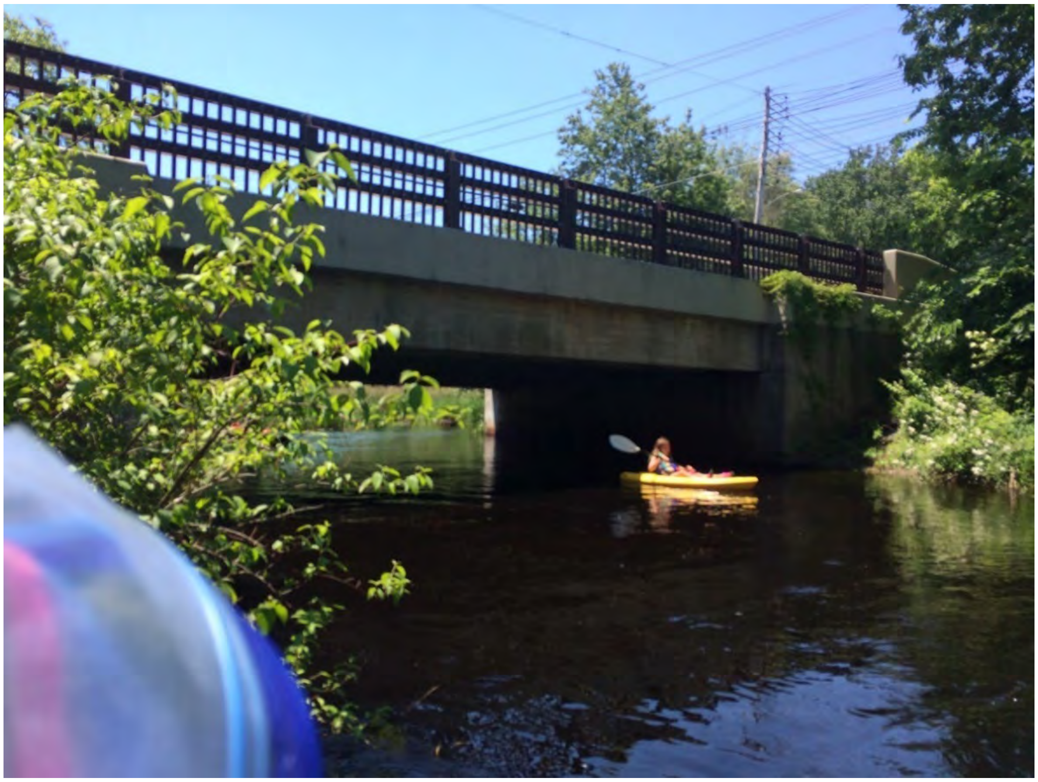

Figure 7. East Grove Street Bridge Viewed from Downstream

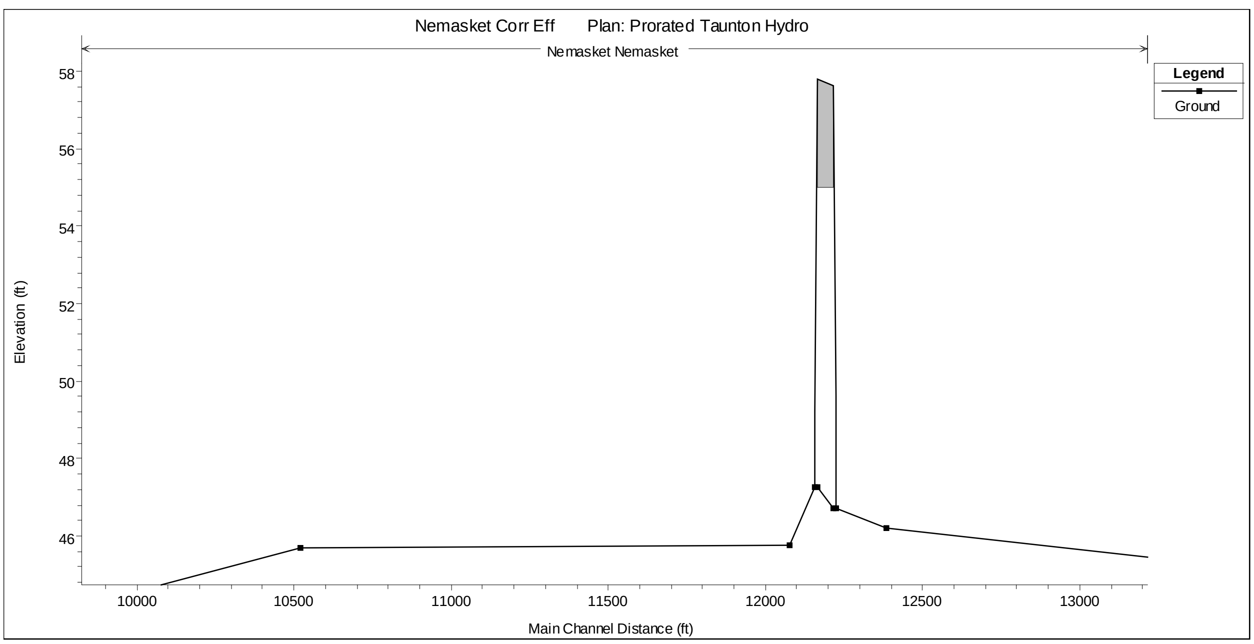

Figure 8. East Grove Street Bridge Channel Profile (Flow from Right to Left; Main Channel Distance Relative to Downstream Limit of Study Area)

2.3.4 I-495 Bridge

The I-495 bridge (**Figure 9**) spans 38 feet and is located 2.8 miles downstream of the Assawompset Pond Dam. With a barrel length[17] of 135 feet, the I-495 bridge is the longest bridge on the Nemasket River within the study area. The bridge was originally built between 1958 and 1962 (**Figure 10**).

Based on the existing HEC-RAS model produced by FEMA, the bottom of the I-495 bridge stands at a height 12 feet above the channel thalweg below. In the area immediately upstream of the bridge, the channel has a bankfull width of 48 feet; immediately downstream, the bankfull width was measured at 28 feet. This is indicative of slight-to-moderate impounded conditions upstream of the I-495 Bridge.

Figure 9. I-495 Bridge Viewed from Upstream

[17] "Barrel length" refers to the total length of a bridge or culvert parallel to the direction of river flow.

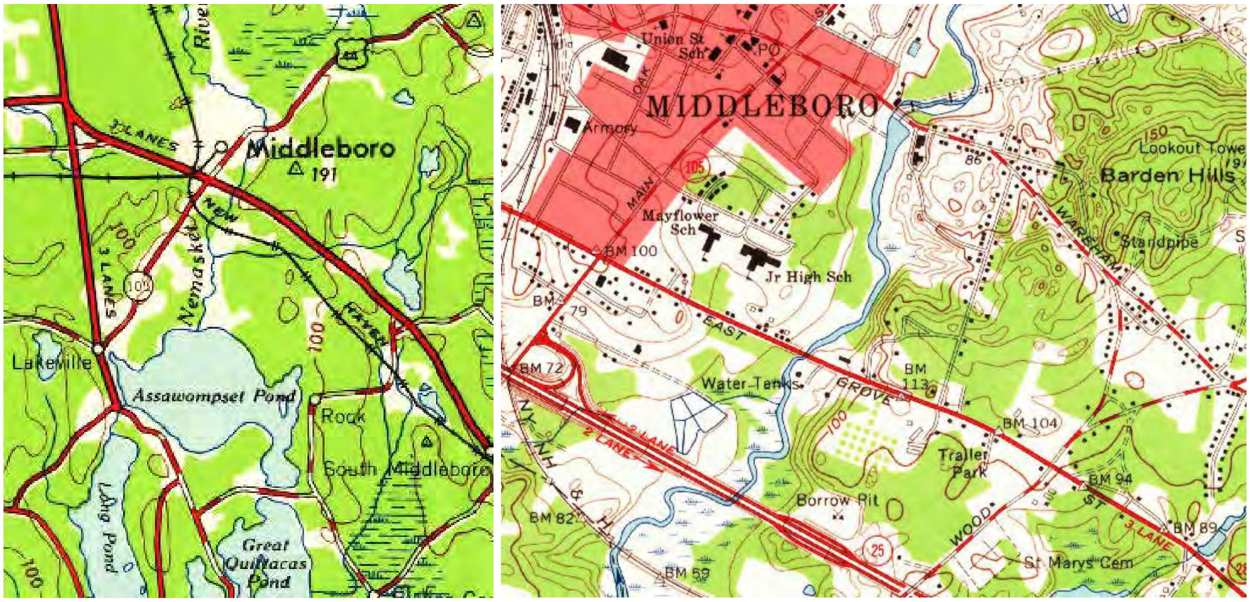

Figure 10. Map of Rhode Island, 1958 (left) and Bridgewater, 1962 (right) (USGS)

2.3.5 MBTA Bridge

The MBTA bridge (**Figure 11**) was originally built as the part of the Old Colony and Fall River Railroad at some point between 1844 (the beginning of construction for the Old Colony Rail) and 1855 (**Figure 12**). The bridge spans 40 feet and is located 2.5 miles downstream of the Assawompset Pond Dam. The bottom of the bridge deck is approximately 11 feet higher than the river thalweg. OE conducted a survey of the bridge on April 27 and 28, 2021, during which nine transects of river bathymetry were collected. Granite headwalls on either end of the bridge taper in from 71 feet wide upstream of the bridge to a width of 40 feet under the bridge, then taper back out to 77 feet wide downstream of the bridge. The bankfull width of the river upstream of the MBTA bridge was measured at 66 feet, while downstream a bankfull width of 64 feet was measured.

Figure 11. The MBTA Bridge Viewed from Upstream

Figure 12. Map of Middleborough, 1855 (H.F. Walling, available through Harvard University); MBTA Bridge circled in blue

2.3.6 Old Bridge Street Bridge

The Old Bridge Street bridge (**Figure 13**) was built in 1910 to replace the previous bridge located at what was then Bridge Street; a bridge has been in place at Bridge Street since at least 1831. The Old Bridge Street bridge spans 35 feet and is located 2.0 miles downstream of the Assawompset Pond Dam. The bridge is blocked to vehicle access by a steel guard rail, and now serves as a foot bridge. A parking area to the west is used to access a boat launch upstream of the bridge. HW surveyed the Old Bridge Street bridge on April 23, 2021 and collected four transects of river bathymetry and measured bridge geometry. The bridge is a concrete arch, approximately 13 feet above the river thalweg at its highest point. Stone headwalls on either end of the bridge provide earth support to the roadway outside of the bridge.

Channel bottom material is similar upstream and downstream of Old Bridge Street: sandy in the channel, with silt along the banks. The upstream channel width was measured to be 49 feet. Downstream of Old Bridge Street, channel material is generally sandy with gravel; sediment in the left bank is silty. The channel width downstream of the bridge was measured to be 61 feet. The channel width in the vicinity of Old Bridge Street appears to have been altered by human activities (such as filling near the bridge embankments and dredging near what is now a canoe launch), so channel widths at this location do not correspond to a “natural” bankfull width.

Figure 13. Old Bridge Street Bridge Viewed from Upstream

2.3.7 Bridge Street Bridge

The Bridge Street Bridge (**Figure 14**) was built in 1968[18] as part of a roadway construction project to redirect traffic from Bridge Street around the then newly constructed Ocean Spray production and storage facility (**Figure 15**).

The bridge spans 78 feet and is located 1.9 miles downstream of the Assawompset Pond Dam. The Bridge Street Bridge is only 350 feet upstream of Old Bridge Street. HW surveyed the Bridge Street bridge on April 23, 2021 and collected three transects of river bathymetry as well as measurements of bridge geometry. The bridge stands on three rows of nine piers, each 9 inches in diameter (**Figure 37**). The bottom of the bridge deck is approximately 13 feet above the channel thalweg. Rip rap abutments slope from the bridge headwalls down to the channel, narrowing the channel width to approximately 40 feet wide at the bottom of the abutments.

Material upstream of Bridge Street is sandy with gravel within the majority of the channel and is silty along the left bank. The upstream channel width was measured to be 76 feet. Downstream of Bridge Street, the channel material is sandy; material along both banks is silty. The downstream channel width was measured at 43 feet. As with the Old Bridge Street Bridge, channel dimensions

[18] MassDOT, “National Bridge Inspection Standards (NBIS) Underwater Bridge Inspection: Bridge Street / Nemasket River,” November 7, 2019

in the vicinity of the Bridge Street appear to have been altered from “natural” dimensions by humans.

Figure 14. Bridge Street Bridge Viewed from Upstream

Figure 15. Assawompset Pond, 1963 (left) and 1978 (right) (USGS)

2.3.8 Vaughan Street

The Vaughan Street bridge (**Figure 16**) has been in place since at least 1831 and was most recently rebuilt in 2002[19]. The bridge spans 35 feet and is located approximately 0.6 miles downstream of the Assawompset Pond Dam. HW surveyed the bridge on April 23, 2021, collecting four transects of river bathymetry and measuring bridge geometry. The bottom of the bridge is approximately 11 feet higher than the channel thalweg. Headwalls provide earth support on either end of the bridge; the headwalls are each 7 feet tall, with tops of the walls 1.5 feet below the bottom of the bridge. A staff gage has been installed on the upstream side of the bridge.

Material in the channel upstream and downstream of the Vaughan Street bridge is sandy with gravel and cobble. The channel width immediately upstream and downstream of the bridge ranges from 45-55 feet; this portion of the channel was likely filled in to construct the bridge. Transects measured farther than 150 feet upstream and downstream of the bridge had channel widths between 60-70 feet. About 200 feet downstream of the bridge, a hand-excavated channel dating back to 1816 was created to bypass a series of bends in the Nemasket River to support steamboat passage[20].

Figure 16. Vaughan Street Bridge Viewed from Downstream

[19] MassDOT, "National Bridge Inspection Standards (NBIS) Bridge Inspection Reports: Vaughan Street / Nemasket River," June 6, 2018

[20] Thayer, D., "History"

2.3.9 Assawompset Pond Dam

The Assawompset Pond Dam (National ID MA03154) was constructed at the headwaters of the Nemasket River, which is also the outlet point of the Assawompset Pond Complex (APC). The dam was constructed from 1884 to 1894 in order to provide a stable water supply to the communities surrounding the APC[21]. Currently, the cities of Taunton and New Bedford withdraw drinking water from the APC based on water withdrawal permits associated with the APC. The dam is owned by Taunton and operated jointly by the two cities. It is classified by the office of Dam Safety (ODS) as a Large, Significant Hazard (Class II) structure[22].

The Assawompset Pond Dam consists of five gates, each approximately 6 feet wide. At either end of each gate is a stone pier with a metal frame that allows the placement of wooden boards (or "stop logs") in the gates (**Figure 17**). The boards are each approximately 6 inches tall, while the gates are each between 5 and 6 feet tall. East of the gates is a 2-foot wide concrete Denil fish ladder, which was constructed in 1968[23] and was the first Denil fish ladder to be constructed in Massachusetts[24]. East of the fish ladder is an approximately 100-foot emergency spillway comprised of a 40-foot concrete surface and a 60-foot gravel path (**Figure 18**).

Figure 17. Stone Piers with Boarded Gates Comprising Assawompset Pond Dam

[21] CDM, "Assawompset Pond Dam Phase I Inspection/Evaluation Report," November, 2006
[22] Ibid.
[23] MA DMF and Middleborough-Lakeville HFC, "Sustainable Fishery Plan"
[24] Thayer, D., "History"

Figure 18. Assawompset Pond Gates, Fish Ladder, and Spillway. Photo taken by Outback Engineering

Between June 11 and 18, 2020, OE conducted a survey of the Assawompset Pond Dam and of the Nemasket River from the dam to 600 feet downstream. As part of the survey, OE collected information on dam geometry and channel bathymetry across 19 transects along the Nemasket. In the area downstream of the dam, the channel has a bankfull width of approximately 60 feet. A small berm (approximately 1 foot tall) has been constructed on the river-right side of the channel beginning at the dam and extending 200 feet downstream. On the river-left side of the channel, a 5-foot-tall berm has been constructed that extends 100 feet downstream of the dam.

In addition to collecting topographic and bathymetric data, OE probed the channel centerline downstream of the dam over a distance of 1,850 feet. In the first 300 feet downstream of the dam, probed material was generally coarse sand, with some gravel observed in the soil near the dam. Beyond 300 feet downstream of the dam, channel material was generally fine to medium sands. Per OE, "preliminary probing of the river bottom appears to indicate that sediment may be being transported as far as approximately 1,150 feet downstream of the dam spillway, where a stoney/rocky river bottom was observed. The river bottom elevation in this area is approximately 48.0 feet, which is assumed to be the natural river bottom elevation.[25]"

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[25] Outback Engineering, "Alternatives Analysis Memo," February 23, 2021

3 Hydrologic and Hydraulic Modeling

HW developed a hydrologic and hydraulic (H&H) model of the subject reach of the Nemasket River to provide an understanding of how the Assawompset Pond Dam, Wareham Street Dam, bridges and other river crossings, and river channel morphology affect water levels, flow velocities, sediment transport, fish passage, habitat, and related conditions along the riparian corridor within the project area. Specifically, this analysis assessed the potential future impacts of alterations to the dams and bridges along the Nemasket River, as well as alterations of the river channel morphology.

Hydrology, in this context refers to the volume of precipitation-derived water from the watershed conveyed to the river under different storm and flow conditions, while hydraulics refers to the flow characteristics of the river resulting from those hydrologic inputs under the same set of flow conditions.

Because of the different hydraulic conditions of the riverine Nemasket River and the lacustrine[26] Assawompset Pond Complex, two separate hydraulic models were utilized in the development of the H&H model for this project. The first stage of modeling focused on the impacts of alterations to the Wareham Street Dam, bridges and culverts, and river channel morphology in relation to the Nemasket River. The second stage of modeling focused on the impacts of alterations to the Assawompset Pond Dam in relationship to the Assawompset Pond Complex.

The hydraulic model selected for use on the first stage of this project was the U.S. Army Corps of Engineers (USACE) Hydraulic Engineering Center – River Analysis System (HEC-RAS) software. HEC-RAS models the hydraulics of water flow through natural rivers and other channels. The user defines the channel extents, cross-sectional dimensions, and hydrologic flows; based on those inputs, HEC-RAS calculates the water surface elevation profile, velocities, and depths within the channel. HEC-RAS can also be used to determine the effects of various obstructions such as bridges and culverts in the channel and floodplain.

For this project, HEC-RAS was run under steady state flow conditions, which refers to the conditions where the fluid (i.e., water) properties at a single point in the system do not change over time. The hydrologic flow inputs to the model for the relevant flow events are described in **Section 3.1** below. The model was developed using one-dimensional, subcritical flow hydraulics. One dimensional HEC-RAS models are well-suited for situations like the current study where hydraulic changes occur predominantly in one dimension (i.e., from upstream to downstream along the centerline of the channel). Two and three (adding vertical and lateral variance) dimensional models are more complex and require significantly more input data, as well as more advanced modeling software.

The HEC-RAS model developed for this project was adapted from a HEC-RAS model of the Nemasket River previously developed by FEMA in 2013. HW conducted an extensive topographic and bathymetric survey in order to update the FEMA model, described below in **Section 3.2**. Evaluation of proposed dam removal, bridge replacement, and channel restoration scenarios are described in **Section 3.3**.

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[26] "Lacustrine" refers to lake-based features.

The hydraulic model selected for the second stage of this project was HydroCAD (Version 10.20), a software which combines USDA Soil Service hydrology and hydraulic techniques (commonly known as SCS TR-55 and TR-20) to generate estimates of stormwater inflow, storage, and outflow. HydroCAD is well-suited for modeling large volumes of water flowing into and out of basins and reservoirs. As such, HydroCAD was an optimal hydraulic model to use for understanding the impacts of potential changes to the Assawompset Pond Dam on the storage capacity and flood attenuation in the Assawompset Pond Complex. The inputs, development, and results of the HydroCAD model are described in greater detail in **Section 3.4**.

3.1 Hydrology

According to information obtained using the United States Geologic Survey (USGS) StreamStats program, the Nemasket River watershed at its most downstream point in the study area is approximately 39,900 acres (62.3 square miles), shown below in **Figure 19**. Landcover types and areas are described below in **Table 1**.

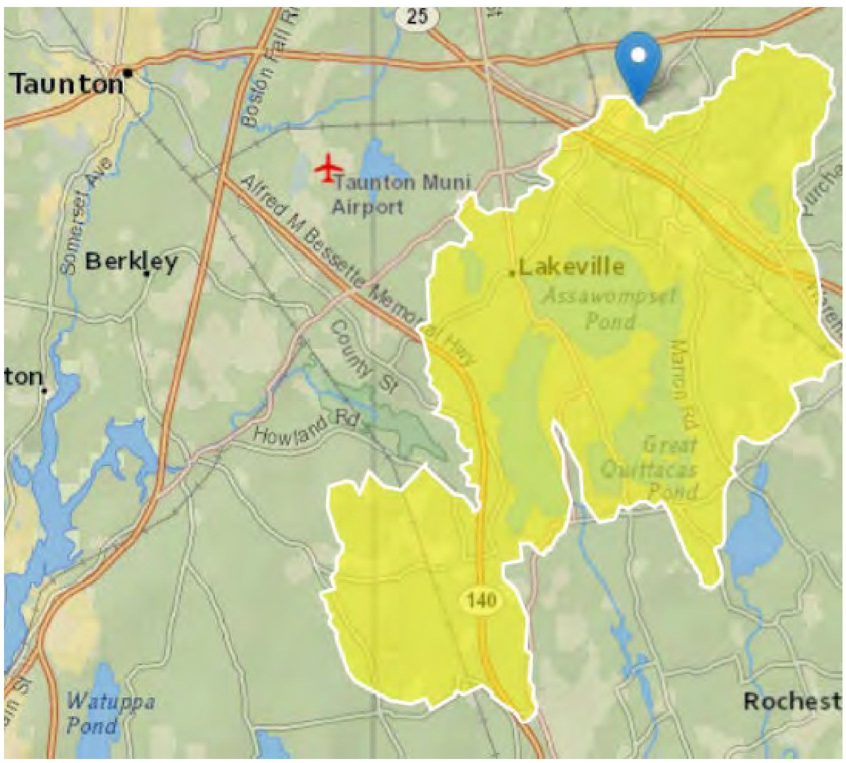

Figure 19. StreamStats Watershed Delineation of Nemasket River at Wareham Street Dam

Table 1. Landcover Distribution of Nemasket River Watershed within Study Area

Landcover Type	Area	Proportion of Watershed
Forest	36.3	58.3%
Waterbody/Wetland	19.7	31.6%
Impervious	2.7	4.4%
Other	3.6	5.7%
Total	**62.3**	**100%**

To predict water surface elevation (WSE) within the Nemasket River study area (from the river's headwaters at the Assawompset Pond Dam to downstream of the Wareham Street Dam), estimates for flow rates at various statistical return intervals are required. Daily and peak flow rates were estimated using six hydrological estimation methods, based on a combination of basin characteristics and empirical observations.

Site-specific, Nemasket River stage and flow measurements were taken at the Vaughan Street river crossing on 17 occasions by the Massachusetts Division of Ecological Restoration (DER) between May 2005 and August 2013. Additionally, WSE measurements at the Assawompset Pond and at Vaughan Street have been recorded on a near daily basis by the New Bedford Water Department since at least January 2010.

Of the six hydrological methods used in developing the Nemasket River H&H model, two methods (FEMA and StreamStats) utilized previously developed equations for estimating peak flows, while the remaining four were based on site-specific data collected from Assawompset Pond, the Nemasket River, and the Taunton River. Because site-specific data along the Nemasket was only collected at the Vaughan Street river crossing, initial peak flow estimates were evaluated and compared for the Nemasket at Vaughan Street. The various methods used are described below.

3.1.1 FEMA Method

In the 2013 H&H model of the Nemasket River developed by the Federal Emergency Management Agency (FEMA), peak flow magnitudes are estimated based on a series of seven regression equations developed by USGS in 2010[27]. The regression models were based on observed stream flow from streams in Rhode Island, southeastern Massachusetts, and eastern Connecticut. Because no USGS flow gage exists for the Nemasket River, the nearest downstream USGS gage (USGS 01108000: Taunton River near Bridgewater, MA) was utilized to calibrate the USGS regression models used by FEMA. The hydrological model estimates flood flow rates from three input variables: basin drainage area, basin stream density, and basin storage. Values for drainage area and stream density were obtained using USGS StreamStats software, while basin storage was obtained from the FEMA Flood Insurance Study (FIS) for Plymouth County, MA.[28] Calculated peak flows from the FEMA Method are shown below in **Table 2**.

Table 2. FEMA Method Peak Flow Statistics

Recurrence Interval	Estimated Flow (cfs)
5-year	344
10-year	424
25-year	554
50-year	651
100-year	772
200-year	856
500-year	993

[27] Zarriello et al., "Magnitude of Flood Flows for Selected Annual Exceedance Probabilities in Rhode Island Through 2010," U.S. Geological Survey Scientific Investigations Report 2012-5109, Version 1.2, March 2013

[28] Federal Emergency Management Agency, "Flood Insurance Study for Plymouth County, Massachusetts (All Jurisdictions)," Flood Insurance Study Number 25023CV001D, Revised July 22, 2020

3.1.2 StreamStats Hydrology Method

StreamStats is a USGS software program that generates estimates of stream properties such as peak flow rates, low-flow statistics, and bankfull width. To do so, StreamStats uses regression models based on basin characteristics such as basin drainage area, mean basin elevation, and basin storage. Different models are developed regionally; Nemasket River statistics are generated from the Massachusetts collection of models[29][30], which are based on streamflow data from Massachusetts, Rhode Island, Connecticut, New York, Vermont, and New Hampshire. StreamStats-generated flow statistics are shown below in **Table 3**.

Table 3. StreamStats Flow Statistics

Recurrence Interval	Estimated Flow (cfs)
95% Exceedance	3.98
2-year	412
5-year	657
10-year	845
25-year	1,110
50-year	1,320
100-year	1,540
200-year	1,770
500-year	2,100

Notably, the flow statistics generated by StreamStats are significantly higher than those produced by the FEMA Method; StreamStats flows generally exceed FEMA flows by a factor of two. As discussed above, the FEMA Method was developed using flow data from the Taunton River downstream of the Nemasket River for calibration, while the StreamStats method was developed using rivers and streams within other watersheds.

Based on flow data recorded from Assawompset Pond, Nemasket River, and Taunton River, HW developed four additional hydrological methods to better evaluate the flow statistics of the Nemasket.

[29] Zarriello, P.J., "Magnitude of Flood Flows at Selected Annual Exceedance Probabilities for Streams in Massachusetts," U.S. Geological Survey Scientific Investigation Report 2016-5156, 2017

[30] Ries and Friesz, "Methods for Estimating Low-Flow Statistics for Massachusetts Streams," U.S. Geological Survey Water-Resources Investigations Report 00-4135, 2000

3.1.3 Assawompset Pond Hydrology Method

The Assawompset Pond Hydrology Method was developed using a combination of recorded WSE data in the Assawompset Pond, WSE data in the Nemasket River at the Vaughan Street Bridge, and Nemasket River flow data at the Vaughan Street Bridge. WSE data at the Assawompset Pond has been collected daily by the New Bedford Water Department at the Assawompset Pond pump house in Lakeville (**Figure 20**) from January 2010 through the present. The New Bedford Water Department has also collected WSE data at Vaughan Street periodically since April 2012 (**Figure 21**). Vaughan Street WSE and flow data were also collected by the Massachusetts Division of Ecological Restoration (DER) on 17 days between 2005 and 2013. In April 2021, HW collected an additional pair of WSE and flow measurements at Vaughan Street.

Figure 20. Assawompset Pond Pump House Near Pocksha Pond in Lakeville – photo by Christine Hochkeppel, Wicked Local

Figure 21. Vaughan Street Bridge – Staff Gauge Along Rear Abutment

The Assawompset Pond Method was developed using a three-step process in order to estimate the range of flows expected on a daily basis.

First, Using the data collected by New Bedford, HW assessed the relationship between WSE at the Assawompset Pond and the Nemasket River at Vaughan Street, shown in **Figure 22**. A strong linear relationship (R^2 = 0.802) was observed between WSE values at the two locations. Therefore, Assawompset Pond WSE was determined to be a good predictor for Nemasket River WSE at Vaughan Street.

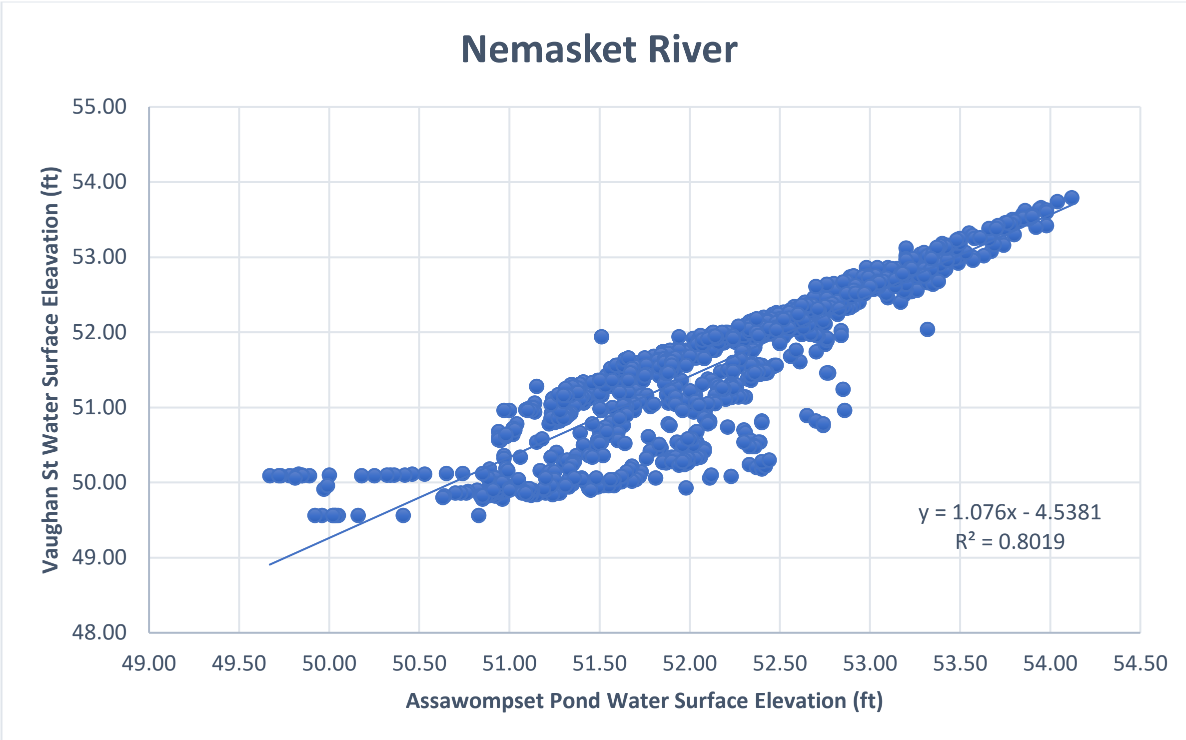

Figure 22. Water Surface Levels at the Assawompset Pond and Nemasket River at Vaughan Street

Second, using the data collected by DER, as well as the pair of flow and water surface measurements collected by HW, HW then assessed the relationship between WSE and discharge[31] in the Nemasket River in order to generate a rating curve for the Nemasket (**Figure 23**). A strong power relationship ($R^2 = 0.879$) was observed between WSE and discharge at the Vaughan Street crossing of the river. Therefore, the Nemasket River rating curve was determined to be a good model for predicting discharge from WSE at Vaughan Street.

[31] "Discharge" as mentioned in this report is used interchangeably with "flowrate." Discharge and flowrate are both measured in terms of volume of water moving through the river over a given time. In the case of this report, the units of discharge are cubic feet per second, or "cfs."

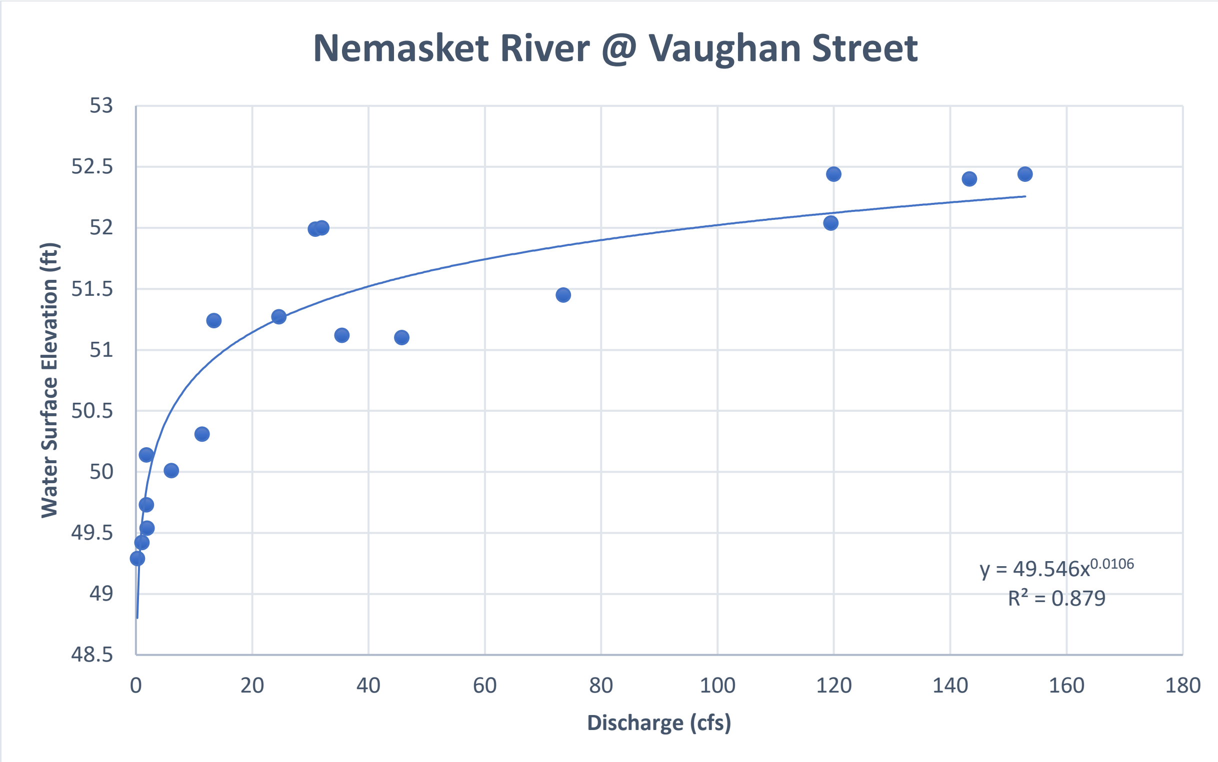

Figure 23. Rating Curve for Nemasket River at Vaughan Street Bridge

Third, an extrapolated record for Nemasket River flows was developed. To do so, the linear regression between Assawompset Pond and Nemasket River WSE's was applied to the complete record of daily Assawompset Pond WSE measurements gathered by New Bedford. Then, the rating curve developed for the Nemasket at Vaughan Street was applied to the regression-generated Vaughan Street WSE values. The result of this process is a daily exceedance probability curve for Nemasket River flows at Vaughan Street based on recorded WSE values at the Assawompset Pond. The daily exceedance probability curve[32] is shown in **Figure 24**.

Using the exceedance probability curve, predicted Nemasket flow statistics at select daily exceedance probabilities are ultimately generated, shown below in **Table 4**.

[32] A "daily exceedance probability curve" shows the likelihood that a given flowrate will occur or be exceeded on any given day. Low flow rates are very likely to be exceeded, and therefore have high exceedance probabilities (closer to 100%, or 1.0), while high flow rates are less likely to be exceeded (exceedance probabilities closer to 0%). These curves are helpful for determining the typical range of flowrates in a river, with less of a focus on rare flood events that occur only one time per year or less.

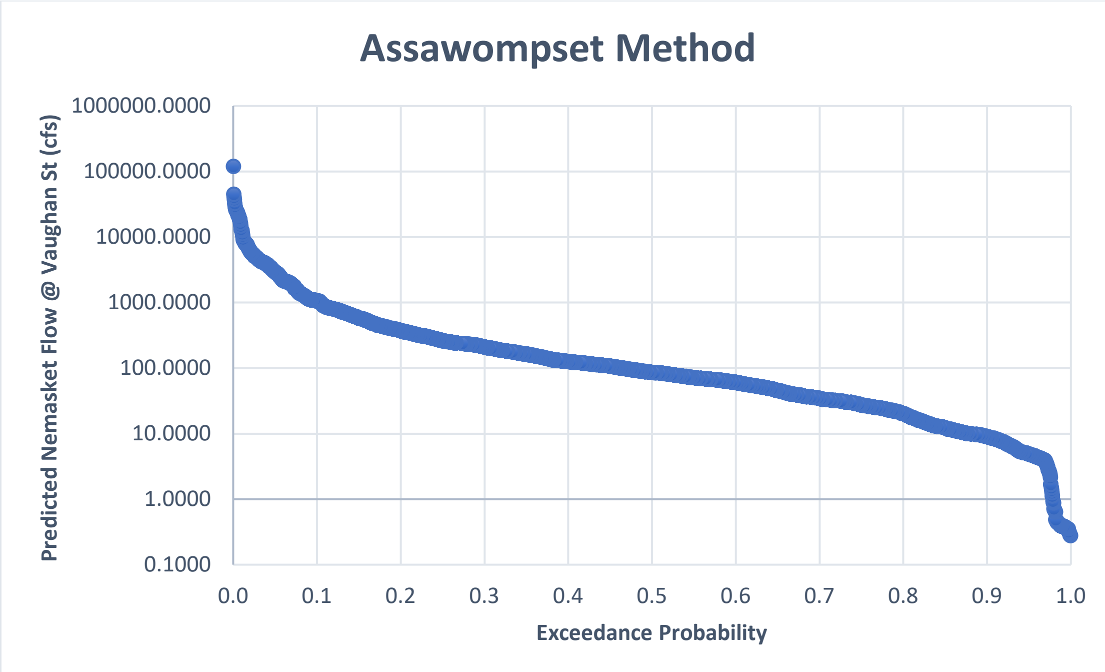

Figure 24. Daily Exceedance Probability Curve for the Nemasket River Based on Recorded Assawompset Pond WSE

Table 4. Predicted Daily Exceedance Probability Statistics for the Nemasket River Based on Assawompset WSE

Exceedance Probability	Estimated Flow (cfs)
95%	4.89
75%	27.72
50%	87.05
25%	263.50
5%	2941.83

3.1.4 Taunton River Hydrology Methods

The Taunton River Hydrology Method was developed using a combination of flow data measured in the Nemasket River at the Vaughan Street bridge by DER (previously discussed in the Assawompset Pond Hydrology Method Section) and gauged flow data for the Taunton River recorded by USGS. Taunton Flow data was measured by USGS Gage No. 01108000, located just downstream of the confluence of the Nemasket and Taunton Rivers in Bridgewater, MA. Gauged flow measurements range in date from 1929 to the present.

The Taunton River Method was developed using a two-step process in order to estimate the range of flows expected on a daily and annual basis.

First, using the data collected by DER and USGS, HW assessed the relationship between discharge at the Taunton and Nemasket Rivers (**Figure 25**). A moderately good linear relationship ($R^2 = 0.774$) was observed for the 17 days in which flow was measured at both sites. Therefore, Taunton River discharge was determined to be a suitable predictor for Nemasket River flow at the Vaughan Street Bridge.

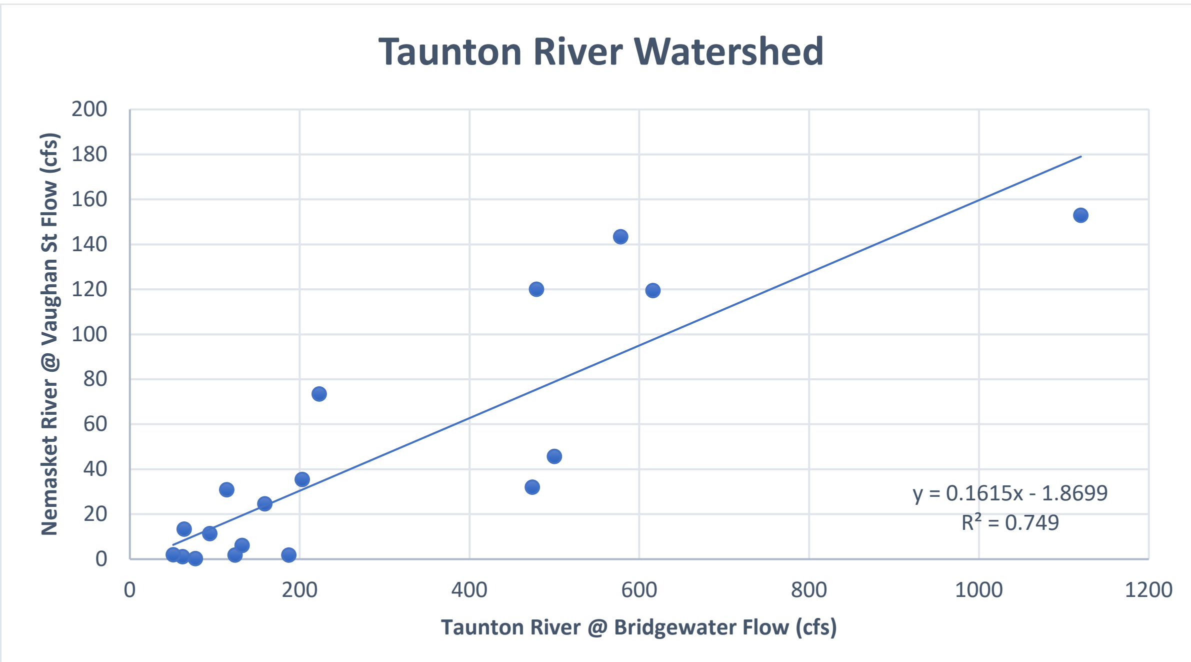

Figure 25. Nemasket and Taunton River Discharge Measurements

Second, an extrapolated record for Nemasket River flow was developed based on the gauged measurements of Taunton River flow, available from USGS from 1996 to present. Based on the regression equation shown in **Figure 25**, daily flow measurements at the Taunton River were converted into a daily exceedance probability curve for the Nemasket River (**Figure 26**). Likewise, peak flow statistics for the Nemasket River were predicted based on peak flow statistics for the Taunton River using the linear regression shown in **Figure 25**.

Predicted Nemasket River flow statistics at select exceedance probabilities are shown in **Table 5**. Predicted Nemasket River peak flow statistics are shown in **Table 6**.

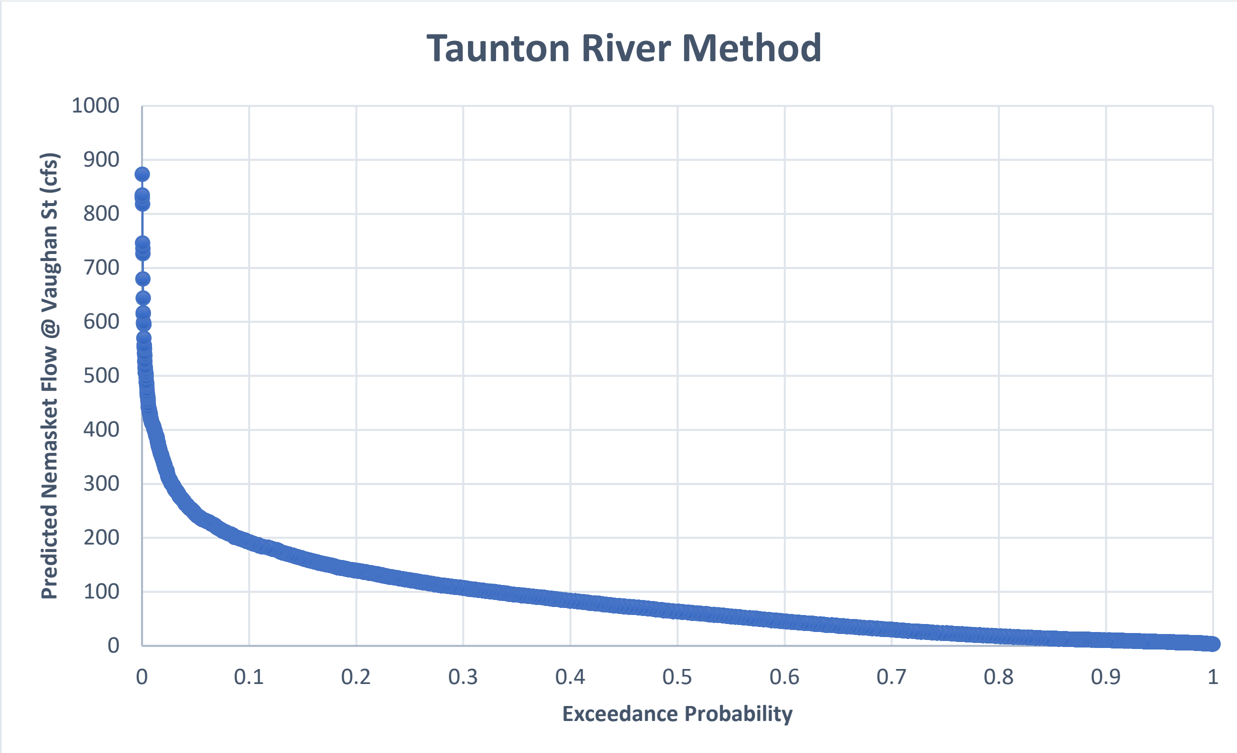

Figure 26. Daily Exceedance Probability Curve for the Nemasket River Based on Recorded Taunton River Flow

Table 5. Predicted Daily Exceedance Probability Statistics Based on Taunton River Flows

Exceedance Probability	Estimated Flow (cfs)
95%	7.66
75%	23.81
50%	64.18
25%	121.68
5%	245.23

Table 6. Predicted Peak Flow Statistics Based on Taunton River Flows

Recurrence Interval	Estimated Flow (cfs)
2-year	411.26
5-year	526.56
10-year	611.78
25-year	720.40
50-year	800.61
100-year	882.48
200-year	964.36
500-year	1,076.32

3.1.5 Prorated Taunton River Hydrology Method

As a simple comparison to the Taunton River Hydrology Method, an alternative Prorated Taunton River Hydrology Method was developed using a single-step process. In this alternative hydrologic method, flow estimates are based on the theoretical relationship of drainage areas between the Taunton River basin and the Nemasket River subbasin, rather than being based on empirically measured flow rates along both rivers.

In the Prorated Taunton River Method, Nemasket flow statistics were estimated based on the ratio of the drainage area of the Nemasket River at Vaughan Street (49.7 square miles) to the drainage area of the Taunton River at the Bridgewater USGS gage (262 square miles). Flow statistics for the Taunton River at the gage were prorated based on this ratio; the results are shown in **Table 7**.

Table 7. Comparison of Flow Statistics Predicted Using the Taunton River and Prorated Taunton River Methods

Flow Event	Estimated Flow (cfs)	
	Taunton River Method	Prorated Taunton River Method
95% Exceedance	7.66	11.19
75% Exceedance	23.81	30.16
50% Exceedance	64.18	77.59
25% Exceedance	121.68	145.12
5% Exceedance	245.23	290.23
2-year	411.26	468.55
5-year	526.56	599.44
10-year	611.78	696.18
25-year	720.40	819.48
50-year	800.61	910.53
100-year	882.48	1,003.49
200-year	964.36	1,096.44
500-year	1,076.32	1,223.53

While the Prorated Taunton values are slightly higher than those of the Taunton River Method, the two methods offer close predictions of Nemasket River flow. Further comparison of the methods is discussed below.

3.1.6 Method Analysis and Scaled Assawompset Pond Hydrology Method

As described above, HW assessed five main hydrological methods to predict flow statistics for the Nemasket River, three of which were developed by HW. Those methods include:

1. FEMA Method: an estimate of annual exceedance flows developed by FEMA based on a series of regression equations that use basin drainage area, basin stream density, and basin storage as input variables;
2. StreamStats Method: an estimate of annual exceedance flows developed by USGS based on a series of regression equations that use basin drainage area, mean basin elevation, and basin storage as input variables;
3. Assawompset Pond Method: an estimate of daily exceedance flows developed by HW based on the relationship between observations of Assawompset Pond water levels, Nemasket River water levels, and Nemasket River flow rates;
4. Taunton River Method: an estimate of daily and annual exceedance flows developed by HW based on the relationship between observations of Taunton River flow rates and Nemasket River flow rates; and
5. Prorated Taunton River Method: an estimate of daily and annual exceedance flows based on the ratio of the drainage area of the Taunton River and the Nemasket River.

Two of the hydrologic methods developed by HW are based on empirically observed data: (1) the Assawompset Pond Method, based on WSE data in the pond; and (2) the Taunton River Method, based on flow data in the Taunton and Nemasket Rivers. While these two methods are more site-specific than the other methods that were assessed, the two methods significantly diverge in predictions of less frequent, higher flows, as shown in **Table 8**.

Table 8. Comparison of Daily Flow Statistics for Nemasket River Using Two Methodologies

Exceedance Probability	Estimated Flow (cfs)	
	Assawompset Method	Taunton River Method
95%	4.89	7.66
75%	27.72	23.81
50%	87.05	64.18
25%	263.50	121.68
5%	2,941.83	245.23

To better evaluate the accuracy of the empirically based models, HW developed an observed vs. predicted (OP) regression, shown in **Figure 27**. The OP regression compared observed vs. predicted values of both methods to a 1:1 line (the gray line in **Figure 27**), demonstrating goodness of fit (GOF) between regression predictions and observed values. For models in which predicted values are in line with observed values, their OP regression should be close to the 1:1 GOF line. This is typically true of linear regression models (such as the Taunton River Model) but may not be true of models based on exponential, logarithmic, or power functions.

While the Taunton River Method regression is indeed perfectly coincident with the 1:1 GOF line, the Assawompset Method regression overpredicts flow values compared to observed measurements. This is due to the fact that the Assawompset Method uses a power function (the Nemasket Rating curve), which predicts exponentially greater flows in the Nemasket River at high water levels in the Assawompset Pond, as compared to the linear Taunton River Method.

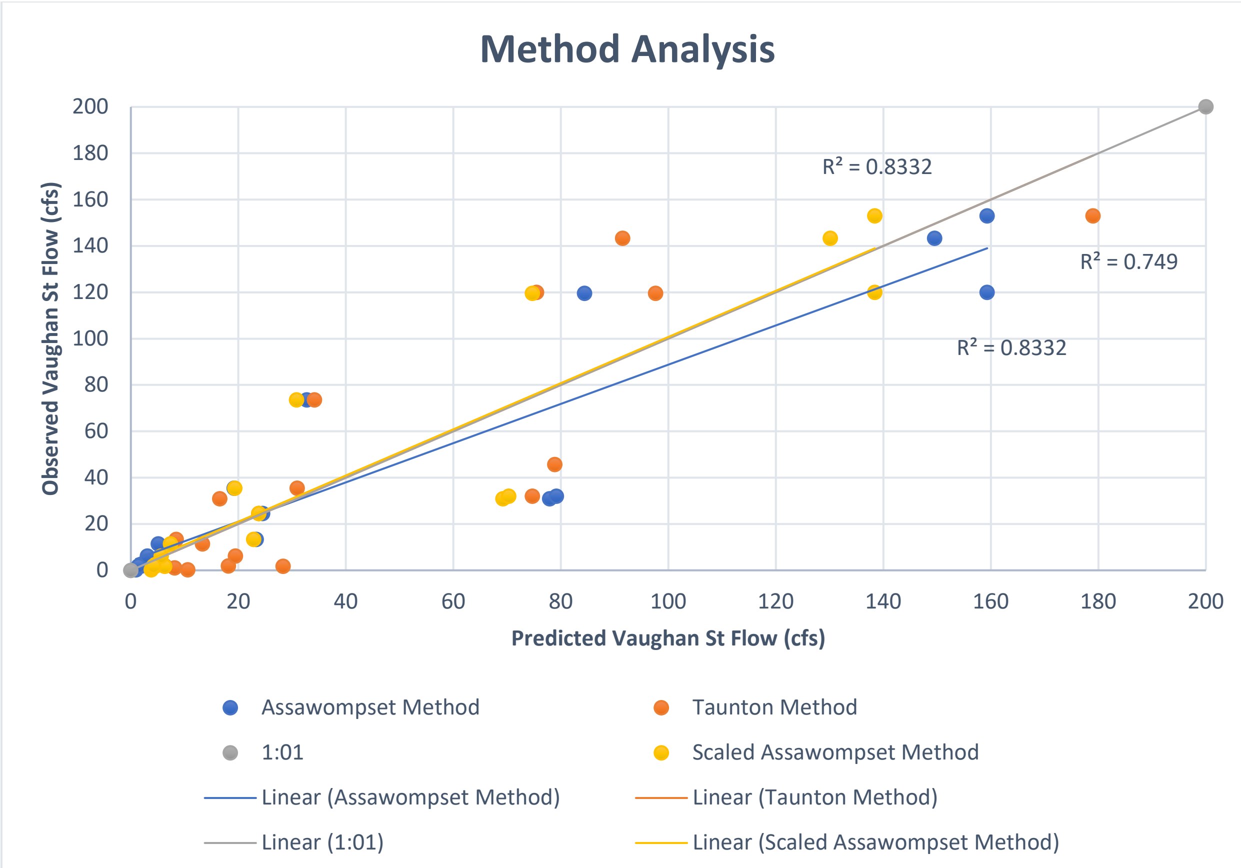

Figure 27. OP Regression of Assawompset and Taunton Hydrologic Methods

In order to correct for the overestimation of the Assawompset Method, a Scaled Assawompset Method was created to better match the 1:1 GOF line. To do so, a scale factor of 0.85 was applied to the Assawompset Method. As with the Taunton and Assawompset Methods, a daily exceedance probability curve was developed for the Scaled Assawompset Method (**Figure 28**). Predicted Nemasket River flows at select exceedance probabilities are shown in **Table 9**.

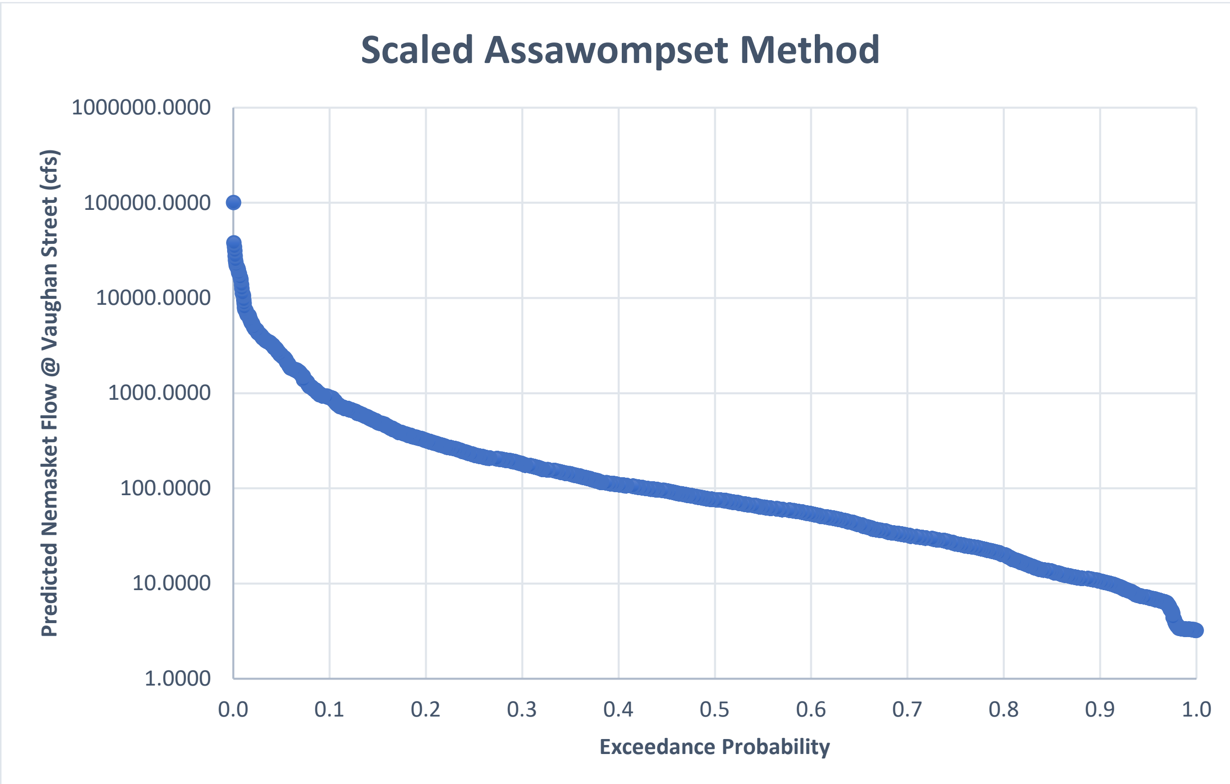

Figure 28. Daily Exceedance Probability for the Nemasket River, Scaled from the Assawompset Hydrology Method

Table 9. Predicted Daily Exceedance Probability Statistics, Scaled from the Assawompset Hydrology Method

Exceedance Probability	Estimated Flow (cfs)
95%	7.15
75%	26.56
50%	76.99
25%	226.97
5%	2,503.55

A summary of predicted flow statistics for the six hydrological methods used is shown in **Table 10**. As discussed above, the flow statistics predicted by StreamStats are approximately two times greater than those predicted using the FEMA Method. Assessing the Assawompset and Taunton River Methods, it is clear that the Assawompset Method significantly overestimates flows greater than the 50% duration event. Even after scaling the Assawompset Method to coincide with a 1:1 GOF line, the predicted values for both the Assawompset and Scaled Assawompset Methods exceed those of the Taunton River Method by a factor of 10 for the 5% duration flow. Moreover, both Assawompset Methods' predictions of the 5% duration flow exceed the 500-year flow prediction generated by StreamStats. Thus, the Assawompset Methods appear to produce overpredictions of Nemasket flow.

By contrast, the Taunton River Method appears to produce a middle ground between the FEMA and StreamStats methods. While the 95% duration and 2-year flows of the Taunton River Method are quite close to the StreamStats flows, predictions for higher flows in the Taunton River Method converge toward values produced by the FEMA Method; the 100-, 200-, and 500-year flows predicted by the Taunton River Method are no more than 110 cfs greater than those of the FEMA Method.

Additional evaluation of the Taunton River Method compared to the Prorated Taunton River Method was conducted using the Hydraulic Engineering Center River Analysis System (HEC-RAS) model developed for this project (discussed in greater detail below). Based on FEMA flood insurance rate map (FIRM) No. 25023C0431 (**Appendix B** – FIRM Panel), the 100-year base flood elevation of the Assawompset Pond is 57.0 feet. When the Taunton River Method hydrology was incorporated into the HEC-RAS model, the predicted WSE was only 56.8 feet, slightly less than the FEMA elevation. By comparison, the Prorated Taunton River Method hydrology yielded a predicted value of 57.3 feet.

Water levels in the Assawompset Pond were observed at a peak elevation of at least 56.5 feet during the recent 2010 flooding event[33], which followed 5.5 inches of rainfall from March 13 to 16, 2.7 inches of rainfall from March 23 to 24, and 6.5 inches of rainfall from March 30 to 31[34]. Although none of these events individually surpassed the National Oceanic and Atmospheric Administration (NOAA) estimate of the 50-year storm event (6.86 inches), let alone the 100-year storm event (7.66), peak flow rates in nearly two-thirds of gaged streams and rivers in southeastern New England reached 100-year records[35].

In light of the FEMA base flood elevation of 57.0 feet, the 2010 Assawompset Pond water levels likely corresponded to a return interval somewhere between the 50- and 100-year return interval. The WSE predictions offered by the Prorated Taunton River Method, which exceed the FEMA 100-year water level in the Assawompset Pond by 0.3 feet, are more apt for evaluating flood scenarios along the Upper Nemasket River and at the Assawompset Pond.

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[33] MassDEP, "Assawompset Pond Complex (APC) Update – On Year Later", April 11, 2011

[34] National Oceanic and Atmospheric Administration, "Climate Data Online," accessed November 7, 2022

[35] Zarriello, P.J. and Bent, B.C., "Elevation of the March-April 2010 flood high water in selected river reaches in central and eastern Massachusetts," 2011, US Geological Survey Open-File Report 2010-1315

Table 10. Comparison of Predicted Nemasket Flow Statistics Among Hydrological Methods

Flow Event	**Estimated Flow (cfs)**					
	FEMA Method	StreamStats Method	Assawompset Method	Taunton Method	Prorated Taunton	Scaled Assawompset
95% Exceedance	-	3.98	4.89	7.66	11.19	7.15
5% Exceedance	-	-	2941.83	245.23	290.23	2503.55
2-year	-	412	-	411.26	468.55	-
5-year	344	657	-	526.56	599.44	-
10-year	424	845	-	611.78	696.18	-
25-year	554	1110	-	720.40	819.48	-
50-year	651	1320	-	800.61	910.53	-
100-year	772	1540	-	882.48	1,003.49	-
200-year	856	1770	-	964.36	1,096.44	-
500-year	993	2100	-	1,076.32	1,223.53	-

For the reasons described above, the Prorated Taunton River Method was selected to inform the hydrology of the Nemasket River in the H&H model developed by HW.

3.1.7 Longitudinal Variation

To account for longitudinal variations in stream flow at different stations along the Nemasket River, the flow statistics generated from the Prorated Taunton River Method were scaled based on the ratio of the drainage area at seven locations along the Nemasket River to the drainage area at Vaughan Street. The locations correspond to those of the original FEMA H&H Study: the Assawompset Pond Dam, Bridge Street, Wareham Street, Nemasket Street, Plymouth Street, Murdock Street, and the MBTA Commuter Railroad Bridge. A depiction of the longitudinal variation in predicted flow along the Nemasket is shown in **Figure 29**.

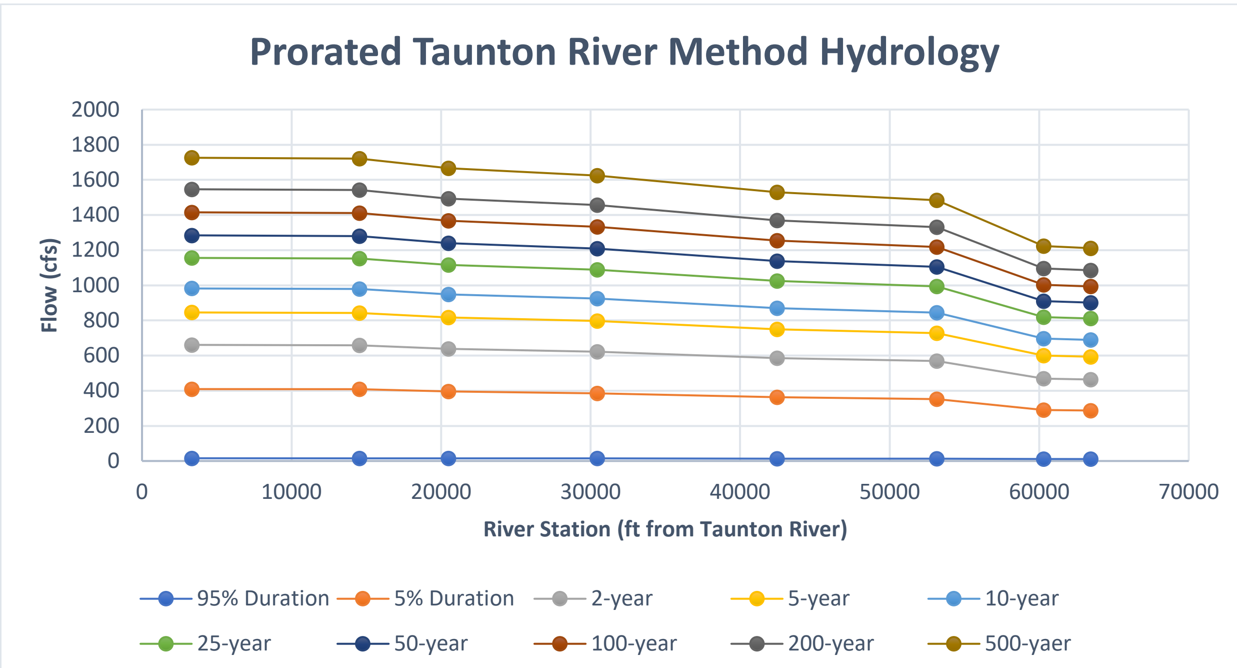

Figure 29. Longitudinal Variation in Nemasket River Flow Predicted Under Prorated Taunton River Method

3.2 Existing Conditions Hydraulic Model

The HEC-RAS model developed for this project was adapted from a HEC-RAS model of the Nemasket River previously developed by FEMA in 2013. In order to adapt the model, HW followed the procedure described in Section 60.3 (d) (3) of the National Flood Insurance Program (the "no-rise" certification procedure), which is a typical process for modeling the impacts of dam or bridge alterations in a river for which a hydraulic model already exists.

The "no-rise" procedure is a three-step process. First, the Currently Effective Model (or, Existing Model) is obtained from FEMA. Second, the Existing Model is shortened to include only the study area by removing river cross sections, bridges, and dams outside of the study area. This version of the model is known as the Duplicate Effective Model. The Duplicate Effective Model is calibrated to ensure that its hydraulic outputs match those of the Existing Model for the study area. Third and finally, a Corrected Effective Model is developed by adding more detailed site-specific conditions to the study area. This level of detail is obtained through topographic and bathymetric survey of the study area, particularly at river crossings and dams.

Once the Corrected Effective Model is developed, it is used as a baseline from which proposed changes are measured.

3.2.1 Interpretation of HEC-RAS Graphics

This report includes a number of graphics generated by HEC-RAS. One such figure is shown below as a guide to understanding the various river components depicted by the HEC-RAS software.

Figure 30 depicts a typical HEC-RAS cross section of a bridge. In this figure:

- The cross section shows a view of the bridge from **upstream on top** and a view of the bridge from **downstream on bottom**.
- The **bridge** is represented by **gray features**. This includes the bridge itself as well as the roadway or embankment on either side of the channel.
- The **top of the bridge** and road are shown as a **red line**, while the **bottom of the bridge** is shown as a **green line**.
- The **white space** above the black or blue dotted lines represents **open space**, which can convey flow or may be airspace, depending on the depth of water at any given time.
- The **white space** under the black or blue dotted lines represents the **channel bottom** or the banks of the river, extending out into its floodplain and beyond.

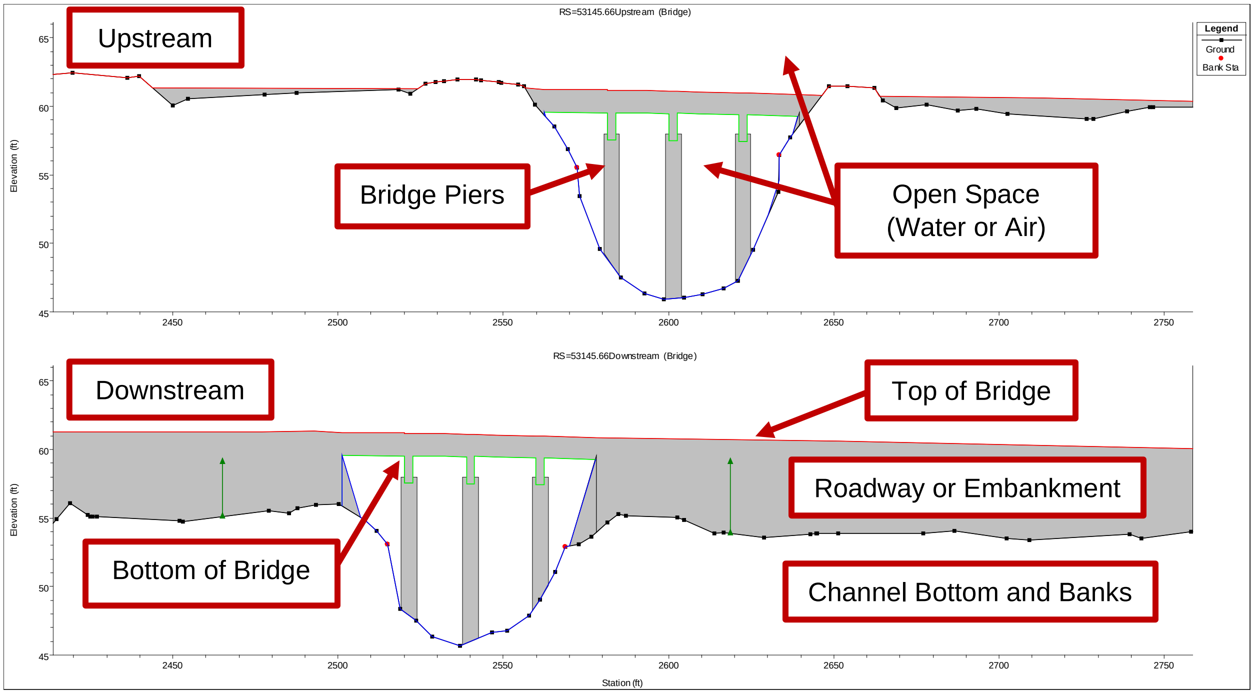

Figure 30. Typical HEC-RAS Cross Section

Figure 31 depicts a typical HEC-RAS longitudinal profile across two bridges. In this figure:

- The **flow direction** is from **right to left**.
- The **bridges** are represented by **gray rectangles**. The upstream limits of the bridge appear as thin black lines on either side.
- **Water** is shown as a **blue region**, with the **water surface elevation** for a given flow rate appearing as a **thin blue line**.
- The **white space** under the black dotted line represents the **channel bottom** along the thalweg, or lowest point in the channel.
- The **white space** over the water surface represents air.
- **Main channel distance**, shown on the horizontal axis, indicates the distance upstream from the downstream end of the study area (River Station 347+65, approximately 7,700 feet downstream of Wareham Street).

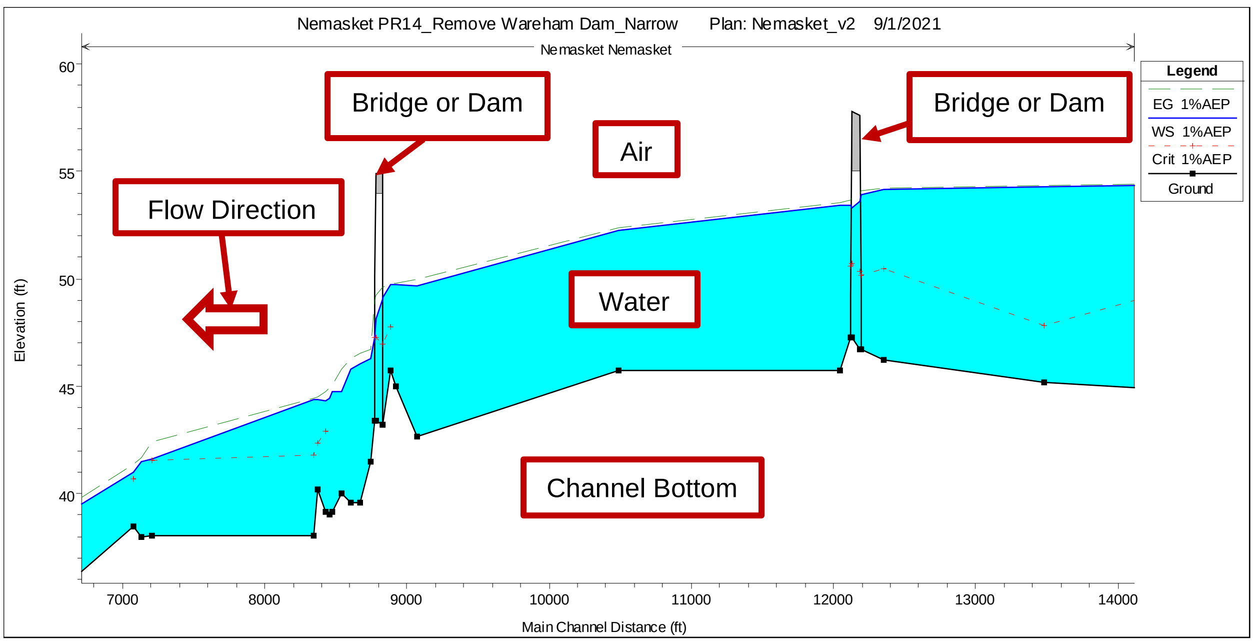

Figure 31. Typical HEC-RAS Longitudinal Profile

3.2.2 Existing FEMA Model

The HEC-RAS model developed for this project was based on a HEC-RAS model of the Nemasket River developed in 2013 by FEMA. The FEMA HEC-RAS model represents the entire 12-mile stretch of the river, from its headwaters at the Assawompset Pond Dam to its mouth at the Taunton River. A total of 99 channel transects were incorporated into the model; topography and bathymetry used in the transects were obtained from a combination of field inspections by USGS staff, channel profile plots,[36] and LIDAR data. A total of thirteen bridges, one culvert, and four

[36] Federal Emergence Management Agency, "Flood Insurance Study: Plymouth Country, Massachusetts," Flood Insurance Study Number 25023CV003D, 2008

inline structures are modelled along the run of the Nemasket. Roughness coefficients for the channel and banks were based on field observations[37], aerial photo inspection, and USGS Water Supply Papers 2339[38] and 2441[39]. Hydrology for the FEMA HEC-RAS model was determined using the FEMA Method (discussed above) at 7 points along the Nemasket River. River geometry of the Existing Model including transects and river centerline is mapped below as **Figure 33**.

3.2.3 Duplicate Effective Model

The Duplicate Effective Model is a simplification of the Existing Model in which transects have been removed that extend beyond the scope of this project. Specifically, transects downstream of the East Main Street bridge are truncated from the model. The downstream slope boundary condition is also adjusted in order to meet the FEMA requirement that base flood elevation (BFE) predictions along the river differ by no more than 0.5 feet from those of the Existing Model[40]. River geometry of the Duplicate Effective Model is shown below as **Figure 34**. As shown in **Figure 32**, the Duplicate Effective Model exactly matches the BFE of the Existing Model within the study area. Between East Main Street Bridge and downstream of the Wareham Street Dam, BFE predictions vary by no more than 0.03 feet, thereby meeting the FEMA criteria.

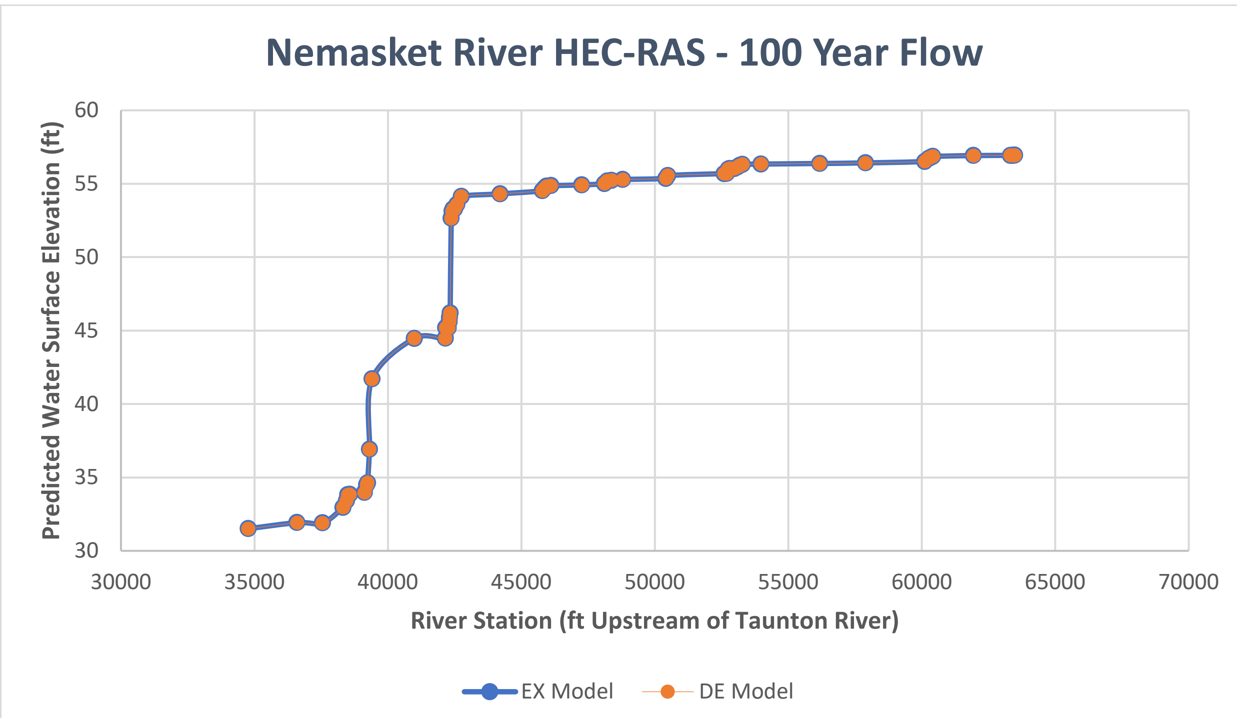

Figure 32. Longitudinal Flow Profile of Existing and Duplicate Effective Models

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[37] Truesdale, P.S., "Nemasket River Shoreline Survey," MassDEP Southeast Regional Office, 2011

[38] Acrement and Schneider, "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains," United States Geological Survey, Water Supply Paper 2339, 1989

[39] Coon, W.F., "Estimation of Roughness Coefficients for Natural Stream Channels with Vegetated Banks," United States Geological Survey, Water Supply Paper 2441, 2011

[40] FEMA, "Instructions for Completing the Application Forms for Conditional Letters of Map Revision and Letters of Map Revision," revised August 2018

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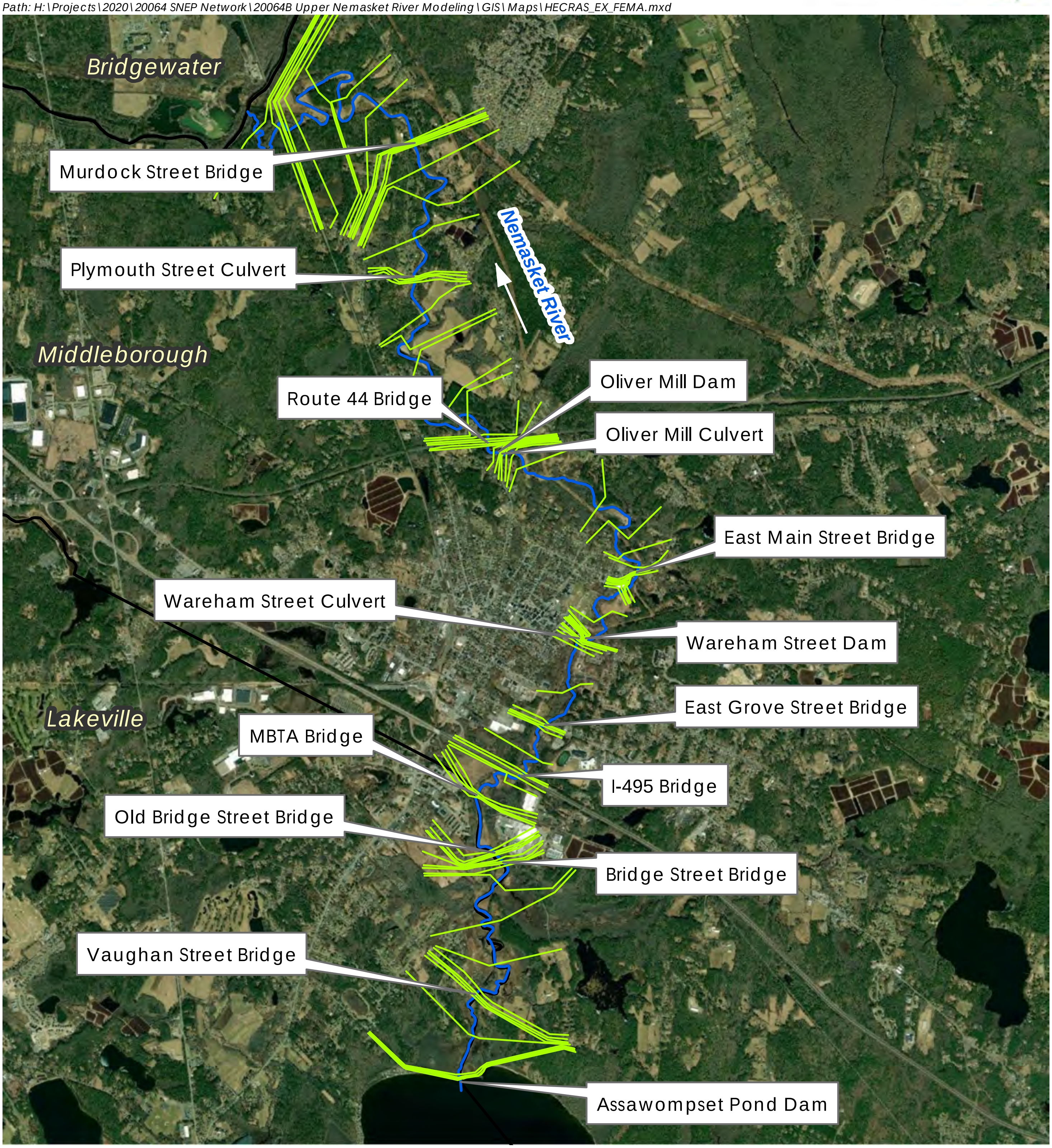

Date: 4/11/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Existing Cross Sections
Nemasket River
Municipal Boundary

Feet
0 2,250 4,500

Upper Nemasket River Hydrology and Hydraulics Study

Figure **33**
Existing FEMA HEC-RAS Model

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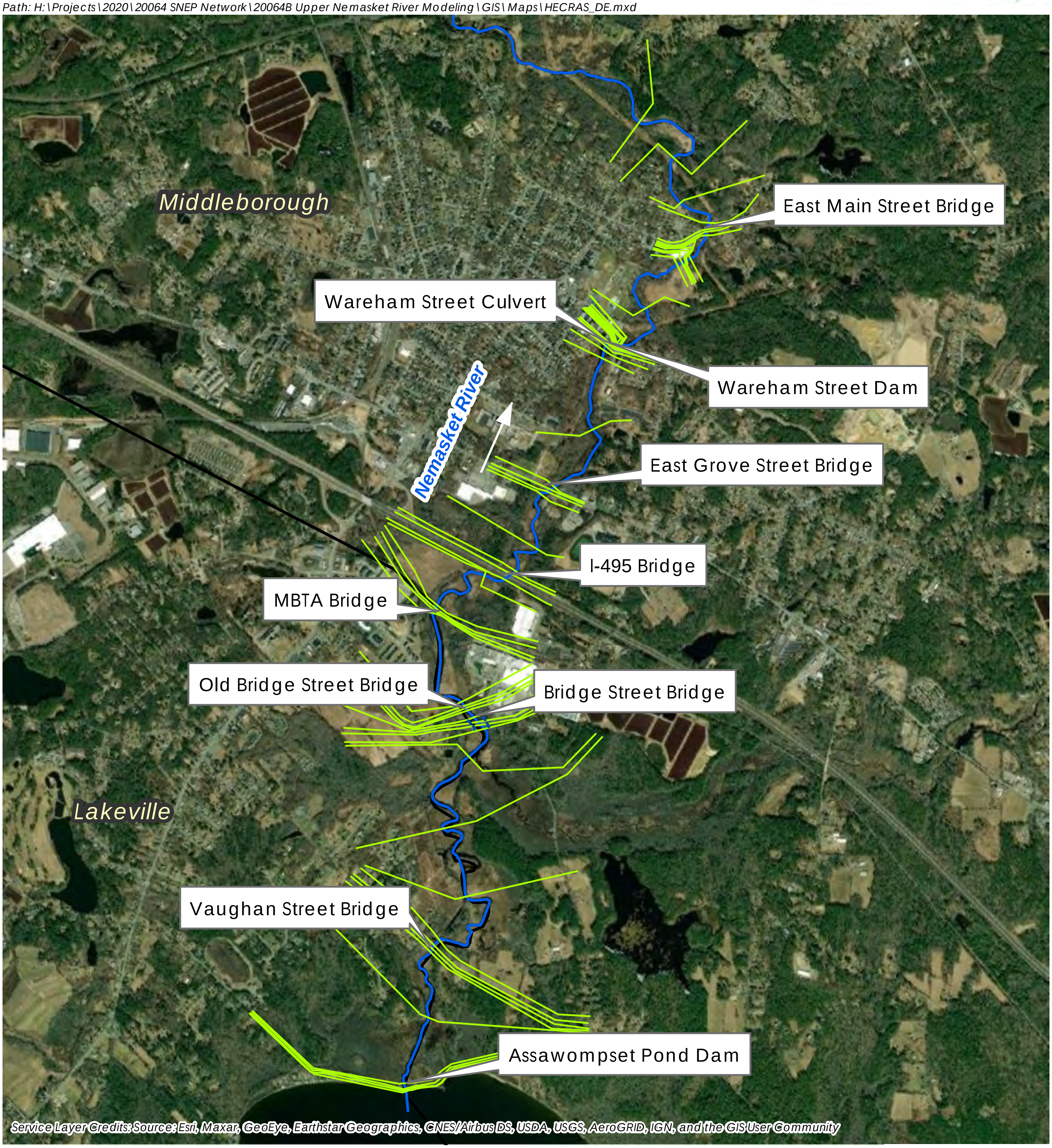

Date: 3/18/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Duplicate Effective Cross Sections
Nemasket River
Municipal Boundary

Feet
0 1,000 2,000

Upper Nemasket River Hydrology and Hydraulics Study

Figure **34**
Duplicate Effective HEC-RAS Model

3.2.4 Data Collection

In order to improve the accuracy of the Duplicate Effective model, HW conducted a number of field assessments along the Nemasket River. Data was collected at six inline structures and river crossings: the Assawompset Pond Dam, the Vaughan Street Bridge; the Bridge Street Bridge; the Old Bridge Street Bridge; the MBTA Bridge; and the Wareham Street dam, weir, culvert, and fish ladder. Data collected at structures included dam and culvert inverts and dimensions, top and bottom chord elevations along bridges, and dimensions of piers and embankments. Additionally, topographic and bathymetric data was collected in the vicinity of the river crossings using traditional total point station survey methodology. Dimensions of measured structures are described above. Discharge was measured immediately downstream of the Vaughan Street Bridge on April 23, 2021.

Survey and data collection at the Assawompset Pond Dam and at the MBTA Bridge was conducted by Outback Engineering Inc. (OE) between June 11-18, 2020 and between April 27-28, 2020, respectively. The existing conditions plans produced as a result of this survey are attached as **Appendix C**. HW surveyed the four other river crossings and dams on April 20 and 23, 2021. Photos from the HW survey are shown below in **Figure 35 - Figure 38**.

Figure 35. Wareham Street Fish Ladder

Figure 36. Survey Equipment on Old Bridge Street Bridge

Figure 37. Measuring Pier Width of Bridge Street Bridge

Figure 38. Assawompset Pond Dam Piers and Gates

3.2.5 Corrected Effective Model

After synthesizing the data collected by OE and HW, a Corrected Effective Model was developed by making alterations to the Duplicate Effective Model. Alterations included the addition of 14 river transects, adjustments of low and high bridge chords, and adjustments to structure dimensions. For example, **Figure 39** and **Figure 40** demonstrate how the Bridge Street Bridge was altered from the Duplicate Effective Model to the Corrected Effective Model. At Bridge Street, both the low and high chords of the roadway were raised based on surveyed elevations, while the piers of the bridge were reduced in size to reflect field measurements (**Figure 37**). Upstream and downstream transects were also adjusted based on surveyed channel bathymetry.

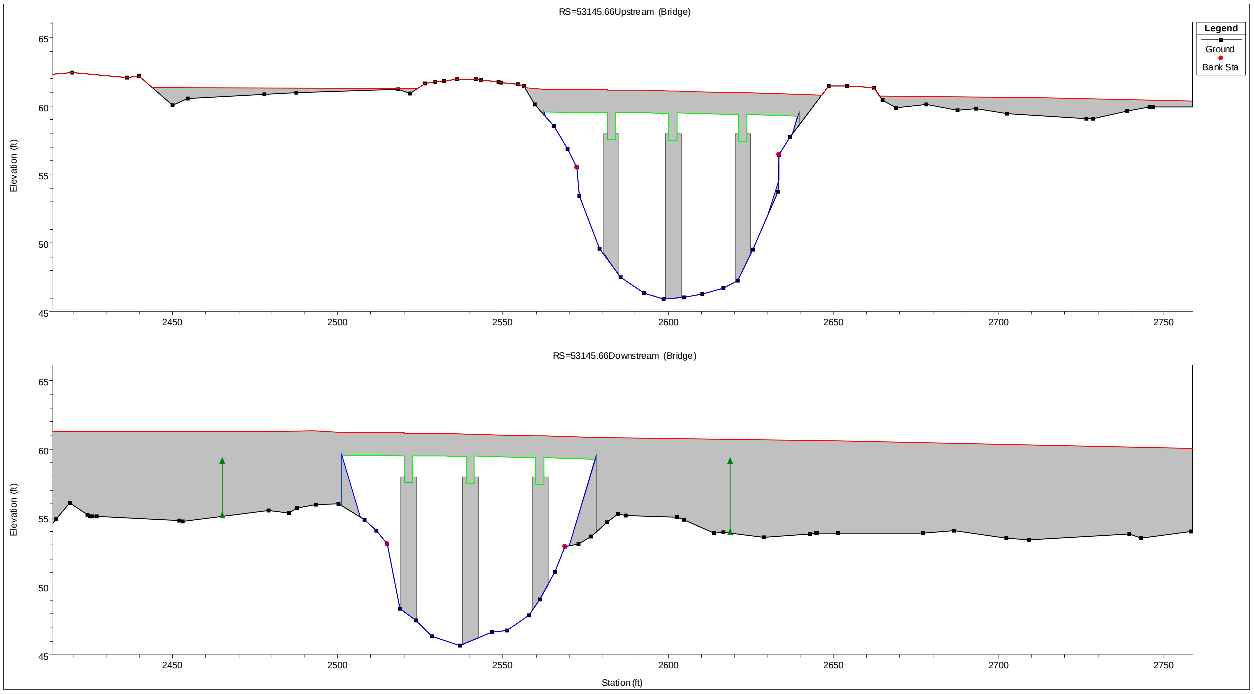

Figure 39. Bridge Street Bridge Duplicate Effective HEC-RAS Transect, unchanged from Existing Model

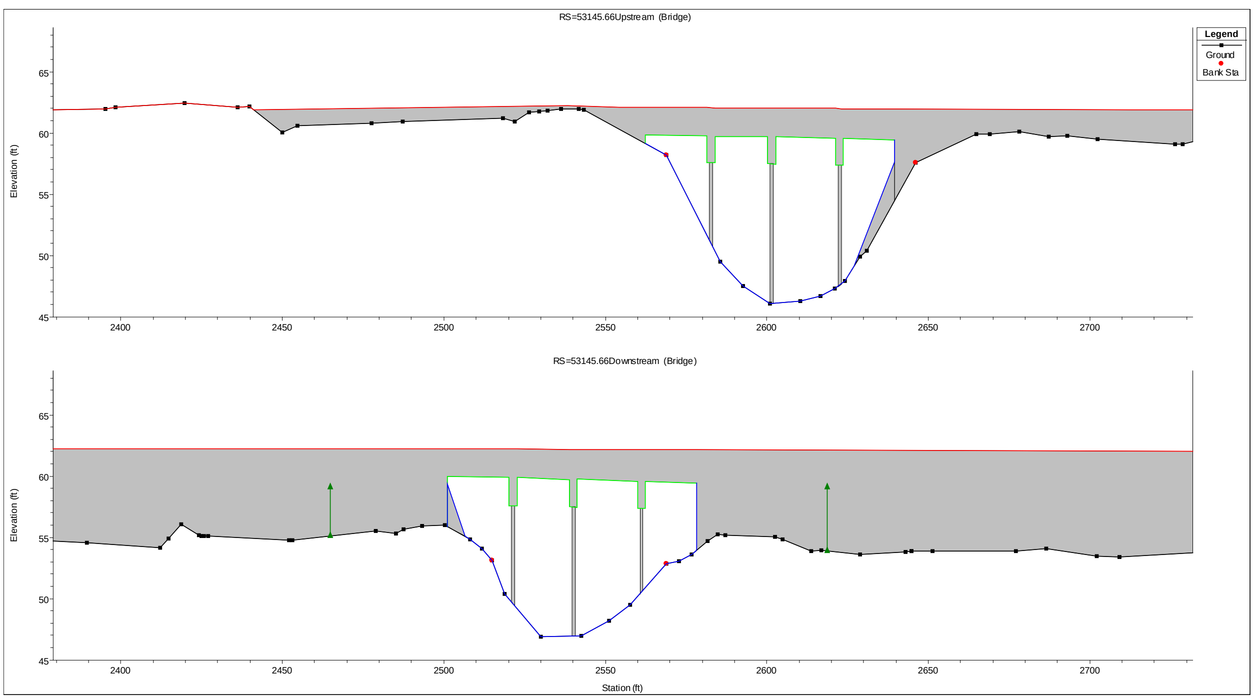

Figure 40. Bridge Street Bridge Corrected Effective HEC-RAS Transect, in which roadway elevation, pier width, and rip rap location were corrected

After incorporating adjustments to river geometry that were measured in the field, HW calibrated the HEC-RAS model based on observed flows and WSE's measured at the Vaughan Street crossing. As discussed above, flow rate and WSE measurements were collected on 17 occasions by DER and once by HW. To calibrate the model, HW adjusted the Manning's roughness coefficient ("n") value of the river cross sections. A description of the existing conditions of the river crossings and dams, as well as adjustments made in the corrected effective model, is included below.

3.2.6 Bankfull Width Determination

Due to over a century of human impacts in the form of bridges, culverts, and dams along the Nemasket River, the morphology of the river within the study area is altered from its naturalized state. As such, determination of what may be considered a "natural" bankfull width requires estimation from reference points outside of the impacted area of the Nemasket. HW selected the area downstream of the Wareham Street Weir as a reference reach from which to measure bankfull dimensions. Locations of bankfull width measurements are mapped below in **Figure 41**. Bankfull measurements are shown below in **Table 11**.

Table 11. Reference Reach Bankfull Width Measurements

Bankfull Location	Bankfull Width (ft)
BF1	53.2
BF2	63.6
BF3	61.6
Average	**59.5**

In addition to the measurements collected in the field, HW used StreamStats to obtain supplemental estimates of bankfull width and flow at four river crossings: Wareham Street, Bridge Street, Vaughan Street, and the Assawompset Pond Dam. StreamStats estimates are based on polynomial regression developed from 27 streams located in Massachusetts and in drainage basins bordering Massachusetts[41]. Bankfull width and flow estimates produced using StreamStats are shown below in **Table 12**.

Table 12. StreamStats Bankfull Width Estimates

Bankfull Location	Drainage Area (sq mi)	Bankfull Width (ft)	Bankfull Flow (cfs)
Assawompset Pond Dam	49.2	59.3	347
Vaughan Street	49.7	59.5	349
Bridge Street	60.5	64.4	408
Wareham Street	62.3	65.3	421

The bankfull estimates provided by StreamStats are consistent with the measurements collected by HW at the reference reach downstream of the Wareham Street Dam and Weir. The StreamStats bankfull width estimate at Wareham Street is only 4.8 feet greater than the average bankfull width measurement collected just downstream of Wareham Street; the StreamStats

[41] Bent, G.C., and Waite, A.M., 2013, Equations for estimating bankfull channel geometry and discharge for streams in Massachusetts: U.S. Geological Survey Scientific Investigations Report 2013-5155, 62 p., (http://dx.doi.org/10.3133/sir20135155/)

estimate at Wareham Street is only 1.7 feet greater than the maximum bankfull width measurement collected by HW. The estimates provided for bankfull flow are also consistent with the hydrology profile estimated using the Prorated Taunton River Method: the bankfull flow at Vaughan Street (349 cfs) is squarely between the 5% daily exceedance flow (290 cfs) and the 2-year flow (469 cfs). Additionally, the StreamStats estimates for bankfull width only increase by 6 feet over the run of the river within the study area, indicating that the natural dimensions of the river at Vaughan Street (the upstream-most river crossing) are similar to those measured at the reference reach.

For this project, we used the field-measured bankfull width for locations in the immediate vicinity of Wareham Street and then scaled the bankfull width down for locations moving upstream proportional to the decreasing watershed contributing areas. Estimates for the bankfull width at each river crossing is shown below in **Table 13**.

Table 13. HW Bankfull Width Estimates

Bankfull Location	Bankfull Width Estimate (ft)
Wareham Street	59.5
East Grove Street	59.3
I-495	59.1
MBTA Bridge	58.8
Old Bridge Street	58.7
Bridge Street	58.7
Vaughan Street	54.2
Assawompset Pond Dam	54.0

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Date: 4/11/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Bankfull Width Measurement
Nemasket River
Municipal Boundary

Feet
0 100 200

Upper Nemasket River Hydrology and Hydraulics Study

Figure **41**
Nemasket River Reference Reach

3.3 Proposed Conditions Hydraulic Model

Using HEC-RAS, HW developed 17 proposed conditions hydraulic models in order to assess various alterations to river crossings, dams, and channel alignments. The methodology and results of each modelled scenario are discussed below. All proposed conditions models were analyzed at the 95% daily exceedance, 5% daily exceedance, 1-year, 2-year, 10-year, and 100-year flows based on the hydrology developed using the Prorated Taunton River Method. A full comparison of predicted WSE's for each flow event is included as **Attachment A**.

In several proposed conditions scenarios, river crossings were modified to provide sufficient size to achieve flood reduction and to support riparian ecology. To determine the optimal river crossing size to promote aquatic organism passage, river connectivity, and wildlife passage along the riverbanks, the Massachusetts River and Stream Crossing Standards (Stream Crossing Standards) developed by the River and Stream Continuity Partnership were used. These guidelines are summarized below:

1. Spans that preserve the natural stream channel are strongly preferred.
2. If a culvert is used, then it should be embedded a minimum of 2 feet.
3. The stream crossing spans the channel width (a minimum of 1.2 times the bankfull width).
4. Natural bottom substrate exists within the structure.
5. The stream crossing is designed with appropriate bed fords and streambed characteristics so that the water depths and velocities are comparable to those found in the natural channel at a variety of flows.
6. Openness of the crossing is greater than 0.82. Openness is defined as the ratio of a crossing's open area (height times width) to its length (the distance from the midpoints of the structure's entrance and exit).
7. Banks should be present on each side of the stream matching the horizontal profile of the existing stream banks.

Nearly all river crossings on the Nemasket are bridges, meeting standards 1, 2, 4, and 5 ipso facto. The minimum channel width was calculated using the average bankfull width within the reference reach:

$$1.2 \text{ X } 59.5 \text{ feet} = 71.4 \text{ feet}$$

As shown previously in **Table 13**, the bankfull width at the reference reach downstream of Wareham Street is estimated to be the widest natural bankfull width throughout the study area. In all proposed models, bridge replacements were designed to meet the minimum width requirements calculated at this reference reach. This is a conservative design approach since the bankfull width is estimated to decrease gradually moving upstream. This is appropriate for the planning-level of the current H&H study; future studies of individual river crossings may reasonably investigate narrower spans.

Descriptions of river crossing modifications modelled in each proposed conditions scenario are discussed at length below in order from downstream to upstream. Proposed scenarios are summarized below in **Table 14**. Of the river crossings assessed, only the Bridge Street Bridge (with a span of 78 feet) meets the minimum required span width of 71.4 feet identified above; for this reason, replacement of the Bridge Street Bridge was not evaluated among proposed restoration scenarios. We note that the analyzed scenarios were developed by the project and consulting team and vetted for overall feasibility with the project steering committee[42].

Table 14. Proposed Scenario Summary

Proposed Scenario	Description
PR1	• Removal of the Wareham Street Dam and Wareham Street Weir • Modification of the Wareham Street Culvert to meet Stream Crossing Standards
PR2	• Modification of the East Grove Street Bridge to meet Stream Crossing Standards
PR3	• Modification of the I-495 Bridge to meet Stream Crossing Standards
PR4	• Modification of the MBTA Bridge to meet Stream Crossing Standards
PR5	• Removal of the Old Bridge Street Bridge
PR6	• Modification of the Vaughan Street Bridge to meet Stream Crossing Standards
PR7	• Dredging the Nemasket River downstream of the Assawompset Pond Dam • Installation of a sheet pile "water control structure" to trap suspended sediment
PR1/2	• Hybrid of PR1 and PR2
PR1/4	• Hybrid of PR1 and PR4
PR1/5	• Hybrid of PR1 and PR5
PR1/2/4/5 (PR Optimal)	• Hybrid of PR1, PR2, PR4, and PR5
PR Channel	• Restoration of the channel downstream of the Assawompset Pond Dam to approximate the natural bankfull width
PR1 C	• Hybrid of PR1 and PR Channel
PR1/2 C	• Hybrid of PR1/2 and PR Channel
PR1/4 C	• Hybrid of PR1/4, and PR Channel
PR1/5 C	• Hybrid of PR1/5, and PR Channel
PR Optimal C	• Hybrid of PR Optimal and PR Channel

Results summaries are presented below for each of the 17 above-described proposed conditions scenarios. Results are described in relation to the dam or bridge which is altered in each proposed scenario, as well as in relation to the Assawompset Pond Dam for consistent comparison of flood level reduction at the upstream-most point of the model. Because the impacts of proposed bridge and dam scenarios on WSEs are generally larger upstream of modified structures than downstream, results are given with reference to the upstream side of all structures.

This upstream-oriented summary is also used to describe the Assawompset Pond Dam, even though the upstream side of the dam is the vast reservoir of the Assawompset Pond Complex rather than the Nemasket River. Based on observation of the Assawompset Pond Dam during large flood events, there is little difference between the WSE upstream and downstream of the dam when water levels are high and the stop logs are removed from the structure. To approximate

[42] More information on the stakeholder and public engagement process surrounding this project is available in the companion report entitled "Upper Nemasket River Enhancement Plan Community Engagement Report," prepared by Commonplace Landscape and Planning, October 2022

water level management in the Assawompset Pond Complex, the Assawompset Pond Dam was indeed modeled without stoplogs in all proposed conditions models. As such, description of the upstream side of the Assawompset Pond Dam is assumed to be a reasonable proxy for water levels immediately downstream of the dam in this study.

3.3.1 Interpretation of HEC-RAS Results

This report includes a number of tables summarizing HEC-RAS results. One such table is shown below as a guide to understanding the results of the hydraulic modeling discussed in this report.

Table 15 shows typical results of a proposed scenario model. In this table:

- The **recurrence interval** column indicates the recurrence interval of the flow events that were modeled. This generally includes the 95% and 5% exceedance flows (equivalent to relatively low and high flows that would be expected any given year) and the 2-, 10-, and 100-year flows (equivalent to flows that have a 50%, 10% and 1% chance of occurring any given year).
- The **Assawompset Dam – US** column indicates the predicted water levels immediately upstream of the Assawompset Pond Dam under each flow event. Sub-columns *Existing* and *PR* provide a comparison between existing water levels upstream of the dam and water levels under a given proposed restoration scenario.
- **Additional columns** (below: "Wareham Street – US") indicate the predicted water levels immediately upstream of structures which are proposed to be altered under a given proposed scenario. For simplicity, additional structures are excluded from the summary tables in the report. The full results of each model are included in **Attachment A**.
- **Reductions in water level** are indicated by asterisks (*) within the table. Meanings of each number of asterisks are consistent throughout the report.

Table 15. Example HEC-RAS Results Table

	Assawompset Dam - US		**Wareham Street - US**	
Recurrence Interval	Existing	PR1	Existing	PR1
95% Exceedance	49.93	49.93	44.71	*40.04****
5% Exceedance	53.76	*53.60**	49.83	*43.58****
2-year	54.77	*54.55**	50.82	*44.58****
10-year	55.90	*55.59**	51.94	*45.62****
100-year	57.27	*56.81**	53.19	*46.65****

**indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

3.3.2 PR1 – Remove Wareham Street Dam

The Wareham Street Dam and Weir are the most downstream man-made channel obstructions along the course of the Upper Nemasket River within the study area. Under existing conditions, the two structures cause the largest increase in water surface elevation over the shortest longitudinal distance of any structure (dam or bridge) throughout the Nemasket. Over just 250 longitudinal feet, the 100-year return frequency water elevation is predicted to drop by 8 feet from the impoundment upstream of the dam to the channel downstream of the weir – an average hydraulic gradient of over 3%.

Just upstream of the Wareham Street Dam, the Wareham Street Culvert has a combined span of 24 feet. This span is 35.5 feet narrower than the minimum channel width of 71.4 feet required by the Stream Crossing Standards.

In **PR1**, both the dam and weir were removed, and the Wareham Street Culvert was replaced with a bridge spanning 85 feet. The elevation of the channel bottom after removal of the dam and the weir was determined based on the existing channel bottom prior to installation of the dam[43]. The banks in the vicinity of the culvert were widened to a minimum of 60 feet, approximately equal to the estimated bankfull width of the Nemasket River at the reference reach. The modified bridge was calculated to have an open area of 875 square feet over a length of 45 feet, yielding an openness ratio of 19.4. The existing fish ladder was modelled as being removed and filled in. A comparison of existing and proposed cross sections upstream and downstream the Wareham Street Culvert are shown in **Figure 42** and **Figure 43**.

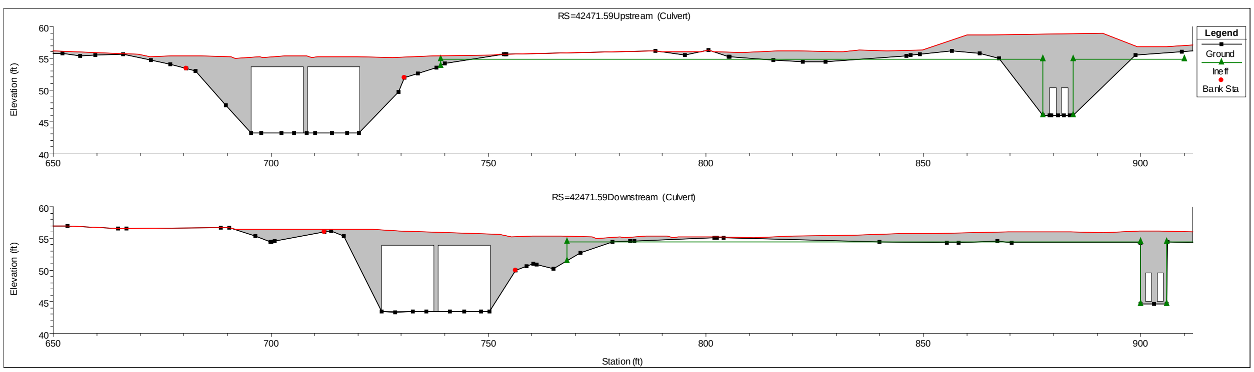

Figure 42. Cross Section of Wareham Street Culvert in Corrected Effective Model

[43] "Nemasket River at Wareham Street, Middleborough", Contract No. 2194, March 1962

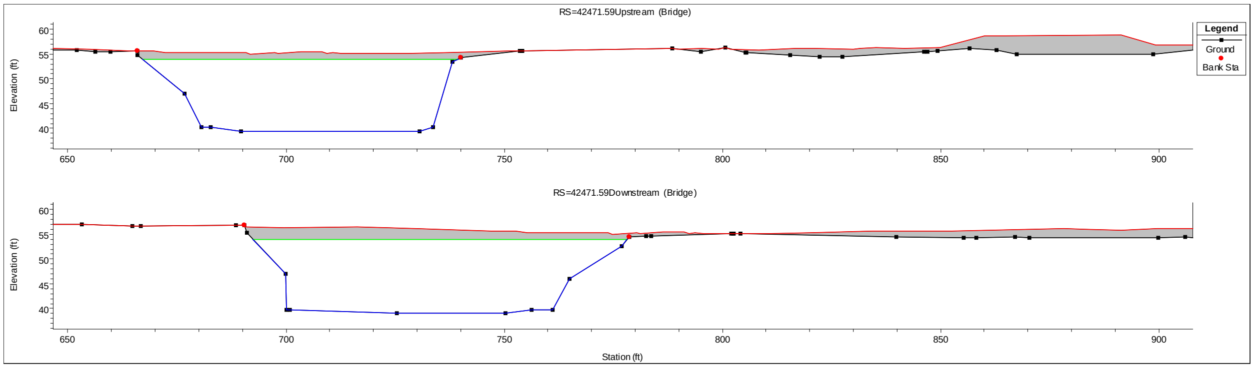

*Figure 43. Cross Section of Modified Wareham Street Bridge in **PR1***

In addition to removing the weir and dam structures from the HEC-RAS model for **PR1** and modifying the Wareham Street Culvert, HW assessed the sediment transport potential of channel substrate throughout the Nemasket River study area. During the site visit conducted by HW on April 20, 2021, soft sediment consisting of fine to medium sand and silt was identified while probing the impoundment upstream of the Wareham Street Dam (**Figure 44**). Based on the depth of sediment measured during probing, HW adjusted the HEC-RAS model to account for the volume of soft sediment that would be expected to transport downstream as a result of increased channel velocities immediately after removal of the dam and weir.

Sediment transport was also predicted to occur upstream of the Wareham Street Dam impoundment all the way to upstream of East Grove Street. Based on the channel substrate characteristics of the reference reach as well as the sediment sampling conducted by OE downstream of the Wareham Street Dam, HW predicted that the smallest particle size in a stable, naturalized Nemasket channel section would be medium to coarse sand in the main channel and sand and silt on the banks. In locations where the velocity of the Nemasket increased significantly following dam and weir removal, sediment transport was assumed to occur until shear stress in the river was lower than threshold values for transport. Sediment transport is expected to occur to the greatest extent during the bankfull flow, approximately equal to the 2-year flow event.

The threshold values utilized were 0.33 pounds per square foot (psf) for 1" diameter gravel, 0.075 psf for coarse sand and 0.045-0.05 psf for silt[44]. The river profile that is anticipated under stabilized (post-transport) channel conditions is shown in **Figure 45**. Predicted shear stress and velocity within the channel before and after sediment transport is shown in **Table 16**. Because the 2-year flow is predicted to be confined within the banks (i.e., the channel is entrenched) upstream of Wareham Street under **PR1**, shear stress and velocity are not included at bank stations.

[44] "Engineering Field Handbook Notice 210-WI-119, Companion Document 580-10", Natural Resources Conservation Service, February 2009

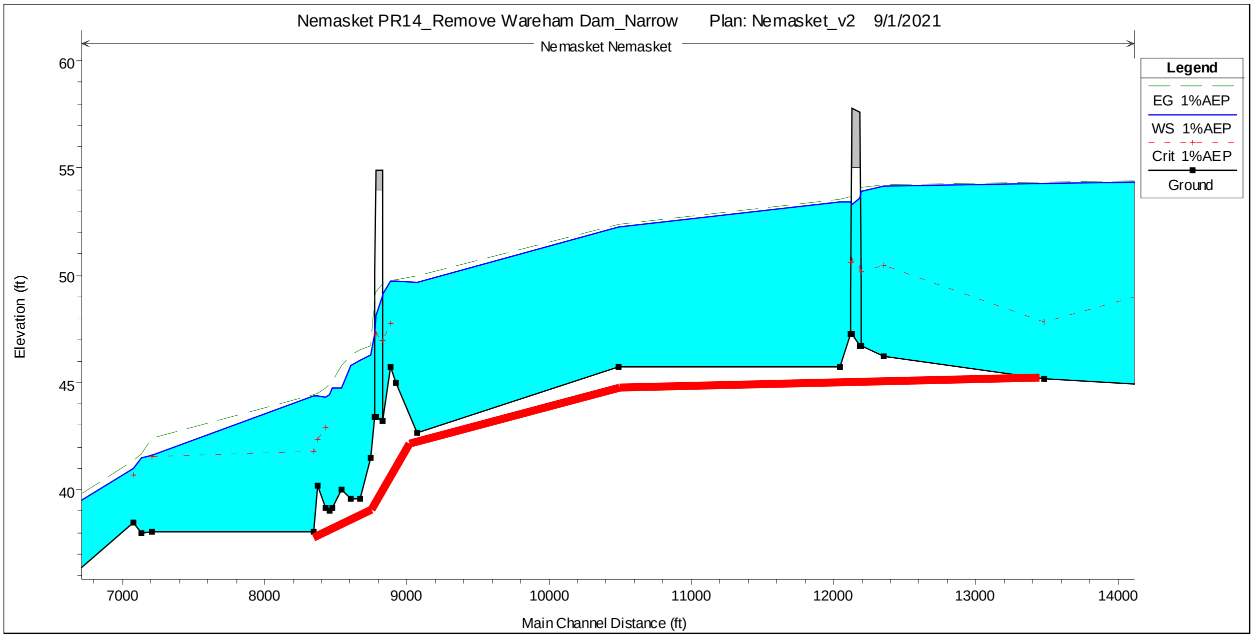

Figure 44. Longitudinal Profile of Wareham Street and East Grove Street in Corrected Effective Model – Sediment Transport above Red Line

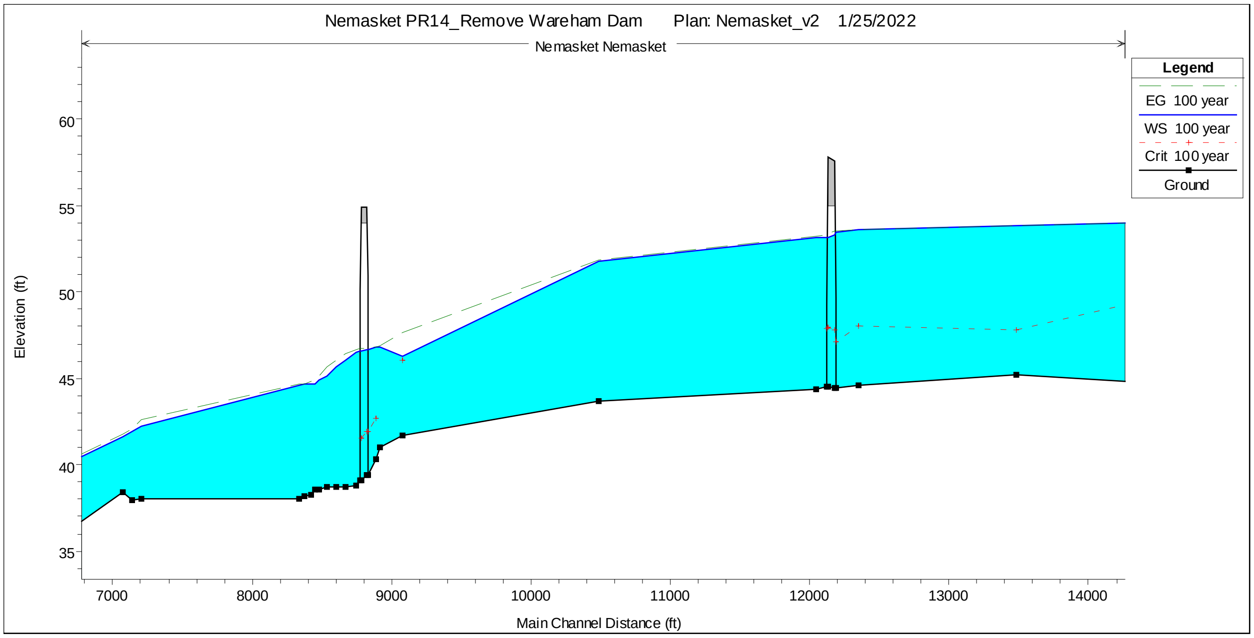

*Figure 45. Longitudinal Profile of Wareham Street and East Grove Street in **PR1** – Sediment Removed via Transport*

*Table 16. **PR1** Sediment Transport Potential*

		US Shear Stress (psf)			US Velocity (ft/sec)		
		Existing	Dam and Weir Removed, Culvert Replaced	Dam and Weir Removed, Culvert Replaced + Sediment Transport	Existing	Dam and Weir Removed, Culvert Replaced	Dam and Weir Removed, Culvert Replaced + Sediment Transport
East Grove Street	LB	-	-	-	-	-	-
	Channel	0.25	0.25	0.12	2.03	2.59	1.43
	RB	0.08	0.06	0.01	0.72	0.54	0.19
Wareham Street	LB	-	-	-	-	-	-
	Channel	0.19	0.66	0.23	1.80	4.62	1.91
	RB	0.17	-	-	1.46	-	-

Sediment transported as a result of **PR1** is predicted to consist of particle sizes greater than or equal to silt, which has a settling velocity of 0.15 feet per second[45]. During flows just under the bankfull width (i.e., the 5% daily exceedance flow), fine grained sediment that transports upstream of the Wareham Street Dam and Weir is predicted to settle along the banks of the Nemasket starting approximately 600 feet downstream of East Main Street and continuing along the banks downstream. During lower flows (i.e., the 50% and 95% daily exceedance flows), silt is predicted to settle as early as 200 feet downstream of Wareham Street. Predicted sediment degradation and aggradation locations are included below as **Figure 46**[46].

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Dam and upstream of Wareham Street are shown below in **Table 17**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR1** is included in **Attachment B**.

*Table 17. Selected **PR1** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		Wareham Street - US	
Recurrence Interval	Existing	PR1	Existing	PR1
95% Exceedance	49.93	49.93	44.71	*40.04*****
5% Exceedance	53.76	*53.60**	49.83	*43.58*****
2-year	54.77	*54.55**	50.82	*44.58*****
10-year	55.90	*55.59**	51.94	*45.62*****
100-year	57.27	*56.81**	53.19	*46.65*****

** indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

---

[45] Rouse, H., "Engineering Hydraulics", 1950

[46] **Figure 46**, as well as other Predicted Sediment Transport figures included herein, depict *general* regions of sediment transport and settling. The entire volume of sediment that leaves a transport area is unlikely to accumulate in all settling areas; some volume of sediment is expected to continue downstream of the study area, and may not settle at any point in the Nemasket or Taunton Rivers.

Removal of the Wareham Street Dam and Weir and replacement of the Wareham Street Culvert with a bridge meeting the Stream Crossing Standards is predicted to decrease WSE's during all flow events. The impacts of these proposed modifications are most pronounced in the vicinity of Wareham Street. During the 100-year flow, water levels in the impoundment upstream of Wareham Street are predicted to drop by 6.54 feet. Reductions in 100-year flood elevation of more than 1 foot are predicted as far upstream as the MBTA Bridge; 100-year flood elevation reductions of more than 0.5 feet are predicted upstream all the way to Vaughan Street. Upstream of the Assawompset Pond Dam, 100-year flood levels are predicted to decrease by 0.46 feet.

Inundation maps for the 2- and 100-year flows are included below as **Figure 47** and **Figure 48**. Under the 2-year flow, **PR1** is predicted to completely eliminate the impoundment upstream of Wareham Street, and flow is expected to be confined to the riverbanks from Wareham Street to East Grove Street. Reductions in inundated area are also seen downstream of the I-495 Bridge. Under the 100-year flow, **PR1** is predicted to significantly reduce size of the impoundment upstream of Wareham Street. Reductions in inundated area are most significant between Wareham Street up to the MBTA Bridge.

Because the barrier created by the Wareham Street Dam and Weir is so significant, **PR1** represents the most effective individual restoration scenario at reducing flood elevations and increasing average gradient, flow velocities, and sediment transport capacity along the Upper Nemasket. Reductions in WSE are both larger and more widespread than any individual scenario discussed below.

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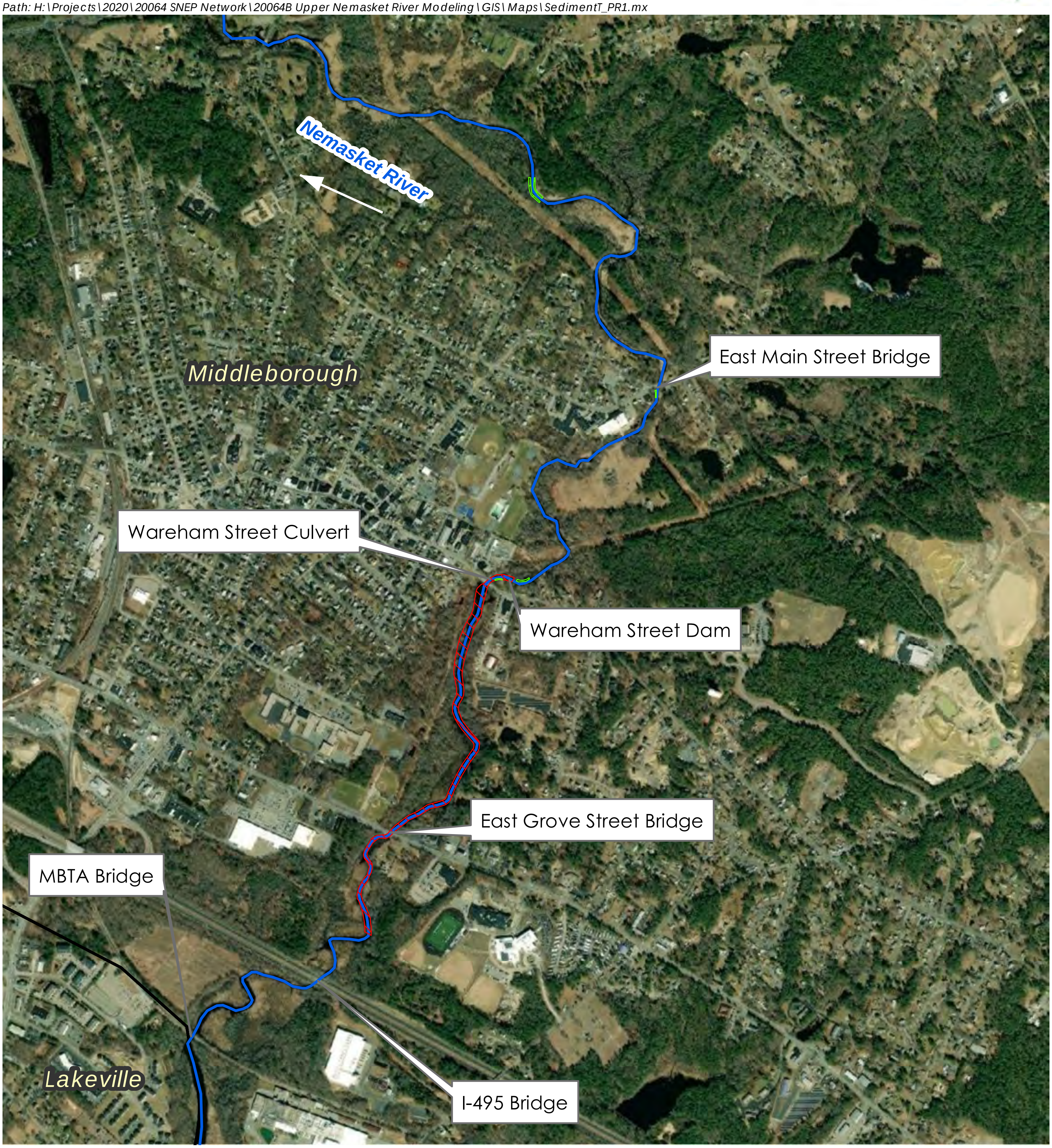

Date: 4/12/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Predicted Sediment Settling Area
- Predicted Sediment Transport Area
- Nemasket River
- Municipal Boundary

Feet
0 750 1,500

Upper Nemasket River Hydrology and Hydraulics Study

Figure **46**
Predicted Sediment Transport – PR1
Wareham Street Dam Removal and Culvert Replacement

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

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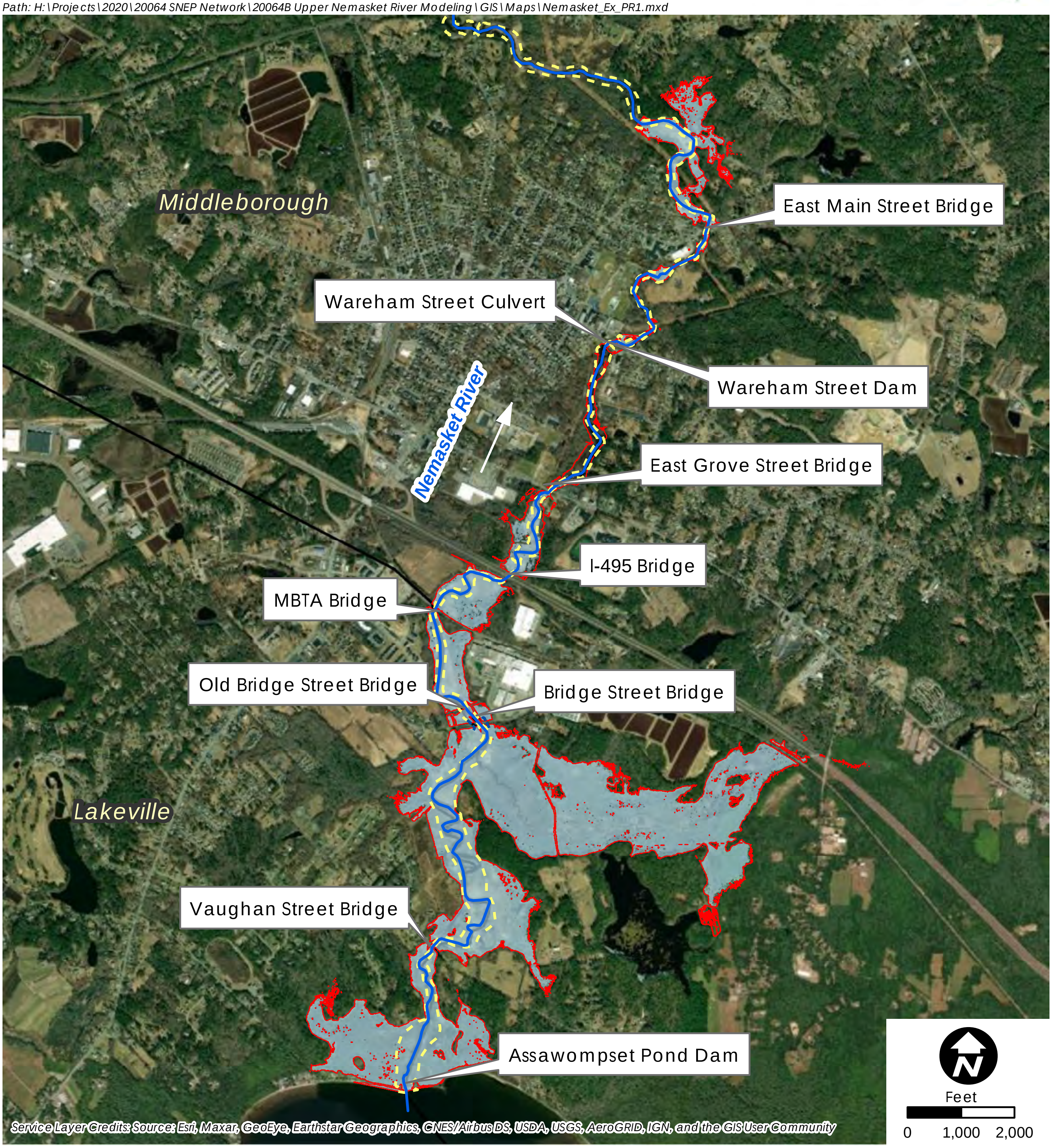

Date: 3/29/2023
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Nemasket River
- PR 1 2-year inundation
- Existing 2-year inundation
- FEMA Zone AE: Regulatory Floodway
- Municipal Boundary

Upper Nemasket River Hydrology and Hydraulics Study

Figure **47**
2-year Flood Inundation Area for Existing vs. Proposed Conditions 1
Wareham Street Dam Removal and Culvert Replacement

Horsley Witten Group
Sustainable Environmental Solutions
90 Route 6A • Unit 1 • Sandwich, MA 02563
508-833-6600 • horsleywitten.com

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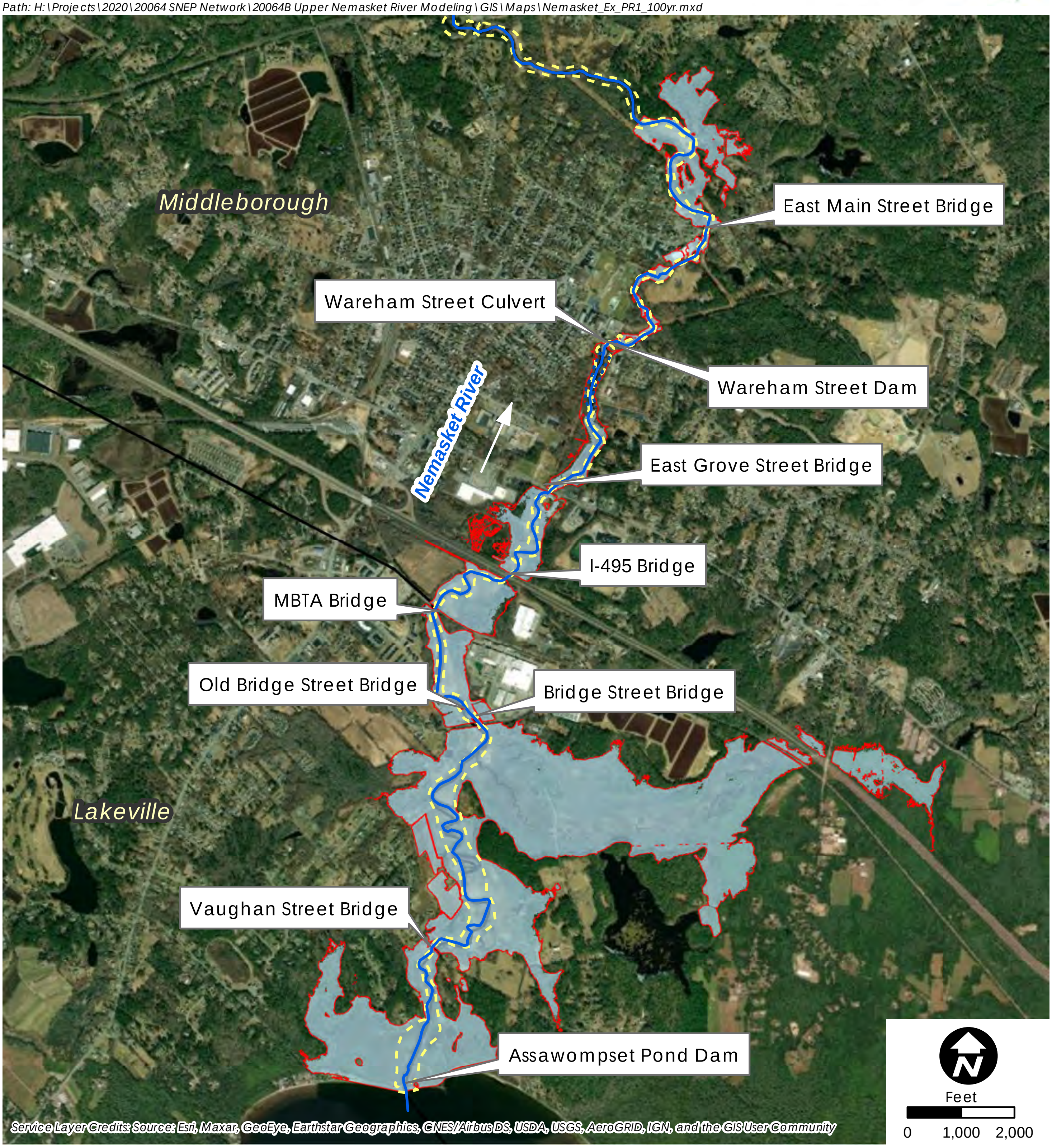

Date: 3/29/2023
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Nemasket River
- PR 1 100-year inundation
- Existing 100-year inundation
- FEMA Zone AE: Regulatory Floodway
- Municipal Boundary

Upper Nemasket River Hydrology and Hydraulics Study

Figure 4**8**
100-year Flood Inundation Area for Existing vs. Proposed Conditions 1
Wareham Street Dam Removal and Culvert Replacement

3.3.3 PR2 – Modify East Grove Street Bridge

At present, the East Grove Street Bridge spans 22 feet, which is 37.5 feet less than the average bankfull width of the reference reach and 49.5 feet less than the minimum channel width of 71.4 feet required by the Stream Crossing Standards. In **PR2**, the bridge was widened to a span of 80 feet, the banks were widened to 60 feet, and the floodplains were restored within the bridge span (**Figure 49** and **Figure 50**). The modified bridge was calculated to have an open area of 525 square feet over a length of 50 feet, yielding an openness ratio of 10.5.

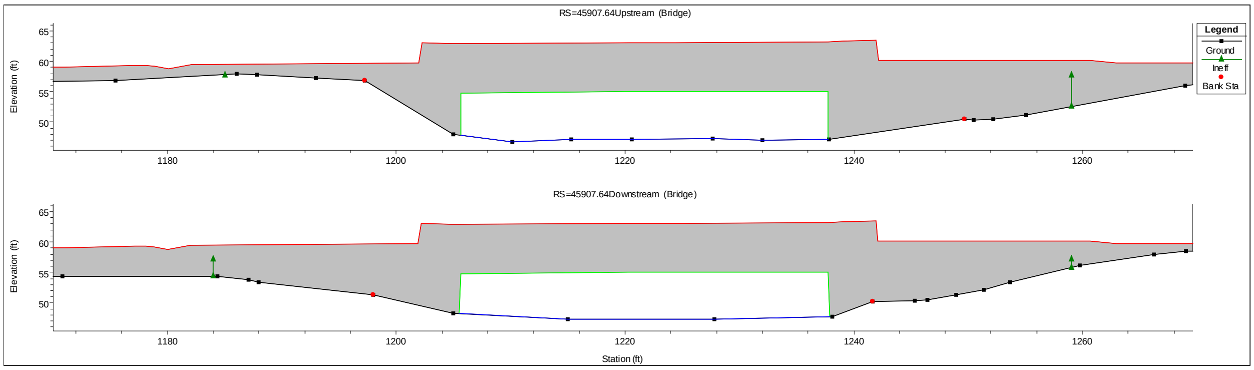

Figure 49. Cross Section of East Grove Street Bridge in Corrected Effective Model

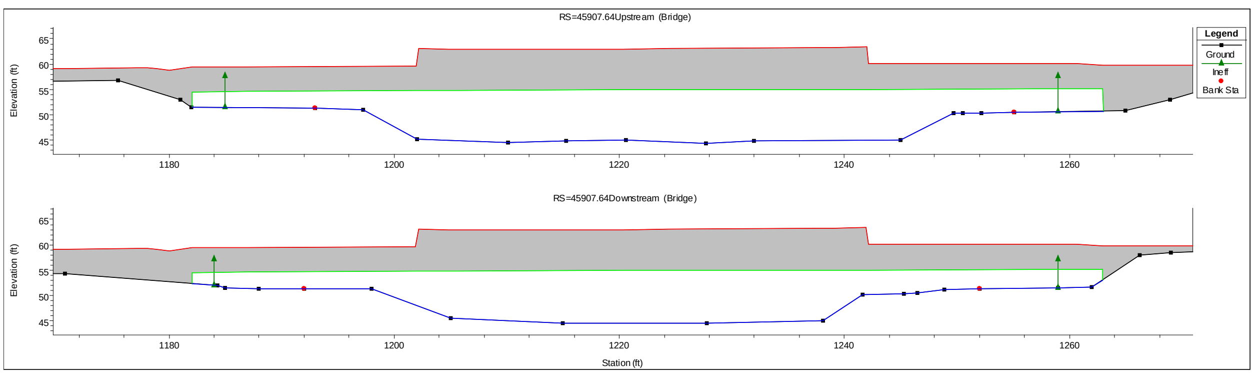

Figure 50. Cross Section of Modified East Grove Street Bridge in ***PR2***

In addition to modifying the width of the bridge, HW assessed sediment transport potential at the East Grove Street Bridge. Because the bridge is considerably narrower than the natural bankfull width of the stream, sediment has accumulated in the channel upstream of the bridge (**Figure 51**). This process of aggradation occurs when water velocities slow above a contraction point in the river. To account for sediment transport that would be expected to occur if the East Grove Street Bridge were widened, HW assessed the shear stress and velocity of the Upper Nemasket River at various stages following the implementation of **PR2**. Initial modelling indicated that shear stress on the banks would be sufficient to induce transport of silt materials (0.045-0.05 psf shear stress required[47]), while shear stress on the main channel bottom would be sufficient to result in transport of material as large as fine gravel/coarse sand (0.075 psf shear stress required[48]). Supplemental modelling was conducted to analyze the extent to which sediment transport is

[47] Engineering Field Handbook Notice, 2009

[48] Ibid.

expected to occur. Sediment transport is predicted to occur upstream and within the East Grove Street Bridge, as shown in **Figure 52**. The shear stress and velocity of the river upstream of the Grove Street Bridge before and after sediment transport are shown below in **Table 18**. Although shear stress and velocity values are expected to decrease under **PR2**, the widening of the existing channel constriction at the East Grove Street Bridge is expected to free accumulated sediment to transport.

*Table 18. **PR2** Sediment Transport Potential*

	US Shear Stress (psf)			US Velocity (ft/sec)		
	Existing	Bridge Widened	Bridge Widened + Sediment Transport	Existing	Bridge Widened	Bridge Widened + Sediment Transport
LB	-	0.03	0.01	-	0.36	0.19
Channel	0.25	0.15	0.07	2.03	1.55	1.14
RB	0.08	0.06	0.02	0.72	0.64	0.36

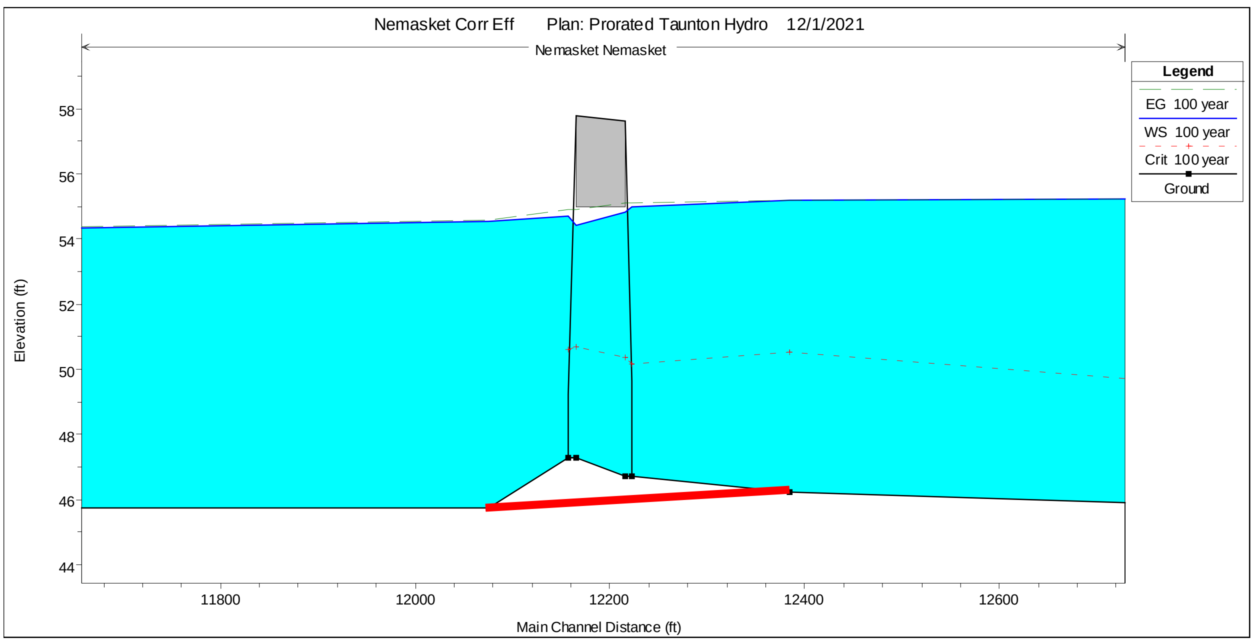

Figure 51. Longitudinal Profile of East Grove Street Bridge in Corrected Effective Model – Sediment Transport above Red Line

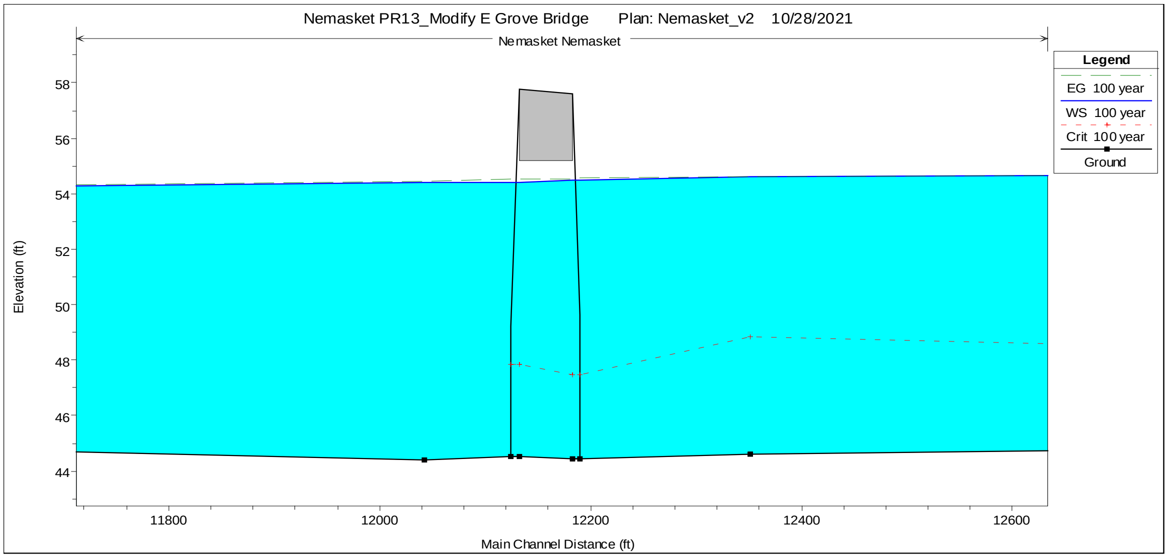

*Figure 52. Longitudinal Profile of East Grove Street Bridge in **PR2** – Sediment Removed via Transport*

Sediment transported as a result of **PR2** is predicted to consist of grain sizes less than or equal to silt. Silt is predicted to settle only at velocities of 0.15 feet per second or lower[49], while larger grain particles are able to settle at higher velocities. During flows just under the bankfull flow (i.e., the 5% daily exceedance flow), transported sediment is predicted to settle along the banks of the Nemasket starting at around 700 feet downstream of East Grove Street and continuing downstream. During low flows (i.e., the 95% daily exceedance flow), fine grained sediment is predicted to settle in the impoundment 300 feet upstream of the Wareham Street Culvert and Dam. Predicted sediment degradation and aggradation locations are shown below on **Figure 53**.

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Dam and upstream of the Grove Street Bridge are shown below in **Table 19**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR2** is included in **Attachment B**.

*Table 19. Selected **PR2** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**Grove Street Bridge - US**	
Recurrence Interval	Existing	PR2	Existing	PR2
95% Exceedance	49.93	49.93	47.95	*46.52****
5% Exceedance	53.76	*53.70**	51.57	*51.25**
2-year	54.77	*54.68**	52.65	*52.31**
10-year	55.90	*55.77**	53.75	*53.35**
100-year	57.27	*57.06**	54.99	*54.51**

**indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*

49 Rouse, H., "Engineering Hydraulics", 1950

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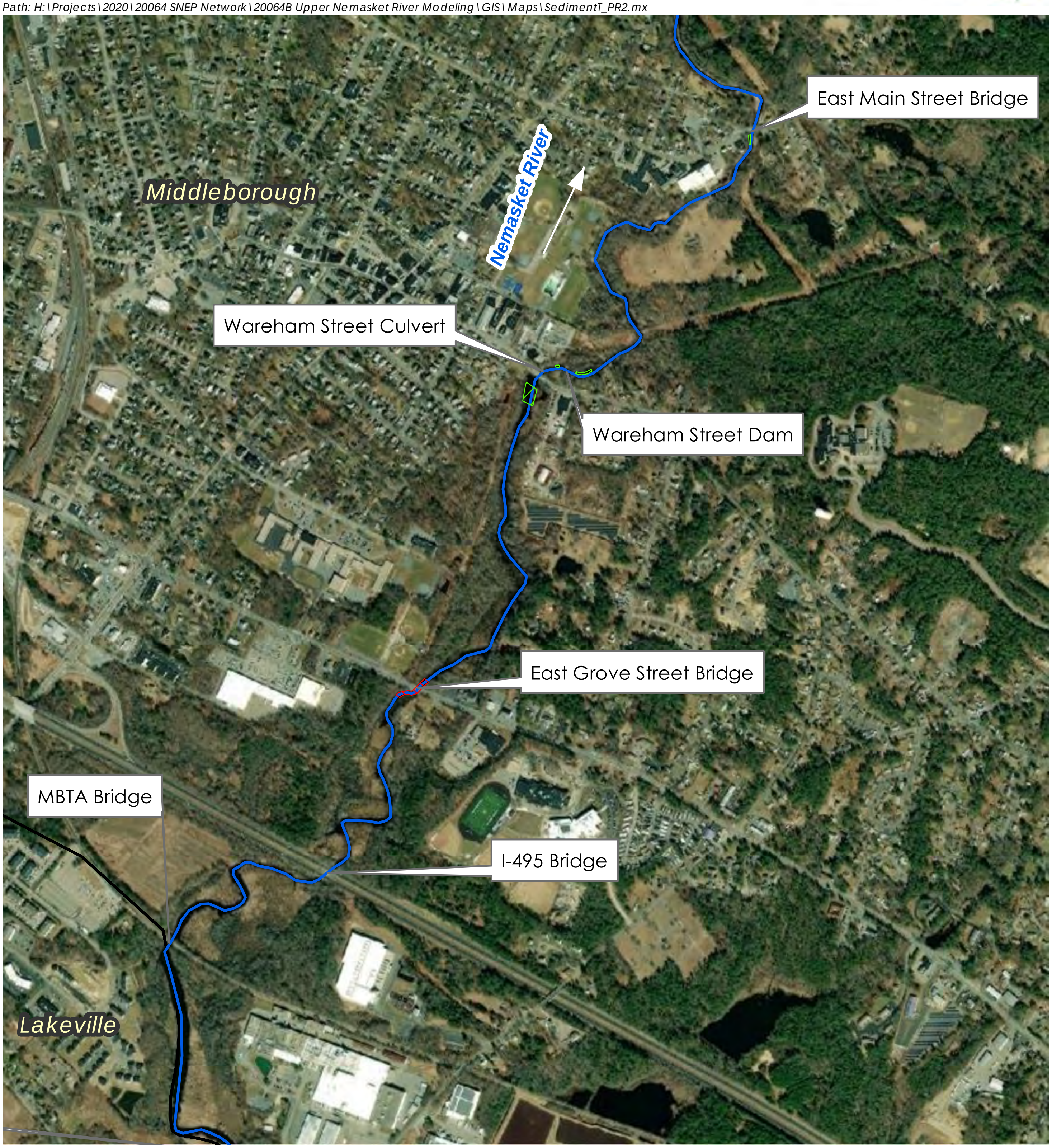

Date: 4/12/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Predicted Sediment Settling Area
- Predicted Sediment Transport Area
- Nemasket River
- Municipal Boundary

N

Feet
0 500 1,000

Upper Nemasket River Hydrology and Hydraulics Study

Figure **53**
Predicted Sediment Transport – PR2
East Grove Street Bridge Modification

Widening the Grove Street Bridge and its banks is predicted to decrease WSE's during all flow events, with the greatest decreases located in the vicinity of Grove Street. The greatest decrease during flood events is predicted under the 100-year flow, during which WSE's are expected to drop by 0.21 feet upstream of the Assawompset Pond Dam and 0.48 feet upstream of the Grove Street Bridge. Based on the HEC-RAS analysis, modifying the East Grove Street Bridge represents the single most effective bridge modification in terms of WSE reduction. Because of the bridge's location toward the downstream end of the study area, **PR2** is predicted to reduce flooding over a relatively large area, as all points upstream are expected to see lower flood elevations. The relatively large area of impact combined with the significant drop in flood elevations predicted by HEC-RAS make **PR2** the single most effective bridge modification scenario of all bridge alternatives assessed.

3.3.4 PR3 – Modify I-495 Bridge

The existing I-495 Bridge spans 38 feet, which is 21.5 feet narrower than the average bankfull width measured at the reference reach and 33.4 feet narrower than the minimum river crossing width of 71.4 feet required by the Stream Crossing Standards. Under **PR3**, the bridge was widened to a span of 80 feet wide (**Figure 54** and **Figure 55**). Both upstream and downstream banks were widened to a width of 60 feet, and the floodplain was restored within the span of the bridge. The modified bridge was calculated to have an open area of 837 square feet over a length of 135 feet, yielding an openness ratio of 6.2.

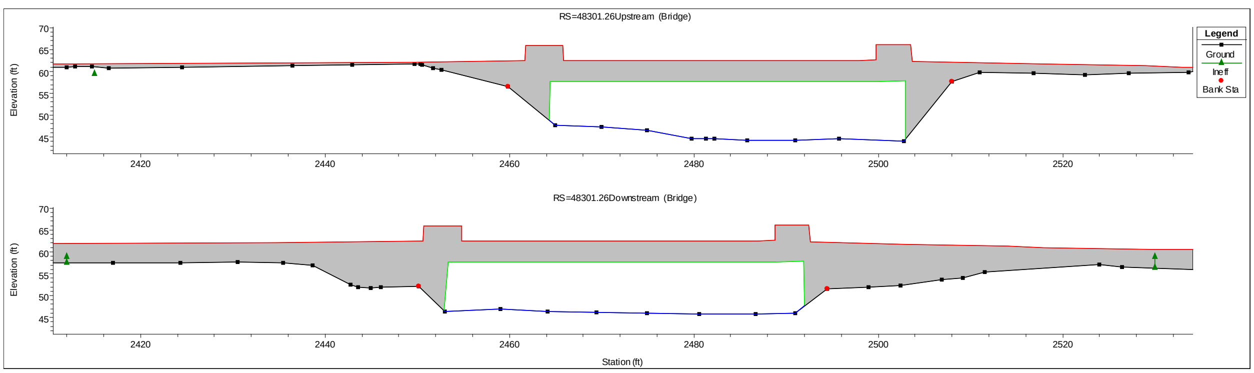

Figure 54. Cross Section of I-495 Bridge in Corrected Effective Model

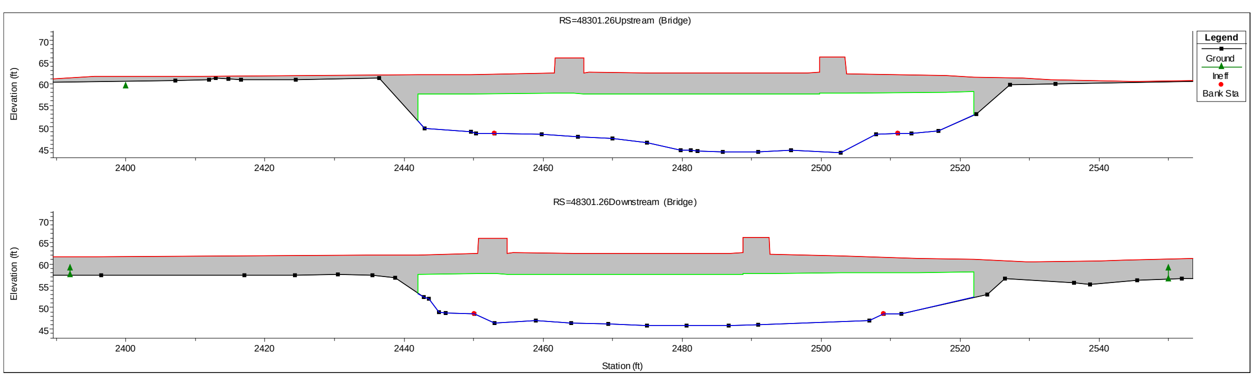

*Figure 55. Cross Section of Modified I-495 Bridge in **PR3***

Significant sediment transport is not anticipated as a result of **PR3**. As shown in **Table 20**, shear stress within the main channel during the 2-year flow is expected to reduce as a result of bridge modification, while shear stress at the banks is not expected to exceed the transport threshold of 0.045 psf[50]. Likewise, velocity within the channel is expected to decrease as a result of **PR3**, and increases in water velocity at the banks do not exceed transport thresholds for silt of 1.75 feet per second[51].

*Table 20. **PR3** Sediment Transport Potential*

	US Shear Stress (psf)		**US Velocity (ft/sec)**	
	Existing Conditions	Bridge Modified	Existing Conditions	Bridge Modified
LB	-	0.03	-	0.41
Channel	0.13	0.07	1.52	1.13
RB	-	0.03	-	0.38

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of the I-495 Bridge are shown in **Table 21**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR3** is included in **Attachment B**.

*Table 21. Selected **PR3** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**I-495 Bridge - US**	
Recurrence Interval	Existing	PR3	Existing	PR3
95% Exceedance	49.93	49.93	48.03	48.03
5% Exceedance	53.76	53.74	52.07	52.03
2-year	54.77	54.73	53.17	*53.09**
10-year	55.90	55.86	54.29	*54.17**
100-year	57.27	*57.16**	55.56	*55.39**

**indicates reduction in WSE of 0.05 feet or greater*

The analysis of **PR3** indicates that reductions in WSE's are predicted for larger flow events, with minimal impact to WSE's predicted during flows less than the 2-year event. Upstream of the Assawompset Pond Dam, significant reductions in flood elevations are only predicted during the 100-year flow (0.11 feet lower). Upstream of I-495 under the same flow, a WSE reduction of 0.17 feet is predicted. While the impacts of **PR3** on flooding upstream of the Assawompset Pond Dam are lower than all other bridge modification scenarios analyzed, the relatively downstream position of I-495 causes flood reduction impacts to be felt across a substantial stretch of the river – flood level reduction occurs over a length of 15,000 linear feet during the 100-year storm. The I-495 Bridge is second to the East Grove Street Bridge (discussed in **Section 3.3.3** above) in terms of area of flood reduction among bridge modification scenarios.

[50] Engineering Field Handbook Notice, 2009
[51] Ibid.

3.3.5 PR4 – Modify MBTA Bridge

The existing MBTA Bridge spans 40 feet, which is 19.5 feet narrower than the average bankfull width at the reference reach and 31.4 feet less than the minimum channel width of 71.4 feet required by the Stream Crossing Standards. Under **PR4**, the bridge was modified to have an expanded width of 80 feet (**Figure 56** and **Figure 57**). The embankments on either side of the bridge were widened by 20 feet on either side, restoring flood storage above the top of the bank. The bankfull width was widened to 65 feet, the average of the bankfull widths immediately upstream and downstream of the existing bridge (and only 5 feet greater than the bankfull width in the reference reach). With an open area of 783 square feet over a length of 15 feet, the modified bridge is calculated to have an openness area of 52.2, well over the minimum ratio of 0.82.

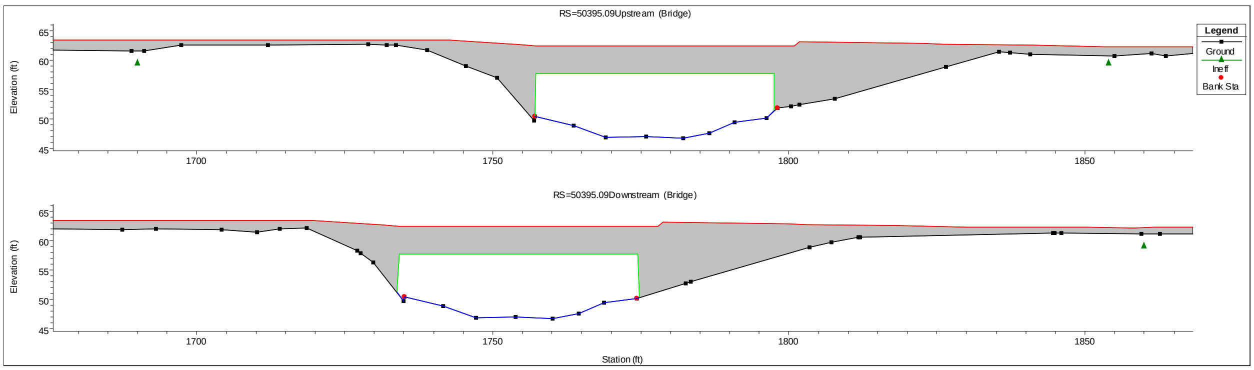

Figure 56. Cross Section of Existing MBTA Bridge in Corrected Effective Model

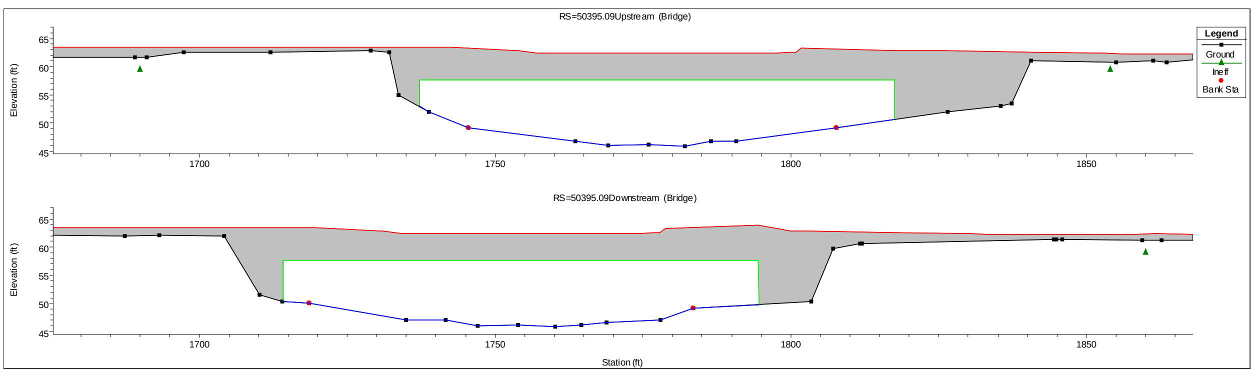

*Figure 57. Cross Section of Modified MBTA Bridge in **PR4***

In addition to modifying the width of the bridge and banks, HW assessed sediment transport potential at the MBTA Bridge. Based on the survey conducted by OE, a buildup of silt was observed inside and upstream of the bridge, while scouring was observed downstream of the bridge (**Figure 58**). Initial modelling indicated that shear stress would surpass the threshold required to cause transport of silt particles along the banks and coarse sand/fine gravel on the channel bottom (threshold values of 0.045 and 0.075 psf, respectively[52]). Supplemental modelling was conducted to analyze the extent to which sediment transport is expected to occur. Sediment transport is predicted to occur primarily at the accumulation of silt upstream of the MBTA Bridge, as shown in **Figure 59**. The shear stress and velocity of the river upstream of the MBTA Bridge

[52] Engineering Field Handbook Notice, 2009

before and after sediment transport are shown below in **Table 22**. Although shear stress and velocity values are expected to decrease under **PR4**, the widening of the existing channel constriction at the MBTA Bridge is expected to free accumulated sediment to transport.

*Table 22. **PR4** Sediment Transport Potential*

	US Shear Stress (psf)			US Velocity (ft/sec)		
	Existing	Bridge Widened	Bridge Widened + Sediment Transport	Existing	Bridge Widened	Bridge Widened + Sediment Transport
LB	0.07	0.04	0.02	0.50	0.42	0.33
Channel	0.30	0.11	0.07	2.24	1.40	1.14
RB	0.05	0.05	0.02	0.41	0.48	0.39

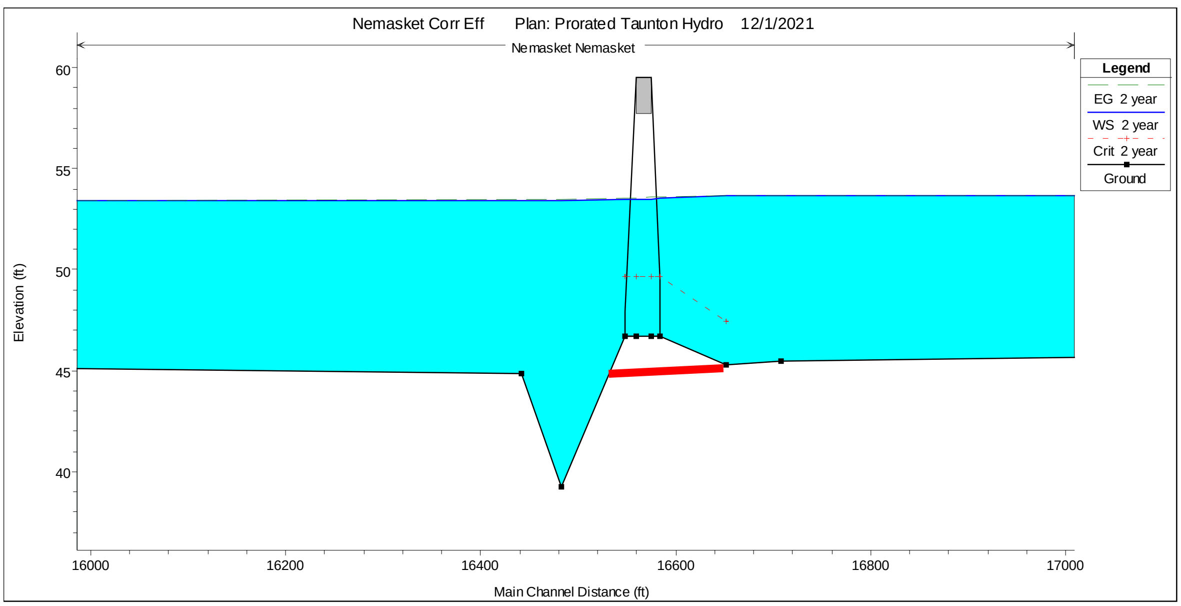

Figure 58. Longitudinal Profile of MBTA Bridge in Corrected Effective Model – Sediment Transport Above Red Line

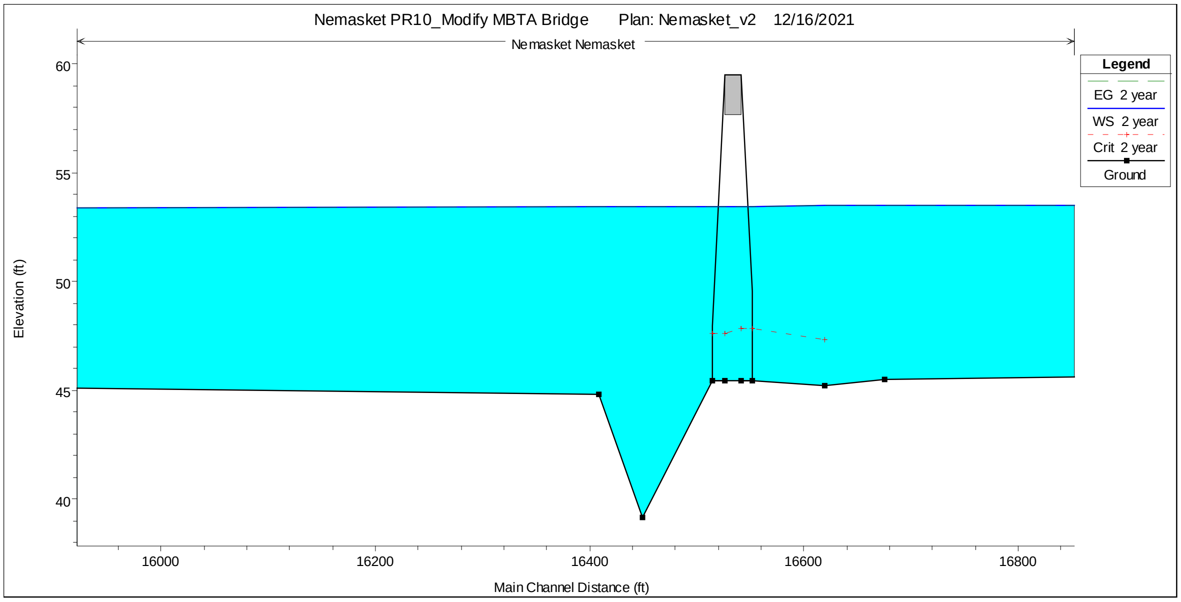

*Figure 59. Longitudinal Profile of MBTA in **PR4** – Sediment Removed via Transport*

Sediment transported as a result of **PR4** is predicted to consist of grain sizes less than or equal to silt. As discussed above, silt is predicted to settle at velocities of 0.15 feet per second or lower[53]; larger grain particles are able to settle at higher velocities. During flows just under the bankfull flow (i.e., the 5% exceedance flow), transported sediment is predicted to settle along the banks of the Nemasket immediately downstream of the MBTA Bridge. Sediment will continue to settle along the banks downstream to the I-495 Bridge and beyond. During low flows (i.e., the 95% exceedance flow), channel velocities will be slow enough that transported silt will be able to settle within the channel between the MBTA and I-495 Bridges. Predicted sediment degradation and aggradation locations are included below as **Figure 60**.

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of the MBTA Bridge are shown below in **Table 23**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR4** is included in **Attachment B**.

*Table 23. Selected **PR4** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**MBTA Bridge - US**	
Recurrence Interval	Existing	PR4	Existing	PR4
95% Exceedance	49.93	49.93	48.09	48.06
5% Exceedance	53.76	53.73	52.45	52.42
2-year	54.77	54.71	53.51	*53.45**
10-year	55.90	*55.82**	54.64	*54.54**
100-year	57.27	*57.12**	55.97	*55.81**

** indicates reduction in WSE of 0.05 feet or greater*

[53] Rouse, H., "Engineering Hydraulics", 1950

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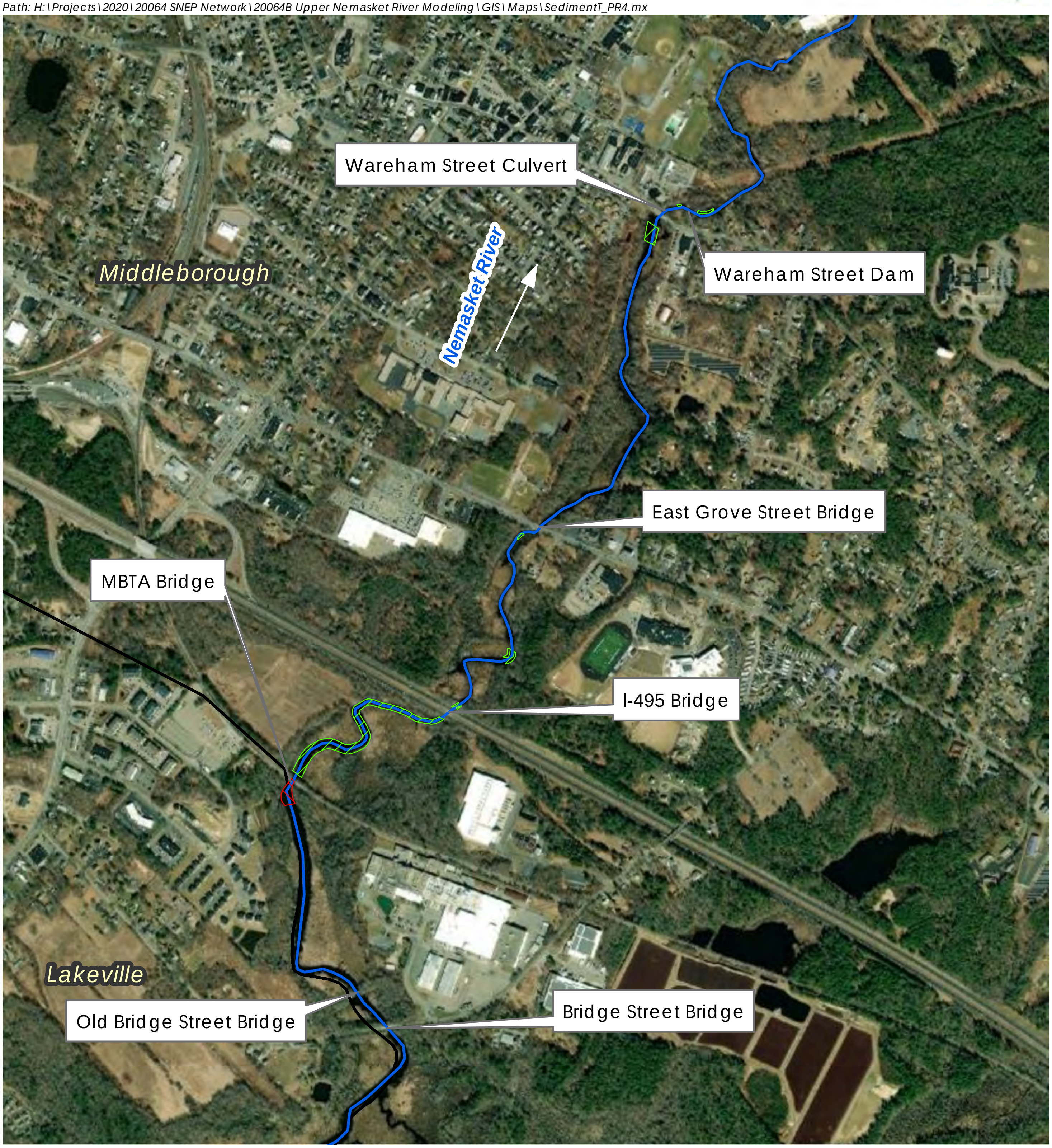

Date: 4/12/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Predicted Sediment Settling Area
- Predicted Sediment Transport Area
- Nemasket River
- Municipal Boundary

Feet
0 600 1,200

Upper Nemasket River Hydrology and Hydraulics Study

Figure **60**

Predicted Sediment Transport PR4
MBTA Bridge Modification

The widening of the MBTA Bridge and its banks is predicted to decrease WSE's most significantly during larger flow events. The greatest decrease in flood elevation is predicted under the 100-year flow, under which WSE's are predicted to drop by around 0.15 feet upstream of the Assawompset Pond Dam and 0.16 feet upstream of the MBTA Bridge. No significant reductions in flood elevation are predicted for flows under the 2-year event. Based on the HEC-RAS analysis, **PR4** is a fairly effective scenario at reducing flooding during rare flood events.

3.3.6 PR5 – Remove Old Bridge Street Bridge

PR5 involves the demolition and removal of the Old Bridge Street Bridge, as well as removal of the embankments and roadway on either side of the bridge. As discussed above, the bridge is no longer trafficked by vehicles, and it is assumed that its removal would have no negative impacts on circulation.

In HEC-RAS, the bridge structures were completely removed from **PR5**, as shown upstream and downstream of the bridge in **Figure 61** and upstream of the bridge in **Figure 62**. The upstream and downstream ineffective flow areas, included in the existing conditions model to account for contraction and expansion of the river flow through the bridge, were removed from the cross sections adjacent to the bridge in the **PR5** model. Additionally, small berms on the upstream left bank and downstream right bank were removed from the **PR5** model, replicating bank restoration activities that could help reconnect the Upper Nemasket River its original floodplain.

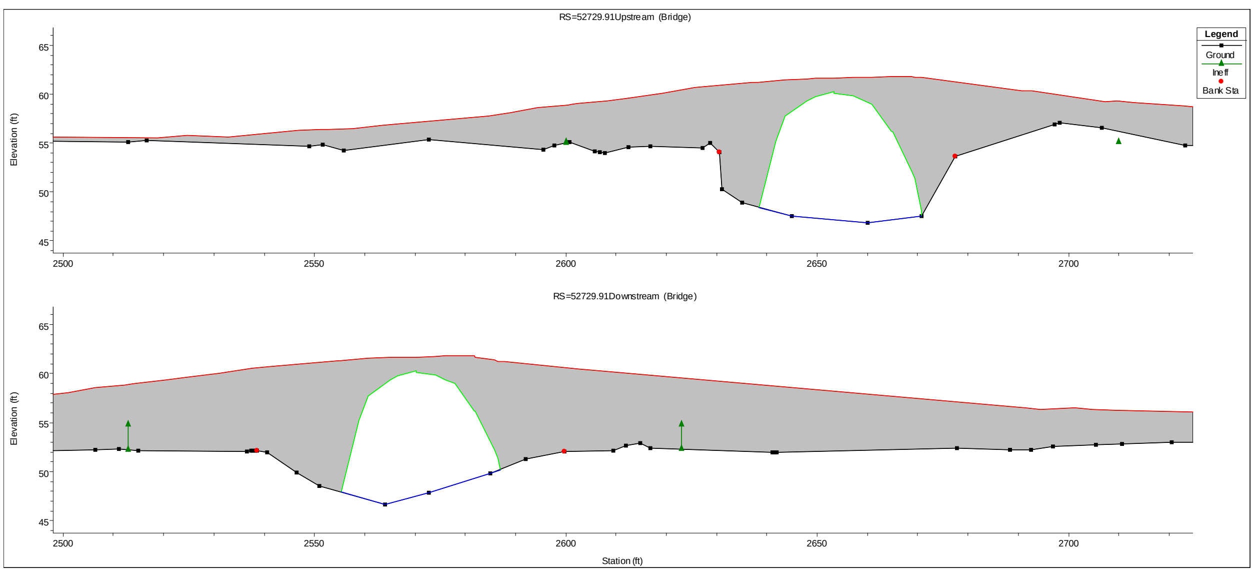

Figure 61. Cross Section of Old Bridge Street Bridge in Corrected Effective Model

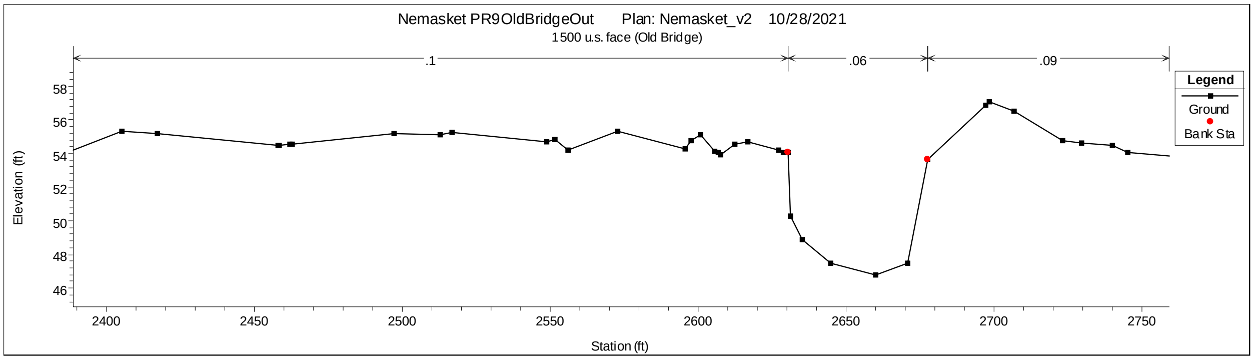

*Figure 62. Cross Section Immediately Upstream of Old Bridge Street Bridge After Removal in **PR5***

Significant sediment transport is not anticipated as a result of **PR5**. As shown in **Table 24**, shear stress within the main channel during the 2-year flow is expected to reduce as a result of bridge removal, while shear stress at the banks is not expected to exceed the transport threshold of 0.045 psf[54]. Likewise, velocity within the channel is expected to decrease as a result of **PR5**, and increases in water velocity at the banks do not exceed transport thresholds for silt of 1.75 feet per second[55].

*Table 24. **PR5** Sediment Transport Potential*

	US Shear Stress (psf)		US Velocity (ft/sec)	
	Existing Conditions	Bridge Removed	Existing Conditions	Bridge Removed
LB	-	0.01	-	0.10
Channel	0.19	0.18	1.79	1.73
RB	0.00	0.01	0.10	0.34

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of Old Bridge Street are shown below in **Table 25**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR5** is included in **Attachment B**.

*Table 25. Selected **PR5** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		Old Bridge Street - US	
Recurrence Interval	Existing	PR5	Existing	PR5
95% Exceedance	49.93	49.93	48.20	48.17
5% Exceedance	53.76	53.73	52.78	52.69
2-year	54.77	*54.70**	53.92	*53.77**
10-year	55.90	*54.82**	55.06	*54.95**
100-year	57.27	*57.09**	56.52	*56.25**

** indicates reduction in WSE of 0.05 feet or greater*

[54] Engineering Field Handbook Notice, 2009
[55] Ibid.

The demolition and removal of the Old Bridge Street Bridge is predicted to decrease WSE's most significantly during larger flow events. The largest drop in water levels is predicted during the 100-year flow, in which the WSE is predicted to drop by 0.18 feet upstream of the Assawompset Dam and by 0.27 feet upstream of Old Bridge Street. The impacts of **PR5** are diminished for lower flow events, with negligible drops in WSE during flows with less than a 2-year annual recurrence interval. Overall, **PR5** is a relatively effective scenario in terms of reducing water levels during rare flood events.

3.3.7 PR6 – Modify Vaughan Street Bridge

The existing Vaughan Street Bridge spans 35 feet, which is 24.5 feet narrower than the average reference reach bankfull width and 36.4 feet narrower than the minimum channel width of 71.4 feet required according to the Stream Crossing Standards. Under **PR6**, the two abutments on either side of the bridge were removed and the overall span of the bridge was widened to 80 feet (**Figure 63** and **Figure 64**). The banks of the Nemasket were widened slightly: both banks were pulled back 10 feet on the upstream side and 2 feet on the downstream side to match the approximately 60-foot bankfull width measured at the reference reach. With an open area of 629 square feet over a length of 38 feet, the openness ratio of the modified Vaughan Street Bridge is calculated to be 16.6, surpassing the minimum ratio of 0.82.

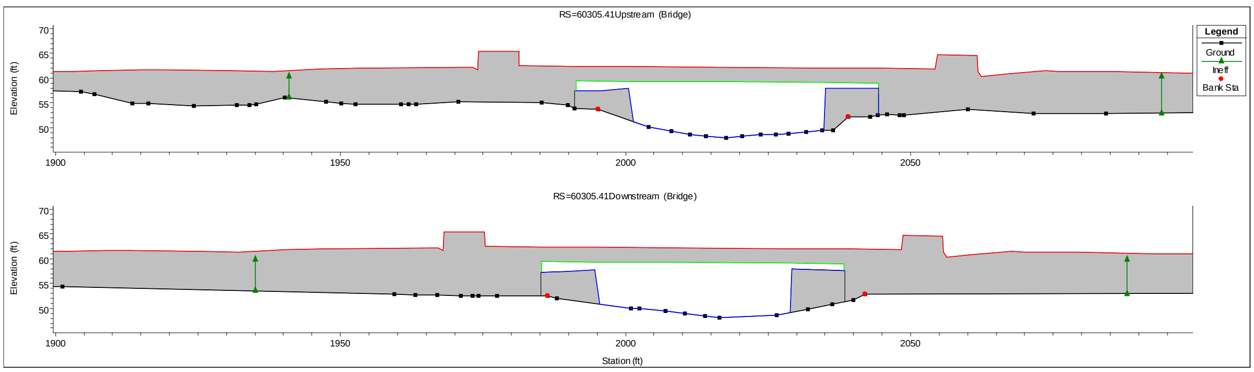

Figure 63. Cross Section of Vaughan Street Bridge in Corrected Effective Model

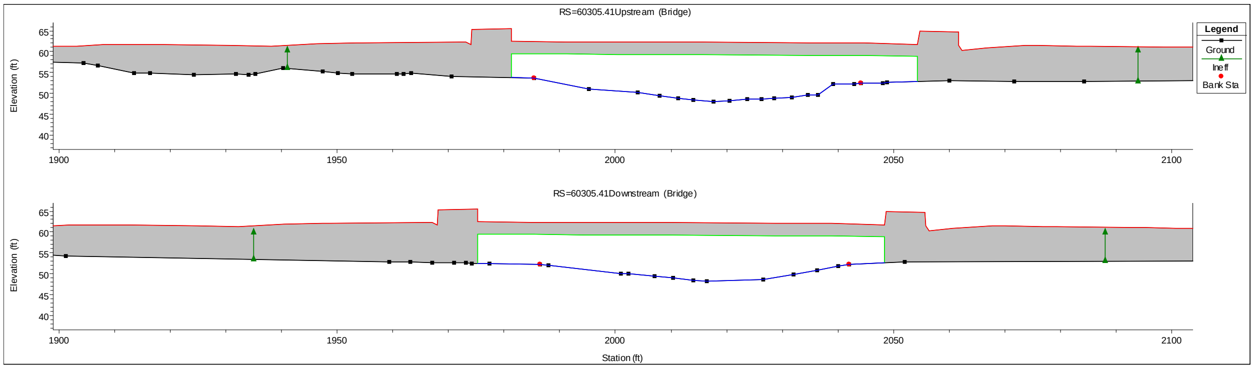

*Figure 64. Cross Section of Modified Vaughan Street Bridge in **PR6***

Significant sediment transport is not anticipated as a result of **PR6**. As shown in **Table 26**, shear stress during the 2-year flow within the main channel and along the banks is expected to reduce as a result of bridge modification. Likewise, velocity within the channel is expected to decrease as a result of **PR6** both within the channel and along the banks.

*Table 26. **PR6** Sediment Transport Potential*

	US Shear Stress (psf)		US Velocity (ft/sec)	
	Existing Conditions	Bridge Modified	Existing Conditions	Bridge Modified
LB	0.02	0.01	0.19	0.16
Channel	0.14	0.10	1.51	1.28
RB	0.05	0.04	0.37	0.34

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of the Vaughan Street Bridge are shown below in **Table 27**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR6** is included in **Attachment B**.

*Table 27. Selected **PR6** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		Vaughan Street - US	
Recurrence Interval	Existing	PR6	Existing	PR6
95% Exceedance	49.93	49.93	49.31	49.31
5% Exceedance	53.76	53.73	53.49	53.47
2-year	54.77	*54.71**	54.56	*54.51**
10-year	55.90	*55.79**	55.73	*55.63**
100-year	57.27	*57.11**	57.09	*56.98**

** indicates reduction in WSE of 0.05 feet or greater*

By widening the Vaughan Street Bridge, WSEs in the Upper Nemasket River are predicted to drop upstream of Vaughan Street and the Assawompset Pond Dam primarily during larger flow events. The WSE reduction is largest under the 100-year flow, during which flood elevations are predicted to decrease by 0.16 feet upstream of the Assawompset Pond Dam and by 0.11 feet upstream of Vaughan Street. No reduction in WSE is predicted during flows less than the 2-year event. As a whole, **PR6** is fairly effective at reducing flood elevations in the Upper Nemasket, although benefits are concentrated in a section of approximately 3,000 feet at the upstream end of the river.

3.3.8 PR7 – Sediment Trap and Dredging Downstream of Assawompset Pond Dam

PR7 was developed based on the plan prepared by OE entitled "Preliminary Concept Improvement Plan at Assawompset Pond Dam Spillway and Nemasket River," attached as **Appendix D**. The plan proposes dredging the Upper Nemasket River downstream of the Assawompset Pond Dam to approximate the dimensions of the channel in 1894, the year that construction of the dam began. The dam would remain unaltered in this scenario.

In addition to dredging the channel of the Upper Nemasket, a 60-foot-long section of sheet pile is proposed to be installed in the channel perpendicular to the flow of the river. The sheet pile is proposed as a "water control structure," with the goal of trapping suspended sediment for easy removal via excavator. Based on historic reports of sediment erosion from the shores of the

Assawompset Pond, sand is anticipated to be the dominant sediment type suspended within the Upper Nemasket in the vicinity of the Assawompset Pond Dam[56].

The sediment trap is proposed with a top elevation 4 feet above the bottom of the channel, with a 14-foot-wide low flow outlet set 2 feet lower than the top of the structure. A 12-foot-wide berm on the right bank of the river is proposed to assist with access to the sediment trap. A cross section of the dredged channel and water control section as modelled in HEC-RAS is included below as **Figure 65**.

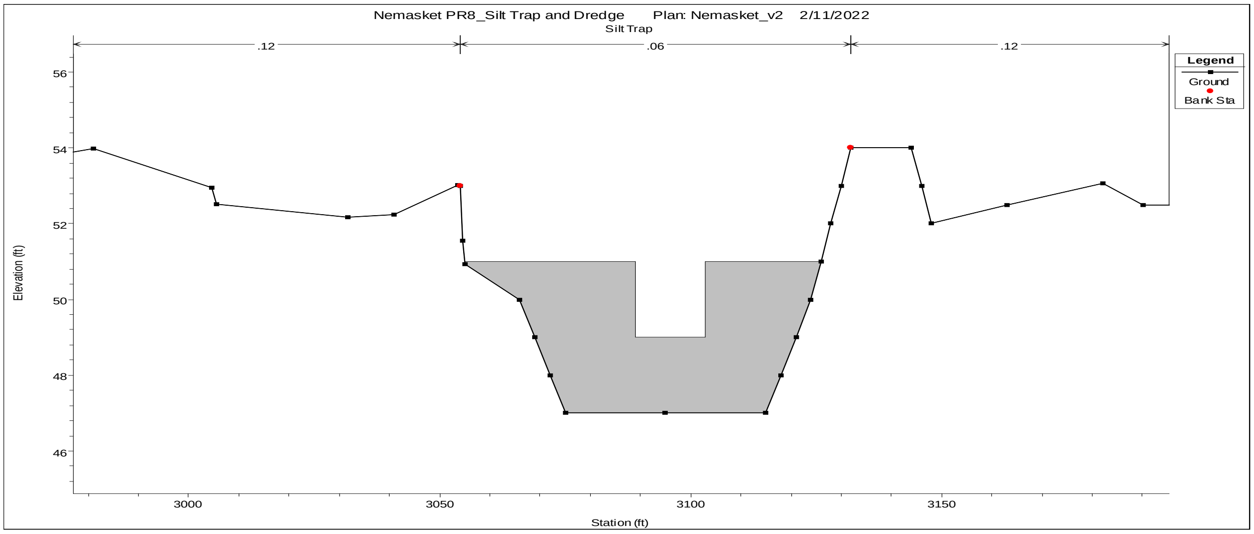

*Figure 65. Proposed Sediment Trap and Dredged Channel Under **PR7***

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of the sediment trap are presented below in **Table 28**. A longitudinal profile showing predicted WSE's during the 100-year flow under **PR7** is included in **Attachment B**.

*Table 28. Selected **PR7** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**Sediment Trap - US**	
Recurrence Interval	Existing	PR7	Existing	PR7
95% Exceedance	49.93	*49.74**	49.92	*49.73**
5% Exceedance	53.76	53.76	53.74	53.74
2-year	54.77	54.78	54.75	54.76
10-year	55.90	55.90	55.89	55.90
100-year	57.27	57.28	57.27	57.27

** indicates reduction in WSE of 0.05 feet or greater*

As seen above, the water surface level impacts of **PR7** are most prominent during lower flow events such as the 95% daily exceedance flow. WSE's are predicted to drop by 0.19 feet near the Assawompset Pond Dam and upstream of the sediment trap during the 95% exceedance

[56] "Nemasket River Corridor Public Water Based Recreation and Fish and Wildlife Development Resource Conservation and Development Plan," U.S. Department of Agriculture Soil Conservation Service, March 1982

flow. As shown in **Attachment A**, WSE's are unchanged relative to existing conditions downstream of the sediment trap.

Under **PR7**, water velocities are modelled as running slowly between the Assawompset Pond Dam and the proposed sediment trap relative to downstream sections of the Upper Nemasket River. The peak velocity predicted between the dam and the sediment trap is 0.31 feet per second under the 5% daily exceedance flow. Because this peak velocity is lower than the required settling velocity for the fine to medium sand (0.6 feet per second[57]) that is suspended in this portion of the river, suspended sand is predicted to settle within the sediment trap under all modelled flows.

While the proposed dredging and sediment trap plan reduces WSE's in the Upper Nemasket during more common, low flow events, it appears to have minimal impact on large flood events. Because the sediment loading rate in the Upper Nemasket River is not fully understood, the maintenance requirements and lifespan of the sediment trap are unknown. **PR7** offers a potentially short-term solution to sedimentation downstream of the Assawompset Pond Dam, with only marginal benefits to flood control and potential barriers to aquatic organism passage. Impacts to fish passage are discussed at greater length below.

3.3.9 Hybrid Scenarios

In addition to the individual dam removal and bridge modification scenarios described above, HW evaluated the impacts of four hybrid restoration scenarios. Hybrid scenarios combined the Wareham Street Dam and Weir removal scenario (**PR1**) with one or more bridge modification scenario. Bridge modification scenarios were selected for evaluation based on the predicted reduction in flood levels, reduction in inundated area, and perceived feasibility of modification activities.

The bridge modifications selected for to be evaluated alongside **PR1** included the East Grove Street Bridge (**PR2**), the MBTA Bridge (**PR4**), and the Old Bridge Street Bridge (**PR5**). Each bridge modification was evaluated as a single additional modification alongside PR1, resulting in three initial hybrid scenarios. A fourth hybrid scenario combined all four of the above scenarios (**PR1/2/4/5**) as an "optimal" maximum impact restoration scenario.

Modification of the I-495 Bridge (**PR3**) was not selected for hybrid evaluation due to a slightly smaller impact on flood elevation reduction than either **PR4** or **PR5**, as well as anticipated obstacles related to permitting and constructability of an interstate highway retrofit. Modification of the Vaughan Street Bridge (**PR6**) was not selected as a priority for hybrid evaluation due to a relatively small reduction in inundated area.

A longitudinal profile for **PR1** and the hybrid scenarios showing the predicted WSE of the Upper Nemasket River during the 100-year flow is included in **Attachment B**.

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[57] Rouse, H., "Engineering Hydraulics", 1950

3.3.9.1 PR1/2 – Remove Wareham Street Dam and Modify East Grove Street Bridge

Hybrid scenario **PR1/2** combined the Wareham Street Dam and Weir removal and Wareham Culvert replacement (**PR1**) with the East Grove Street Bridge modification (**PR2**) discussed above. Sediment transport was evaluated using the same methodology as in **PR1** and **PR2**. Because transport predicted in **PR1** extended upstream past East Grove Street and was deeper than **PR2**, the post-transport longitudinal profile of **PR1/2** matched that of **PR1** (**Figure 45**). Transport is predicted to occur until shear stress does not exceed threshold values for gravel (0.33 psf) in the channel or silt (0.045 psf) along the banks[58]. Pre- and post-transport shear and velocity values during the 2-year flow are shown below in **Table 29**.

*Table 29. **PR1/2** Sediment Transport Potential*

		US Shear Stress (psf)		US Velocity (ft/sec)	
		PR1/2 (Pre-Transport)	PR1/2 + Sediment Transport	PR1/2 (Pre-Transport)	PR1/2 + Sediment Transport
East Grove Street	LB	0.02	-	0.18	-
	Channel	0.22	0.13	2.37	1.45
	RB	0.07	0.01	0.63	0.17
Wareham Street	LB	-	-	-	-
	Channel	0.66	0.23	4.62	1.91
	RB	-	-	-	-

Locations of predicted sediment degradation and aggradation are included below as **Figure 66**.

[58] Engineering Field Handbook Notice, 2009

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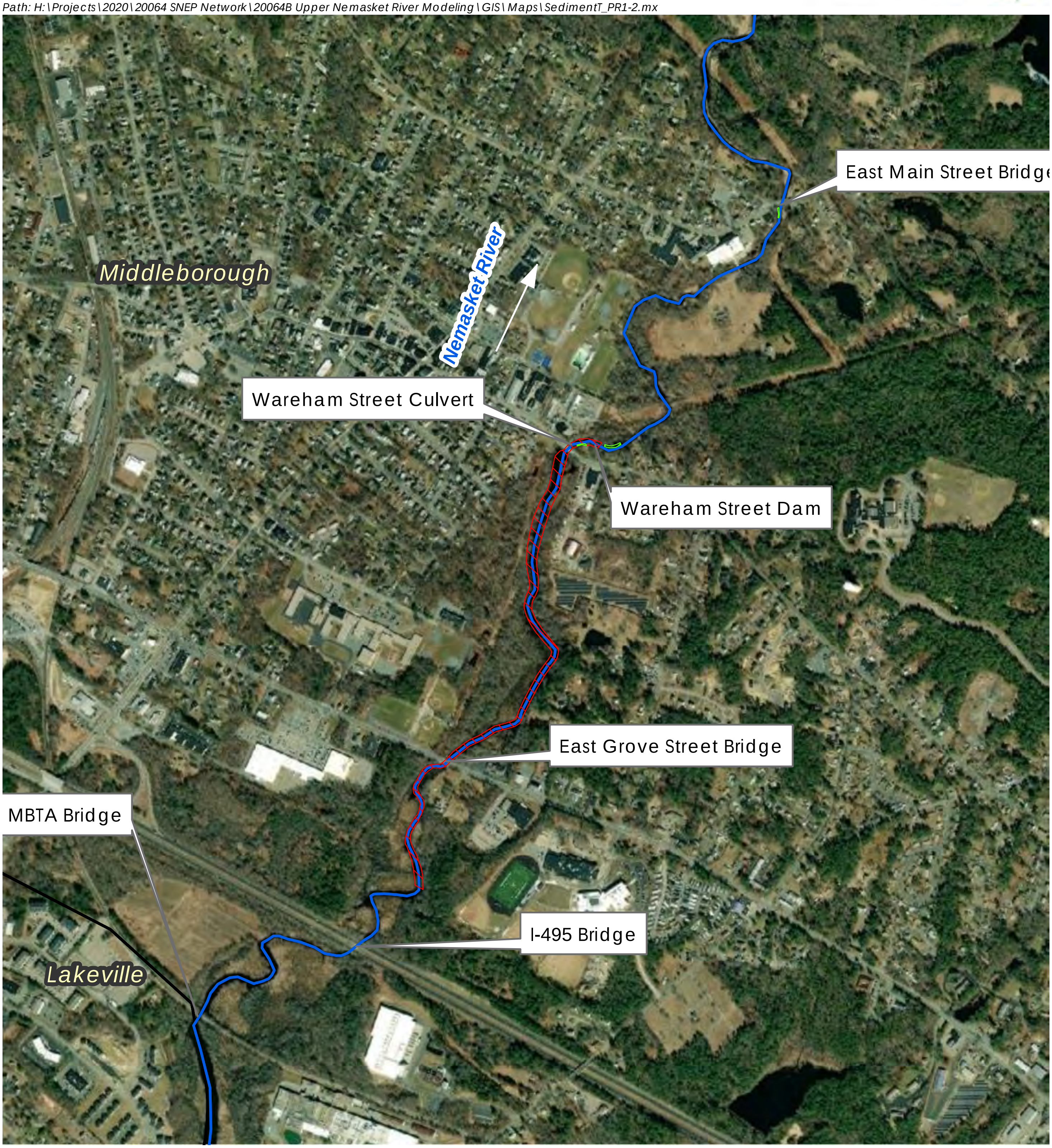

Date: 4/12/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Predicted Sediment Settling Area
Predicted Sediment Transport Area
Nemasket River
Municipal Boundary

Feet
0 600 1,200

Upper Nemasket River Hydrology and Hydraulics Study

Figure **66**

Predicted Sediment Transport PR1/2

Wareham Street Dam Removal and Culvert Replacement, East Grove Street Bridge Modification

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of East Grove Street and Wareham Street are presented below in **Table 30**. A longitudinal profile showing predicted WSE's during the 100-year flow under hybrid scenario **PR1/2** is included in **Attachment B**.

*Table 30. Selected **PR1/2** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**East Grove Street - US**		**Wareham Street - US**	
Recurrence Interval	Existing	PR1/2	Existing	PR1/2	Existing	PR1/2
95% Exceedance	49.93	49.93	47.95	*45.58****	44.71	*40.10****
5% Exceedance	53.76	*53.60**	51.57	*49.54****	49.83	*43.60****
2-year	54.77	*54.56**	52.65	*52.02***	50.82	*44.59****
10-year	55.90	*55.59**	53.75	*52.19****	51.94	*45.60****
100-year	57.27	*56.78**	54.99	*53.29****	53.19	*46.62****

**indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

Although **PR1** and **PR2** appeared to be the two most effective individual restoration scenarios for flood reduction along the Upper Nemasket, the hybrid scenario **PR1/2** results in only slightly lower WSE's than **PR1** alone. For example, the 100-year WSE prediction upstream of the Assawompset Pond Dam is only 0.03 feet lower in **PR1/2** (56.78 feet) than in **PR1** (56.81 feet). The benefits of modifying the East Grove Street Bridge are most noticeably seen directly upstream of East Grove Street. Predicted WSE's are 0.2 feet lower upstream of East Grove Street in **PR1/2** (53.29 feet) as compared to **PR1** (53.49 feet).

The minor difference in **PR1** versus **PR1/2** is due to the proximity of Wareham Street to East Grove Street. As East Grove Street is the next-upstream crossing from Wareham Street, much of the sediment transport that would occur as a result of **PR1** extends up to East Grove Street. While widening East Grove Street and allowing sediment to migrate away from the upstream impoundment is highly effective at reducing upstream water levels in **PR2**, the East Grove Street impoundment is predicted to be curtailed just as effectively under **PR1**. As discussed below, bridge modifications proposed at a greater distance away from Wareham Street are predicted to have a greater overall impact on flood reduction.

3.3.9.2 PR1/4 – Remove Wareham Street Dam and Modify MBTA Bridge

Hybrid scenario **PR1/4** combined the Wareham Street Dam and Weir removal and Wareham Culvert replacement (**PR1**) with the MBTA Bridge modification (**PR4**) discussed above. Sediment transport was evaluated using the same methodology as in **PR1** and **PR4**. Longitudinal profiles of the Upper Nemasket following sediment transport matched those of **Figure 45** and **Figure 59**. Transport is predicted to occur until shear stress at Wareham Street and East Grove Street does not exceed threshold values for gravel (0.33 psf) in the channel or silt (0.045 psf) along the banks[59]. Although shear stress upstream of the MBTA Bridge is predicted to exceed the fine gravel transport threshold value of 0.075 psf in the main channel[60], shear stress is predicted to decrease relative to existing conditions in which main channel shear is 0.30 psf. Therefore, transport is not expected to occur beyond the substrate that has accumulated upstream of the MBTA Bridge (**Figure 58**). Shear stress and velocities predicted under the 2-year flow for hybrid **PR1/4** are shown below in **Table 31**.

*Table 31. **PR1/4** Sediment Transport Potential*

		US Shear Stress (psf)		**US Velocity (ft/sec)**	
		PR1/4 (Pre-Transport)	PR1/4 + Sediment Transport	PR1/4 (Pre-Transport)	PR1/4 + Sediment Transport
MBTA Bridge	LB	0.02	0.03	0.30	0.34
	Channel	0.08	0.09	1.67	1.27
	RB	0.02	0.03	0.29	0.34
East Grove Street	LB	-	-	-	-
	Channel	0.25	0.12	2.59	1.43
	RB	0.06	0.01	0.54	0.19
Wareham Street	LB	-	-	-	-
	Channel	0.66	0.23	4.62	1.91
	RB	-	-	-	-

Locations of predicted sediment degradation and aggradation are included below as **Figure 67**.

[59] Engineering Field Handbook Notice, 2009
[60] Ibid.

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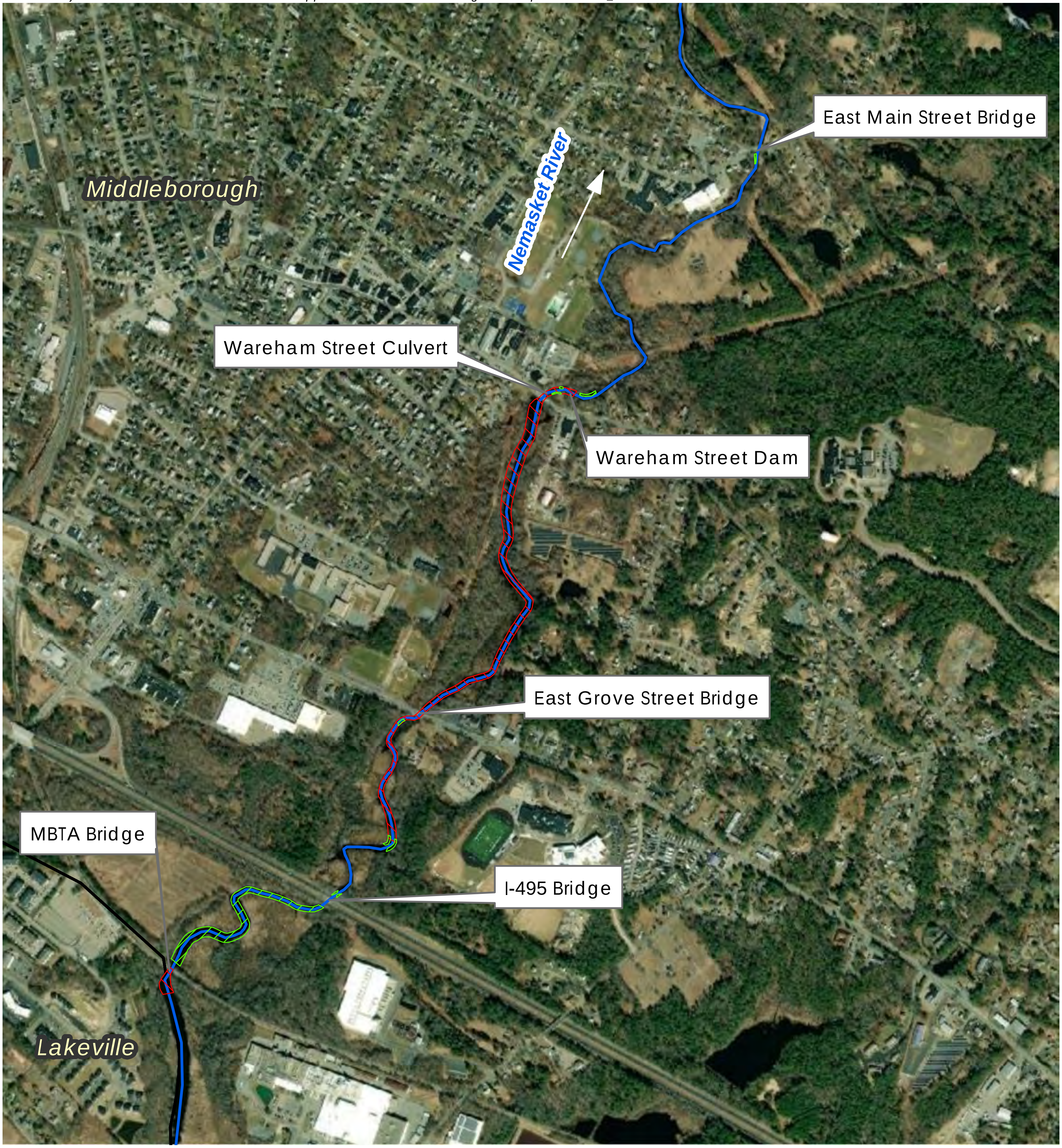

Date: 4/20/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

- Predicted Sediment Settling Area
- Predicted Sediment Transport Area
- Nemasket River
- Municipal Boundary

Feet
0 600 1,200

Upper Nemasket River Hydrology and Hydraulics Study

Figure **67**

Predicted Sediment Transport PR1/4
Wareham Street Dam Removal and Culvert Replacement, MBTA Bridge Modification

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam and upstream of the MBTA bridge and Wareham Street are presented below in **Table 32**. A longitudinal profile showing predicted WSE's during the 100-year flow under hybrid scenario PR1/4 is included in **Attachment B**.

*Table 32. Selected **PR1/4** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**MBTA Bridge - US**		**Wareham Street - US**	
Recurrence Interval	Existing	PR1/4	Existing	PR1/4	Existing	PR1/4
95% Exceedance	49.93	49.93	48.09	*46.97****	44.71	*40.04*****
5% Exceedance	53.76	*53.60**	52.45	*51.50***	49.83	*43.58*****
2-year	54.77	*54.51**	53.51	*52.76***	50.82	*44.58*****
10-year	55.90	*55.49**	54.64	*53.72***	51.94	*45.62*****
100-year	57.27	*56.63***	55.97	*54.81****	53.19	*46.65*****

**indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

The combined effect of **PR1** and **PR4** distributes flood reduction benefits more widely than the hybrid of Wareham Street alterations and East Grove Street Bridge modification (**PR1/2**). Like **PR1/2**, hybrid **PR1/4** is predicted to lower WSE's significantly upstream of Wareham Street. Additionally, WSE's upstream of the MBTA Bridge are predicted to drop to a greater extent under **PR1/4**. During the 100-year flow, water levels are predicted to be approximately 0.3 feet lower upstream of the MBTA Bridge under **PR1/4** (55.10 feet) than under **PR1/2** (55.38 feet). WSE's at the Assawompset Pond Dam are expected to drop an additional 0.15 feet during the 100-year flow under **PR1/4** (56.63 feet) relative to **PR1/2** (56.78 feet).

3.3.9.3 PR1/5 – Remove Wareham Street Dam and Remove Old Bridge Street Bridge

Hybrid scenario **PR1/5** combined the Wareham Street Dam and Weir removal and Wareham Culvert replacement (**PR1**) with the Old Bridge Street Bridge removal (**PR5**) discussed above. Sediment transport was evaluated using the same methodology as in **PR1**. Longitudinal profiles of the Nemasket upstream of Wareham Street following sediment transport matched those of **Figure 45**. Unlike **PR5** alone, the combined impacts of the **PR1** modifications in **PR1/5** resulted in an increase in shear stress and channel velocity upstream of Old Bridge Street. Sediment that has accumulated between the MBTA Bridge and Old Bridge Street Bridge as well as sediment upstream of Bridge Street is expected to transport until shear values approach those of existing conditions. Sediment accumulation is identified below in **Figure 68**. The estimated longitudinal profile following sediment transport is shown in **Figure 69**.

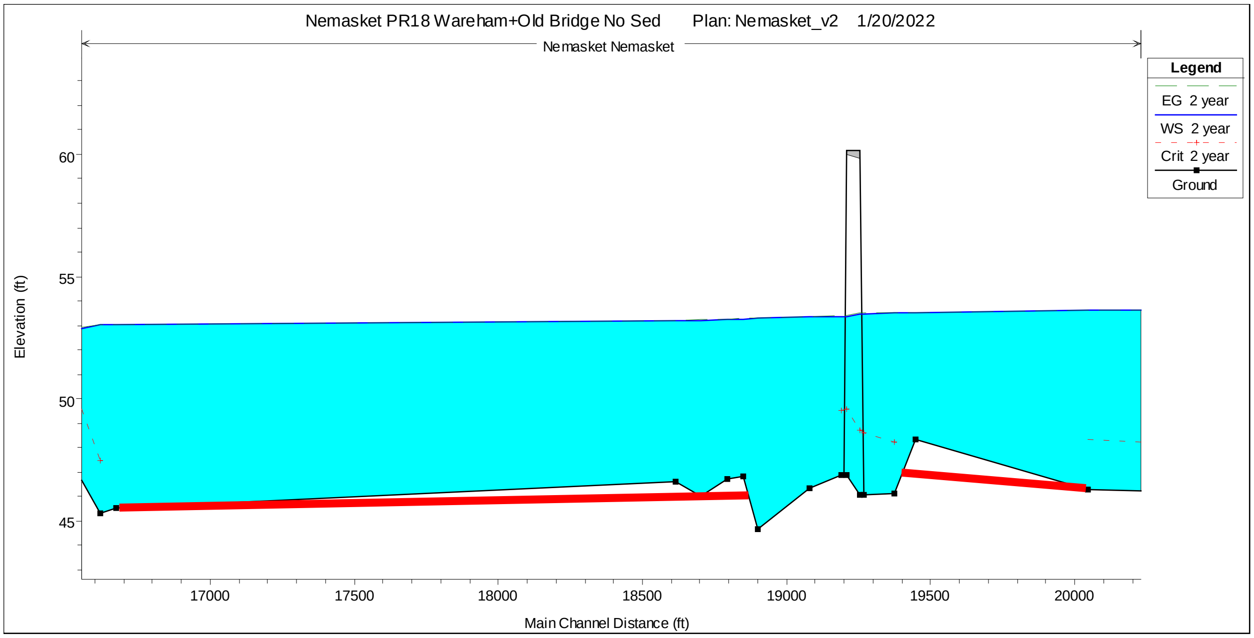

Figure 68. Longitudinal Profile of Old Bridge Street and Bridge Street Bridge Prior to Sediment Transport Analysis – Sediment Transport above Red Line

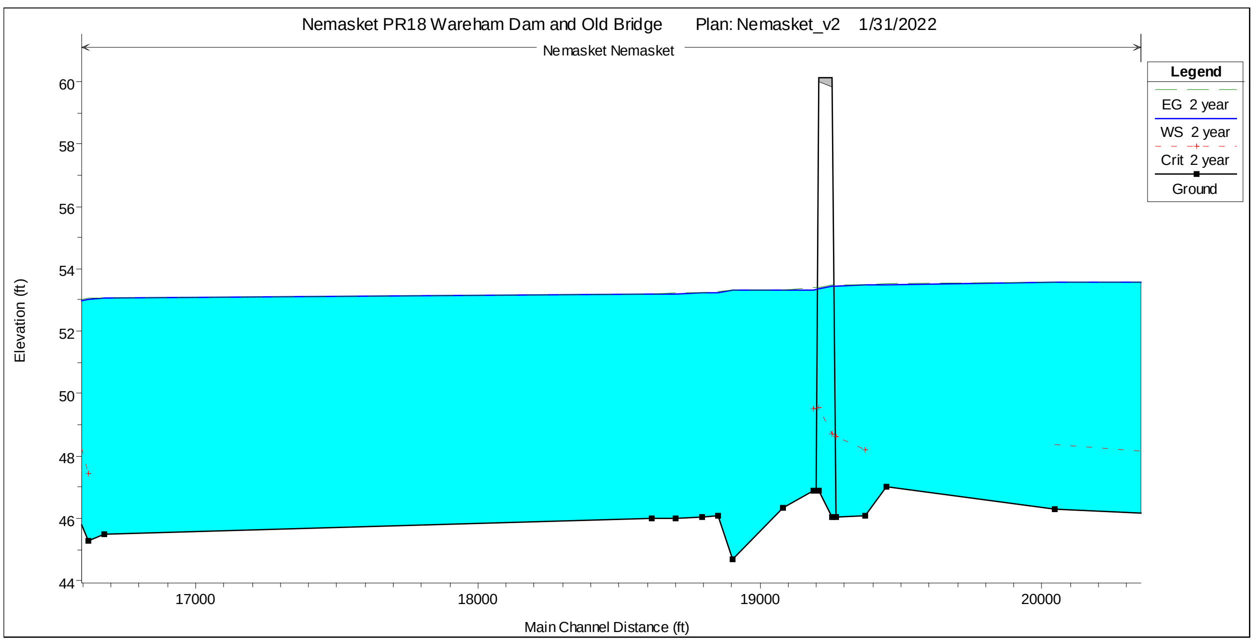

*Figure 69. Longitudinal Profile of Old Bridge Street and Bridge Street Bridge in Hybrid **PR1/5** – Sediment Removed via Transport*

Under existing conditions, the main channel shear stress reaches 0.19 psf under the 2-year flow; the main channel velocity under the 2-year flow is 1.79 feet per second (**Table 24**). Sediment transport upstream of Old Bridge Street was iteratively modelled until shear stress and velocity in the channel approximated existing conditions. Transported sediment is expected to be sand. Material underlying the transported sand is expected to be fine gravel (threshold shear velocity =

0.33 psf), which will not be transported following the transport of accumulated sand. Shear stress and velocities predicted under the 2-year storm are shown below in **Table 33**.

*Table 33. **PR1/5** Sediment Transport Potential*

		US Shear Stress (psf)		**US Velocity (ft/sec)**	
		PR1/5 (Pre-Transport)	PR1/5 + Sediment Transport	PR1/5 (Pre-Transport)	PR1/5 + Sediment Transport
Old Bridge Street	LB	-	-	-	-
	Channel	0.24	0.20	1.98	1.82
	RB	0.02	0.02	0.31	0.27
East Grove Street	LB	-	-	-	-
	Channel	0.12	0.12	1.43	1.43
	RB	0.01	0.01	0.19	0.19
Wareham Street	LB	-	-	-	-
	Channel	0.23	0.23	1.91	1.91
	RB	-	-	-	-

Locations of predicted sediment degradation and aggradation are included below as **Figure 70**.

Sediment transported in the vicinity of Old Bridge Street as a result of **PR1/5** is predicted to consist of particles with grain sizes greater than or equal to sand. As discussed above, sand is predicted to settle at velocities less than 0.6 feet per second[61]. During flows just under the bankfull flow (i.e., the 5% daily exceedance flow), transported sediment is predicted to settle along the banks of the Nemasket 500 feet downstream of Old Bridge Street and within the main channel 1,000 feet downstream of Old Bridge Street. During lower flows (i.e., the 95% flow), sand and larger sediment is predicted to be able to settle at any point downstream of Old Bridge Street.

[61] Rouse, H., "Engineering Hydraulics", 1950

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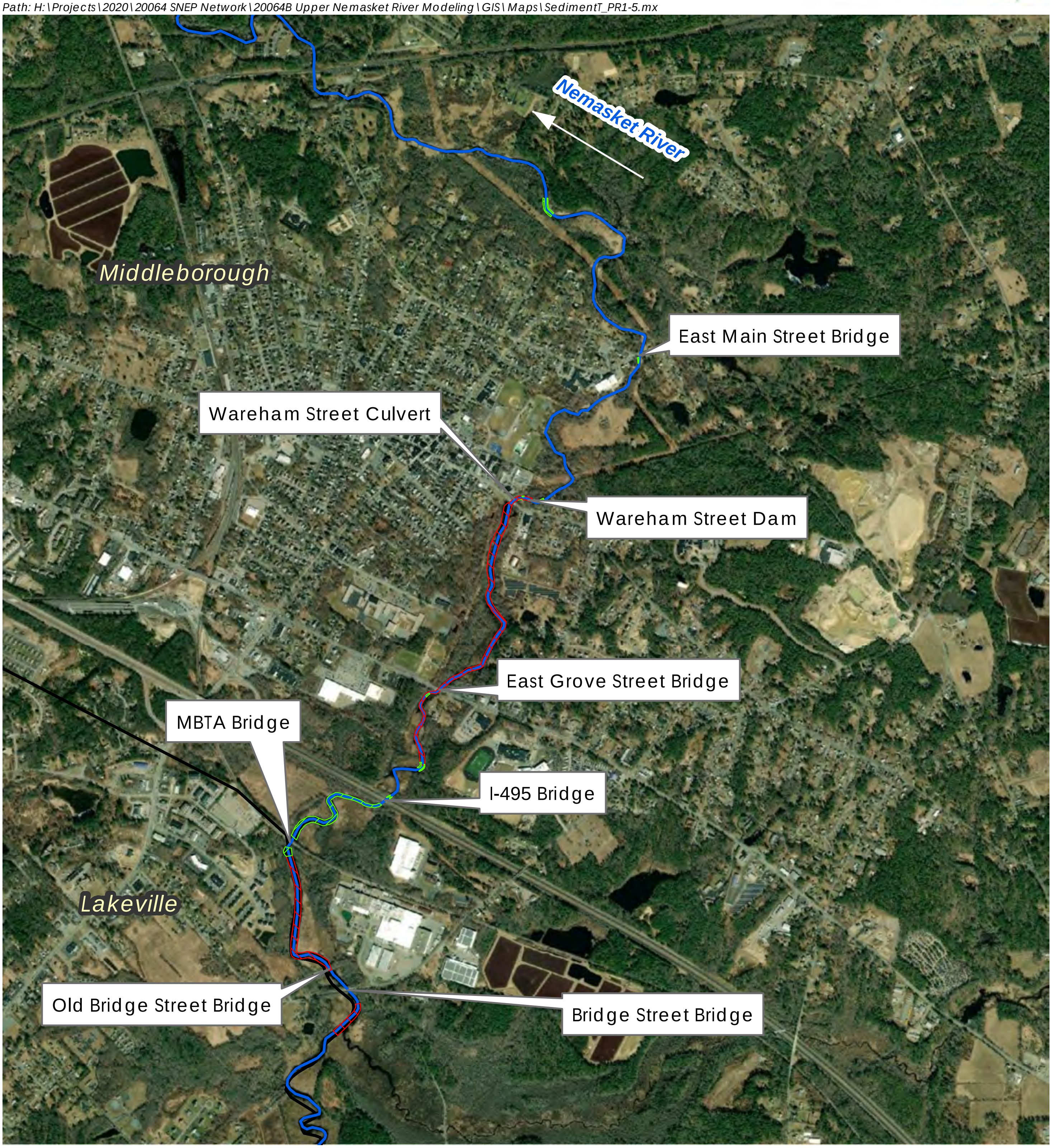

Date: 4/20/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Predicted Sediment Settling Area
Predicted Sediment Transport Area
Nemasket River
Municipal Boundary

Feet
0 1,000 2,000

Upper Nemasket River Hydrology and Hydraulics Study

Figure **70**

Predicted Sediment Transport PR1/5
Wareham Street Dam Removal and Culvert Replacement, Old Bridge Street Bridge Removal

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam, Old Bridge Street, and Wareham Street are presented below in **Table 34**. A longitudinal profile showing predicted WSE's during the 100-year flow under hybrid scenario **PR1/5** is included in **Attachment B**.

*Table 34. Selected **PR1/5** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**Old Bridge Street - US**		**Wareham Street - US**	
Recurrence Interval	Existing	PR1/5	Existing	PR1/5	Existing	PR1/5
95% Exceedance	49.93	49.93	48.20	*47.79**	44.71	*40.01*****
5% Exceedance	53.76	*53.50**	52.78	*52.00***	49.83	*43.58*****
2-year	54.77	*54.50**	53.92	*53.23***	50.82	*44.59*****
10-year	55.90	*55.45**	55.18	*54.25***	51.94	*45.60*****
100-year	57.27	*56.59***	56.52	*55.44****	53.19	*46.62*****

** indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

The combined effects of **PR1** and **PR5** are predicted to cause a significant and widespread reduction in flood volumes, comparable to those predicted by hybrid Wareham Street alterations and MBTA Bridge modification scenario (**PR1/4**). **PR1/5** results in the greatest reduction in flood elevations at the Assawompset Pond Dam of any of the two-modification hybrids described above. For example, the 100-year flood elevation is predicted to decrease by 0.68 feet from existing conditions (57.27 feet) under **PR1/5** (56.59 feet). While **PR1/4** results in a greater reduction of flood levels in the 2,200 feet between Old Bridge Street and the MBTA Bridge, the 10,700-foot section of the Upper Nemasket between the Assawompset Pond Dam and Old Bridge Street shows greater flood reduction under **PR1/5**.

3.3.9.4 PR1/2/4/5 (PR Optimal) – Remove Wareham Street Dam, Modify East Grove Street Bridge, Modify MBTA Bridge, and Remove Old Bridge Street Bridge

The "optimal" hybrid scenario **PR1/2/4/5** (hereafter referred to as **PR Optimal**) combined the Wareham Dam and Weir removal and Culvert replacement described in **PR1** with the East Grove Street, MBTA, and Old Bridge Street Bridge modifications described in **PR2**, **PR4**, and **PR5**, respectively. Individual restoration scenarios are described above. Sediment transport analysis under **PR Optimal** utilized the same methodology as **PR1** (**Figure 45**), **PR2** (**Figure 52**), **PR4** (**Figure 59**), and **PR1/5** (**Figure 69**) to approximate post-restoration substrate profiles. Channel shear stress and velocity are predicted to be slightly higher at upstream of Old Bridge Street (+0.02 psf, +0.08 feet per second) and the MBTA Bridge (+0.01 psf, +0.01 feet per second) than under the respective two-modification hybrid scenarios described above. Channel shear stress and velocity are not expected to increase at East Grove Street or Wareham Street relative to **PR1/2**. Because the increases relative to **PR1/4** and **PR1/5** are relatively small, the extents of sediment transport are assumed to be the same in the optimal hybrid **PR Optimal** as in the two-modification hybrids. Predicted shear stress and velocity under the 2-year flow are shown for selected crossings in **Table 35**.

*Table 35. **PR Optimal** Sediment Transport Potential*

		PR Optimal (Pre-Transport)	PR Optimal + Sediment Transport	PR Optimal (Pre-Transport)	PR Optimal + Sediment Transport
Old Bridge Street	LB	-	-	-	-
	Channel	0.20	0.22	1.84	1.90
	RB	0.02	0.02	0.26	0.23
MBTA Bridge	LB	0.05	0.03	0.44	0.34
	Channel	0.15	0.09	1.56	1.28
	RB	0.04	0.03	0.42	0.34
East Grove Street	LB	-	-	-	-
	Channel	0.52	0.13	2.70	1.45
	RB	0.12	0.01	0.77	0.17
Wareham Street	LB	-	-	-	-
	Channel	0.23	0.23	1.91	1.91
	RB	-	-	-	-

Locations of predicted sediment degradation and aggradation are included below as **Figure 71**.

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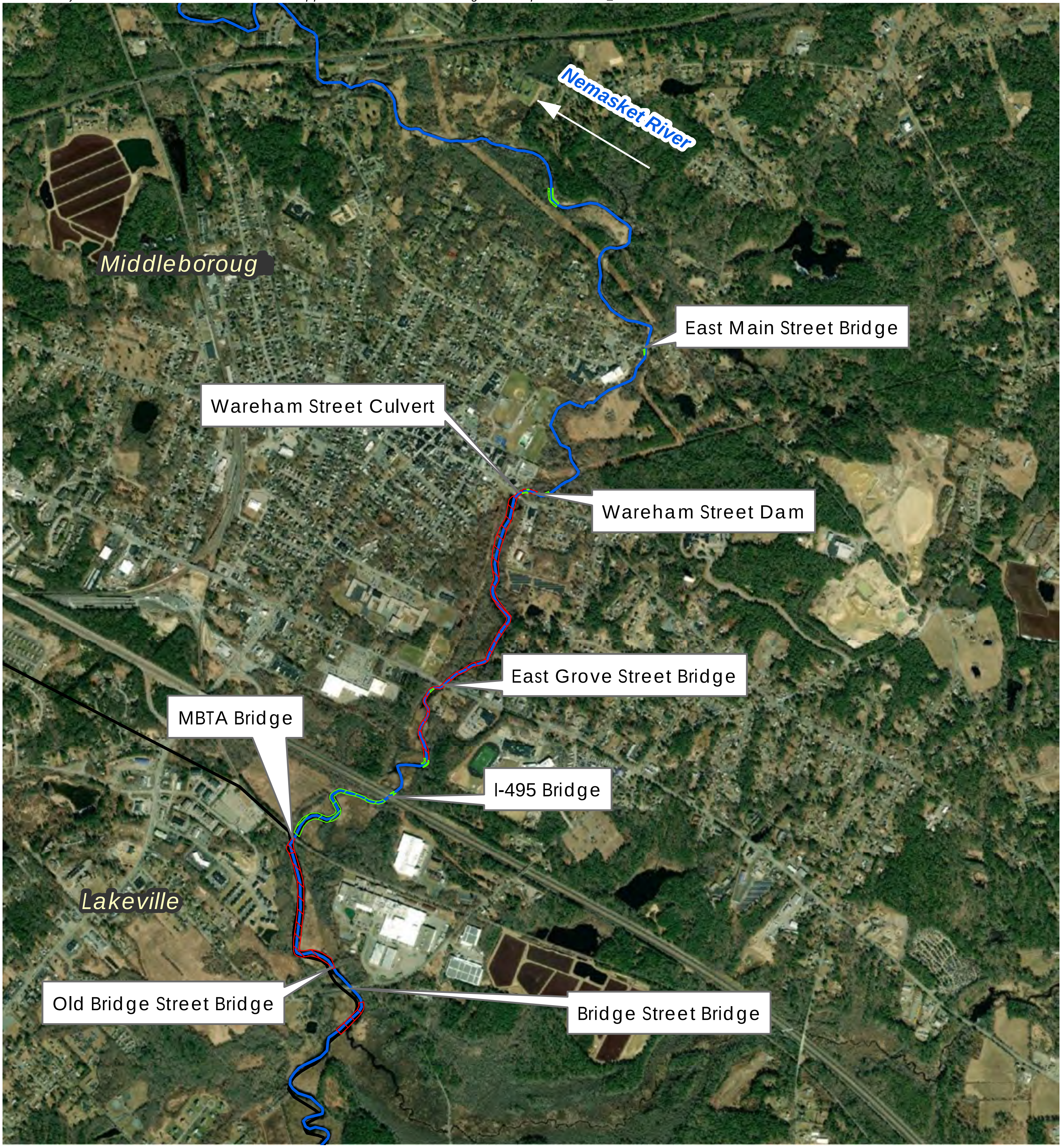

Date: 4/20/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Predicted Sediment Settling Area
Predicted Sediment Transport Area
Nemasket River
Municipal Boundary

Feet
0 1,000 2,000

Upper Nemasket River Hydrology and Hydraulics Study

Figure **71**

Predicted Sediment Transport PR Optimal Wareham Street Dam Removal and Culvert Replacement, East Grove Street and MBTA Bridge Modifications, and Old Bridge Street Bridge Removal

Results of the HEC-RAS analysis for all flow events upstream of the Assawompset Pond Dam, Old Bridge Street, the MBTA Bridge, East Grove Street, and Wareham Street are presented below in

Table 36. A longitudinal profile showing predicted WSE's during the 100-year flow under hybrid scenario **PR Optimal** is included in **Attachment B**.

*Table 36. Selected **PR Optimal** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam - US		**Old Bridge Street - US**		**MBTA Bridge - US**		**East Grove Street - US**		**Wareham Street - US**	
Recurrence Interval	Existing	PR Optimal	Existing	PR Optimal	Existing	PR Optimal	Existing	PR Optimal	Existing	PR Optimal
95% Exceedance	49.93	49.93	48.20	*47.33 ***	48.09	*46.97 ****	47.95	*45.58 ****	44.71	*40.10 *****
5% Exceedance	53.76	*53.57 **	52.78	*51.83 ***	52.45	*51.50 ***	51.57	*49.54 ****	49.83	*43.60 *****
2-year	54.77	*54.45 **	53.92	*53.04 ***	53.51	*52.75 ***	52.65	*50.86 ****	50.82	*44.59 *****
10-year	55.90	*55.34 ***	55.18	*53.98 ****	54.64	*53.69 ***	53.75	*52.19 ****	51.94	*45.60 *****
100-year	57.27	*56.39 ***	56.52	*55.03 ****	55.97	*54.74 ****	54.99	*53.17 ****	53.19	*46.62 *****

** indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

A comparison of predicted WSE's for the existing conditions, Wareham Street alterations scenario (**PR1**), and all four hybrid scenarios under the 100-year flow is shown below in **Table 37**. A longitudinal profile that visualizes the results shown in **Table 37** is included in **Attachment B**.

Table 37. Selected 100-Year Flow Results for Wareham Dam Removal Scenarios – Predicted WSE (ft)

Scenario	**Assawompset Dam - US**	**Old Bridge Street - US**	**MBTA Bridge - US**	**East Grove Street - US**	**Wareham Street - US**
EX	57.27	56.52	55.97	54.99	53.13
PR1	*56.81**	*55.83***	*54.99***	*53.49****	*46.65*****
PR1/2	*56.78**	*55.78***	*54.92****	*53.29****	*46.62*****
PR1/4	*56.63***	*55.52****	*54.81****	*53.49****	*46.65*****
PR1/5	*56.59***	*55.44****	*55.00****	*53.49****	*46.62*****
PR Optimal	*56.39***	*55.03****	*54.74****	*53.29****	*46.62*****

** indicates reduction in WSE of 0.05 feet or greater*
*** indicates reduction in WSE of 0.50 feet or greater*
**** indicates reduction in WSE of 1.00 feet or greater*
***** indicates reduction in WSE of 2.00 feet or greater*

Hybrid scenario **PR Optimal** provides the greatest flood reduction benefits of all proposed scenarios. 100-year flood levels are expected to drop by nearly 0.9 feet at the Assawompset Pond Dam, 1.5 feet at Old Bridge Street, 1.2 feet at the MBTA bridge, and 1.7 feet at East Grove Street. The significant drop in predicted flood elevations is due to the combined impact of removing the Wareham Street Dam and Weir as well as the four bridge and culvert modifications evaluated under **PR Optimal**.

Inundation maps for the 2- and 100-year flows are shown below in **Figure 72** and **Figure 73**. Under the 2-year flow, **PR Optimal** is predicted to eliminate the impoundment upstream of Wareham Street, and flow is expected to be confined to the riverbanks from Wareham Street to slightly upstream of East Grove Street. Reductions in inundated area are most significant between East Grove Street and I-495. Slight reductions in inundated area are observed upstream of I-495 up to Vaughan Street. Under the 100-year flow, **PR Optimal** is predicted to significantly reduce the size of the impoundment upstream of Wareham Street. Reductions in inundated area are significant from Wareham Street up to the MBTA Bridge, as well as along Fall Brook to the east. Modest reductions in inundated area are predicted between the MBTA Bridge and the Assawompset Pond Dam. Reductions in inundated area and impacted buildings during the 100-year flow are quantified below in **Table 38**.

Table 38. Inundation Impacts Under 100-Year Flow

Scenario	Flooded Area (acres)	Buildings Impacted
EX	723	27
PR1	680	23
PR Optimal	653	19

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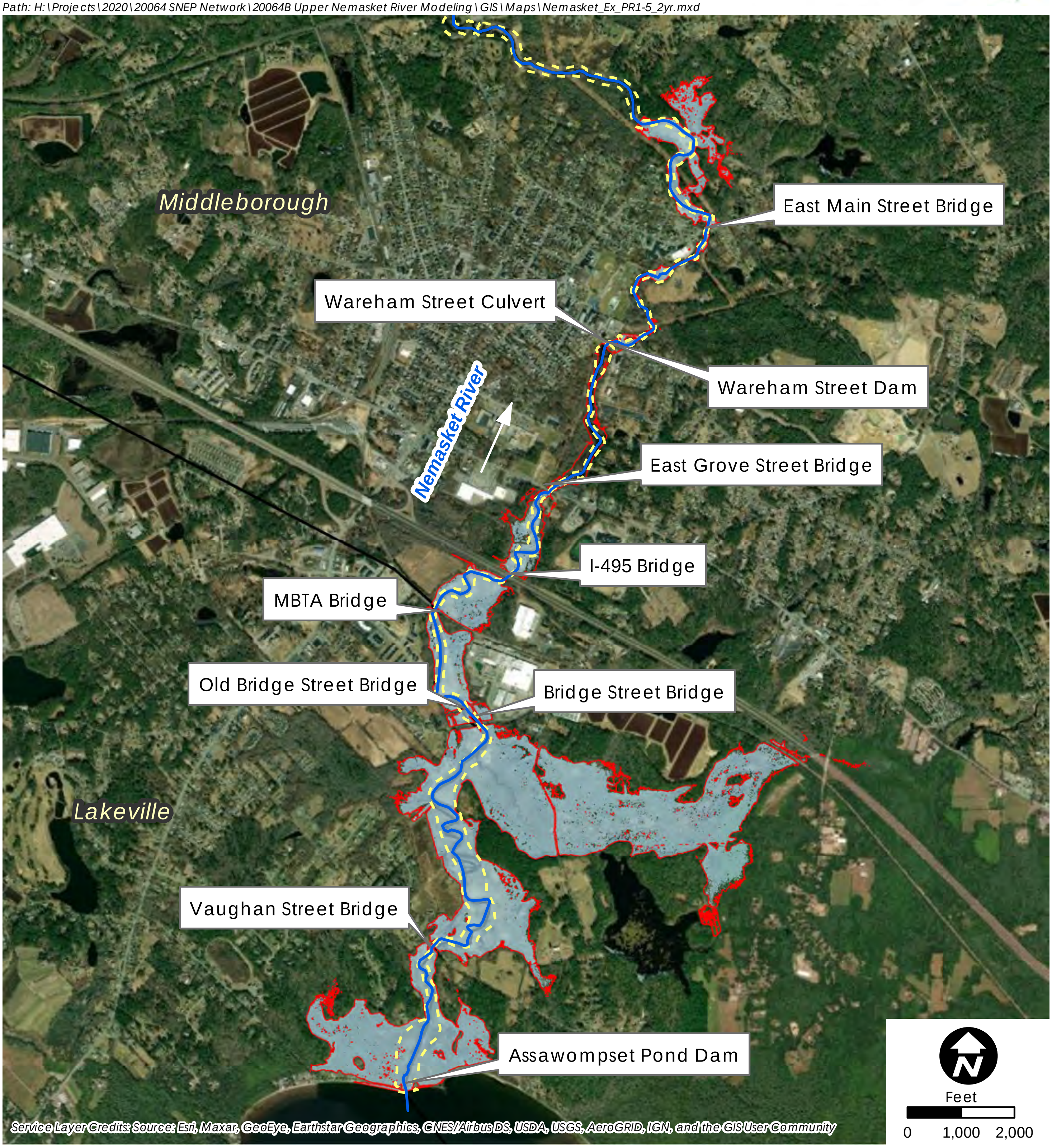

Date: 3/29/2023
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

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Nemasket River
PR1,2,4&5 2-year inundation
Existing 2-year inundation
FEMA Zone AE: Regulatory Floodway
Municipal Boundary

Upper Nemasket River Hydrology and Hydraulics Study

Figure 7**2**
2-year Flood Inundation Area for Existing vs. Proposed Conditions 1, 2, 4 &5
Wareham Street Dam Removal and Culvert Replacement, East Grove Street, MBTA Bridge Modifications, and Old Bridge Street Bridge Removal

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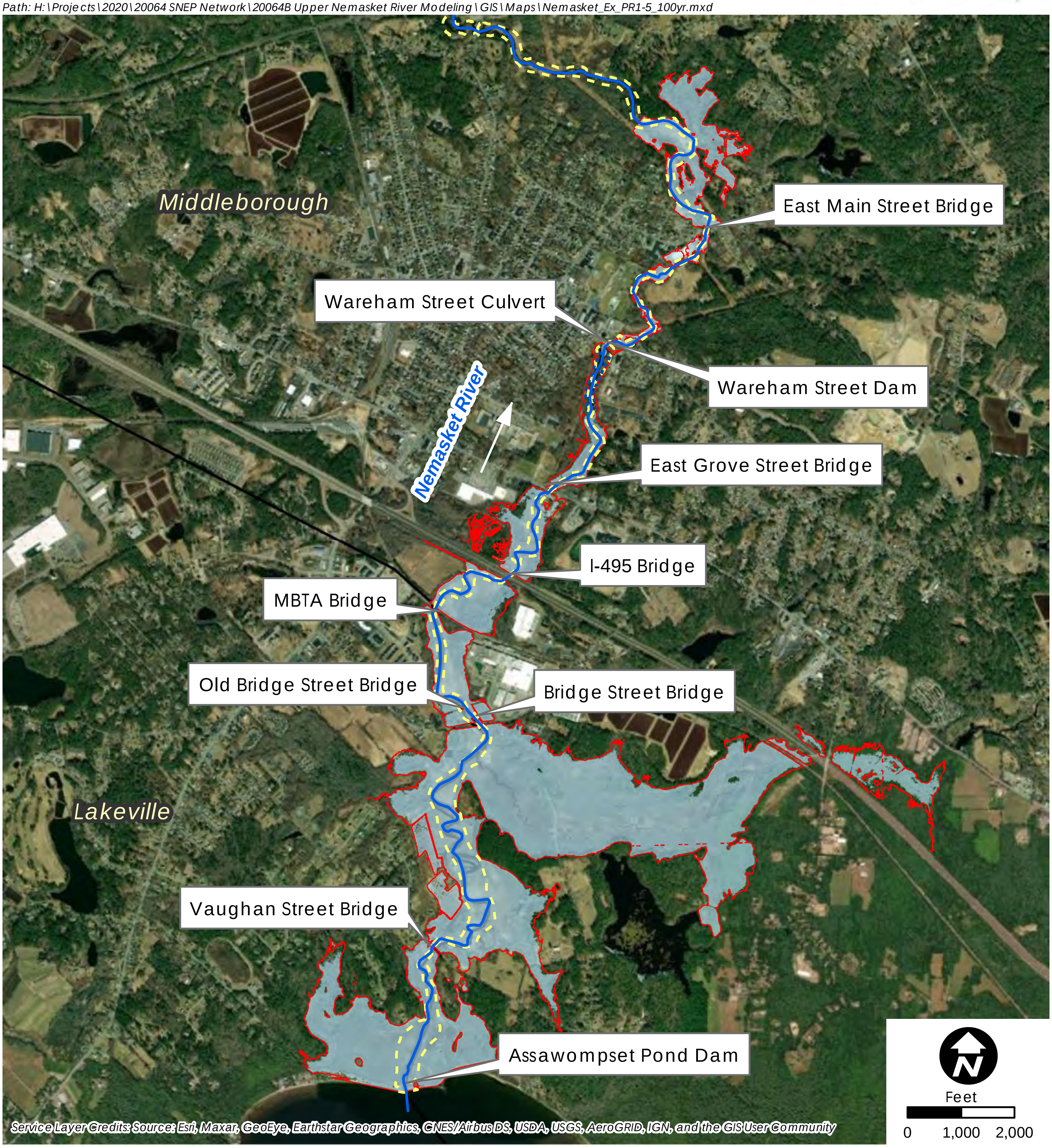

Date: 3/29/2023
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

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Nemasket River
PR1,2,4&5 100-year inundation
Existing 100-year inundation
FEMA Zone AE: Regulatory Floodway
Municipal Boundary

Upper Nemasket River Hydrology and Hydraulics Study

Figure 73

100-year Flood Inundation Area for Existing vs. Proposed Conditions 1, 2, 4 &5 Wareham Street Dam Removal and Culvert Replacement, East Grove Street, MBTA Bridge Modifications, and Old Bridge Street Bridge Removal

3.3.10 PR Channel – APC Outlet Channel Modification

The headwaters of the Nemasket River at the outlet of the Assawompset Pond Complex (APC) have been located at or near their current position since at least 1831, predating the construction of the Assawompset Pond Dam (**Figure 74**). During or immediately after the construction of the Assawompset Pond Dam began in 1894[62], the channel downstream of the APC outlet was widened to accommodate the width of flow over the dam's emergency spillway. At some point, a 1-2 foot berm was constructed on the river-right bank along the first 200 feet of the Upper Nemasket downstream of the Assawompset Pond Dam, most likely using the spoils that accumulated from dredging the channel previously. The berm disconnects a small portion of the Upper Nemasket at its headwaters from the adjacent floodplain, limiting flood storage and lateral connectivity of the Upper Nemasket. Additionally, the widened channel downstream of the dam outlet slows flow velocities, resulting in increased settlement of suspended sediment as well as dense vegetative growth at the channel bottom near the headwater.

Figure 74. Middleborough Town Map (1831, 1855) and USGS Map of Plymouth County (1888)

HW evaluated the impact of restoring the headwaters of the Nemasket to match natural bankfull dimensions. As described above, HW estimated the natural bankfull width at the reference reach downstream of Wareham Street to be approximately 59.5 feet. To calculate the natural bankfull width of the Upper Nemasket River downstream of the Assawompset Pond Dam, HW prorated the bankfull width estimate of 59.5 feet by the ratio of the StreamStats estimate of bankfull width at the Assawompset Pond Dam (59.3 feet) to the StreamStats estimate of bankfull width at Wareham Street (65.3 feet)[63]. As a result, HW estimated the natural bankfull width at the Assawompset Pond Dam to be 54.0 feet. That more naturalized channel geometry is shown below as **Figure 75**.

[62] Maddigan, M., "Nemasket River Herring: A History", The History Press, 2014

[63] Bent, G.C. and Waite, A.M., "Equations"

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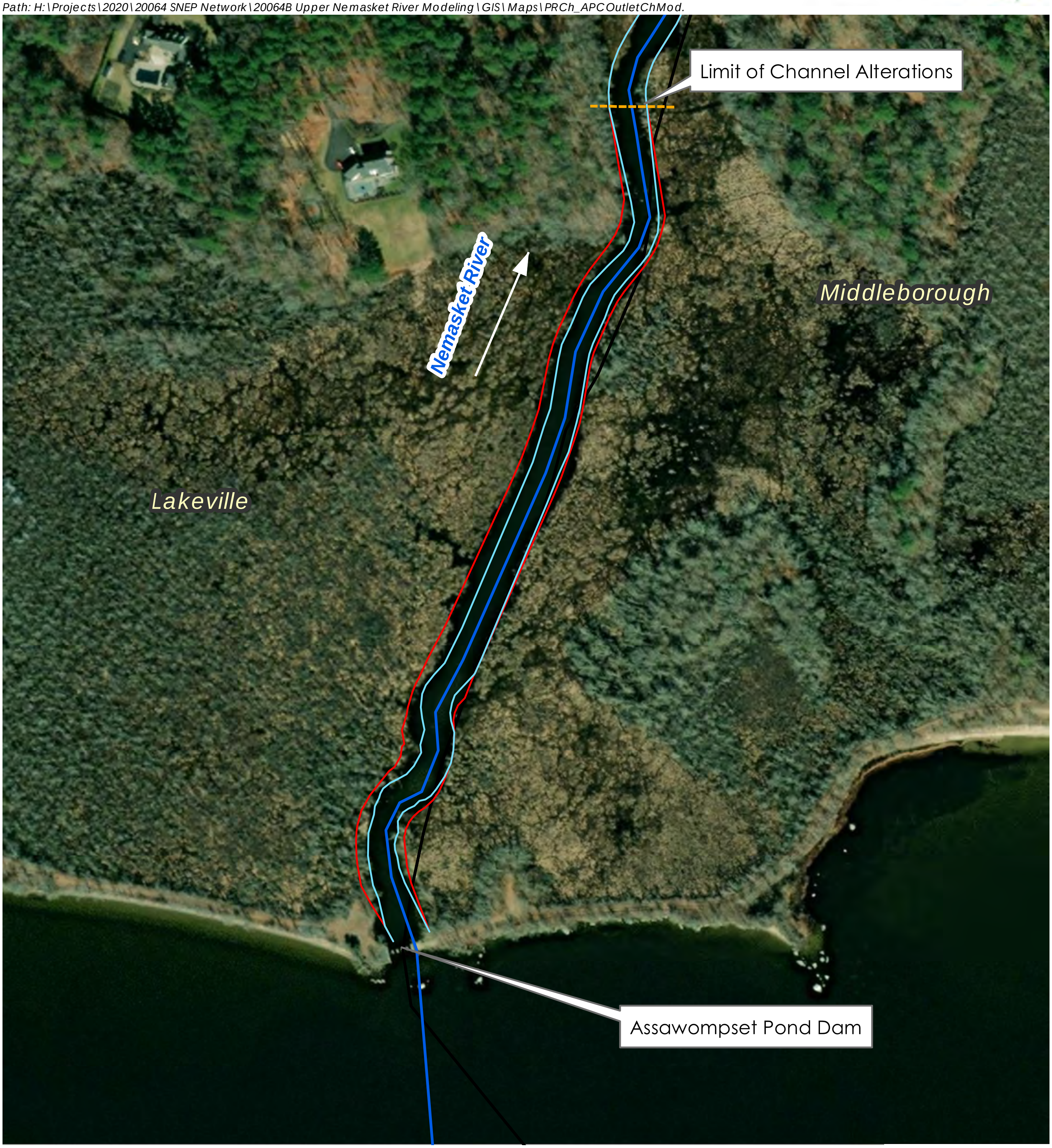

Date: 4/11/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

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Proposed Riverbanks
Existing Riverbanks
Nemasket River
Municipal Boundary

Feet
0 125 250

Upper Nemasket River Hydrology and Hydraulics Study

Figure **75**
PR Channel – APC Outlet Channel Modification

The existing channel at the headwaters of the Nemasket has a bankfull width that ranges from 90-95 feet. In the proposed APC outlet channel conditions, the bankfull width was decreased by approximately 35-40 feet over a longitudinal distance of 1,500 feet in order to achieve an estimated natural bankfull width of 54 feet. In addition to narrowing the channel, HW also evaluated the benefit of removing the 1-2 foot berm on the river-right side of the Upper Nemasket near the dam. Berm removal is anticipated to decrease flood elevations by some extent by restoring connectivity with the adjacent floodplain.

As mentioned above, sediment aggrades between the Assawompset Pond Dam and Vaughan Street due to the artificially wide channel in this stretch of the river. **Figure 76** shows the approximate extent of the sediment accumulation between the dam and Vaughan Street. Under **PR Channel**, a portion of this accumulated sediment was removed to resemble the approximate natural slope of the river channel in this area. A longitudinal profile of the proposed channel is shown in **Figure 77**.

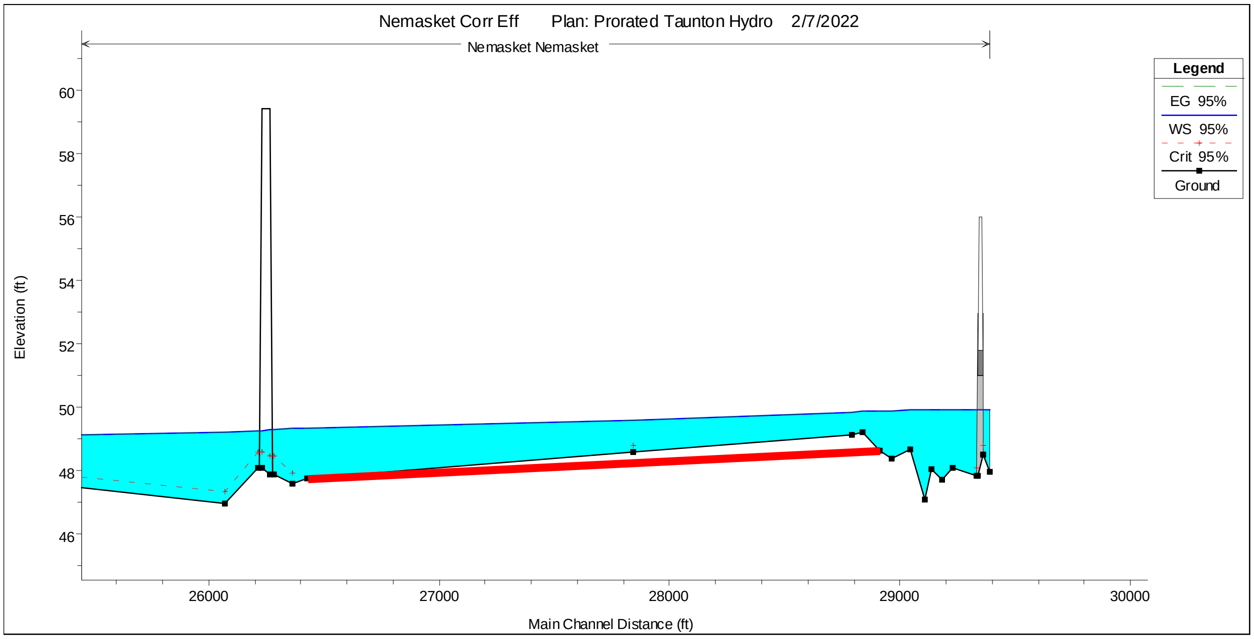

Figure 76. Longitudinal Profile Between Assawompset Pond Dam and Vaughan Street in Corrected Effective Model – Sediment Transport Shown Above Red Line

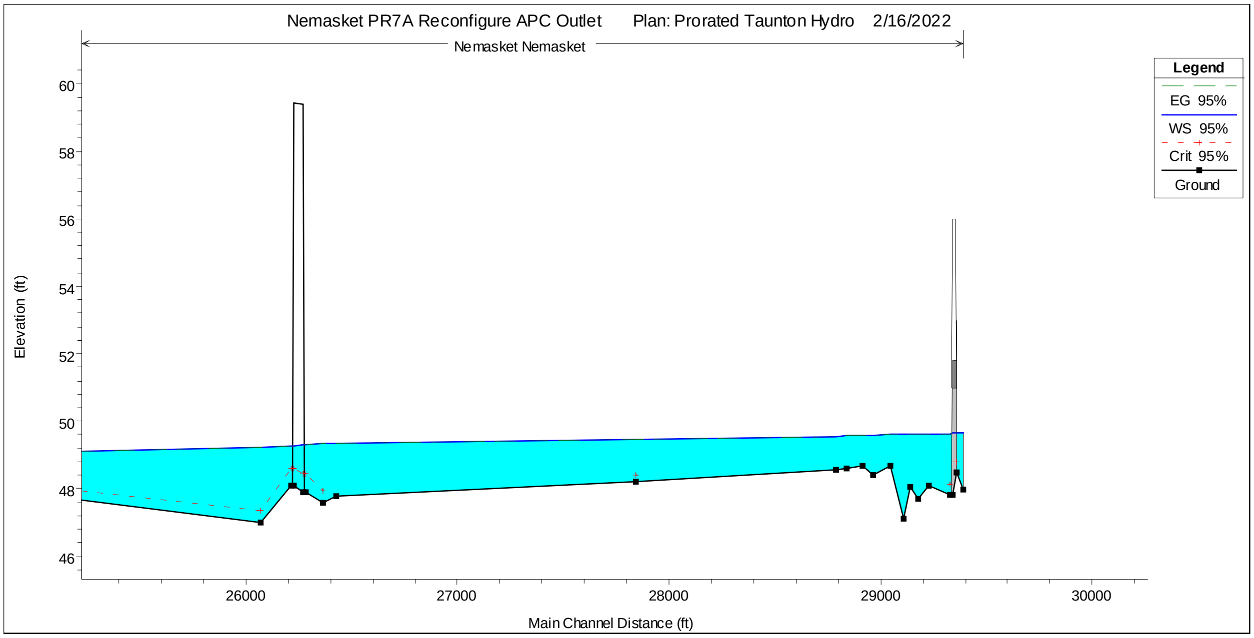

*Figure 77. Longitudinal Profile Between Assawompset Pond Dam and Vaughan Street in **PR Channel***

Results of the channel reconfiguration scenario are shown below in **Table 39** and **Table 40**. Narrowing the channel of the Upper Nemasket along the extents described above would result in very slight (less than 0.05 feet) increase in WSE's during all flows. The narrower channel would increase water velocities slightly for all modeled flow events in areas greater than 200 feet downstream of the Assawompset Pond Dam. For the upstream-most 200 feet of the Upper Nemasket, water velocities would also increase for most day-to-day flow conditions but decrease slightly for higher flow scenarios under **PR Channel** conditions. Velocity reduction for larger flow events immediately downstream of the dam is due to the proposed removal of the berm on the right bank of the Upper Nemasket, which would reconnect this portion of the river to its natural floodplain.

*Table 39. Selected **PR Channel** HEC-RAS Results – Predicted WSE (ft)*

	Assawompset Dam – US		Assawompset Dam – DS		200 ft DS of APC Dam	
Recurrence Interval	Existing	PR Channel	Existing	PR Channel	Existing	PR Channel
95% Exceedance	49.93	49.64	49.92	49.63	49.92	49.61
5% Exceedance	53.76	53.78	53.75	53.77	53.74	53.76
2-year	54.77	54.78	54.76	54.77	54.75	54.77
10-year	55.90	55.91	55.89	55.90	55.89	55.90
100-year	57.27	57.28	57.27	57.27	57.27	57.27

*Table 40. Selected **PR Channel** HEC-RAS Results – Predicted Velocity (fps)*

	Assawompset Dam – US		Assawompset Dam – DS		200 ft DS of APC Dam	
Recurrence Interval	Existing	PR Channel	Existing	PR Channel	Existing	PR Channel
95% Exceedance	0.18	0.28	0.14	0.17	0.21	0.30
5% Exceedance	0.05	0.05	0.53	0.36	0.36	0.42
2-year	0.06	0.06	0.35	0.27	0.25	0.27
10-year	0.07	0.07	0.26	0.22	0.19	0.21
100-year	0.07	0.07	0.21	0.19	0.16	0.18

Despite the increased velocity of the channel predicted to occur under **PR Channel**, no additional sediment transport is anticipated to occur in the upper portion of the Nemasket from channel alterations alone. Velocities do not approach the threshold for transport of the sand observed along the Upper Nemasket in this area (1.75 feet per second[64]). Shear stress values are expected to reach a peak of 0.02 psf, which is less than the threshold value for sand of around 0.075 psf[65].

Though no additional degradation of the existing sandy channel bottom downstream of the Assawompset Pond Dam is expected, the increase in velocity 200 and more feet downstream of the dam is likely to reduce the amount of sediment that settles within the main channel of the Upper Nemasket in this area. During the 5% daily exceedance flow, the increase from 0.36 feet per second to as much as 0.42 feet per second is predicted to increase the size of particles that settle from 0.6 mm (medium to coarse sand) to 0.7 mm (coarse sand). This increase in the size of particles that settle would be expected to reduce the rate of sedimentation downstream of the Assawompset Pond Dam.

HW also assessed whether the proposed channel modification would have significantly different results under each of the Wareham Street Dam removal scenarios. Results of each dam removal scenario combined with the channel modification are shown below in **Table 41** for high, 5% exceedance flow conditions, which are expected to yield the highest water velocity and shear stress values of the flow events that were evaluated. Wareham Street Dam removal would result in a slight increase in channel velocities throughout the length of the Upper Nemasket downstream of the Assawompset Pond Dam considered for modification. More than 200 feet from the dam, velocities increase by around 0.1 feet per second relative to **PR Channel**. Within 200 feet of the dam, velocities increase by only 0.05 feet per second relative to **PR Channel**.

[64] Engineering Field Handbook Notice, 2009

[65] Ibid.

Table 41. Selected 5% Exceedance Flow Results for Channel Modification Scenarios – Predicted Velocity (fps)

Scenario	Assawompset Dam – US	Assawompset Dam – DS	200 ft DS of APC Dam
EX	0.05	0.53	0.36
PR Channel	0.05	0.36	0.42
PR1 C	0.05	0.41	0.49
PR1/2 C	0.05	0.41	0.49
PR1/4 C	0.05	0.42	0.51
PR1/5 C	0.05	0.42	0.50
PR Optimal C	0.05	0.43	0.51

*"C" indicates addition of **PR Channel** modification to original proposed scenario*

Under all scenarios in which the Wareham Street Dam is removed, the peak shear stress predicted along the modified channel downstream of the APC outlet is 0.03 psf. This shear stress is lower than the threshold value for sand transport (0.06 psf). While this implies that no additional sediment transport is expected to be triggered within the area of the modified channel, the increased channel velocity from 0.36 feet per second to as much as 0.51 feet per second is predicted to increase the size of particles that settle from 0.6 mm (medium to coarse sand) to 0.8 mm (coarse sand).

Less substantial changes in velocity are expected during low flows. As shown in **Table 40**, velocities 200 feet downstream of the Assawompset Pond Dam are predicted to increase by only 0.01 feet per second under the 95% exceedance flow. Within 200 feet of the dam, velocities are predicted to decrease by 0.01 feet per second. Predicted changes in velocity under the 95% exceedance flow are identical in **PR Channel** and in all channel modification scenarios that included removal of the Wareham Street Dam. As shown below in **Table 42**, maximum water depth under **PR Channel** is expected to decrease by about 0.3 feet relative to existing conditions; reductions in water level are not expected to prevent fish passage between the APC outlet and Vaughan Street. These changes in maximum water depth are identical among all scenarios in which the Wareham Street Dam is also removed. Reductions in water depth are most attributable to the removal of accumulated sediment in the channel modification area. Fish passage is discussed at greater length below.

*Table 42. Selected 95% Exceedance Flow Results for **PR Channel** – Predicted Maximum Depth*

Scenario	Assawompset Dam - US	Assawompset Dam - DS	200 ft DS of APC Dam
EX	1.43	2.09	1.86
PR Channel	1.14	1.80	1.55

3.3.11 Fish Passage

The target species of concern identified for goals of improving fish passage are the alewife and blueback herring. These herring species require a minimum water depth of 0.5 feet in order to navigate through river and stream channels[66]. Alewife and blueback have a maximum burst speed of 3.5 feet per second[67]. In order to ensure that conditions are favorable to herring passage under proposed scenarios, HW evaluated the depth during annual low flow conditions (95% exceedance flow) and the channel velocity during annual high flow conditions (5% exceedance flow).

Results of the low flow depth analysis at river crossings are shown below in **Table 43**. During the 95% exceedance flow, water depths are currently below guidance criteria at the Wareham Street fish ladder to support herring passage. The shallowest channel depth predicted during low flow conditions is 0.25 feet, which occurs just downstream of the Wareham Street Culvert. Within both the Wareham Street and Assawompset Pond Dam fish ladders flow is not continuous, and herring passage is, therefore, sometimes impossible. Only scenarios that include the removal of the Wareham Street Dam and Weir and replacement of the Wareham Street Culvert can ensure fish passage is possible during low flow conditions.

The low flow depth analysis also indicates that two individual scenarios – removal of the Wareham Street Dam and Weir (**PR1**) and modification of the East Grove Street Bridge (**PR2**) – would increase flow depths downstream of East Grove Street. Though East Grove Street is currently navigable under low flow conditions, increasing flow depths would provide more area for passage and protect herring from avian predators. However, **PR1** and **PR2** would result in lower flow depths downstream of the I-495 and MBTA Bridges. This reduction in depth would not prevent fish passage entirely.

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[66] Chase, B., *Diadromous Fish Passage Guidelines*, Massachusetts Division of Marine Fisheries, September 1, 2020

[67] *Fish Passage and Screening Design*, Natural Resources Conservation Service, National Engineering Handbook Part 654, Technical Supplement 14N, August 2007

Table 43. Selected 95% Exceedance Flow Results – Predicted Maximum Depth (ft)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
Wareham Street Weir	0.62	1.49	0.63	0.63	0.63	0.63	0.63	0.63	1.49	1.49	1.49	1.49
Wareham Street Culvert & Fish Ladder	**0.25 ***	1.21	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	1.27	1.21	1.27	1.27
East Grove Street	0.58	1.06	2.01	0.57	0.57	0.57	0.57	0.57	1.06	1.06	1.06	1.06
I-495 Bridge	2.25	0.83	0.99	2.25	2.25	2.25	2.25	2.25	0.83	0.83	0.83	0.83
MBTA Bridge	1.34	0.85	0.85	1.34	2.63	1.34	1.34	1.34	0.85	1.53	0.85	1.53
Old Bridge Street	1.47	1.22	1.22	1.47	1.44	1.43	1.47	1.47	1.22	1.22	1.74	1.18
Bridge Street	1.32	1.13	1.13	1.32	1.29	1.30	1.32	1.32	1.13	1.13	0.98	0.75
Vaughan Street	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Assawompset Pond Dam	2.09	2.09	2.09	2.09	2.09	2.09	2.09	1.90	2.09	2.09	2.09	2.09

***bold asterisk** indicates depth below guidance criteria for herring passage

Figures of the 95% exceedance flow maximum depth at modelled river stations under all proposed scenarios are included as **Attachment C**. Under existing conditions, seven locations were identified with water depth below guidance criteria for herring passage during the 95% flow. One shallow location is upstream of the I-Beam Bridge (part of an access road behind Middleboro Trailer World, outside of the study area but included in the H&H model), four of these locations are in the vicinity of the Wareham Street Dam, one is upstream of East Grove Street, one is upstream of Bridge Street, and one is approximately 1 mile downstream of Vaughan Street. No proposed scenarios alleviate these low-depth locations. As shown below in **Table 44**, no location in either the 50% or 5% exceedance flows has a maximum depth prohibitive to herring passage.

Table 44. Shallowest Maximum Channel Depth Along Upper Nemasket River (ft)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
95% Exceedance Flow	**0.18 ***	**0.17 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.17 ***	**0.17 ***	**0.17 ***	**0.17 ***
50% Exceedance Flow	1.08	0.74	1.08	1.08	1.08	1.08	1.08	1.08	0.76	0.74	0.76	0.76
5% Exceedance Flow	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84

***bold asterisk** indicates depth below guidance criteria for herring passage

Results of the annual high flow analysis are shown below in **Table 45**. During the 5% exceedance flow, channel depths reach a minimum of 1.84 feet over the course of the Upper Nemasket, meaning that in no location does flow depth constitute a barrier to fish passage. The lowest flow depth was found to occur within the Wareham Street fish ladder.

Annual velocities outside of flood events are expected to peak during the 5% exceedance flow. Based on the results of the existing conditions high flow analysis, main channel velocities in the vicinity of river crossings during the 5% flow are never expected to exceed 3.5 feet per second, the maximum burst speed of herring. The highest velocities under existing conditions occur at the Wareham Street fish ladder and at Old Bridge Street. Removal of the Wareham Street Dam and Weir and modification of the Wareham Street Culvert (**PR1**) would decrease velocities at Wareham Street, but would increase velocities at both Old Bridge Street and at the MBTA Bridge. Hybrid scenarios which combined **PR1** with modification of the MBTA Bridge (**PR1/4** and **PR Optimal**) would decrease velocities at the MBTA Bridge, partially offsetting the increased velocities caused by **PR1**. Likewise, hybrid scenarios which combined PR1 with removal of the Old Bridge Street Bridge (**PR1/5** and **PR Optimal**) would decrease velocities at Old Bridge Street, mitigating the increased velocities caused by **PR1**. Only the optimal hybrid scenario **PR Optimal** is predicted to decrease channel velocities at all three locations. **PR Optimal** is also the only scenario in which channel velocities during the 5% exceedance flow are expected to remain under 2 feet per second throughout the Upper Nemasket.

Table 45. Selected 5% Exceedance Flow Results – Predicted Channel Velocity (fps)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
Wareham Street Dam	1.40	1.15	1.39	1.39	1.39	1.39	1.39	1.39	1.15	1.15	1.15	1.15
Wareham Street Culvert & Fish Ladder	2.19	1.52	2.19	2.19	2.19	2.19	2.19	2.19	1.52	1.52	1.52	1.52
East Grove Street	2.40	1.98	1.20	2.41	2.41	2.41	2.41	2.41	1.76	1.98	1.98	1.76
I-495 Bridge	1.33	1.73	1.43	0.88	1.33	1.33	1.33	1.33	1.73	1.73	1.73	1.73
MBTA Bridge	1.80	2.29	1.92	1.83	0.80	1.80	1.80	1.80	2.30	0.97	2.29	0.97
Old Bridge Street	2.17	2.53	2.27	2.20	2.22	1.22	2.17	2.17	2.54	2.64	1.70	1.80
Bridge Street	1.49	1.75	1.56	1.51	1.52	1.52	1.49	1.49	1.76	1.83	1.81	1.89
Vaughan Street	1.56	1.65	1.59	1.57	1.58	1.57	1.12	1.56	1.65	1.67	1.67	1.69
Assawompset Pond Dam	0.53	0.59	0.55	0.53	0.54	0.54	0.54	0.53	0.43	0.60	0.42	0.61

Figures of the predicted channel velocity during the 5% exceedance flow under all proposed scenarios are included as **Attachment D**. Under existing conditions, the entire length of the Upper Nemasket River study area is predicted to have channel velocities under 3.5 feet per second during the 5% flow, indicating that velocity is not currently an inhibiting factor to herring passage. This also is true for all proposed scenarios in which the Wareham Street Dam remains intact. Under scenarios in which the Wareham Street Dam is proposed to be removed (i.e., dam-out scenarios), a portion of the river 300 feet upstream of the dam is expected to have velocities in excess of 3.5 feet per second during the 5% flow. Conversely, **Table 46** shows that peak channel velocities during the 50% flow are slightly in excess of the maximum herring burst speed under only *dam-in* scenarios; no dam-out scenarios result in excessive channel velocities under the 50% flow. During the 50% flow, peak velocities under dam-in scenarios occur downstream of the Wareham Street Weir, presenting a potential passage issue for herring attempting to access the Wareham Street fish ladder. In no scenario do channel velocities exceed maximum herring burst speeds under the 95% flow.

Table 46. Maximum Velocity Along Upper Nemasket River (fps)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
95% Exceedance Flow	2.75	2.88	2.88	2.75	2.75	2.75	2.75	2.75	2.88	3.35	2.88	2.38
50% Exceedance Flow	**3.51 ***	3.22	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	3.04	3.22	3.04	3.04
5% Exceedance Flow	3.39	**6.61 ***	3.39	3.39	3.39	3.39	3.39	3.39	**6.60 ***	**6.61 ***	**6.60 ***	**6.60 ***

***bold asterisk** indicates prohibitive velocity for herring passage

In addition to assessing low flow and high flow conditions downstream of bridges, HW evaluated flow conditions at inline river structures. The Wareham Street Dam and fish ladder is discussed above in order to compare existing conditions at Wareham Street to dam removal scenarios. Additional results for the existing conditions of the Nemasket at the Wareham Street fish ladder are shown below in **Table 47** along with results at the Assawompset Pond Dam fish ladder and at the proposed sediment trap 200 feet downstream of the Assawompset Pond Dam modelled in **PR7**. Results at both the Assawompset Pond Dam and at Wareham Street do not differ between existing and proposed conditions (with the exception of scenarios in which the Wareham Street Dam is removed), so only one envelope of results is shown.

Table 47. Selected HEC-RAS Results at Inline Structures

	Assawompset Pond Dam Fish Ladder		Sediment Trap (PR7)		Wareham Street Fish Ladder	
Recurrence Interval	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)
95% Exceedance	**-***	**-***	0.73	0.85	**-***	**-***
50% Exceedance	0.86	1.06	2.38	1.10	3.51	0.54
5% Exceedance	3.16	0.76	4.74	0.12	5.04	1.58

***bold asterisk** indicates insufficient depth or prohibitive velocity for herring passage per guidance criteria

During low flow conditions, both the Assawompset Pond Dam and the Wareham Street fish ladders are currently impassable, as water levels are simulated to be too low to yield flow within the ladders. For flows greater than or equal to the median (50% exceedance) flow, water depths meet guidance criteria in both fish ladders to allow flow, and water velocities do not exceed navigable speeds for herring. The sediment trap proposed under **PR7** does not inhibit passage for herring under any flow condition. However, the sediment trap is anticipated to create an obstacle to bottom dwelling fish such as eels.

3.3.12 Recreation

The Nemasket River is a popular destination for canoeing and kayaking[68], and is host to public recreation as well as commercial tours[69]. Three existing canoe and kayak launch points are recommended within the study area at Vaughan Street, Old Bridge Street, and Wareham Street, as shown in the Upper Nemasket River guide prepared by the Taunton River Watershed Alliance (TWRA) (**Appendix E**). The Upper Nemasket is generally easy to navigate by canoe, with the exception of a small section of more rapid flow just downstream of Wareham Street. TWRA classifies this 0.75-mile section as having Class I rapids. Due to the presence of both the Wareham Street Dam and the Assawompset Pond Dam, it is impossible to canoe the entire length of the Nemasket River without portaging.

In order to ensure that recreational access is not inhibited by proposed restoration activities, HW evaluated the impacts on water depth and velocity associated with the proposed restoration scenarios. A canoe carrying a single passenger generally sits 5 inches below the surface of the water[70], although any additional items or people in the canoe may result in a lower position below the water surface. A minimum depth of 10 inches (0.8 feet) is a conservative estimate for depth requirements given a range of canoe passenger and equipment loads[71]. A channel velocity of about 2 miles per hour (2.9 feet per second) is the maximum speed for beginner paddlers to be able to navigate both upstream and downstream[72].

Maximum channel depths at river crossings under low flow conditions (i.e., the 95% exceedance flow) are reproduced below from **Table 43** as **Table 48**. Under existing conditions, flow depths downstream of the Wareham Street Weir and downstream of East Grove Street are below guidance criteria for canoe passage during low flow conditions. Maximum flow depths in these two locations exceed guidance criteria for canoe passage only under scenarios in which the Wareham Street Dam and Weir are removed and the Wareham Street Culvert is modified (**PR1**, **1/2**, **1/4**, **1/5**, and **PR Optimal**).

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[68] "Nemasket River", Discover Middleborough. Retrieved February 11, 2022 from https://www.discovermiddleborough.com/discover/nemasket-river

[69] "Nemasket River Guided Tour", Nemasket Kayak Center. Retrieved February 11, 2022 from http://www.nemasketkayak.com/nkc-nemasket-river-guided-tour.html

[70] C., "How to Kayak in Shallow Water", Paddle Geek. Retrieved February 11, 2022 from https://paddlegeek.com/kayak-in-shallow-water/

[71] Carmody, A., "How Deep Does a Canoe Sit in the Water?", Hydro Pursuit. Retrieved February 11, 2022 from https://hydropursuit.com/how-deep-does-a-canoe-sit-in-the-water/

[72] Thornton, J., "Can I Canoe or Kayak Upstream?", Sports Rec, July 2011. Retrieved February 11, 2022 from https://www.sportsrec.com/can-canoe-kayak-upstream-8697685.html

Table 48. Selected 95% Exceedance Flow Results – Predicted Maximum Depth (ft)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
Wareham Street Weir	**0.62 ***	1.49	**0.63 ***	**0.63 ***	**0.63 ***	**0.63 ***	**0.63 ***	**0.63 ***	1.49	1.49	1.49	1.49
Wareham Street Culvert & Fish Ladder	**0.25 ***	1.21	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	**0.25 ***	1.27	1.21	1.27	1.27
East Grove Street	**0.58 ***	1.06	2.01	**0.57 ***	**0.57 ***	**0.57 ***	**0.57 ***	**0.57 ***	1.06	1.06	1.06	1.06
I-495 Bridge	2.25	0.83	0.99	2.25	2.25	2.25	2.25	2.25	0.83	0.83	0.83	0.83
MBTA Bridge	1.34	0.85	0.85	1.34	2.63	1.34	1.34	1.34	0.85	1.53	0.85	1.53
Old Bridge Street	1.47	1.22	1.22	1.47	1.44	1.43	1.47	1.47	1.22	1.22	1.74	1.18
Bridge Street	1.32	1.13	1.13	1.32	1.29	1.30	1.32	1.32	1.13	1.13	0.98	**0.75***
Vaughan Street	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Assawompset Pond Dam	2.09	2.09	2.09	2.09	2.09	2.09	2.09	1.90	2.09	2.09	2.09	2.09

***bold asterisk** indicates below guidance depth for canoe passage

Figures of the 95% exceedance flow maximum depth at modelled river stations under all proposed scenarios are included as **Attachment C**. Under existing conditions, ten general locations were identified which are predicted to have below guidance water depth for canoe navigation during the 95% flow. As discussed above, one of these shallow locations (downstream of East Grove Street) reaches depths above guidance criteria for canoe navigation for all Wareham Street Dam removal scenarios. **Table 44** is reproduced below as **Table 49**, which demonstrates that during the 5% exceedance flow, water depths are above guidance criteria for canoe navigation under all restoration scenarios. Under the 50% exceedance flow, water levels exceed guidance criteria for canoe navigation during all Wareham Street Dam-in scenarios; during dam-out scenarios, water depths at the shallowest locations are slightly below guidance criteria navigable depths.

Table 49. Shallowest Maximum Channel Depth Along Upper Nemasket River (ft)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
95% Exceedance Flow	**0.18 ***	**0.17 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.18 ***	**0.17 ***	**0.17 ***	**0.17 ***	**0.17 ***
50% Exceedance Flow	1.08	**0.74 ***	1.08	1.08	1.08	1.08	1.08	1.08	**0.76 ***	**0.74 ***	**0.76 ***	**0.76***
5% Exceedance Flow	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84

*** bold asterisk** indicates below guidance depth for canoe passage

Maximum channel velocities at river crossings under annual high flow conditions (i.e., the 5% exceedance flow) are reproduced below from **Table 45** as **Table 50**. Under high flow conditions, main channel velocities are never expected to exceed 2.9 feet per second, the maximum velocity in which a beginner canoer would be expected to be able to paddle upstream. The highest velocities at river crossings occur at East Grove Street (during Wareham Dam-in scenarios) and at Old Bridge Street (during Old Bridge Street Bridge-intact scenarios).

Table 50. Selected 5% Exceedance Flow Results – Predicted Channel Velocity (fps)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
Wareham Street Dam	1.40	1.15	1.39	1.39	1.39	1.39	1.39	1.39	1.15	1.15	1.15	1.15
Wareham Street Culvert & Fish Ladder	2.19	1.52	2.19	2.19	2.19	2.19	2.19	2.19	1.52	1.52	1.52	1.52
East Grove Street	2.40	1.98	1.20	2.41	2.41	2.41	2.41	2.41	1.76	1.98	1.98	1.76
I-495 Bridge	1.33	1.73	1.43	0.88	1.33	1.33	1.33	1.33	1.73	1.73	1.73	1.73
MBTA Bridge	1.80	2.29	1.92	1.83	0.80	1.80	1.80	1.80	2.30	0.97	2.29	0.97
Old Bridge Street	2.17	2.53	2.27	2.20	2.22	1.22	2.17	2.17	2.54	2.64	1.70	1.80
Bridge Street	1.49	1.75	1.56	1.51	1.52	1.52	1.49	1.49	1.76	1.83	1.81	1.89
Vaughan Street	1.56	1.65	1.59	1.57	1.58	1.57	1.12	1.56	1.65	1.67	1.67	1.69
Assawompset Pond Dam	0.53	0.59	0.55	0.53	0.54	0.54	0.54	0.53	0.43	0.60	0.42	0.61

Figures of the 5% exceedance flow maximum channel velocity at modelled river stations under proposed scenarios are included as **Attachment D**. Under existing conditions, two locations were identified in which channel velocities are predicted to exceed navigable speeds for beginner paddlers: Wareham Street and the I-Beam Bridge (part of an access road behind Middleboro Trailer World, outside of the study area but included in the H&H model). During Wareham Street Dam-out scenarios, an additional location 300 feet upstream of Wareham Street is predicted to exceedance guidance criteria for beginner paddlers. Maximum channel velocities under all scenarios for various flows are reproduced from **Table 46** as **Table 51** below. Peak velocities under all scenarios during both the 50% and 5% exceedance flows exceed guidance criteria for beginner paddlers to navigate upstream over the entire length of the Upper Nemasket. Peak velocities are more navigable during the 5% flow for Wareham Dam-in scenarios; during dam-out scenarios, velocities are expected to be nearly double those of dam-in scenarios 300 feet upstream of Wareham Street. Likewise, peak velocities during the 50% flow are lower for dam-in scenarios than dam-out scenarios, creating potential challenges to navigate fully through Wareham Street during median annual flows if the dam were to be removed. Velocities are expected to be below guidance criteria for beginner paddlers during the 95% flow for all scenarios except **PR1/4** (Wareham Street Dam out and MBTA Bridge modified), during which channel velocities at Old Bridge Street are predicted to increase as a result of downstream bridge modifications and the associated sediment transport.

Table 51. Maximum Velocity Along Entire Upper Nemasket River Study Area (fps)

Crossing (DS)	EX	PR1	PR2	PR3	PR4	PR5	PR6	PR7	PR 1/2	PR 1/4	PR 1/5	PR Optimal
95% Exceedance Flow	2.75	2.88	2.88	2.75	2.75	2.75	2.75	2.75	2.88	**3.35 ***	2.88	2.38
50% Exceedance Flow	**3.51 ***	**3.22 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.51 ***	**3.04 ***	**3.22 ***	**3.04 ***	**3.04 ***
5% Exceedance Flow	**3.39 ***	**6.61 ***	**3.39 ***	**3.39 ***	**3.39 ***	**3.39 ***	**3.39**	**3.39 ***	**6.60 ***	**6.61 ***	**6.60 ***	**6.60 ***

*** bold asterisk** indicates prohibitive velocity for upstream navigation by beginner paddlers

In addition to the locations identified above which are expected to present depths below guidance criteria for canoe passage or velocities above guidance criteria for beginner paddlers, it should be noted that the existing Assawompset Pond Dam and Wareham Street Dam create existing barriers to navigation by boat. Theoretically, the Assawompset Pond Dam is currently navigable only when all wooden stop logs are removed from its stone piers, typically during high flows (although paddlers and boats are never allowed in Assawompset Pond per current regulations). The Wareham Street Dam is never navigable and is marked with warning signs to indicate that paddlers should avoid approaching the Wareham Street Culvert. Only **PR1** and other associated dam-out hybrid scenarios are expected to remove this physical barrier, and even then, velocities are still expected to exceed guidance criteria for beginner paddlers during median and high flows. The sediment trap proposed under **PR7** would create an additional barrier to canoe passage during the 95% flow due to below-criteria depth above the spillway. Predicted depths and velocities at each inline structure are reproduced from **Table 47** below as **Table 52**.

Table 52. Selected HEC-RAS Results at Inline Structures

	Assawompset Pond Dam Fish Ladder		**Water Control Structure (PR7)**		**Wareham Street Fish Ladder**	
Recurrence Interval	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)	Depth (ft)	Velocity (fps)
95% Exceedance	**-***	**-***	**0.73***	0.85	**-***	**-***
50% Exceedance	0.86	1.06	2.38	1.10	3.51	0.54
5% Exceedance	3.16	0.76	4.74	0.12	5.04	1.58

*** bold asterisk** indicates insufficient depth or prohibitive velocity for canoe passage per guidance criteria

3.4 Assawompset Pond Dam Modification

The existing Assawompset Pond Dam is between 118 and 128 years old and is operated with the primary intent to maintain water storage within the APC. The dam was not originally designed for flood protection or to control outflow from the ponds. Water levels in the APC are managed primarily through the use of five stacks of stop logs at the dam, which are added and removed by personnel from both the Taunton and New Bedford Water Departments. Each bay holds 3-4 stop logs, which vary in height from 7-12 inches. The dam is in “Fair” condition as of the most recent dam inspection report, dated November 2006[73]. The middle piers of the dam have been found to slide downstream during cold weather, most likely due to ice pressure. The shifting piers were not found to be a cause of concern for “imminent failure” per the 2006 inspection report, however there is potential for the stop logs to become misaligned with the piers, inhibiting operation. During the 2010 flooding, water levels in the APC reached an elevation of 56.48 feet NAVD88, approximately 0.9 feet above the height of the stone piers and 0.52 feet below the FEMA base flood elevation of 57.0 feet. During periods in which the APC floods , water levels are virtually the same upstream and downstream of the Assawompset Pond Dam (**Figure 78**).

Figure 78. Assawompset Pond Dam During Flood – Photo Courtesy of Bill Napolitano

Due to the age, condition, and performance of the Assawompset Pond Dam under flood conditions, there has been community discussion about potential repairs, modifications, or replacement of the dam. It is possible that the dam could be upgraded to provide more water level and flow control capacity in order to improve the flood control capabilities of the dam, while maintaining capacity for water supply, and also better regulating outflow to the river. HW evaluated five alternative dam configurations to assess whether modifying the width or invert of the dam spillways could alleviate flooding in the vicinity of the APC. Dam alternatives were

[73] “Assawompset Pond Dam Phase I Inspection/Evaluation Report,” CDM, November 2006

evaluated based on: 1) ability to decrease flood elevations in the APC, 2) ability to reduce the time span of inundation during the 100-year flood, and 3) ability to retain water during low flow periods.

Because the HEC-RAS model utilized for evaluation of the various in-river restoration scenarios is a river model, it is less useful for evaluating pond level changes for a large reservoir system like the APC. Therefore, dam configuration alternatives were evaluated separately, outside of the HEC-RAS model, using HydroCAD software. HydroCAD utilizes TR-20 and TR-55 methodologies to model stormwater runoff from watershed areas during heavy rainfall. Values for precipitation depths were obtained from the Northeast Regional Climate Center (NRCC); precipitation depths are shown below in **Table 53**.

Table 53. Design Storm Precipitation Depths

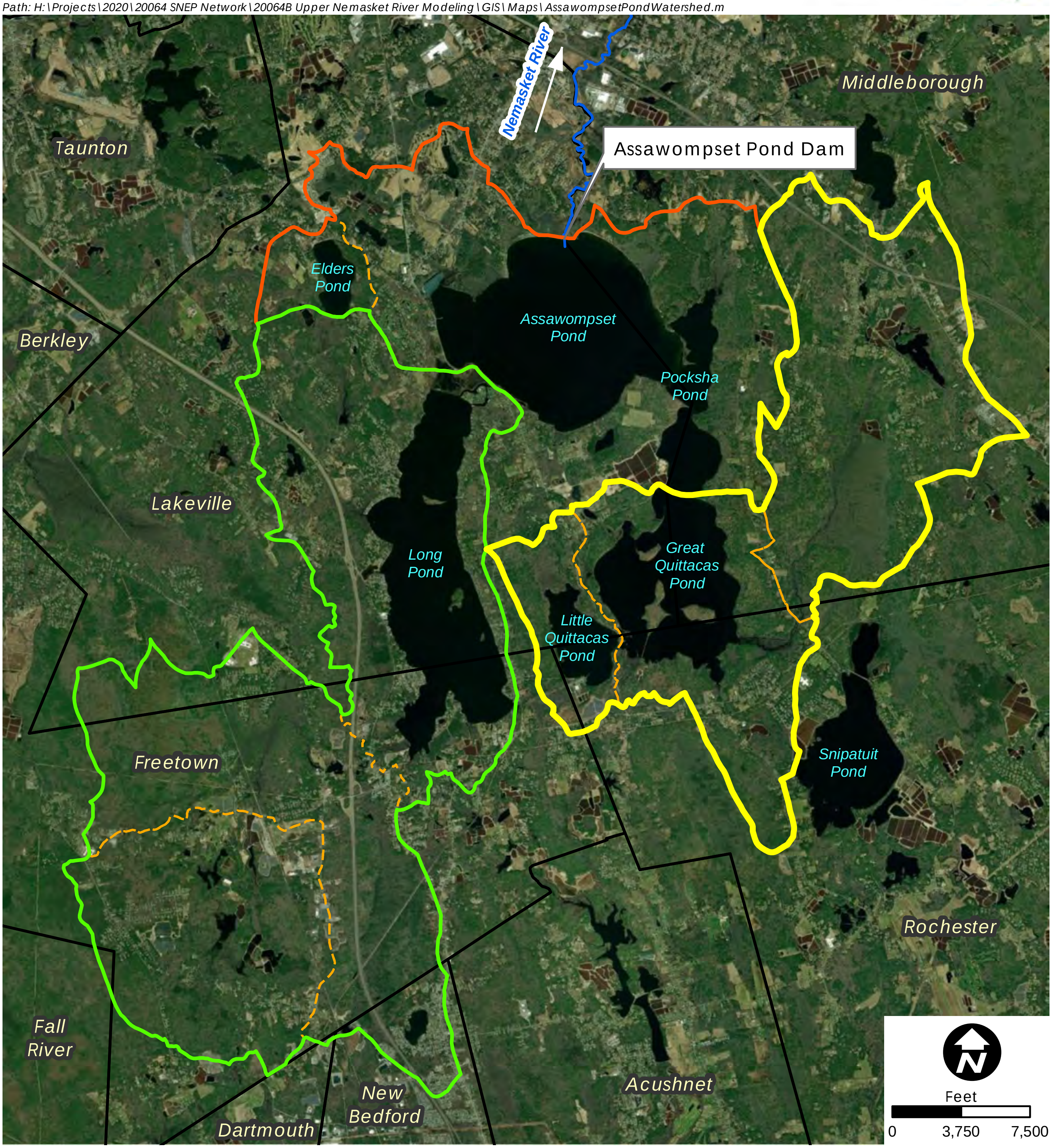
Recurrence Interval	Depth (in)
1-year	2.76
2-year	3.34
10-year	4.94
100-year	8.69

A schematic diagram of the HydroCAD analysis is shown below in **Figure 80**. For the HydroCAD analysis, the APC watershed was broken into three watersheds: Long Pond (including the Long Pond and Fall Brook subwatersheds), Pocksha and Quittacas (including the Pocksha Pond, Little Quittacas Pond, Great Quittacas Pond, and Black Brook subwatersheds), and Assawompset and Elders (including the Assawompset and Elders Pond subwatersheds). The subwatershed delineation of the APC watershed shown below in **Figure 79**. Data on land use and soil type for each watershed was collected from data available to the public through MassGIS. The APC was modelled as a single volume (i.e., a “bathtub model”) based on data collected by UMass Dartmouth and OceanServer Technology, Inc.[74]. The APC volume and land use estimates of watersheds were calibrated based on recorded storm events and APC water levels collected by the New Bedford Water Department.

[74] “New Bedford Ponds Bathymetry, UMass Dartmouth ATMC & OceanServer Technology, Inc., 2008

Horsley Witten Group
Sustainable Environmental Solutions

Path: H:\Projects\2020\20064 SNEP Network\20064B Upper Nemasket River Modeling\GIS\Maps\AssawompsetPondWatershed.m



Date: 4/11/2022
Data Sources: Bureau of Geographic Information (MassGIS), FEMA, ESRI

This map is for informational purposes and may not be suitable for legal, engineering, or surveying purposes.

Watersheds
- Assawompset and Elders Pond
- Long Pond
- Pocksha and Quittacas Ponds
- Subwatersheds
- Nemasket River
- Municipal Boundary

Upper Nemasket River Hydrology and Hydraulics Study

Figure **79**
Assawompset Pond Watershed

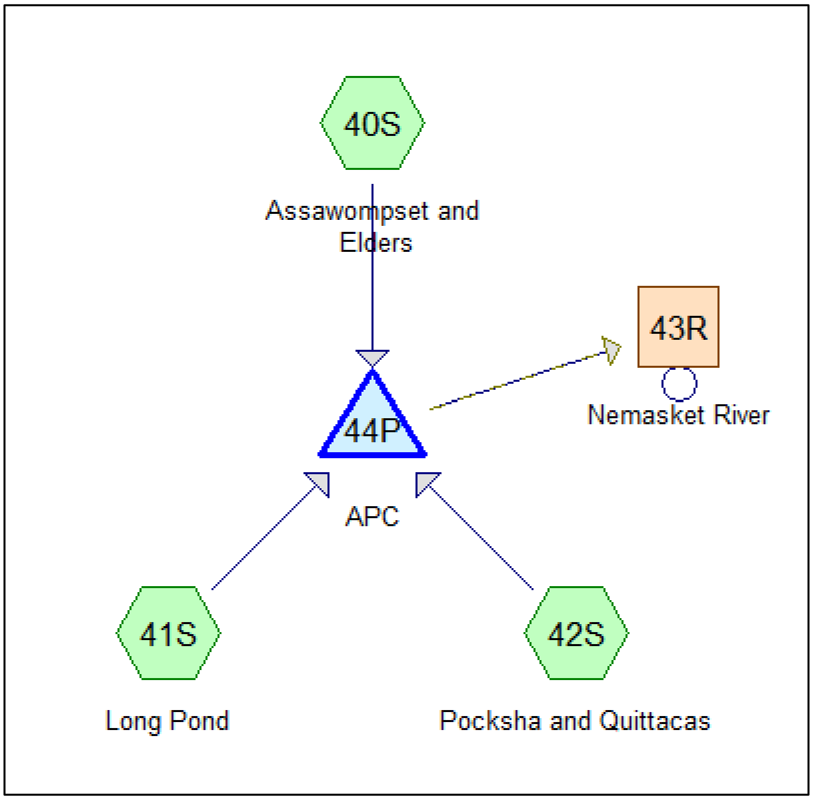


Figure 80. Schematic Diagram of APC HydroCAD Model

As discussed under **Section 2.3** above, the existing APC dam consists of five 6-foot-wide gates with inverts between 50.4 feet and 50.6 feet elevation (NAVD88). The gates are typically filled with stop logs in the late spring through the early fall; the stop log inverts vary by quantity and gate but were assumed to be removed from the dam when modeling flood events. To the east of the gates is a two-foot-wide fish ladder with an upstream invert at 50.6 feet. East of the fish ladder is an approximately 100-foot-long emergency spillway which varies in elevation from 53.2 feet to 54.1 feet. A schematic visualization of the existing Assawompset Pond Dam looking downstream from the pond toward the river is shown below in **Figure 81**.

Existing Assawompset Pond Dam

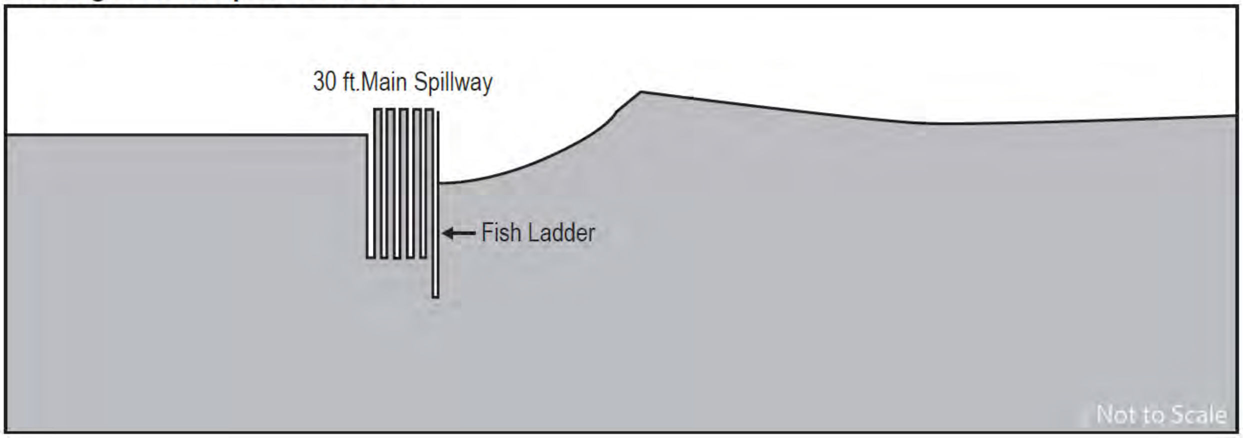


Figure 81. Cross Section of Existing Assawompset Pond Dam

The evaluation of potential dam replacement scenarios discussed here is strictly a hydraulic evaluation. In other words, all scenarios consider only the geometry of potential dam openings that could convey water based on invert elevations and widths of openings. No analysis of actual dam type or design was conducted.

The proposed dam reconfiguration scenarios were designed in part based on the target water level elevations for the APC. Target water levels were most recently established on December 20, 2013 by the Taunton Water Department[75] – an update to the 2011 target levels established by the Assawompset Pond Committee. The 2013 update was issued in order to bring the elevation datum used when measuring the APC from NGVD29 to NAVD88; the absolute elevation of the target levels was unchanged during the update. The 2013 target levels are shown below in **Table 54** and in **Figure 82**. Per the targets, water levels in the APC are allowed to rise beginning in March when precipitation is relatively frequent. Water levels are intended to reach a peak of 51.82 on May 1 in order to meet higher water demand in the summer and in anticipation of decreased precipitation. By September 1, water levels are allowed to decline to a base elevation of 51.32 for the duration of fall and winter.

Table 54. Assawompset Pond Target Levels by Season

Time of Year	Target Pond Elevation (ft NAVD)
January 1 to March 1	51.32
April 1	51.82
May 1	52.82
June 1 to July 1	52.32
August 1	51.82
September 1 to December 31	51.32

[75] Schwartz, B., "Assawompset Pond Target Levels in (NAVD88)", City of Taunton Water Department, December, 2013

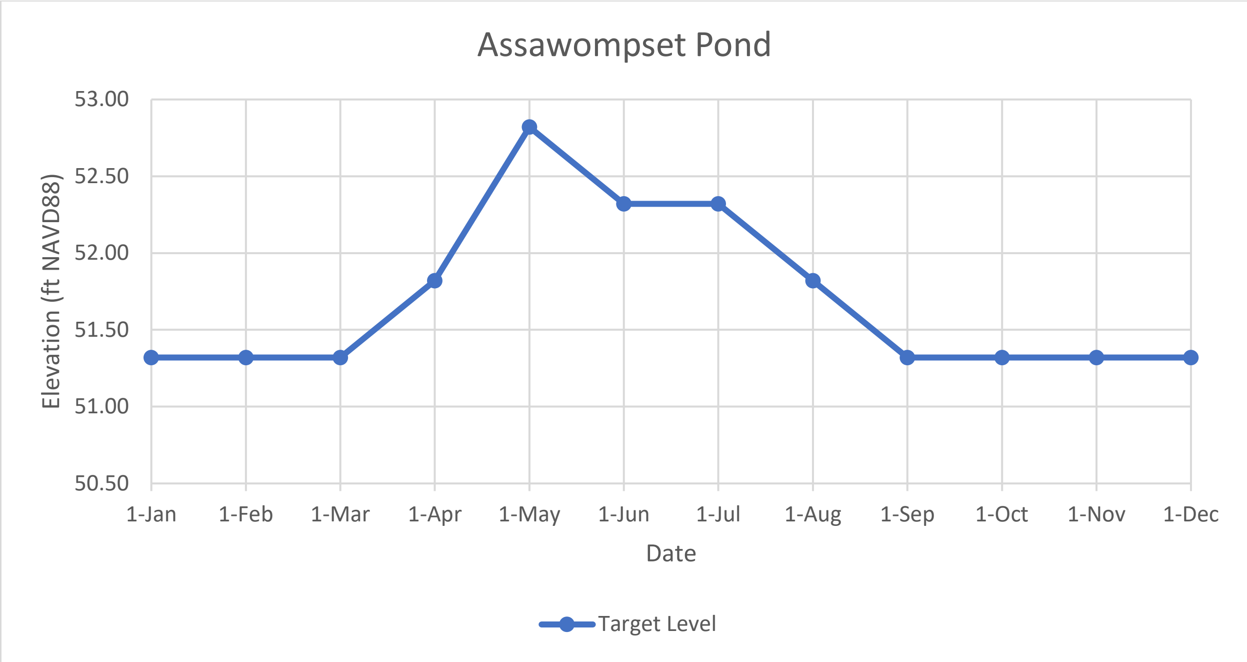


Figure 82. Assawompset Pond Target Levels

Proposed dam configurations utilized the base and peak water elevations to inform the design elevation of the main and overflow spillways, respectively. Main spillways for all proposed configurations were set at elevation 50.40 to match the existing spillway elevation. Although this phase of study did not advance beyond planning level designs, proposed spillways were assumed to be designed with the ability to be raised to an elevation of 51.32 or greater using stop logs or an internal mechanism. Overflow spillways for all proposed configurations were set at elevation 52.82.

In addition to the spillways, a fish ladder was included in the conceptual design of all four proposed dam configurations. The fish ladder was lowered in all proposed scenarios from the existing elevation of 50.6 feet to 49.0 feet. The proposed elevation is intended to allow passage during drought conditions; the existing 99% exceedance elevation in the APC is 50.18 feet[76], 0.4 feet lower than the existing outlet to the fish ladder from the pond.

[76] Fennessy, N, "Analysis of the Assawompset Pond Complex Water Level 1985-2010," 2010

The five proposed dam configurations evaluated by this study are as follows:

APC-PR1:

APC-PR1 consists of a single, 30-foot-wide main spillway at elevation 50.40, a 100-foot-wide overflow spillway at elevation 52.82, and a 5-foot-wide fish ladder at elevation 49.00. This configuration was intended to match the general dimensions of the existing Assawompset Pond Dam, differing only in terms of invert elevations, fish ladder width, and dam condition. A HEC-RAS visualization of the Assawompset Pond Dam under **APC-PR1** is shown below as **Figure 83**.

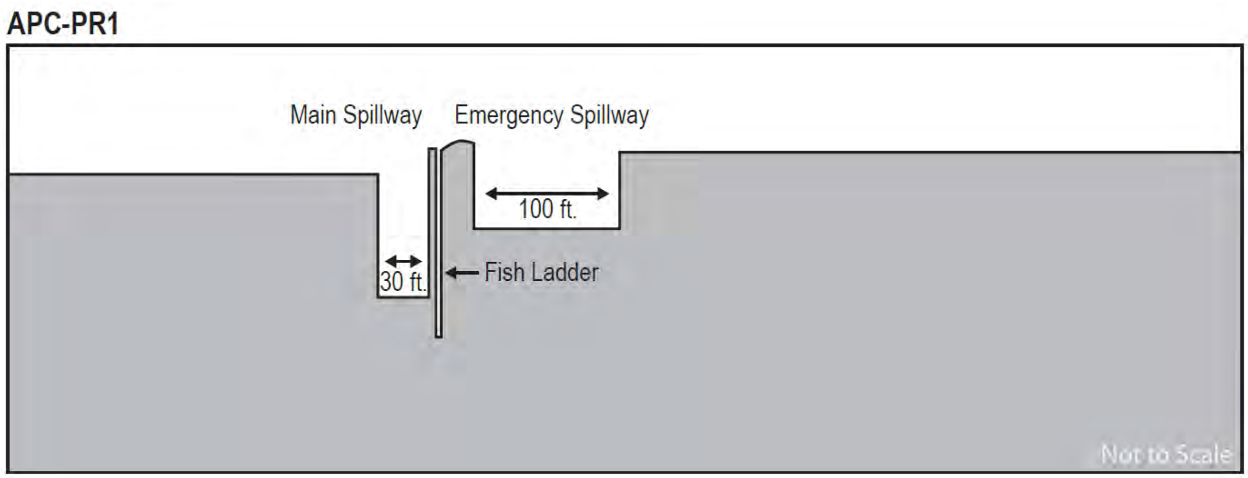


*Figure 83. Cross Section of Assawompset Pond Dam Under **APC-PR1***

APC-PR2:

APC-PR2 consists of a single, 75-foot-wide main spillway at elevation 50.40, a 100-foot-wide overflow spillway at elevation 52.82, and a 5-foot-wide fish ladder at elevation 49.00. This configuration was designed to reduce peak flood elevations while maintaining a main spillway width similar to that of the natural bankfull width of the Upper Nemasket. The main spillway width of 75-feet is estimated to be 20 feet wider than the natural bankfull width of the Upper Nemasket at the outlet of the APC. As discussed in the modelling results below, this is the minimum width required to lower pond levels from 100-year flood elevations to the maximum target pond elevation (52.82) within a 5-day period. A 5-day period is assumed to be a reasonable amount of time for dam managers to forecast weather conditions and adjust the spillway as needed to release water prior to storm events. A HEC-RAS visualization of the Assawompset Pond Dam under **APC-PR2** is shown below as **Figure 84**.

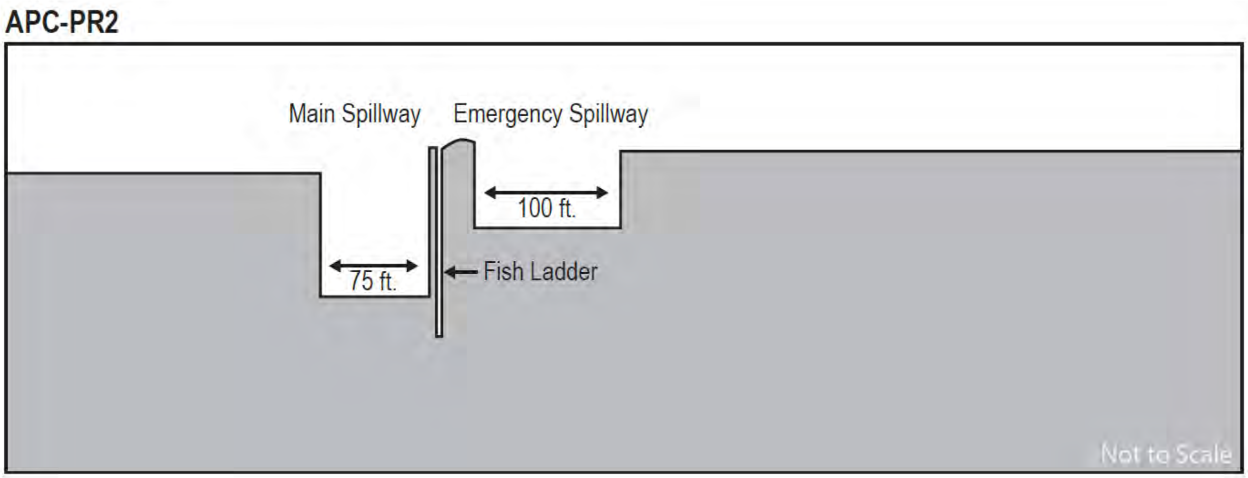


*Figure 84. Cross Section of Assawompset Pond Dam Under **APC-PR2***

APC-PR3:

APC-PR3 consists of a single, 100-foot-wide main spillway at elevation 50.40, a 100-foot-wide overflow spillway at elevation 52.82, and a 5-foot-wide fish ladder at elevation 49.00. This configuration was designed to reduce peak flood elevations and accelerate drainage from the pond during flood conditions without occupying as large of a footprint as other configurations that were evaluated (see **APC-PR4** and **APC-PR5** below). A HEC-RAS visualization of the Assawompset Pond Dam under **APC-PR3** is shown below as **Figure 85**.

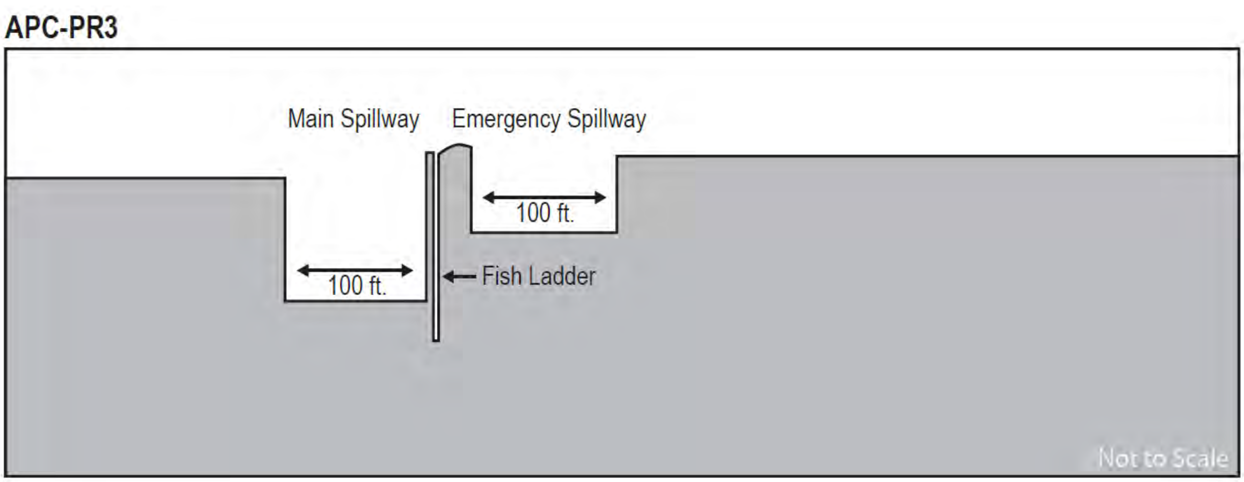


*Figure 85. Cross Section of Assawompset Pond Dam Under **APC-PR3***

APC-PR4:

APC-PR4 consists of a single, 150-foot-wide main spillway at elevation 50.40, a 200-foot-wide overflow spillway at elevation 52.82, and a 5-foot-wide fish ladder at elevation 49.00. This configuration was designed to significantly reduce peak flood elevations by maximizing the flow of water through the main spillway. A HEC-RAS visualization of the Assawompset Pond Dam under **APC-PR4** is shown below as **Figure 86**.

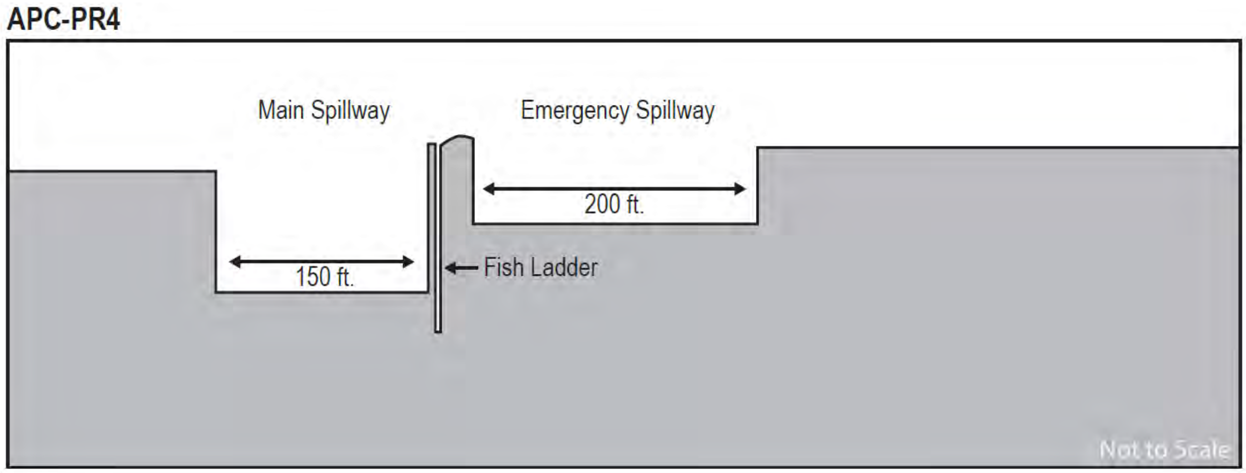


*Figure 86. Cross Section of Assawompset Pond Dam Under **APC-PR4***

APC-PR5:

APC-PR5 consists of a single, 100-foot-wide main spillway at elevation 50.40, a 400-foot-wide overflow spillway at elevation 52.82, and a 5-foot-wide fish ladder at elevation 49.00. This configuration was designed to significantly reduce peak flood elevations through by maximizing flow of water through the overflow spillway while maintaining the sizing of the main spillway from **APC-PR3**. By maintaining the 100-foot width of the main spillway, **APC-PR5** was intended to retain water during drought conditions better than **APC-PR4**. A HEC-RAS visualization of the Assawompset Pond Dam under **APC-PR5** is shown below as **Figure 87**.

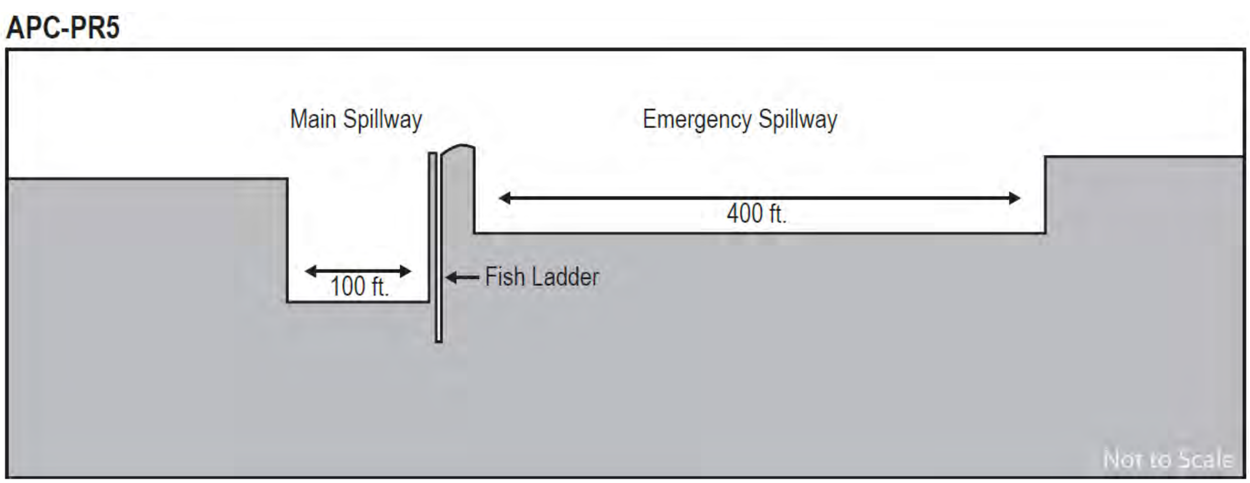


*Figure 87. Cross Section of Assawompset Pond Dam Under **APC-PR5***

3.4.1 Results – Assuming Existing Nemasket River Conditions

The proposed dam reconfiguration scenarios were initially evaluated in HydroCAD with water level conditions in the Upper Nemasket River matching existing conditions (i.e., without any of the potential downstream bridge or dam alterations). In peak flood analyses, the pre-storm water levels in the APC were calibrated based on the peak existing conditions HEC-RAS analysis. Results for the peak flood elevation analysis and APC drop time analyses are shown below in **Table 55**.

HW also evaluated the amount of time required for water levels in the APC to drop from peak 100-year flood elevations to 52.82 feet (the maximum target pond level) and from 52.82 feet to 51.32 feet (the minimum target pond level).

Tailwater in the 100-year pond level drop time analysis was assumed to be low enough for drainage to occur from the overflow spillway. Though observation indicates that tailwater at the dam is generally identical to the APC headwater elevation during flood events, a tailwater differential was necessary for the modelling inputs of HydroCAD. Tailwater values during the 100-year drop time analysis were based on the results of the 50% exceedance flow analysis downstream of the Assawompset Pond Dam under the Existing Conditions HEC-RAS model.

The 52.82 feet to 51.32 feet drop time analysis was intended to evaluate the ability of different dam configurations to retain water during drought conditions. As such, the tailwater for this final parameter was determined based on the 95% exceedance flow analysis downstream of the Assawompset Dam under the Existing Conditions HEC-RAS model. To emulate dam operation during drought conditions, the main spillway of the dam was raised to an elevation of 51.32 feet (approximating the impact of installing boards or raising the spillway mechanically).

Table 55. Results of Dam Reconfiguration Analysis Under Existing Nemasket Conditions

	Peak APC Elevation (ft)				Time to Drop from 100-year El. to 52.82 feet (days)	Time to Drop from 52.82 feet to 51.32 feet (days)**
Dam Scenario	**1-year**	**2-year**	**10-year**	**100-year**		
EX 30’ Main 100’ Emergency	53.75	54.76	55.91	**57.27***	12.9	85.3
APC-PR1 30’ Main 100’ Emergency	53.72	54.76	55.87	**57.08***	9.3	42.3
APC-PR2 75’ Main 100’ Emergency	53.71	54.73	55.81	56.93	4.9	30.5
APC-PR3 100’ Main 100’ Emergency	53.70	54.72	55.78	56.86	3.8	26.9
APC-PR4 150’ Main 200’ Emergency	53.67	54.67	55.69	56.63	2.4	22.2
APC-PR5 100’ Main 400’ Emergency	53.67	54.66	55.65	56.53	2.8	26.9

*** bold asterisk** indicates water level above FEMA 100-year flood elevation of 57.00
** in the 52.82 feet to 51.32 feet drop time analysis, the main spillway was set at elevation 51.32 feet

The peak flood level analysis indicates that all dam configurations evaluated perform approximately the same during the 1- and 2- year storm events. Dam performance differentiates at the 10-year storm. **APC-PR5** is predicted to consistently yield the lowest peak pond levels. During the 10-year storm, **APC-PR5** is predicted to result in a 0.26-foot decrease in flood levels relative to the existing dam configuration. During the 100-year storm, that reduction improves to 0.74 feet. **APC-PR4** and **APC-PR5** differ only slightly in terms of peak flood elevation reduction (0.10 feet difference during the 100-year storm). Notably, neither the existing dam configuration nor **APC-PR1** are predicted to yield 100-year flood levels below the 100-year elevation predicted by FEMA.

The 100-year flood drop time analysis indicates that all proposed dam configurations would reduce the amount of time that it takes for the APC to return to maximum target levels following the 100-year storm. The drop time for **APC-PR1** is 3.6 days lower than that of existing conditions. **APC-PR2** was designed to achieve a drop time below 5 days; the 4.9 day drop time predicted for **APC-PR2** is an 8 day reduction from existing conditions. The drop times for **APC-PR3**, **4**, and **5** are even shorter, and would reduce drop time by 9-10 days relative to existing conditions.

The analyses discussed above focus on flood protection and higher flows. There is of course concern about the dam being able to maintain storage capacity and regulate outflow during low flow conditions. All potential dam scenarios discussed above reflect the maximum opening and maximum water conveyance capacity for each scenario. It is assumed that during actual future dam design for any of these potential scenarios stop logs, gates, or other control structures can be added to restrict flow below maximum conveyance and allow for management of low flow conditions.

3.4.2 Results – Proposed Nemasket River Alterations

Because the river's water level immediately below the dam (tailwater condition when discussing dam conveyance capacity) affects the overall conveyance capacity of any potential dam configuration, HW evaluated the impact of two proposed river alteration scenarios on the various dam modification outcomes. The two scenarios selected were **PR1** (Wareham Street Dam and Weir removal and Culvert modification) and **PR Optimal C** (**PR1** combined with modification of the East Grove Street Bridge, MBTA Bridge, removal of the Old Bridge Street Bridge, and modification of the channel at the outlet of the Assawompset Pond Dam). As with the previous dam analyses, pre-storm water levels in the APC were calibrated based on peak water levels given the existing conditions of the dam; tailwater levels were adjusted based on 50% and 95% exceedance flow elevations downstream of the dam.

The results of the additional dam analyses are shown below in **Table 56** and **Table 57**.

*Table 56. Results of Dam Reconfiguration Analysis Under Nemasket River **PR1***

	Peak APC Elevation (ft)				Time to Drop from 100-year El. to 52.82 feet (days)	Time to Drop from 52.82 feet to 51.32 feet (days)**
Dam Scenario	**1-year**	**2-year**	**10-year**	**100-year**		
EX 30' Main 100' Emergency	53.60	54.55	55.59	56.80	12.4	85.3
APC-PR1 30' Main 100' Emergency	53.58	54.54	55.58	56.68	9.0	42.3
APC-PR2 75' Main 100' Emergency	53.56	54.51	55.51	56.52	4.6	30.5
APC-PR3 100' Main 100' Emergency	53.55	54.50	55.49	56.45	3.6	26.9
APC-PR4 150' Main 200' Emergency	53.52	54.46	55.40	56.23	2.2	22.2
APC-PR5 100' Main 400' Emergency	53.52	54.44	55.36	56.13	2.7	26.9

*** bold asterisk** indicates water level above FEMA 100-year flood elevation of 57.00
** in the 52.82 feet to 51.32 feet drop time analysis, the main spillway was set at elevation 51.32 feet

*Table 57. Results of Dam Reconfiguration Analysis Under Nemasket **PR Optimal C***

	Peak APC Elevation (ft)				Time to Drop from 100-year El. to 52.82 feet (days)	Time to Drop from 52.82 feet to 51.32 feet (days)**
Dam Scenario	**1-year**	**2-year**	**10-year**	**100-year**		
EX 30' Main 100' Emergency	53.60	54.47	55.36	56.39	11.9	85.3
APC-PR1 30' Main 100' Emergency	53.58	54.46	55.35	56.34	8.7	41.6
APC-PR2 75' Main 100' Emergency	53.56	54.43	55.29	56.19	4.5	29.8
APC-PR3 100' Main 100' Emergency	53.55	54.42	55.26	56.12	3.5	26.3
APC-PR4 150' Main 200' Emergency	53.52	54.38	55.17	55.89	2.2	21.7
APC-PR5 100' Main 400' Emergency	53.52	54.36	55.13	55.80	2.6	26.3

*** bold asterisk** indicates water level above FEMA 100-year flood elevation of 57.00
** in the 52.82 feet to 51.32 feet drop time analysis, the main spillway was set at elevation 51.32 feet

The peak APC elevation analysis demonstrates that **PR1** and **PR Optimal C** dramatically reduce the 100-year flood elevation of the APC in all dam configurations. In both Upper Nemasket restoration scenarios, the 100-year flood elevation of the APC given the existing dam conditions is lower than the current FEMA 100-year flood elevation of 57.00. For storms greater than the 1-year storm, **PR Optimal C** is predicted to outperform **PR1** in terms of flood reduction benefits. During the 100-year storm, **PR1** is predicted to reduce peak elevations for each dam configuration by about 0.4-0.5 feet relative to existing Upper Nemasket conditions, **PR Optimal C** would reduce peak elevations by about 0.7-0.9 feet. In the most extreme instance, the combination of **PR Optimal C** and **APC-PR5** is predicted to reduce 100-year flood elevations in the APC by 1.47 feet relative to the existing Upper Nemasket River and Assawompset Pond Dam configurations.

The 100-year flood drop time analysis showed minimal difference between the existing Upper Nemasket River configuration and the proposed Upper Nemasket restoration scenarios. Drop times fell most significantly for the existing dam configuration – by 0.5 days under **PR1** and 1.0 days under **PR Optimal C**. Drop times differ less significantly when comparing proposed dam reconfigurations between different Upper Nemasket restoration alternatives.

Likewise, the 52.82 feet to 51.32 feet drop time analysis yielded minimal differences between drop times under drought conditions for each restoration alternative. The results of the **PR1** drop time analysis were identical to those of the analysis with existing conditions along the Upper Nemasket, most likely because the tailwater conditions during the 95% exceedance flow did not differ between **PR1** and existing conditions. Under **PR Optimal C**, drop times decrease by 0.6-0.7 days for **APC-PR1** through **APC-PR5** relative to under existing Upper Nemasket conditions. This decrease is minimal, suggesting that Upper Nemasket restoration alternatives have a substantial impact on reducing peak flood elevations but little impact on water storage at target water supply levels.

4 SUMMARY

HW assessed seven main Upper Nemasket River restoration scenarios, four hybrid river restoration scenarios, six additional channel alteration scenarios at the outlet of the Assawompset Ponds Complex, and five Assawompset Pond Dam reconfiguration scenarios. The components and results of the scenarios are described below.

4.1 Upper Nemasket River Dam and Bridge Modifications

- **PR1** – Wareham Street Dam and Weir Removal and Culvert Modification

  PR1 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.46 feet and at Wareham Street by 6.54 feet. It is the most impactful individual restoration scenario in terms of flood level reduction. **PR1** is anticipated to result in an increased river gradient, flow velocity, and sediment transport between Wareham Street and East Grove Street. Under **PR1**, herring passage is expected to be restored at Wareham Street and East Grove Street during the 95% and 50% exceedance flows; water velocities may exceed velocity criteria for herring passage at the 5% exceedance flow, the highest velocity flow conditions simulated. Upstream and downstream paddling access would be restored through Wareham Street during the 95% exceedance flow; downstream paddling access would be restored during the 50% and 5% flows. Upstream of Wareham Street, water levels may become slightly below depth criteria for canoe access for conditions under the 50% flow.

- **PR2** – East Grove Street Bridge Modification

  PR2 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.21 feet and at East Grove Street by 0.48 feet. It is the most impactful bridge modification and second most impactful individual restoration scenario (after **PR1**) in terms of flood level reduction. **PR2** is anticipated to result in sediment transport in the vicinity of East Grove Street. Under **PR2**, herring passage is expected to improve to meet minimum depth criteria at East Grove Street during the 95% exceedance flow. Recreational access is expected to become deep enough to meet guidance criteria at East Grove Street during the 95% exceedance flow.

- **PR3** – I-495 Bridge Modification

  PR3 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.11 feet and at I-495 by 0.17 feet. **PR3** is not anticipated to result in a significant amount of sediment transport. Under **PR3**, herring passage and recreational access are not expected to be significantly impacted.

- **PR4** – MBTA Bridge Modification

  PR4 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.15 feet and at the MBTA Bridge by 0.16 feet. **PR4** is anticipated to result in sediment transport in the vicinity of the MBTA Bridge. Under **PR4**, herring passage and recreational access are not expected to be significantly impacted.

- **PR5** – Old Bridge Street Bridge Removal

  PR5 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.18 feet and at Old Bridge Street by 0.27 feet. **PR5** is not anticipated to result in a significant amount of sediment transport. Under **PR5**, herring passage and recreational access are not expected to be significantly impacted. Because Old Bridge Street is no longer in use for vehicle transport, **PR5** may be more practical to implement than other proposed bridge modifications.

- **PR6** – Vaughan Street Bridge Modification

  PR6 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.16 feet and at Vaughan Street by 0.11 feet. It is the least impactful proposed bridge modification in terms of flood reduction area. **PR6** is not anticipated to result in a significant amount of sediment transport. Under **PR6**, herring passage and recreational access are not expected to be significantly impacted.

- Hybrid Scenario **PR1/2** – Wareham Street Dam and Weir Removal and Culvert Replacement and East Grove Street Bridge Modification

  PR1/2 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.49 feet, at East Grove Street by 1.70 feet, and at Wareham Street by 6.57 feet. **PR1/2** is anticipated to result in an increased river gradient, flow velocity, and sediment transport between Wareham Street and East Grove Street. Under **PR1/2**, fish passage is expected to be restored at Wareham Street during the 95% and 50% exceedance flows and at East Grove Street during the 95% exceedance flow; water velocities may exceed velocity criteria for herring passage during the 5% exceedance flow. Upstream and downstream paddling access would be become deep enough to meet guidance criteria at Wareham Street during the 95% exceedance flow; downstream paddling access would be become deep enough to meet guidance criteria during the 50% and 5% flows. Upstream of Wareham Street, water levels may become slightly below depth criteria for canoe access under the 50% flow.

- Hybrid Scenario **PR1/4** – Wareham Street Dam and Weir Removal and Culvert Replacement and MBTA Bridge Modification

  PR1/4 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.64 feet, at the MBTA Bridge by 0.16 feet, and at Wareham Street by 6.54 feet. **PR1/4** is anticipated to result in an increased river gradient, flow velocity, and sediment transport between Wareham Street and East Grove Street and in the vicinity of the MBTA Bridge. Under **PR1/4**, herring passage is expected to be restored at Wareham Street during the 95% and 50% exceedance flows and at East Grove Street during the 95% exceedance flow; water velocities may be exceed velocity criteria to herring passage at the 5% exceedance flow. Upstream and downstream paddling access would become deep enough to meet guidance criteria at Wareham Street during the 95% exceedance flow; downstream paddling access would become deep enough to meet guidance criteria during the 50% and 5% flows. Upstream of Wareham Street, water levels may become slightly below depth criteria for canoe access under the 50% flow. Near Old Bridge Street, water velocities during the 95% flow may be above criteria for upstream canoe navigation.

- Hybrid Scenario **PR1/5** – Wareham Street Dam and Weir Removal and Culvert Replacement and Old Bridge Street Bridge Removal

    PR1/5 is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.68 feet, at Old Bridge Street by 1.08 feet, and at Wareham Street by 6.57 feet. It is the most impactful of the two-alteration hybrid scenarios evaluated in terms of flood reduction. **PR1/5** is anticipated to result in an increased river gradient, flow velocity, and sediment transport between Wareham Street and East Grove Street and in the vicinity of Old Bridge Street. Under **PR1/5**, herring passage is expected to become deep enough to meet guidance criteria at Wareham Street during the 95% and 50% exceedance flows, and at both East Grove and Bridge Streets during the 95% exceedance flow; water velocities may exceed criteria for herring passage at the 5% flow. Upstream and downstream paddling access would become deep enough to meet guidance criteria at Wareham Street during the 95% exceedance flow; downstream paddling access would become deep enough to meet guidance criteria during the 50% and 5% flows. Upstream of Wareham Street, water levels may become slightly below depth criteria for canoe access under the 50% flow.

- Hybrid Scenario PR1/2/4/5 (**PR Optimal**) – Wareham Street Dam and Weir Removal and Culvert Replacement, East Grove Street Bridge Modification, MBTA Bridge Modification, and Old Bridge Street Bridge Removal

    PR Optimal is predicted to decrease 100-year flood elevations in the Assawompset Pond by 0.88 feet, at Old Bridge Street by 1.49 feet, at the MBTA Bridge by 1.23 feet, at East Grove Street by 1.82 feet, and at Wareham Street by 6.57 feet. It is single most effective river restoration scenario analyzed in terms of flood reduction. **PR Optimal** is anticipated to result in an increased river gradient, flow velocity, and sediment transport between Wareham Street and East Grove Street and in the vicinities of the MBTA Bridge and Old Bridge Street. Under **PR Optimal**, herring passage is expected to be restored at Wareham Street during the 95% and 50% exceedance flows, and at both East Grove and Bridge Streets during the 95% exceedance flow; water velocities may exceed criteria for herring passage at the 5% flow. Upstream and downstream paddling access would become deep enough to meet guidance criteria at Wareham Street during the 95% exceedance flow; downstream paddling access would become deep enough to meet guidance criteria during the 50% and 5% flows. Upstream of Wareham Street, water levels may become slightly below depth criteria for canoe access under the 50% flow.

The analysis comprising this H&H Report indicates that several of the river crossings and dams along the Nemasket could be modified or removed to ameliorate flooding along the Nemasket and the Assawompset Pond Complex. Co-benefits to these restoration scenarios include improved fish passage, riverine habitat, sediment transport, and recreational access.

Based on the results of the H&H model, the single most effective restoration project analyzed would be the removal of the Wareham Street Dam and Weir and replacement of the Wareham Street Culvert (**PR1**). This project would result in reduced flood elevations over nearly 4 miles of the Nemasket River, and would result in the greatest magnitude of flood reduction of any scenario analyzed. Removal of the dam would increase the river's gradient for a long stretch of river, increasing flow velocity and sediment transport capacity. Removal of the dam is expected to significantly improve herring passage and recreational access along the Nemasket, despite a few locations in which water velocity in the river is expected to increase.

In conjunction with dam removal and culvert replacement activities at Wareham Street, bridge and channel modifications at other targeted points along the Nemasket could enhance flood reduction benefits within the study area. Removal of the Old Bridge Street Bridge (**PR5**) would be the best candidate for a second restoration project, as the bridge is no longer in use and its removal would confer significant flood reduction benefits. The next most preferable restoration project would be the modification of the MBTA Bridge (**PR4**), which would require more permitting and coordination with other interests than would the Old Bridge Street project but would confer similar flood reduction benefits. The third priority bridge modification would be the East Grove Street Bridge (**PR2**), which also would require significant permitting and coordination but would yield slightly less substantial flood reduction benefits than would the MBTA bridge project.

4.2 Upper Nemasket River Channel Modifications

Potential modification of the Nemasket River channel downstream of the Assawompset Pond Dam is a category of potential restoration opportunity on its own. This area of the river is of significant near-term concern to many in the community as sedimentation and vegetative growth are cited as potential fish barriers during lower flows. Two potential and very different projects for this area were evaluated during this study. Both of these potential projects would do little to improve flooding concerns but could potentially reduce sedimentation in the upper limits of the Nemasket. While either of these potential channel modification projects would most efficiently be done in concert with any desired modification or replacement of the APC dam, they could also be done independently.

- **PR7** – Sediment Trap and Dredge Downstream of Assawompset Pond Dam

  PR7 is predicted to decrease water surface elevations during the 95% exceedance flow by 0.19 feet between the Assawompset Pond and the proposed sediment trap. No flood reduction benefits are predicted for flows greater than or equal to the 5% exceedance event. **PR7** is anticipated to allow suspended sand to settle at the proposed sediment trap during all flow events. Under **PR7**, herring passage is not expected to be significantly impacted, although passage of eels and other bottom dwelling fish would be inhibited. During the 95% flow, water depths over the sediment trap would be too shallow to meet guidance criteria for canoe passage.

The proposed **PR7** sediment trap is simulated to create hydraulic conditions conducive to sediment settling such that accumulated material could conceivably be periodically excavated by mechanical means. However, because the rate of sediment inflow is uncertain, it is unknown at what frequency material removal would need to be conducted to maintain the utility of the structure. There are several other potential concerns with this scenario:

- The ability to permit what is essentially an in-river sediment trap is likely challenging at best, and impossible at worst.
- The proposed sheet piling structure would create potential fish passage limitations during low flow conditions.
- The proposed structure would maintain the existing unnatural channel dimensions and do nothing to restore naturalized flow conditions. It would also not restore river connectivity to adjacent floodplain wetlands.

- **PR Channel** – Modification of the Upper Nemasket River Downstream of the APC Dam to Match Natural Dimensions

PR Channel is predicted to decrease water surface elevations during the 95% exceedance flow by 0.31 feet in the 200 feet downstream of the Assawompset Pond Dam. No flood reduction benefits are predicted for flows greater than or equal to the 5% exceedance event. Channel velocities are predicted to increase incrementally (0.17 feet per second) in the channel modification area, with the exception of the area 200 feet downstream of the Assawompset Pond Dam. In the area immediate downstream of the dam, channel velocities are expected to decrease slightly due to the removal of a man-made berm on the riverbank.

PR Channel is anticipated to cause particles up to 0.7 mm in diameter (medium to coarse sand) to remain in suspension in the vicinity of the Assawompset Pond Dam, an increase existing settling velocity of 0.6 mm (medium sand remains suspended). Coupled with additional dam and bridge improvements downstream of the Assawompset Pond Dam (e.g., Wareham Street alterations, East Grove Street Bridge modification, MBTA Bridge modification, and Old Bridge Street Bridge removal), sediment up to 0.8 mm (coarse sand) would be expected to remain suspended.

This proposed naturalization of the Upper Nemasket River channel would restore a more natural channel geometry and reconnect it to its adjacent floodplain and wetlands. Additional impacts of the narrower channel include:

- Increasing flow velocities during low flow conditions. This would keep additional sediment in suspension, reducing the ability for emergent vegetation to encroach into the channel blocking fish passage.
- Allowing for bank overtopping into the adjacent floodplain improving flood storage to the benefit of downstream receptors and improving habitat functionality from the adjacent floodplain wetlands.

- Mimicking what is anticipated to have been the historic, pre-APC dam river geometry and hydraulics when, presumably, acceptable fish passage occurred for millennia.
- As a self-sustaining, naturalized design, no to minimal maintenance sediment removal would be required.
- Readily permittable following the precedent of many similar river restoration projects in recent decades.
- Likely able to obtain funding through multiple state and federal sources targeting environmental restoration.

4.3 Assawompset Pond Dam Modifications

- **APC-PR1** – 30' Main Spillway and 100' Overflow Spillway

  APC-PR1 is predicted to decrease the 100-year flood elevation in the Assawompset Pond by 0.15 feet given the existing conditions of the Nemasket River; this flooding reduction would not result in floods lower than the FEMA prediction for 100-year flood levels. Combined with restoration scenarios in the Nemasket, APC-PR1 could result in as much as 0.59 feet (**PR1**) to 0.93 feet (**PR Optimal C)** of flood reduction. The **APC-PR1** dam configuration would allow water levels to drop from the 100-year flood elevation to the maximum target water level in the APC in a span of 9.3 days; it would take 42.3 days for water levels to drop from the maximum target to the minimum target water level during drought conditions.

- **APC-PR2** – 75' Main Spillway and 100' Overflow Spillway

  APC-PR2 is predicted to decrease the 100-year flood elevation in the Assawompset Pond by 0.34 feet given the existing conditions of the Nemasket River. Combined with restoration scenarios in the Nemasket, **APC-PR2** could result in as much as 0.75 feet (**PR1**) to 1.08 feet (**PR Optimal C**) of flood reduction. The **APC-PR2** dam configuration would allow water levels to drop from the 100-year flood elevation to the maximum target water level in the APC in a span of 4.9 days; it would take 30.5 days for water levels to drop from the maximum target to the minimum target water level during drought conditions.

- **APC-PR3** – 100' Main Spillway and 100' Overflow Spillway

  APC-PR3 is predicted to decrease the 100-year flood elevation in the Assawompset Pond by 0.41 feet given the existing conditions of the Nemasket River. Combined with restoration scenarios in the Nemasket, **APC-PR3** could result in as much as 0.82 feet (**PR1**) to 1.15 feet (**PR Optimal C**) of flood reduction. The **APC-PR3** dam configuration would allow water levels to drop from the 100-year flood elevation to the maximum target water level in the APC in a span of 3.8 days; it would take 26.9 days for water levels to drop from the maximum target to the minimum target water level during drought conditions.

- **APC-PR4** – 150' Main Spillway and 200' Overflow Spillway

  APC-PR4 is predicted to decrease the 100-year flood elevation in the Assawompset Pond by 0.64 feet given the existing conditions of the Nemasket River. Combined with restoration scenarios in the Nemasket, **APC-PR4** could result in as much as 1.04 feet (**PR1**) to 1.38 feet (**PR Optimal C**) of flood reduction. The **APC-PR4** dam configuration would allow water levels to drop from the 100-year flood elevation to the maximum target water level in the APC in a span of 2.2 days; it would take 22.2 days for water levels to drop from the maximum target to the minimum target water level during drought conditions.

- **APC-PR5** – 100' Main Spillway and 400' Overflow Spillway

  APC-PR5 is predicted to decrease the 100-year flood elevation in the Assawompset Pond by 0.74 feet given the existing conditions of the Nemasket River. Combined with restoration scenarios in the Nemasket, **APC-PR5** could result in as much as 1.14 feet (**PR1**) to 1.47 feet (**PR Optimal C**) of flood reduction. The **APC-PR5** dam configuration would allow water levels to drop from the 100-year flood elevation to the maximum target water level in the APC in a span of 2.8 days; it would take 26.9 days for water levels to drop from the maximum target to the minimum target water level during drought conditions.

Several replacement alternatives at the Assawompset Pond Dam were assessed. Of the alternatives, a configuration consisting of a 75-foot wide main spillway and 100-foot wide emergency spillway (**APC-PR2**) would offer an optimal balance of peak flood elevation reduction and ability to forecast and respond to weather, all without reducing the storage capacity of the pond complex. This scenario has been discussed with representatives of the Taunton and New Bedford water departments and received tentative and conditional support. Other, greater conveyance capacity APC dam options could be considered to maximize those hydraulic benefits. However, the costs for larger conveyance capacity structures would increase significantly without parallel increase for the relative hydraulic benefits.

5 NEXT STEPS

Please note that the hydrologic and hydraulic modelling and proposed designs evaluated at this phase of the project are at the planning-design level. Further data collection, evaluation, and design will be needed prior to advancing the design of any single proposed restoration scenario to the conceptual level, let alone permitting or construction. Such efforts are anticipated to include at least the following:

- Additional field data collection of project areas. This includes:
  - Additional topographic and bathymetric survey of the river and areas that would be used for project implementation;
  - Delineation of wetland resource areas; and
  - Ecological characterization of project areas.
- Further development of H&H model to incorporate additional bathymetric detail. H&H model should be updated to investigate any additional details incorporated into proposed restoration scenarios. Localized impacts in the vicinity of each scenario should be assessed, in addition to river-wide impacts.
- Conceptual design of individual restoration scenarios. Designs should outline basic construction sequence, including:
  - Installation of erosion and sediment controls
  - Site preparation and dewatering, as necessary
  - Demolition of existing structures
  - Installation of new structures, as appropriate
  - Site grading, stabilization, and restoration
- Permit-level design of individual restoration scenarios. Permit-level designs should quantify all impacts to wetland resource areas, in addition to advancing the level of detail of the conceptual designs and any additional field work and analysis that may be required to do so.
- Permitting as required at the local, state, and federal level.
- Final construction-level design and development of specifications for construction process and materials.
- Construction administration, submittal review, and other technical support is anticipated to be needed during project implementation.
- Post-construction monitoring of water levels, wildlife habitat and ecology, sediment transport or accumulation, and other relevant site-specific features as required by a project's permit.

As a follow up to this current project, an expanded H&H modeling project is currently being developed looking at hydrology and hydraulics for the entire APC watershed. This project includes:

- Development of a regional numerical groundwater model to better understand the role of groundwater as it relates to water levels in the Nemasket River and the Assawompset Pond Complex, prioritization of locations for additional groundwater and surface water data collection, and assessment of potential impacts of proposed river restoration projects on drinking water wells within close proximity.
- Extension of the H&H model to include interconnections between the ponds within the Assawompset Pond Complex.
- Additional survey and data collection along the Nemasket River to increase the accuracy of the H&H model at points of interest.
- Collection of sediment samples along the Nemasket River to more accurately estimate sediment transport potential and to evaluate whether any hazardous substances are present in sediment.

This separate project will expand upon and improve the utility of the modeling tools developed during this current Upper Newmarket H&H Assessment to further assess and, potentially, advance selected projects in efforts to improve water resources management and habitat conditions for the APC and Nemasket River. A complete list of project tasks is shown below in **Table 58**.

Table 58. Expanded H&H Model Project Tasks

Project Task
Create a groundwater model conceptual framework and plan for siting data collection infrastructure
Initiate new data collection systems, including 8-12 monitoring wells and 2-3 stream gauging stations
Refine and expand HEC-RAS model to entire length of Nemasket River
Create a conceptual design of APC Dam replacement and Upper Nemasket channel restoration
Create a conceptual design of Wareham Street Dam removal, including written narrative of design
Develop prioritization matrix of potential restoration projects
Engage stakeholders through attendance of APC Steering Committee Meetings, water supplier meetings, and local board meetings
Develop final project report

ATTACHMENT A – HEC-RAS OUPUT OF PROPOSED CONDITIONS MODELS

Legend:

Existing WSE	
WSE higher than EX	WSE = EX (or diff <0.05)
WSE lower than EX (0.05-0.49)	WSE lower than EX (0.5-0.99)
WSE lower than EX (1.0-1.99)	WSE lower than EX (2.0+)

95% Exceedance Flow Results

	#		APC Dam		Vaughan St Bridge		Bridge St Bridge		Old Bridge St Bridge		MBTA Bridge		I-495 Bridge		East Grove Street Bridge		Wareham St Culvert		Wareham Bascule Dam		Wareham Weir	
		River STN:	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
			Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)
	0	EX	49.93	49.92	49.31	49.26	48.24	48.22	48.2	48.14	48.09	48.06	48.03	48.03	47.95	47.55	44.71	44.71	44.7	41.75	40.74	40.6
	Channel	Modify APC Outlet Channel	49.64	49.63	49.31	49.26	48.24	48.22	48.2	48.14	48.09	48.06	48.03	48.03	47.95	47.55	44.71	44.71	44.7	41.75	40.74	40.6
INDIVIDUAL	1	Remove Wareham St Dam	49.93	49.93	49.31	49.26	48.05	48.01	47.98	47.81	47.68	47.21	46.65	46.59	45.59	45.56	40.04	40.01	40.01	40.01	39.7	39.69
	1C	Remove Wareham Dam AND modify channel at APC	49.64	49.63	49.31	49.26	48.05	48.01	47.98	47.81	47.68	47.21	46.65	46.59	45.59	45.56	40.04	40.01	40.01	40.01	39.7	39.69
	2	Modify East Grove Bridge	49.93	49.93	49.31	49.26	48.05	48.01	47.98	47.81	47.68	47.21	46.79	46.76	46.52	46.52	44.7	44.7	44.7	41.75	40.74	40.61
	3	Modify I-495	49.93	49.93	49.31	49.26	48.23	48.21	48.19	48.14	48.09	48.06	48.03	48.03	47.95	47.56	44.7	44.7	44.7	41.75	40.74	40.61
	4	Modify MBTA Bridge	49.93	49.93	49.31	49.26	48.21	48.19	48.16	48.1	48.06	48.06	48.03	48.03	47.95	47.56	44.7	44.7	44.7	41.75	40.74	40.61
	5	Remove Old Bridge St.	49.93	49.93	49.31	49.26	48.22	48.19	48.17	48.13	48.09	48.06	48.03	48.03	47.95	47.56	44.7	44.7	44.7	41.75	40.74	40.61
	6	Modify Vaughan Bridge	49.93	49.93	49.31	49.26	48.24	48.21	48.19	48.14	48.09	48.06	48.03	48.03	47.95	47.56	44.7	44.7	44.7	41.75	40.74	40.61
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	49.74	49.74	49.31	49.26	48.24	48.21	48.19	48.14	48.09	48.06	48.03	48.03	47.95	47.56	44.7	44.7	44.7	41.75	40.74	40.61
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	49.93	49.93	49.31	49.26	48.05	48.01	47.98	47.81	47.68	47.21	46.65	46.59	45.58	45.56	40.1	40.08	40.08	40.07	39.7	39.69
	1/2 C	Wareham Dam, E Grove, APC Channel	49.64	49.63	49.31	49.26	48.05	48.01	47.98	47.81	47.68	47.21	46.65	46.59	45.58	45.56	40.1	40.08	40.08	40.07	39.7	39.69
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	49.93	49.93	49.31	49.26	48.05	48.01	47.97	47.4	46.97	46.96	46.65	46.59	46.59	45.56	40.04	40.01	40.01	40.01	39.7	39.69
	1/4 C	Wareham Dam, MBTA, APC Channel	49.64	49.63	49.31	49.26	48.05	48.01	47.97	47.4	46.97	46.96	46.65	46.59	46.59	45.56	40.04	40.01	40.01	40.01	39.7	39.69
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	49.93	49.93	49.31	49.26	47.91	47.85	47.79	47.77	47.68	47.21	46.65	46.59	45.59	45.56	40.1	40.08	40.08	40.07	39.7	39.69
	1/5 C	Wareham Dam, Old Bridge, APC Channel	49.64	49.63	49.31	49.26	47.91	47.85	47.79	47.77	47.68	47.21	46.65	46.59	45.59	45.56	40.1	40.08	40.08	40.07	39.7	39.69
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	49.93	49.93	49.31	49.26	47.72	47.56	47.33	47.21	46.97	46.96	46.65	46.59	45.58	45.56	40.1	40.08	40.08	40.07	39.7	39.69
	1/2/4/5 C	Wareham Dam, Old Bridge, MBTA, E Grove, APC Channel	49.64	49.63	49.31	49.26	47.72	47.56	47.33	47.21	46.97	46.96	46.65	46.59	45.58	45.56	40.1	40.08	40.08	40.07	39.7	39.69

Difference

	#		APC Dam Upstream	APC Dam Downstream	Vaughan St Upstream	Vaughan St Downstream	Bridge St Upstream	Bridge St Downstream	Old Bridge St Upstream	Old Bridge St Downstream	MBTA Upstream	MBTA Downstream	I-495 Upstream	I-495 Downstream	East Grove Upstream	East Grove Downstream	Wareham St Culvert Upstream	Wareham St Culvert Downstream	Wareham Bascule Dam Upstream	Wareham Bascule Dam Downstream	Wareham Weir Upstream	Wareham Weir Downstream
INDIVIDUAL	1	Remove Wareham St Dam	0	0.01	0	0	-0.19	-0.21	-0.22	-0.33	-0.41	-0.85	-1.38	-1.44	-2.36	-1.99	-4.67	-4.7	-4.69	-1.74	-1.04	-0.91
	2	Modify East Grove Bridge	0	0.01	0	0	-0.19	-0.21	-0.22	-0.33	-0.41	-0.85	-1.24	-1.27	-1.43	-1.03	-0.01	-0.01	0	0	0	0.01
	3	Modify I-495	0	0.01	0	0	-0.01	-0.01	-0.01	0	0	0	0	0	0	0.01	-0.01	-0.01	0	0	0	0.01
	4	Modify MBTA Bridge	0	0.01	0	0	-0.03	-0.03	-0.04	-0.04	-0.03	0	0	0	0	0.01	-0.01	-0.01	0	0	0	0.01
	5	Remove Old Bridge St.	0	0.01	0	0	-0.02	-0.03	-0.03	-0.01	0	0	0	0	0	0.01	-0.01	-0.01	0	0	0	0.01
	6	Modify Vaughan Bridge	0	0.01	0	0	0	-0.01	-0.01	0	0	0	0	0	0	0.01	-0.01	-0.01	0	0	0	0.01
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	-0.19	-0.18	0	0	0	-0.01	-0.01	0	0	0	0	0	0	0.01	-0.01	-0.01	0	0	0	0.01
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	0	0.01	0	0	-0.19	-0.21	-0.22	-0.33	-0.41	-0.85	-1.38	-1.44	-2.37	-1.99	-4.61	-4.63	-4.62	-1.68	-1.04	-0.91
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	0	0.01	0	0	-0.19	-0.21	-0.23	-0.74	-1.12	-1.1	-1.38	-1.44	-1.36	-1.99	-4.67	-4.7	-4.69	-1.74	-1.04	-0.91
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	0	0.01	0	0	-0.33	-0.37	-0.41	-0.37	-0.41	-0.85	-1.38	-1.44	-2.36	-1.99	-4.61	-4.63	-4.62	-1.68	-1.04	-0.91
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	0	0.01	0	0	-0.52	-0.66	-0.87	-0.93	-1.12	-1.1	-1.38	-1.44	-2.37	-1.99	-4.61	-4.63	-4.62	-1.68	-1.04	-0.91

Legend:

Legend	
Existing WSE	
WSE higher than EX	WSE = EX (or diff <0.05)
WSE lower than EX (0.05-0.49)	WSE lower than EX (0.5-0.99)
WSE lower than EX (1.0-1.99)	WSE lower than EX (2.0+)

5% Exceedance Flow Results

Group	#	Scenario	APC Dam Upstream WSE (ft)	APC Dam Downstream WSE (ft)	Vaughan St Bridge Upstream WSE (ft)	Vaughan St Bridge Downstream WSE (ft)	Bridge St Bridge Upstream WSE (ft)	Bridge St Bridge Downstream WSE (ft)	Old Bridge St Bridge Upstream WSE (ft)	Old Bridge St Bridge Downstream WSE (ft)	MBTA Bridge Upstream WSE (ft)	MBTA Bridge Downstream WSE (ft)	I-495 Bridge Upstream WSE (ft)	I-495 Bridge Downstream WSE (ft)	East Grove Street Bridge Upstream WSE (ft)	East Grove Street Bridge Downstream WSE (ft)	Wareham St Culvert Upstream WSE (ft)	Wareham St Culvert Downstream WSE (ft)	Wareham Bascule Dam Upstream WSE (ft)	Wareham Bascule Dam Downstream WSE (ft)	Wareham Weir Upstream WSE (ft)	Wareham Weir Downstream WSE (ft)
		River STN:	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
	0	EX	53.76	53.75	53.49	53.46	52.88	52.82	52.78	52.72	52.45	52.41	52.07	52.01	51.57	51.43	49.83	49.76	49.74	44.87	44.42	42.75
	Channel	Modify APC Outlet Channel	53.78	53.77	53.49	53.46	52.88	52.82	52.78	52.72	52.45	52.41	52.07	52.01	51.57	51.43	49.83	49.76	49.74	44.87	44.42	42.75
INDIVIDUAL	1	Remove Wareham St Dam	53.62	53.6	53.27	53.23	52.28	52.18	52.12	52.01	51.57	51.49	50.78	50.66	49.58	49.47	43.58	43.56	43.56	43.53	42.76	42.74
	1C	Remove Wareham Dam AND modify channel at APC	53.64	53.63	53.27	53.23	52.28	52.18	52.12	52.01	51.57	51.49	50.78	50.66	49.58	49.47	43.58	43.56	43.56	43.53	42.76	42.74
	2	Modify East Grove Bridge	53.7	53.69	53.41	53.38	52.7	52.63	52.58	52.51	52.2	52.15	51.69	51.62	51.25	51.22	49.82	49.74	49.74	44.87	44.42	42.75
	3	Modify I-495	53.74	53.73	53.45	53.42	52.83	52.77	52.72	52.66	52.39	52.34	52.03	52.01	51.56	51.42	49.82	49.74	49.74	44.87	44.42	42.75
	4	Modify MBTA Bridge	53.73	53.72	53.45	53.42	52.79	52.72	52.68	52.62	52.42	52.41	52.07	52.01	51.56	51.42	49.82	49.74	49.74	44.87	44.42	42.75
	5	Remove Old Bridge St.	53.73	53.72	53.46	53.43	52.81	52.75	52.69	52.67	52.45	52.41	52.07	52.01	51.56	51.42	49.82	49.74	49.74	44.87	44.42	42.75
	6	Modify Vaughan Bridge	53.73	53.72	53.47	53.45	52.88	52.82	52.77	52.72	52.45	52.41	52.07	52.01	51.56	51.42	49.82	49.74	49.74	44.87	44.42	42.75
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	53.76	53.75	53.49	53.46	52.88	52.82	52.77	52.72	52.45	52.41	52.07	52.01	51.56	51.42	49.82	49.74	49.74	44.87	44.42	42.75
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	53.62	53.6	53.27	53.22	52.27	52.18	52.11	52	51.57	51.48	50.77	50.65	49.54	49.47	43.6	43.57	43.57	43.55	42.76	42.74
	1/2 C	Wareham Dam, E Grove, APC Channel	53.64	53.63	53.27	53.22	52.27	52.18	52.11	52	51.57	51.48	50.77	50.65	49.54	49.47	43.6	43.57	43.57	43.55	42.76	42.74
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	53.6	53.57	53.25	53.19	52.14	52.04	51.96	51.84	51.5	51.5	50.78	50.66	49.58	49.47	43.58	43.56	43.56	43.53	42.76	42.74
	1/4 C	Wareham Dam, MBTA, APC Channel	53.62	53.61	53.25	53.19	52.14	52.04	51.96	51.84	51.5	51.5	50.78	50.66	49.58	49.47	43.58	43.56	43.56	43.53	42.76	42.74
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	53.5	53.57	53.22	53.18	53.17	52.07	52	51.95	51.57	51.49	50.78	50.66	49.58	49.47	43.6	43.57	43.57	43.55	42.78	42.74
	1/5 C	Wareham Dam, Old Bridge, APC Channel	53.63	53.62	53.22	53.18	53.17	52.07	52	51.95	51.57	51.49	50.78	50.66	49.58	49.47	43.6	43.57	43.57	43.55	42.78	42.74
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	53.57	53.54	53.18	53.14	52.02	51.91	51.83	51.77	51.5	51.49	50.77	50.65	49.54	49.47	43.6	43.57	43.57	43.55	42.76	42.74
	1/2/4/5 C	Wareham Dam, Old Bridge, MBTA, E Grove, APC Channel	53.6	53.6	53.18	53.14	52.02	51.91	51.83	51.77	51.5	51.49	50.77	50.65	49.54	49.47	43.6	43.57	43.57	43.55	42.76	42.74

Difference

Group	#	Scenario	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
INDIVIDUAL	1	Remove Wareham St Dam	-0.14	-0.15	-0.22	-0.23	-0.6	-0.64	-0.66	-0.71	-0.88	-0.92	-1.29	-1.35	-1.99	-1.96	-6.25	-6.2	-6.18	-1.34	-1.66	-0.01
	2	Modify East Grove Bridge	-0.06	-0.06	-0.08	-0.08	-0.18	-0.19	-0.2	-0.21	-0.25	-0.26	-0.38	-0.39	-0.32	-0.21	-0.01	-0.02	0	0	0	0
	3	Modify I-495	-0.02	-0.02	-0.04	-0.04	-0.05	-0.05	-0.06	-0.06	-0.06	-0.07	-0.04	0	-0.01	-0.01	-0.01	-0.02	0	0	0	0
	4	Modify MBTA Bridge	-0.03	-0.03	-0.04	-0.04	-0.09	-0.1	-0.1	-0.1	-0.03	0	0	0	-0.01	-0.01	-0.01	-0.02	0	0	0	0
	5	Remove Old Bridge St.	-0.03	-0.03	-0.03	-0.03	-0.07	-0.07	-0.09	-0.05	0	0	0	0	-0.01	-0.01	-0.01	-0.02	0	0	0	0
	6	Modify Vaughan Bridge	-0.03	-0.03	-0.02	-0.01	0	0	-0.01	0	0	0	0	0	-0.01	-0.01	-0.01	-0.02	0	0	0	0
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	0	0	0	0	0	0	-0.01	0	0	0	0	0	-0.01	-0.01	-0.01	-0.02	0	0	0	0
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	-0.14	-0.15	-0.22	-0.24	-0.61	-0.64	-0.67	-0.72	-0.88	-0.93	-1.3	-1.36	-2.03	-1.96	-6.23	-6.19	-6.17	-1.32	-1.66	-0.01
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	-0.16	-0.18	-0.24	-0.27	-0.74	-0.78	-0.82	-0.88	-0.95	-0.91	-1.29	-1.35	-1.99	-1.96	-6.25	-6.2	-6.18	-1.34	-1.66	-0.01
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	-0.26	-0.18	-0.27	-0.28	0.29	-0.75	-0.78	-0.77	-0.88	-0.92	-1.29	-1.35	-1.99	-1.96	-6.23	-6.19	-6.17	-1.32	-1.64	-0.01
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	-0.19	-0.21	-0.31	-0.32	-0.86	-0.91	-0.95	-0.95	-0.95	-0.92	-1.3	-1.36	-2.03	-1.96	-6.23	-6.19	-6.17	-1.32	-1.66	-0.01

Legend:

Existing WSE	
WSE higher than EX	WSE = EX (or diff <0.05)
WSE lower than EX (0.05-0.49)	WSE lower than EX (0.5-0.99)
WSE lower than EX (1.0-1.99)	WSE lower than EX (2.0+)

2 Year Flow Results

	#		APC Dam		Vaughan St Bridge		Bridge St Bridge		Old Bridge St Bridge		MBTA Bridge		I-495 Bridge		East Grove Street Bridge		Wareham St Culvert		Wareham Bascule Dam		Wareham Weir	
		River STN:	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
			Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)
	0	EX	54.77	54.76	54.56	54.52	54.08	53.99	53.92	53.87	53.51	53.46	53.17	53.08	52.65	52.47	50.82	50.66	50.63	45.62	44.94	43.4
	Channel	Modify APC Outlet Channel	54.78	54.77	54.56	54.52	54.08	53.99	53.92	53.87	53.51	53.46	53.17	53.08	52.65	52.47	50.82	50.66	50.63	45.62	44.94	43.4
INDIVIDUAL	1	Remove Wareham St Dam	54.56	54.55	54.3	54.26	53.62	53.51	53.43	53.35	52.84	52.76	52.04	51.88	50.94	50.78	44.58	44.55	44.55	44.5	43.4	43.39
	1C	Remove Wareham Dam AND modify channel at APC	54.58	54.57	54.3	54.26	53.62	53.51	53.43	53.35	52.84	52.76	52.04	51.88	50.94	50.78	44.58	44.55	44.55	44.5	43.4	43.39
	2	Modify East Grove Bridge	54.68	54.67	54.45	54.41	53.89	53.79	53.72	53.65	53.24	53.18	52.78	52.68	52.31	52.27	50.8	50.63	50.63	45.62	44.94	43.41
	3	Modify I-495	54.73	54.72	54.52	54.48	54	53.91	53.84	53.79	53.41	53.35	53.09	53.07	52.65	52.47	50.8	50.63	50.63	45.62	44.94	43.41
	4	Modify MBTA Bridge	54.71	54.7	54.49	54.45	53.95	53.86	53.79	53.73	53.45	53.45	53.17	53.08	52.65	52.47	50.8	50.63	50.63	45.62	44.94	43.41
	5	Remove Old Bridge St.	54.7	54.69	54.47	54.43	53.93	53.84	53.77	53.76	53.51	53.45	53.17	53.08	52.65	52.47	50.8	50.63	50.63	45.62	44.94	43.41
	6	Modify Vaughan Bridge	54.71	54.7	54.51	54.48	54.08	53.99	53.92	53.87	53.51	53.45	53.17	53.08	52.65	52.47	50.8	50.63	50.63	45.62	44.94	43.41
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	54.78	54.77	54.56	54.52	54.08	53.99	53.92	53.87	53.51	53.45	53.17	53.08	52.65	52.47	50.8	50.63	50.63	45.62	44.94	43.41
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	54.56	54.55	54.3	54.26	53.62	53.5	53.42	53.34	52.83	52.75	52.02	51.86	50.86	50.76	44.59	44.56	44.56	44.52	43.4	43.39
	1/2 C	Wareham Dam, E Grove, APC Channel	54.58	54.57	54.3	54.26	53.62	53.5	53.42	53.34	52.83	52.75	52.02	51.86	50.86	50.76	44.59	44.56	44.56	44.52	43.4	43.39
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	54.51	54.5	54.23	54.18	53.47	53.34	53.25	53.16	52.76	52.75	52.04	51.88	50.94	50.78	44.58	44.55	44.55	44.5	43.4	43.39
	1/4 C	Wareham Dam, MBTA, APC Channel	54.53	54.52	54.23	54.18	53.47	53.34	53.25	53.16	52.76	52.75	52.04	51.88	50.94	50.78	44.58	44.55	44.55	44.5	43.4	43.39
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	54.5	54.49	54.22	54.17	53.44	53.32	53.23	53.22	52.84	52.76	52.04	51.88	50.94	50.78	44.59	44.56	44.56	44.52	43.4	43.39
	1/5 C	Wareham Dam, Old Bridge, APC Channel	54.53	54.52	54.22	54.17	53.44	53.32	53.23	53.22	52.84	52.76	52.04	51.88	50.94	50.78	44.59	44.56	44.56	44.52	43.4	43.39
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	54.45	54.44	54.15	54.1	53.27	53.14	53.04	53.02	52.75	52.75	52.02	51.86	50.86	50.76	44.59	44.56	44.56	44.52	43.4	43.39
	1/2/4/5 C	Wareham Dam, Old Bridge, MBTA, E Grove, APC Channel	54.48	54.47	54.15	54.1	53.27	53.14	53.04	53.02	52.75	52.75	52.02	51.86	50.86	50.76	44.59	44.56	44.56	44.52	43.4	43.39

Difference

	#																					
INDIVIDUAL	1	Remove Wareham St Dam	-0.21	-0.21	-0.26	-0.26	-0.46	-0.48	-0.49	-0.52	-0.67	-0.7	-1.13	-1.2	-1.71	-1.69	-6.24	-6.11	-6.08	-1.12	-1.54	-0.01
	2	Modify East Grove Bridge	-0.09	-0.09	-0.11	-0.11	-0.19	-0.2	-0.2	-0.22	-0.27	-0.28	-0.39	-0.4	-0.34	-0.2	-0.02	-0.03	0	0	0	0.01
	3	Modify I-495	-0.04	-0.04	-0.04	-0.04	-0.08	-0.08	-0.08	-0.08	-0.1	-0.11	-0.08	-0.01	0	0	-0.02	-0.03	0	0	0	0.01
	4	Modify MBTA Bridge	-0.06	-0.06	-0.07	-0.07	-0.13	-0.13	-0.13	-0.14	-0.06	-0.01	0	0	0	0	-0.02	-0.03	0	0	0	0.01
	5	Remove Old Bridge St.	-0.07	-0.07	-0.09	-0.09	-0.15	-0.15	-0.15	-0.11	0	-0.01	0	0	0	0	-0.02	-0.03	0	0	0	0.01
	6	Modify Vaughan Bridge	-0.06	-0.06	-0.05	-0.04	0	0	0	0	0	-0.01	0	0	0	0	-0.02	-0.03	0	0	0	0.01
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	0.01	0.01	0	0	0	0	0	0	0	-0.01	0	0	0	0	-0.02	-0.03	0	0	0	0.01
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	-0.21	-0.21	-0.26	-0.26	-0.46	-0.49	-0.5	-0.53	-0.68	-0.71	-1.15	-1.22	-1.79	-1.71	-6.23	-6.1	-6.07	-1.1	-1.54	-0.01
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	-0.26	-0.26	-0.33	-0.34	-0.61	-0.65	-0.67	-0.71	-0.75	-0.71	-1.13	-1.2	-1.71	-1.69	-6.24	-6.11	-6.08	-1.12	-1.54	-0.01
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	-0.27	-0.27	-0.34	-0.35	-0.64	-0.67	-0.69	-0.65	-0.67	-0.7	-1.13	-1.2	-1.71	-1.69	-6.23	-6.1	-6.07	-1.1	-1.54	-0.01
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	-0.32	-0.32	-0.41	-0.42	-0.81	-0.85	-0.88	-0.85	-0.76	-0.71	-1.15	-1.22	-1.79	-1.71	-6.23	-6.1	-6.07	-1.1	-1.54	-0.01

Legend:

Legend	
Existing WSE	
WSE higher than EX	WSE = EX (or diff <0.05)
WSE lower than EX (0.05-0.49)	WSE lower than EX (0.5-0.99)
WSE lower than EX (1.0-1.99)	WSE lower than EX (2.0+)

10 Year Flow Results

Group	#	Description	APC Dam Upstream WSE (ft)	APC Dam Downstream WSE (ft)	Vaughan St Bridge Upstream WSE (ft)	Vaughan St Bridge Downstream WSE (ft)	Bridge St Bridge Upstream WSE (ft)	Bridge St Bridge Downstream WSE (ft)	Old Bridge St Bridge Upstream WSE (ft)	Old Bridge St Bridge Downstream WSE (ft)	MBTA Bridge Upstream WSE (ft)	MBTA Bridge Downstream WSE (ft)	I-495 Bridge Upstream WSE (ft)	I-495 Bridge Downstream WSE (ft)	East Grove Street Bridge Upstream WSE (ft)	East Grove Street Bridge Downstream WSE (ft)	Wareham St Culvert Upstream WSE (ft)	Wareham St Culvert Downstream WSE (ft)	Wareham Bascule Dam Upstream WSE (ft)	Wareham Bascule Dam Downstream WSE (ft)	Wareham Weir Upstream WSE (ft)	Wareham Weir Downstream WSE (ft)
		River STN:	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
	0	EX	55.9	55.89	55.73	55.68	55.29	55.18	55.06	54.91	54.64	54.57	54.29	54.17	53.75	53.52	51.94	51.65	51.62	46.18	44.86	44
	Channel	Modify APC Outlet Channel	55.91	55.9	55.73	55.68	55.29	55.18	55.06	54.91	54.64	54.57	54.29	54.17	53.75	53.52	51.94	51.65	51.62	46.18	44.86	44
INDIVIDUAL	1	Remove Wareham St Dam	55.6	55.59	55.39	55.33	54.81	54.67	54.55	54.47	53.87	53.73	53.19	52.98	52.31	52.1	45.62	45.58	45.58	45.52	43.99	43.98
INDIVIDUAL	1C	Remove Wareham Dam AND modify channel at APC	55.61	55.61	55.39	55.33	54.81	54.67	54.55	54.47	53.87	53.73	53.19	52.98	52.31	52.1	45.62	45.58	45.58	45.52	43.99	43.98
INDIVIDUAL	2	Modify East Grove Bridge	55.77	55.76	55.58	55.53	55.09	54.97	54.86	54.85	54.29	54.2	53.85	53.7	53.35	53.29	51.91	51.62	51.62	46.18	44.86	44
INDIVIDUAL	3	Modify I-495	55.86	55.85	55.68	55.64	55.23	55.11	55.01	55	54.48	54.4	54.17	54.14	53.74	53.51	51.91	51.62	51.62	46.18	44.86	44
INDIVIDUAL	4	Modify MBTA Bridge	55.82	55.81	55.64	55.59	55.17	55.05	54.95	54.94	54.54	54.53	54.28	54.16	53.74	53.51	51.91	51.62	51.62	46.18	44.86	44
INDIVIDUAL	5	Remove Old Bridge St.	55.77	55.77	55.59	55.54	55.09	54.98	54.91	54.91	54.63	54.56	54.28	54.16	53.74	53.51	51.91	51.62	51.62	46.18	44.86	44
INDIVIDUAL	6	Modify Vaughan Bridge	55.79	55.79	55.63	55.6	55.28	55.17	55.06	54.91	54.63	54.56	54.28	54.16	53.74	53.51	51.91	51.62	51.62	46.18	44.86	44
INDIVIDUAL	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	55.9	55.9	55.73	55.68	55.28	55.17	55.06	54.91	54.63	54.56	54.28	54.16	53.74	53.51	51.91	51.62	51.62	46.18	44.86	44
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	55.59	55.58	55.38	55.32	54.79	54.65	54.53	54.45	53.81	53.7	53.14	52.93	52.19	52.09	45.6	45.57	45.57	45.5	43.99	43.98
COMBO	1/2 C	Wareham Dam, E Grove, APC Channel	55.6	55.6	55.38	55.32	54.79	54.65	54.53	54.45	53.81	53.7	53.14	52.93	52.19	52.09	45.6	45.57	45.57	45.5	43.99	43.98
COMBO	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	55.49	55.49	55.26	55.2	54.61	54.45	54.33	54.23	53.72	53.71	53.19	52.98	52.31	52.1	45.62	45.58	45.58	45.52	43.99	43.98
COMBO	1/4 C	Wareham Dam, MBTA, APC Channel	55.51	55.5	55.26	55.2	54.61	54.45	54.33	54.23	53.72	53.71	53.19	52.98	52.31	52.1	45.62	45.58	45.58	45.52	43.99	43.98
COMBO	1/5	Remove Wareham St Dam AND modify (Old Bridge)	55.45	55.44	55.2	55.14	54.52	54.36	54.25	54.25	53.84	53.73	53.19	52.98	52.31	52.1	45.6	45.57	45.57	45.5	43.99	43.98
COMBO	1/5 C	Wareham Dam, Old Bridge, APC Channel	55.47	55.46	55.2	55.14	54.52	54.36	54.25	54.25	53.84	53.73	53.19	52.98	52.31	52.1	45.6	45.57	45.57	45.5	43.99	43.98
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	55.34	55.34	55.07	55.01	54.28	54.1	53.98	53.97	53.69	53.68	53.14	52.93	52.19	52.09	45.6	45.57	45.57	45.5	43.99	43.98
OPTIMAL	1/2/4/5 C	Wareham Dam, Old Bridge, MBTA, E Grove, APC Channel	55.37	55.36	55.07	55.01	54.28	54.1	53.98	53.97	53.69	53.68	53.14	52.93	52.19	52.09	45.6	45.57	45.57	45.5	43.99	43.98

Difference

Group	#	Description	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
INDIVIDUAL	1	Remove Wareham St Dam	**-0.3**	**-0.3**	**-0.34**	**-0.35**	**-0.48**	**-0.51**	**-0.51**	**-0.44**	**-0.77**	**-0.84**	**-1.1**	**-1.19**	**-1.44**	**-1.42**	**-6.32**	**-6.07**	**-6.04**	**-0.66**	**-0.87**	-0.02
INDIVIDUAL	2	Modify East Grove Bridge	**-0.13**	**-0.13**	**-0.15**	**-0.15**	**-0.2**	**-0.21**	**-0.2**	**-0.06**	**-0.35**	**-0.37**	**-0.44**	**-0.47**	**-0.4**	**-0.23**	-0.03	-0.03	0	0	0	0
INDIVIDUAL	3	Modify I-495	-0.04	-0.04	**-0.05**	-0.04	**-0.06**	**-0.07**	**-0.05**	0.09	**-0.16**	**-0.17**	**-0.12**	-0.03	-0.01	-0.01	-0.03	-0.03	0	0	0	0
INDIVIDUAL	4	Modify MBTA Bridge	**-0.08**	**-0.08**	**-0.09**	**-0.09**	**-0.12**	**-0.13**	**-0.11**	0.03	**-0.1**	-0.04	-0.01	-0.01	-0.01	-0.01	-0.03	-0.03	0	0	0	0
INDIVIDUAL	5	Remove Old Bridge St.	**-0.13**	**-0.12**	**-0.14**	**-0.14**	**-0.2**	**-0.2**	**-0.15**	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.03	0	0	0	0
INDIVIDUAL	6	Modify Vaughan Bridge	**-0.11**	**-0.1**	**-0.1**	**-0.08**	-0.01	-0.01	0	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.03	0	0	0	0
INDIVIDUAL	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	0	0.01	0	0	-0.01	-0.01	0	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.03	0	0	0	0
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	**-0.31**	**-0.31**	**-0.35**	**-0.36**	**-0.5**	**-0.53**	**-0.53**	**-0.46**	**-0.83**	**-0.87**	**-1.15**	**-1.24**	**-1.56**	**-1.43**	**-6.34**	**-6.08**	**-6.05**	**-0.68**	**-0.87**	-0.02
COMBO	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	**-0.41**	**-0.4**	**-0.47**	**-0.48**	**-0.68**	**-0.73**	**-0.73**	**-0.68**	**-0.92**	**-0.86**	**-1.1**	**-1.19**	**-1.44**	**-1.42**	**-6.32**	**-6.07**	**-6.04**	**-0.66**	**-0.87**	-0.02
COMBO	1/5	Remove Wareham St Dam AND modify (Old Bridge)	**-0.45**	**-0.45**	**-0.53**	**-0.54**	**-0.77**	**-0.82**	**-0.81**	**-0.66**	**-0.8**	**-0.84**	**-1.1**	**-1.19**	**-1.44**	**-1.42**	**-6.34**	**-6.08**	**-6.05**	**-0.68**	**-0.87**	-0.02
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Brid	**-0.56**	**-0.55**	**-0.66**	**-0.67**	**-1.01**	**-1.08**	**-1.08**	**-0.94**	**-0.95**	**-0.89**	**-1.15**	**-1.24**	**-1.56**	**-1.43**	**-6.34**	**-6.08**	**-6.05**	**-0.68**	**-0.87**	-0.02

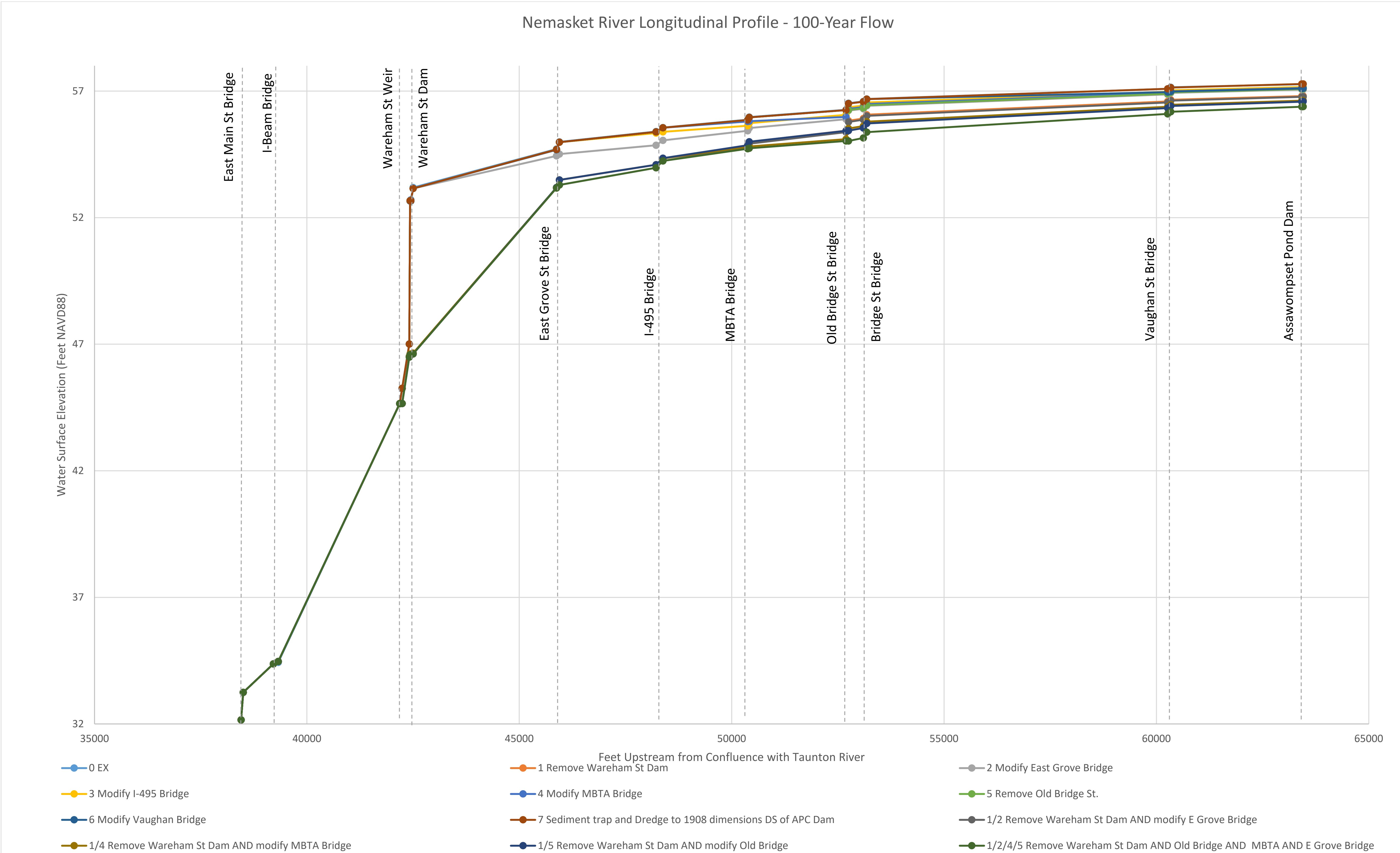
Legend:

Legend	
Existing WSE	
WSE higher than EX	WSE = EX (or diff <0.05)
WSE lower than EX (0.05-0.49)	WSE lower than EX (0.5-0.99)
WSE lower than EX (1.0-1.99)	WSE lower than EX (2.0+)

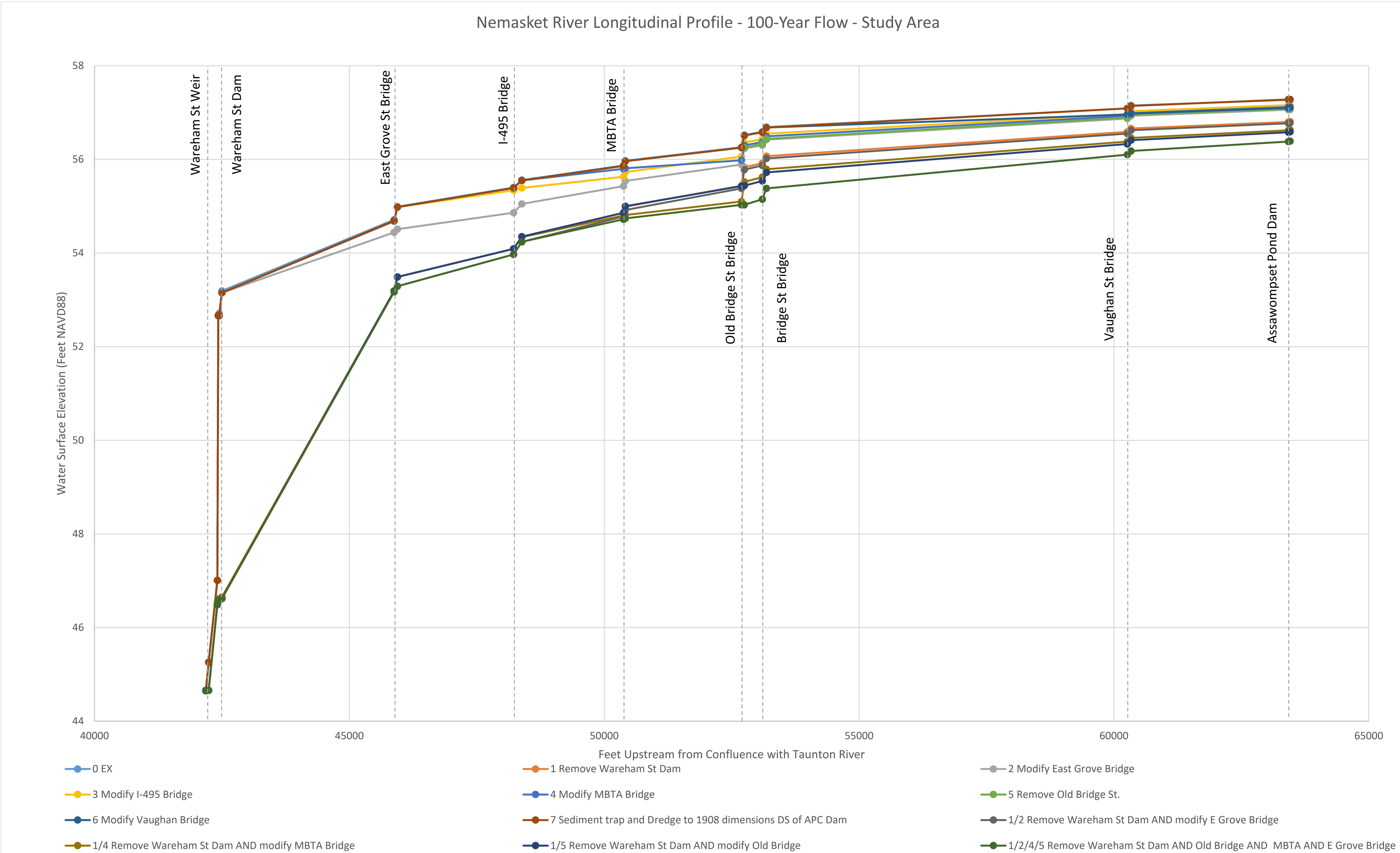
100 Year Flow Results

			APC Dam		Vaughan St Bridge		Bridge St Bridge		Old Bridge St Bridge		MBTA Bridge		I-495 Bridge		East Grove Street Bridge		Wareham St Culvert		Wareham Bascule Dam		Wareham Weir	
		River STN:	63456	63424	60336	60264	53181	53100	52749	52693	50415	50378	48383	48220	45944	45876	42500	42445	42429	42411	42241	42184
	#		Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)	Upstream WSE (ft)	Downstream WSE (ft)
	0	EX	57.27	57.27	57.15	57.09	56.69	56.59	56.52	56.26	55.97	55.87	55.56	55.4	54.99	54.71	53.19	52.71	52.67	47.01	45.25	44.66
	Channel	Modify APC Outlet Channel	57.28	57.27	57.15	57.09	56.69	56.59	56.52	56.26	55.97	55.87	55.56	55.4	54.99	54.71	53.19	52.71	52.67	47.01	45.25	44.66
INDIVIDUAL	1	Remove Wareham St Dam	56.81	56.8	56.66	56.59	56.07	55.92	55.83	55.44	54.99	54.86	54.34	54.09	53.49	53.19	46.65	46.61	46.61	46.52	44.66	44.65
	1C	Remove Wareham Dam AND modify channel at APC	56.82	56.81	56.66	56.59	56.07	55.92	55.83	55.44	54.99	54.86	54.34	54.09	53.49	53.19	46.65	46.61	46.61	46.52	44.66	44.65
	2	Modify East Grove Bridge	57.06	57.06	56.93	56.87	56.42	56.3	56.23	55.89	55.54	55.43	55.05	54.86	54.51	54.44	53.15	52.66	52.66	47.01	45.26	44.66
	3	Modify I-495 Bridge	57.16	57.16	57.03	56.97	56.55	56.43	56.36	56.06	55.73	55.63	55.39	55.34	54.98	54.69	53.15	52.66	52.66	47.01	45.26	44.66
	4	Modify MBTA Bridge	57.12	57.12	56.99	56.93	56.49	56.37	56.3	55.98	55.81	55.8	55.55	55.39	54.98	54.69	53.15	52.66	52.66	47.01	45.26	44.66
	5	Remove Old Bridge St.	57.09	57.08	56.95	56.89	56.44	56.33	56.25	56.25	55.96	55.86	55.55	55.39	54.98	54.69	53.15	52.66	52.66	47.01	45.26	44.66
	6	Modify Vaughan Bridge	57.11	57.1	56.98	56.96	56.68	56.58	56.51	56.25	55.96	55.86	55.55	55.39	54.98	54.68	53.15	52.66	52.66	47.01	45.26	44.66
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	57.28	57.28	57.14	57.09	56.68	56.58	56.51	56.25	55.96	55.86	55.55	55.39	54.98	54.69	53.15	52.67	52.67	47.01	45.26	44.66
COMBO	1/2	Remove Wareham St Dam AND modify E Grove Bridge	56.78	56.77	56.62	56.55	56.02	55.87	55.78	55.38	54.92	54.78	54.24	53.97	53.29	53.17	46.62	46.58	46.58	46.49	44.66	44.65
	1/2 C	Wareham Dam, E Grove, APC Channel	56.78	56.78	56.62	56.55	56.02	55.87	55.78	55.38	54.92	54.78	54.24	53.97	53.29	53.17	46.62	46.58	46.58	46.49	44.66	44.65
	1/4	Remove Wareham St Dam AND modify MBTA Bridge	56.63	56.62	56.46	56.38	55.79	55.62	55.52	55.1	54.81	54.8	54.34	54.09	53.49	53.19	46.65	46.61	46.61	46.52	44.66	44.65
	1/4 C	Wareham Dam, MBTA, APC Channel	56.64	56.63	56.46	56.38	55.79	55.62	55.52	55.1	54.81	54.8	54.34	54.09	53.49	53.19	46.65	46.61	46.61	46.52	44.66	44.65
	1/5	Remove Wareham St Dam AND modify Old Bridge	56.59	56.58	56.41	56.33	55.72	55.54	55.44	55.43	55	54.86	54.35	54.09	53.49	53.19	46.62	46.58	46.58	46.49	44.66	44.65
	1/5 C	Wareham Dam, Old Bridge, APC Channel	56.6	56.59	56.41	56.33	55.72	55.54	55.44	55.43	55	54.86	54.35	54.09	53.49	53.19	46.62	46.58	46.58	46.49	44.66	44.65
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND Old Bridge AND MBTA AND E Grove Bridge	56.39	56.38	56.18	56.1	55.38	55.15	55.03	55.03	54.74	54.72	54.24	53.97	53.29	53.17	46.62	46.58	46.58	46.49	44.66	44.65
	1/2/4/5 C	Wareham Dam, Old Bridge, MBTA, E Grove, APC Channel	56.4	56.39	56.18	56.1	55.38	55.15	55.03	55.03	54.74	54.72	54.24	53.97	53.29	53.17	46.62	46.58	46.58	46.49	44.66	44.65
		Difference																				
INDIVIDUAL	1	Remove Wareham St Dam	**-0.46**	**-0.47**	**-0.49**	**-0.5**	**-0.62**	**-0.67**	**-0.69**	**-0.82**	**-0.98**	**-1.01**	**-1.22**	**-1.31**	**-1.5**	**-1.52**	**-6.54**	**-6.1**	**-6.06**	**-0.49**	**-0.59**	-0.01
	2	Modify East Grove Bridge	**-0.21**	**-0.21**	**-0.22**	**-0.22**	**-0.27**	**-0.29**	**-0.29**	**-0.37**	**-0.43**	**-0.44**	**-0.51**	**-0.54**	**-0.48**	**-0.27**	-0.04	-0.05	-0.01	0	0.01	0
	3	Modify I-495	**-0.11**	**-0.11**	**-0.12**	**-0.12**	**-0.14**	**-0.16**	**-0.16**	**-0.2**	**-0.24**	**-0.24**	**-0.17**	**-0.06**	-0.01	-0.02	-0.04	-0.05	-0.01	0	0.01	0
	4	Modify MBTA Bridge	**-0.15**	**-0.15**	**-0.16**	**-0.16**	**-0.2**	**-0.22**	**-0.22**	**-0.28**	**-0.16**	**-0.07**	-0.01	-0.01	-0.01	-0.02	-0.04	-0.05	-0.01	0	0.01	0
	5	Remove Old Bridge St.	**-0.18**	**-0.19**	**-0.2**	**-0.2**	**-0.25**	**-0.26**	**-0.27**	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.04	-0.05	-0.01	0	0.01	0
	6	Modify Vaughan Bridge	**-0.16**	**-0.17**	**-0.17**	**-0.13**	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.03	-0.04	-0.05	-0.01	0	0.01	0
	7	Ex. APC Dam, Silt trap and Dredge to 1908 dimensions	0.01	0.01	-0.01	0	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.04	-0.04	0	0	0.01	0
COMBO	1/2	Remove Wareham St Dam AND modify (E Grove Bridge)	**-0.49**	**-0.5**	**-0.53**	**-0.54**	**-0.67**	**-0.72**	**-0.74**	**-0.88**	**-1.05**	**-1.09**	**-1.32**	**-1.43**	**-1.7**	**-1.54**	**-6.57**	**-6.13**	**-6.09**	**-0.52**	**-0.59**	-0.01
	1/4	Remove Wareham St Dam AND modify (MBTA Bridge)	**-0.64**	**-0.65**	**-0.69**	**-0.71**	**-0.9**	**-0.97**	**-1**	**-1.16**	**-1.16**	**-1.07**	**-1.22**	**-1.31**	**-1.5**	**-1.52**	**-6.54**	**-6.1**	**-6.06**	**-0.49**	**-0.59**	-0.01
	1/5	Remove Wareham St Dam AND modify (Old Bridge)	**-0.68**	**-0.69**	**-0.74**	**-0.76**	**-0.97**	**-1.05**	**-1.08**	**-0.83**	**-0.97**	**-1.01**	**-1.21**	**-1.31**	**-1.5**	**-1.52**	**-6.57**	**-6.13**	**-6.09**	**-0.52**	**-0.59**	-0.01
OPTIMAL	1/2/4/5	Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Bri	**-0.88**	**-0.89**	**-0.97**	**-0.99**	**-1.31**	**-1.44**	**-1.49**	**-1.23**	**-1.23**	**-1.15**	**-1.32**	**-1.43**	**-1.7**	**-1.54**	**-6.57**	**-6.13**	**-6.09**	**-0.52**	**-0.59**	-0.01

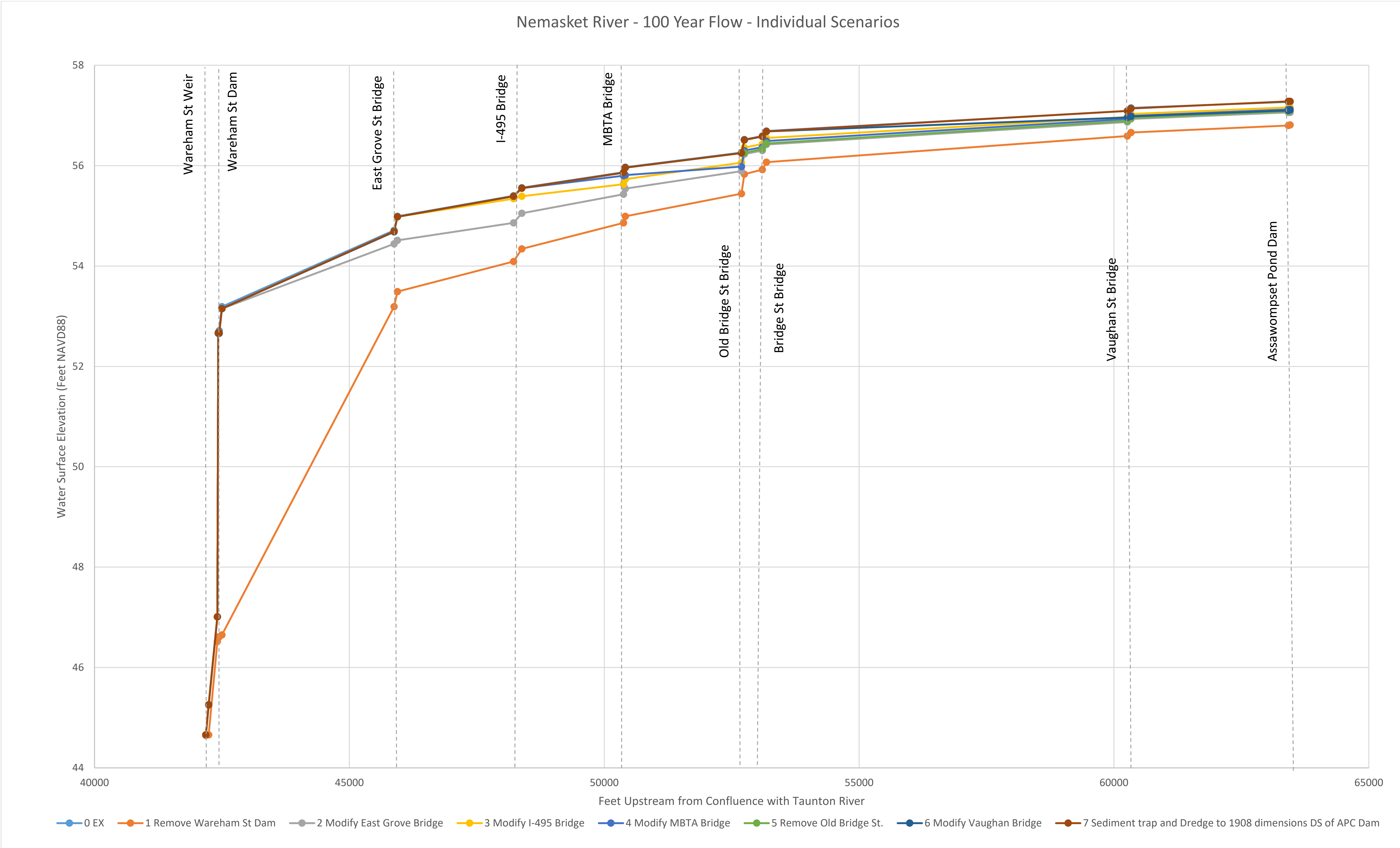
ATTACHMENT B – EXISTING AND PROPOSED WATER SURFACE LONGITUDINAL PROFILES



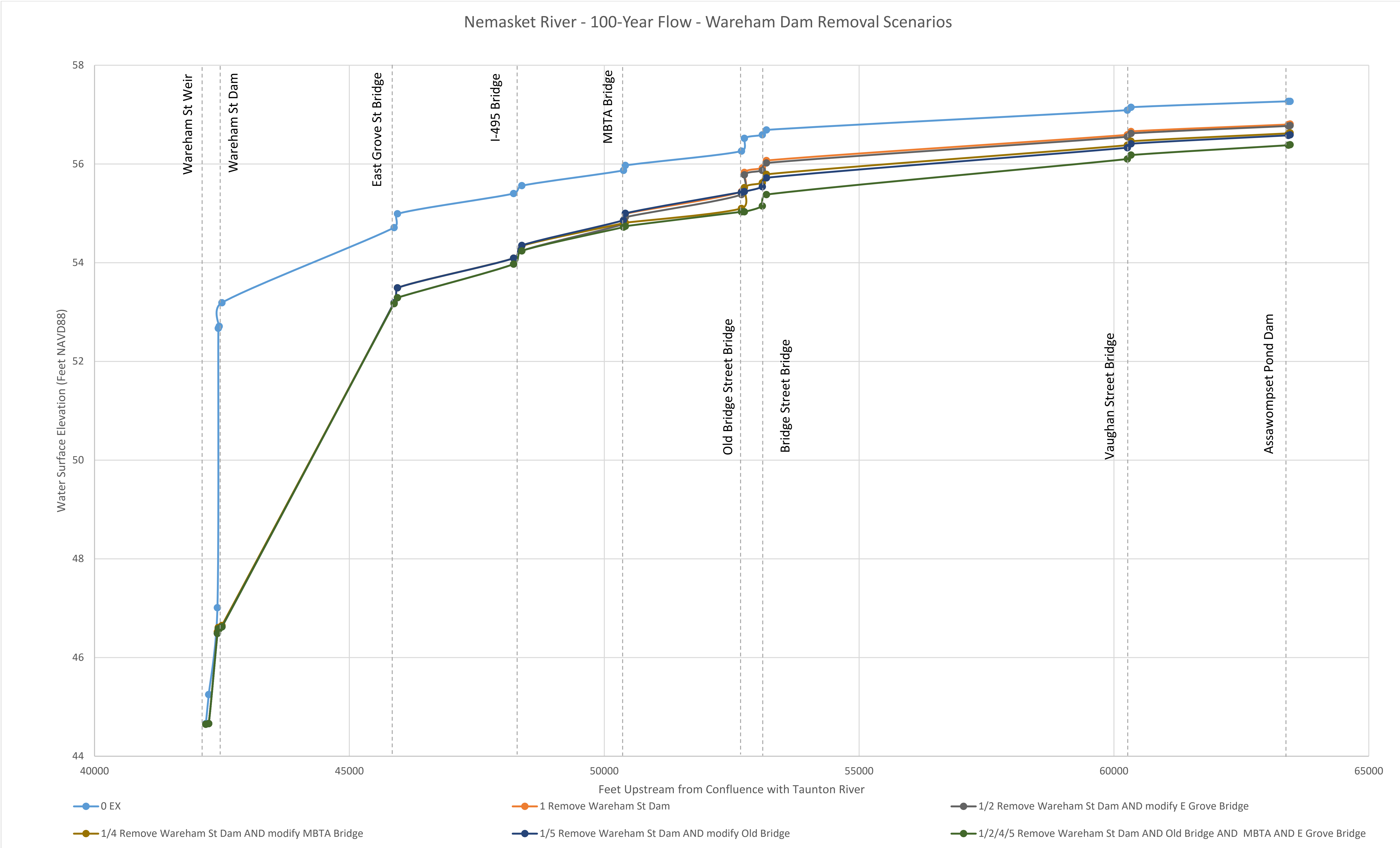
Nemasket River Longitudinal Profile - 100-Year Flow
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
32
37
42
47
52
57
35000
40000
45000
50000
55000
60000
65000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
1 Remove Wareham St Dam
2 Modify East Grove Bridge
3 Modify I-495 Bridge
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge
7 Sediment trap and Dredge to 1908 dimensions DS of APC Dam
1/2 Remove Wareham St Dam AND modify E Grove Bridge
1/4 Remove Wareham St Dam AND modify MBTA Bridge
1/5 Remove Wareham St Dam AND modify Old Bridge
1/2/4/5 Remove Wareham St Dam AND Old Bridge AND MBTA AND E Grove Bridge



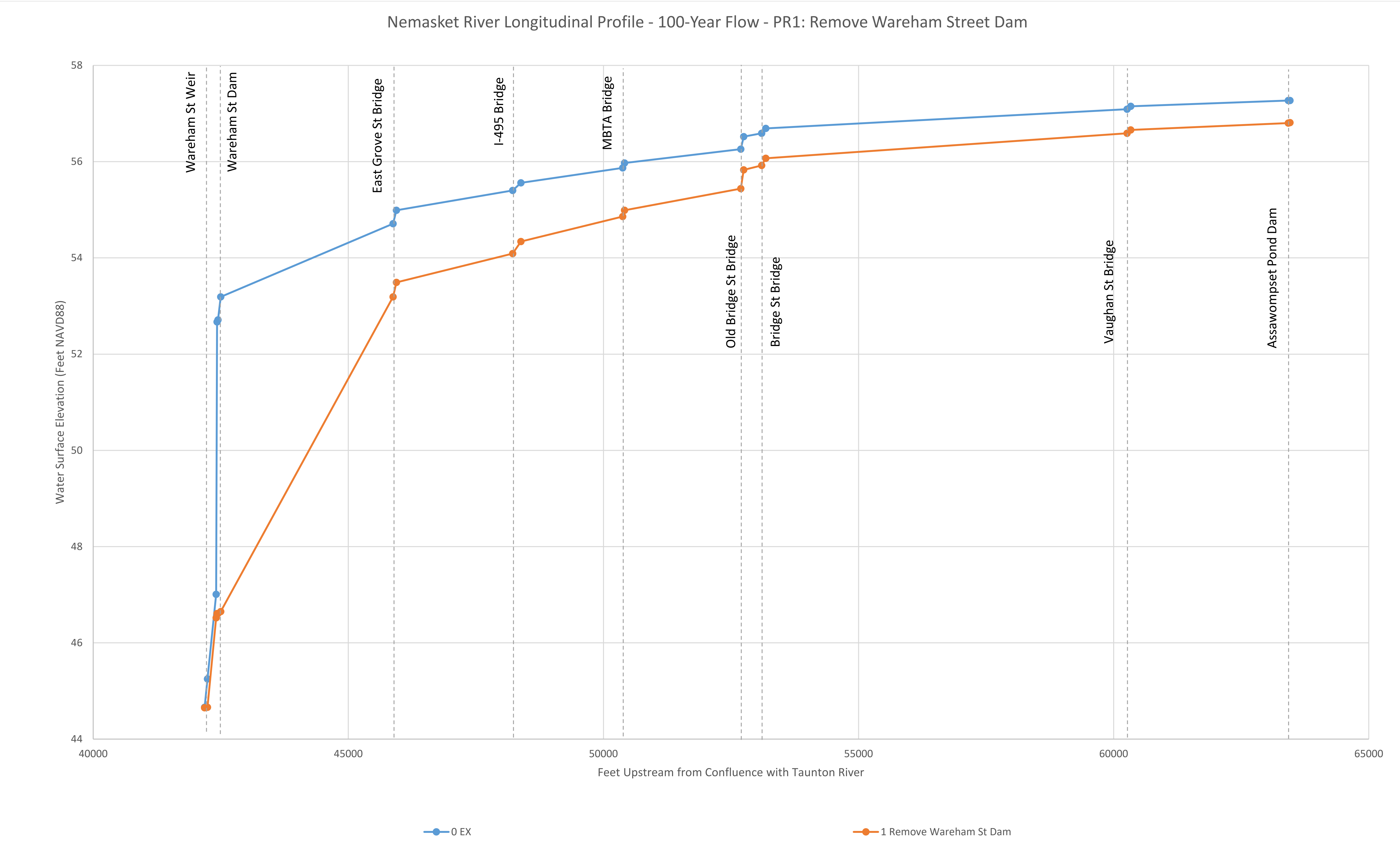
Nemasket River Longitudinal Profile - 100-Year Flow - Study Area
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
1 Remove Wareham St Dam
2 Modify East Grove Bridge
3 Modify I-495 Bridge
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge
7 Sediment trap and Dredge to 1908 dimensions DS of APC Dam
1/2 Remove Wareham St Dam AND modify E Grove Bridge
1/4 Remove Wareham St Dam AND modify MBTA Bridge
1/5 Remove Wareham St Dam AND modify Old Bridge
1/2/4/5 Remove Wareham St Dam AND Old Bridge AND MBTA AND E Grove Bridge



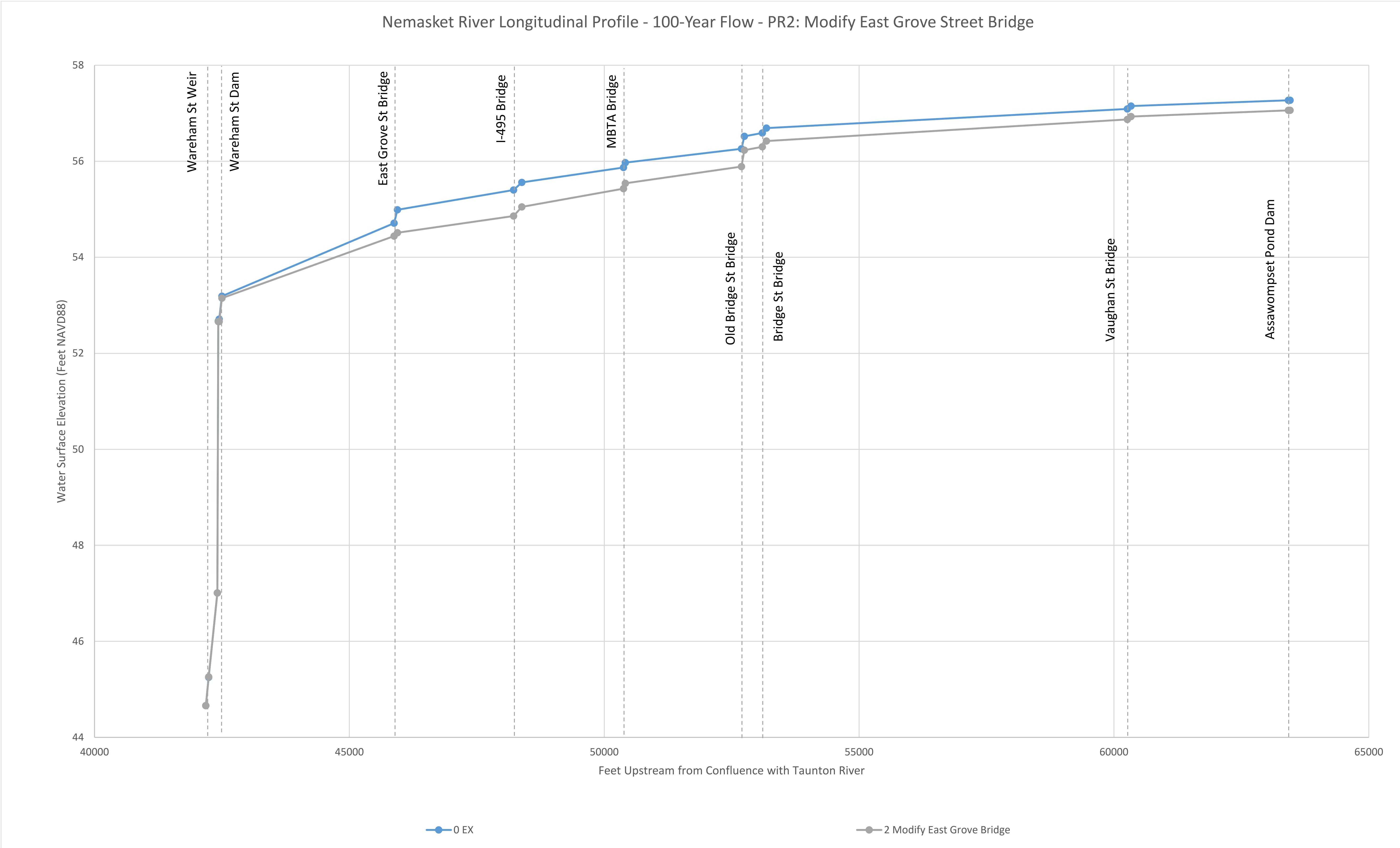
Nemasket River - 100 Year Flow - Individual Scenarios
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
0 EX
1 Remove Wareham St Dam
2 Modify East Grove Bridge
3 Modify I-495 Bridge
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge
7 Sediment trap and Dredge to 1908 dimensions DS of APC Dam

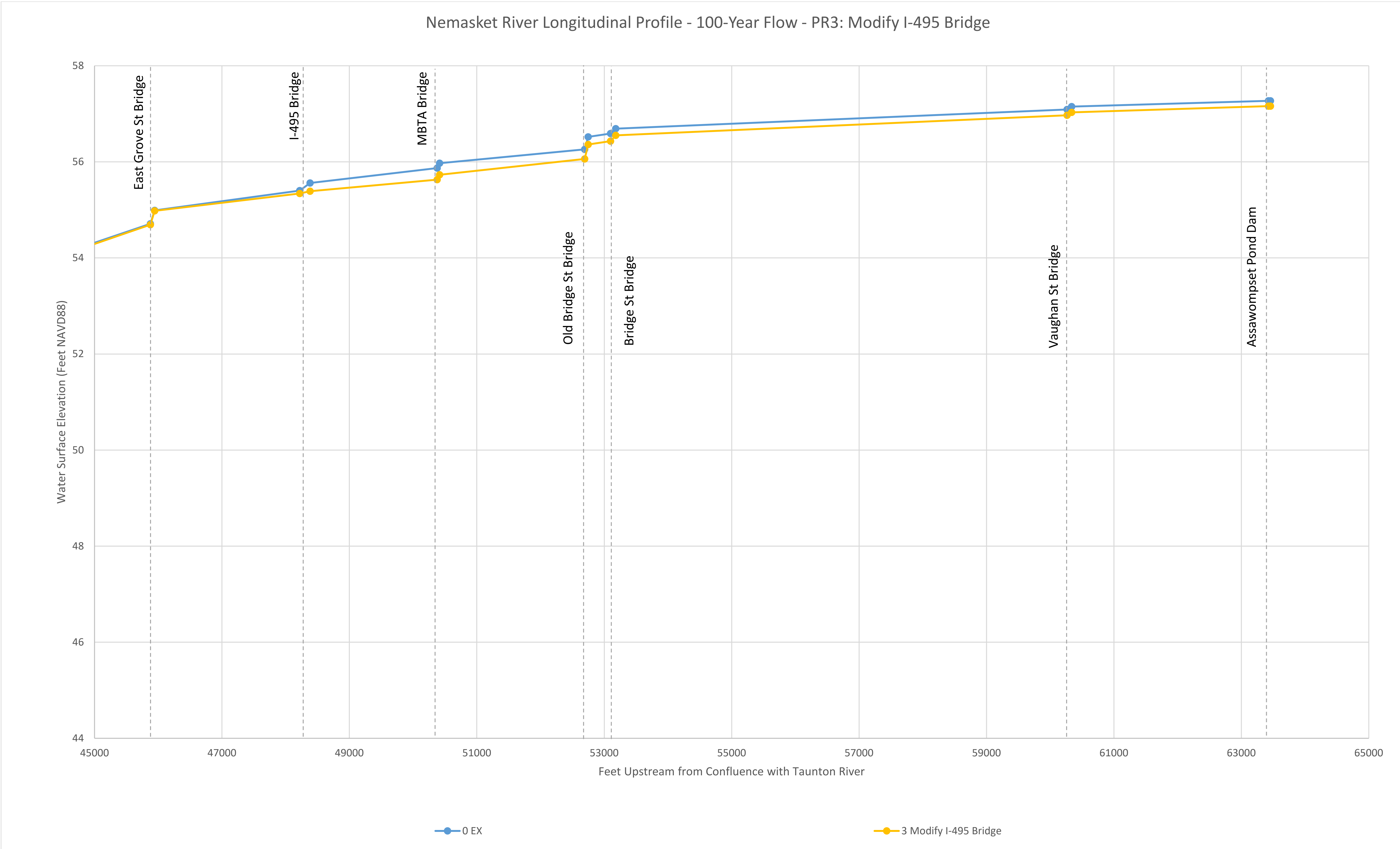


Nemasket River - 100-Year Flow - Wareham Dam Removal Scenarios
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge Street Bridge
Bridge Street Bridge
Vaughan Street Bridge
Assawompset Pond Dam
0 EX
1 Remove Wareham St Dam
1/2 Remove Wareham St Dam AND modify E Grove Bridge
1/4 Remove Wareham St Dam AND modify MBTA Bridge
1/5 Remove Wareham St Dam AND modify Old Bridge
1/2/4/5 Remove Wareham St Dam AND Old Bridge AND MBTA AND E Grove Bridge

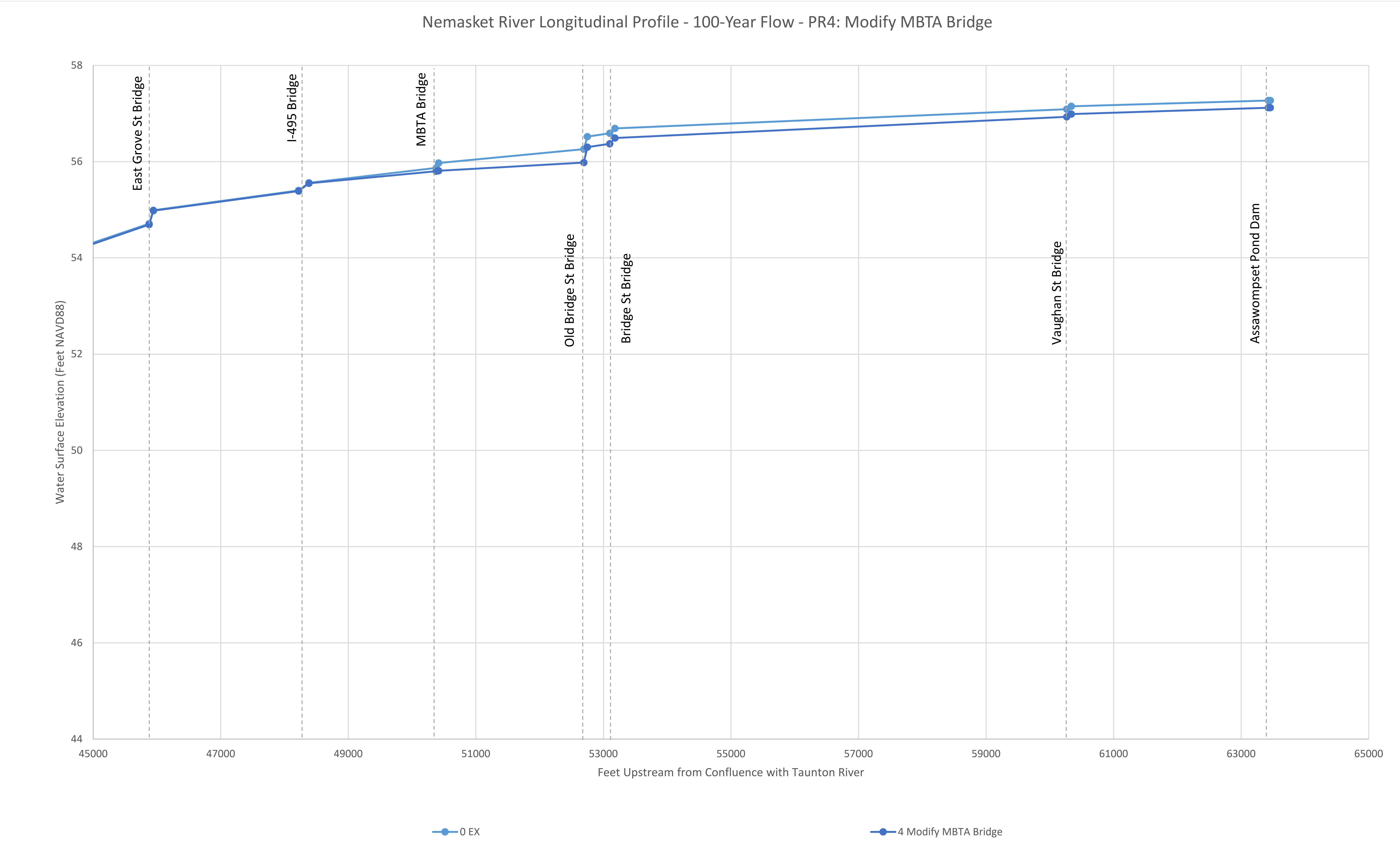


Nemasket River Longitudinal Profile - 100-Year Flow - PR1: Remove Wareham Street Dam
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
44
46
48
50
52
54
56
58
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
1 Remove Wareham St Dam

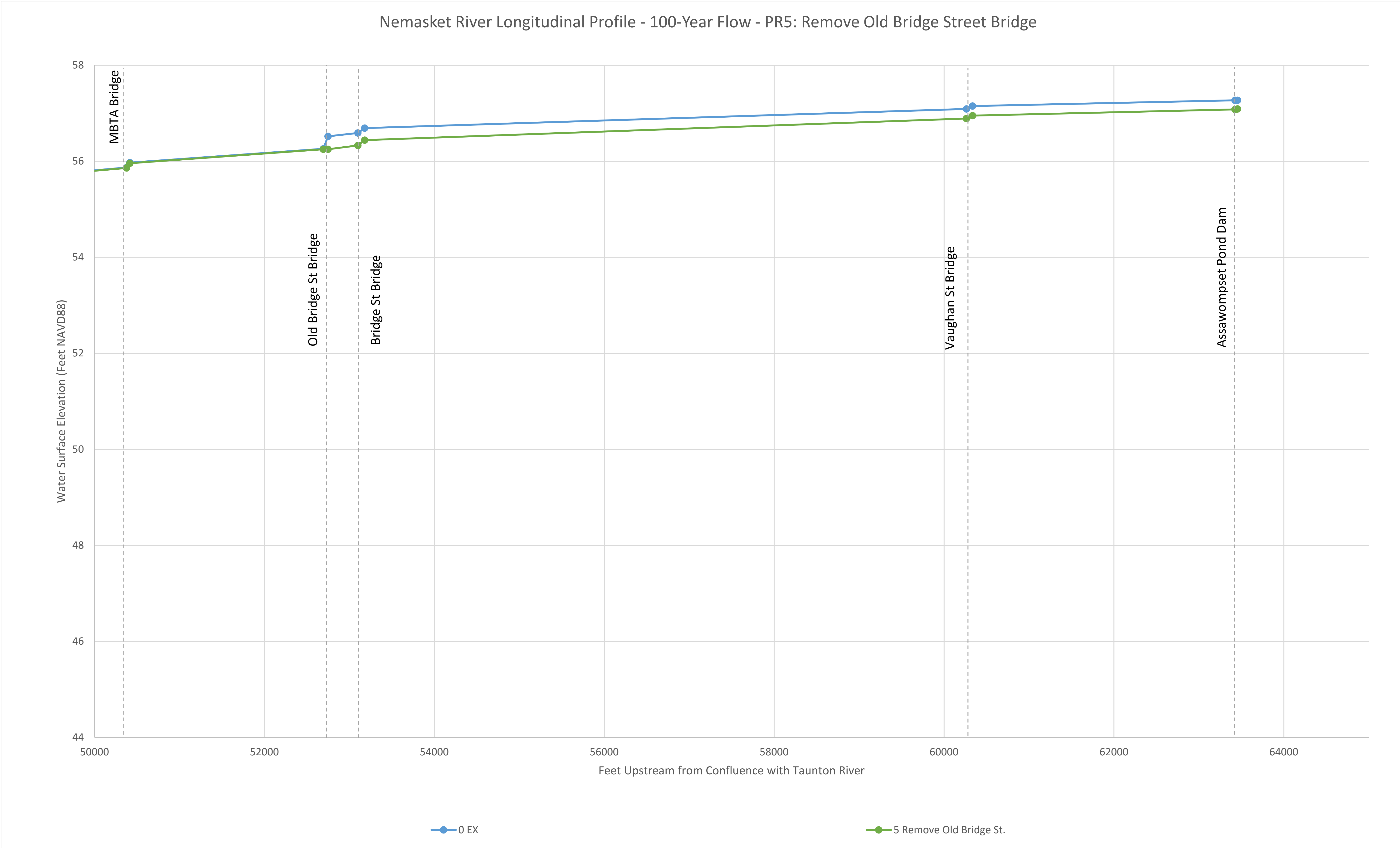

Nemasket River Longitudinal Profile - 100-Year Flow - PR2: Modify East Grove Street Bridge
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
0 EX
2 Modify East Grove Bridge



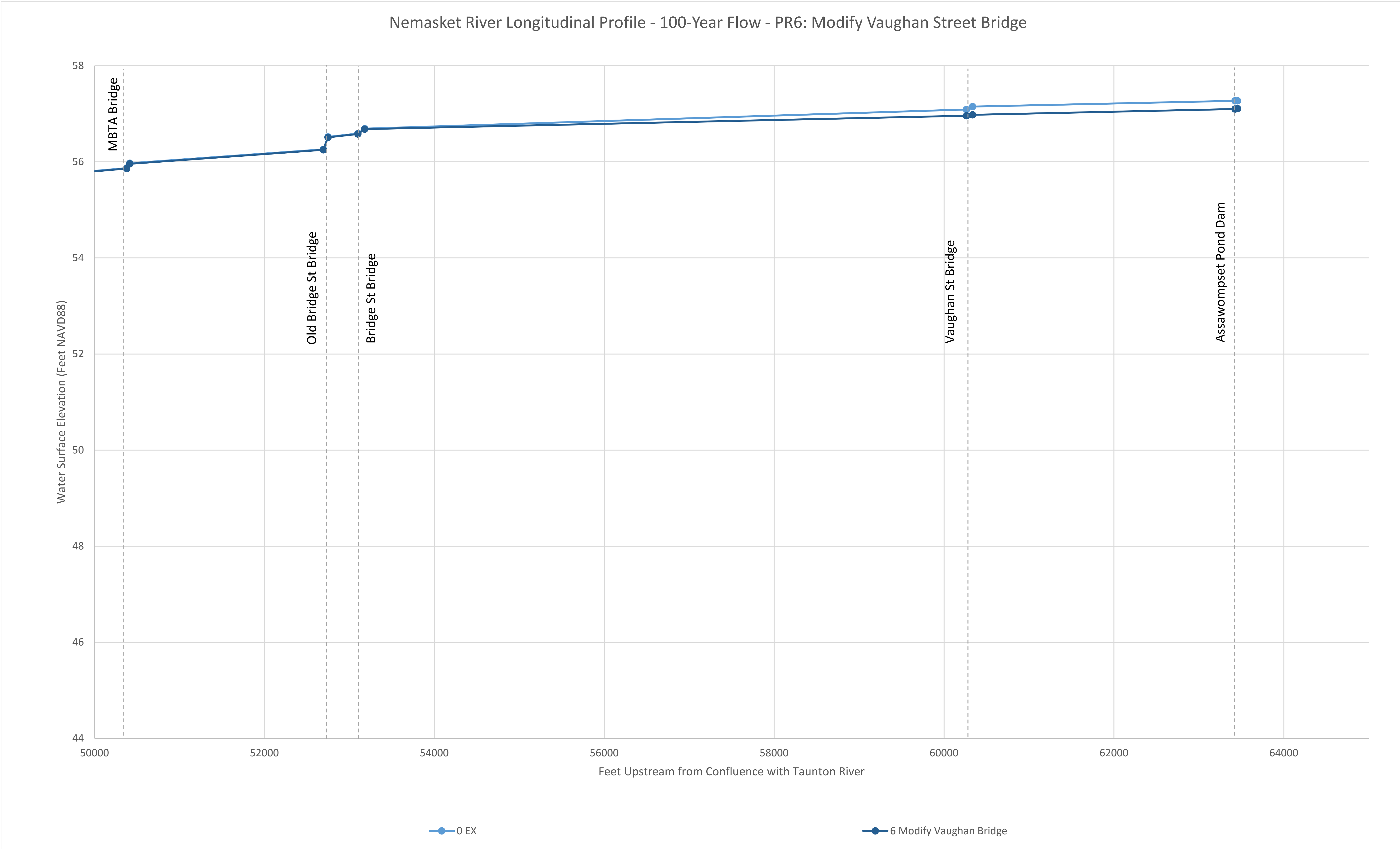
Nemasket River Longitudinal Profile - 100-Year Flow - PR3: Modify I-495 Bridge
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
58
56
54
52
50
48
46
44
45000
47000
49000
51000
53000
55000
57000
59000
61000
63000
65000
0 EX
3 Modify I-495 Bridge



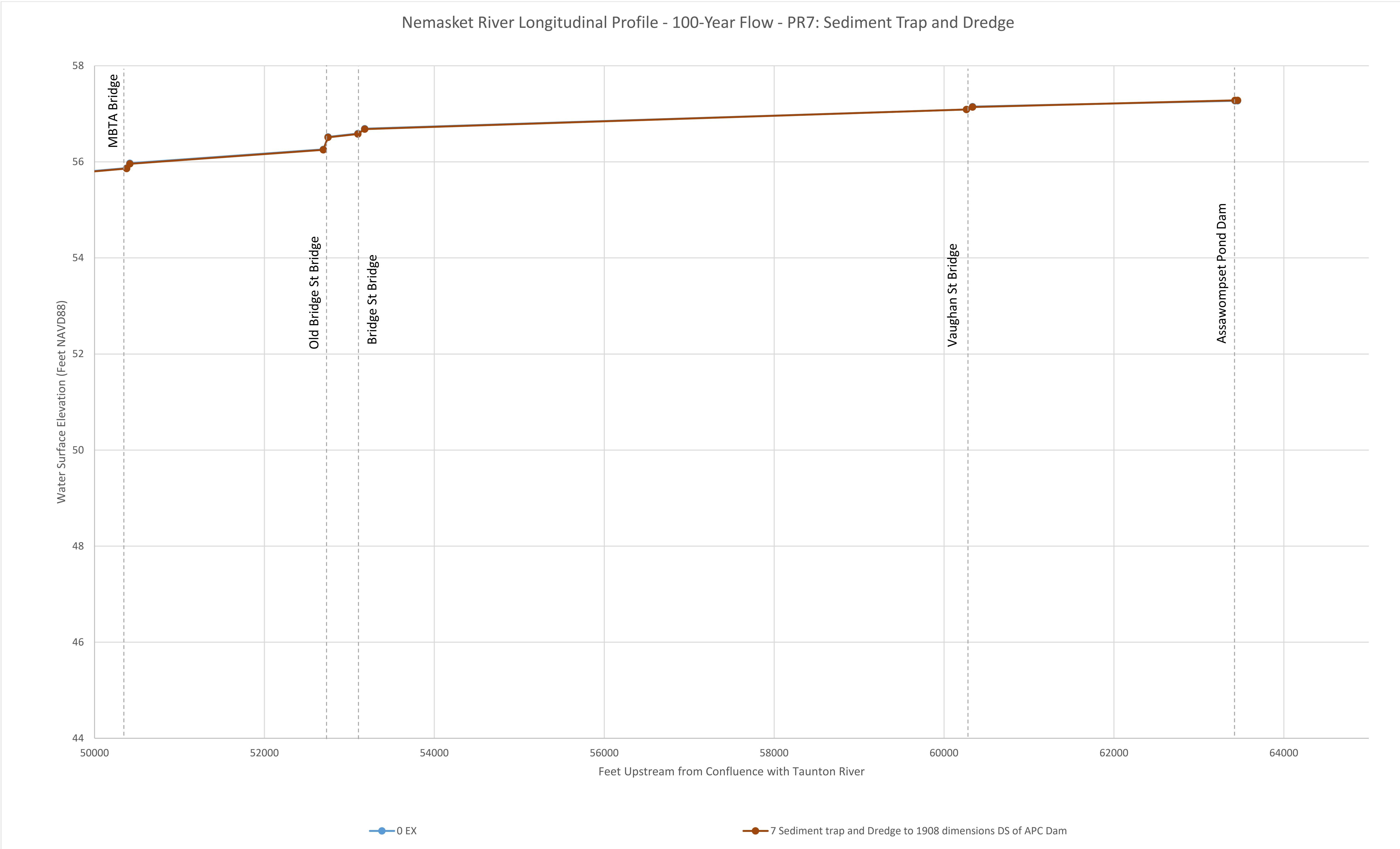
Nemasket River Longitudinal Profile - 100-Year Flow - PR4: Modify MBTA Bridge
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
58
56
54
52
50
48
46
44
45000
47000
49000
51000
53000
55000
57000
59000
61000
63000
65000
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
4 Modify MBTA Bridge

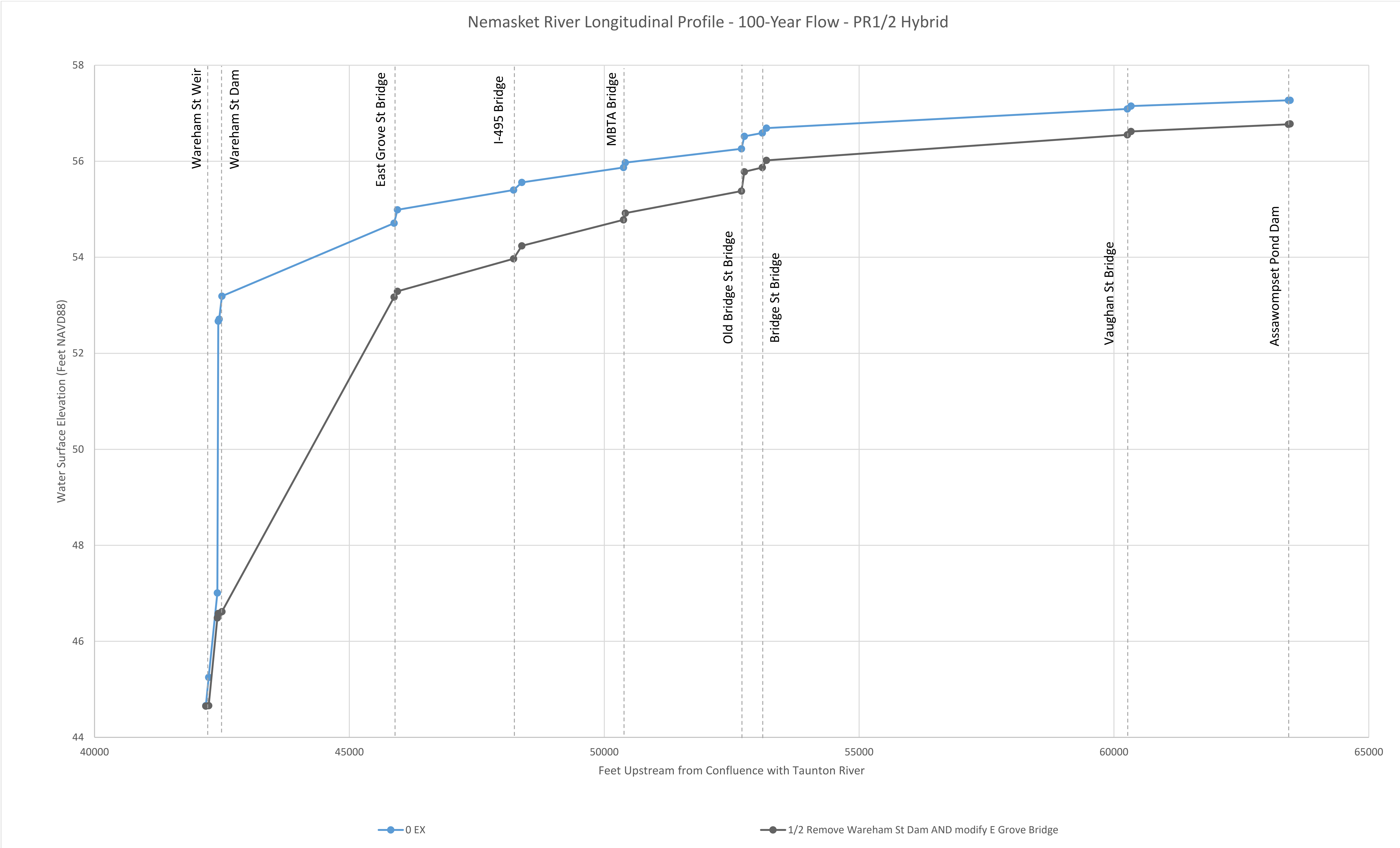


Nemasket River Longitudinal Profile - 100-Year Flow - PR5: Remove Old Bridge Street Bridge
Water Surface Elevation (Feet NAVD88)
58
56
54
52
50
48
46
44
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
50000
52000
54000
56000
58000
60000
62000
64000
Feet Upstream from Confluence with Taunton River
0 EX
5 Remove Old Bridge St.

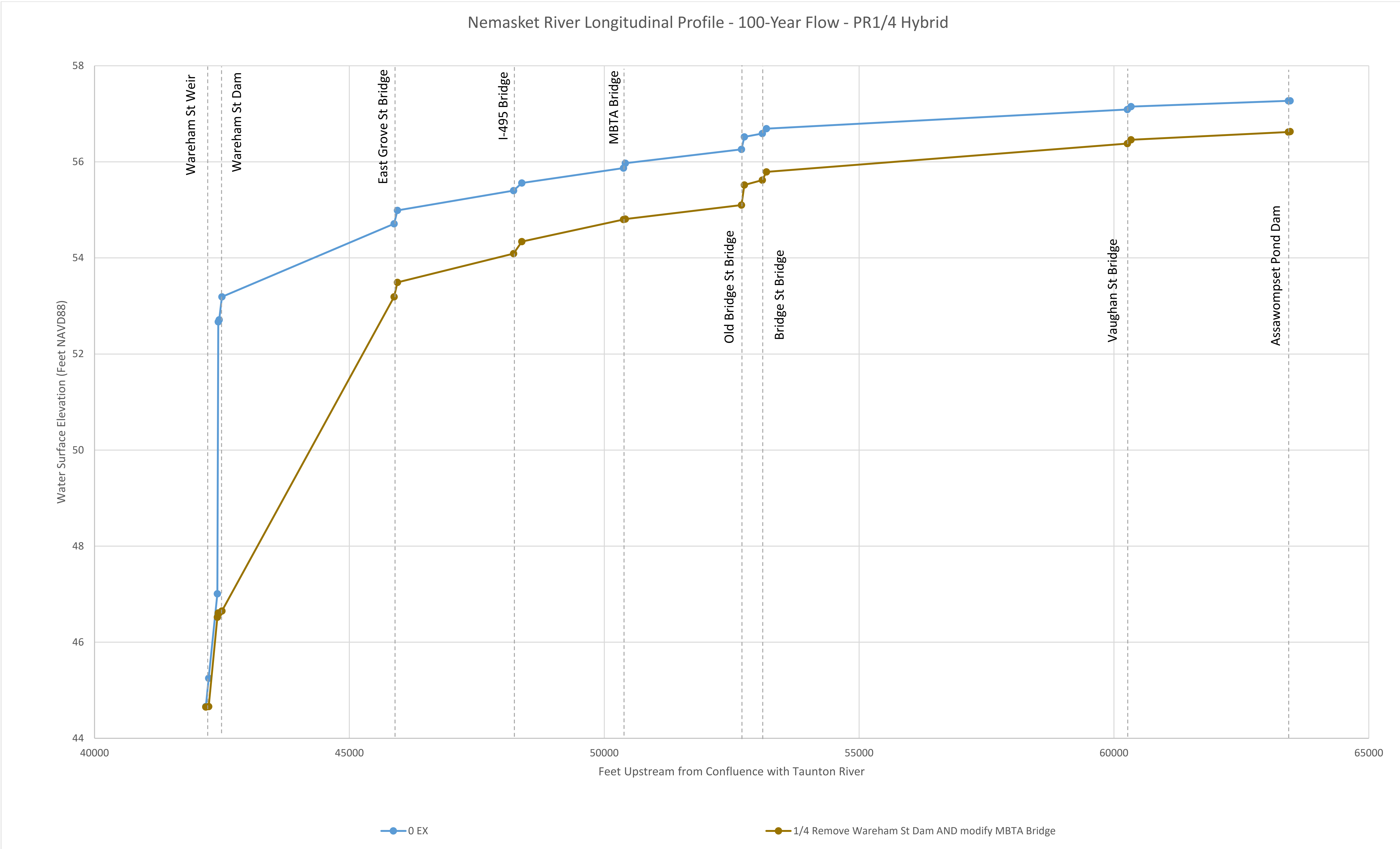


Nemasket River Longitudinal Profile - 100-Year Flow - PR6: Modify Vaughan Street Bridge
Water Surface Elevation (Feet NAVD88)
58
56
54
52
50
48
46
44
50000
52000
54000
56000
58000
60000
62000
64000
Feet Upstream from Confluence with Taunton River
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
6 Modify Vaughan Bridge

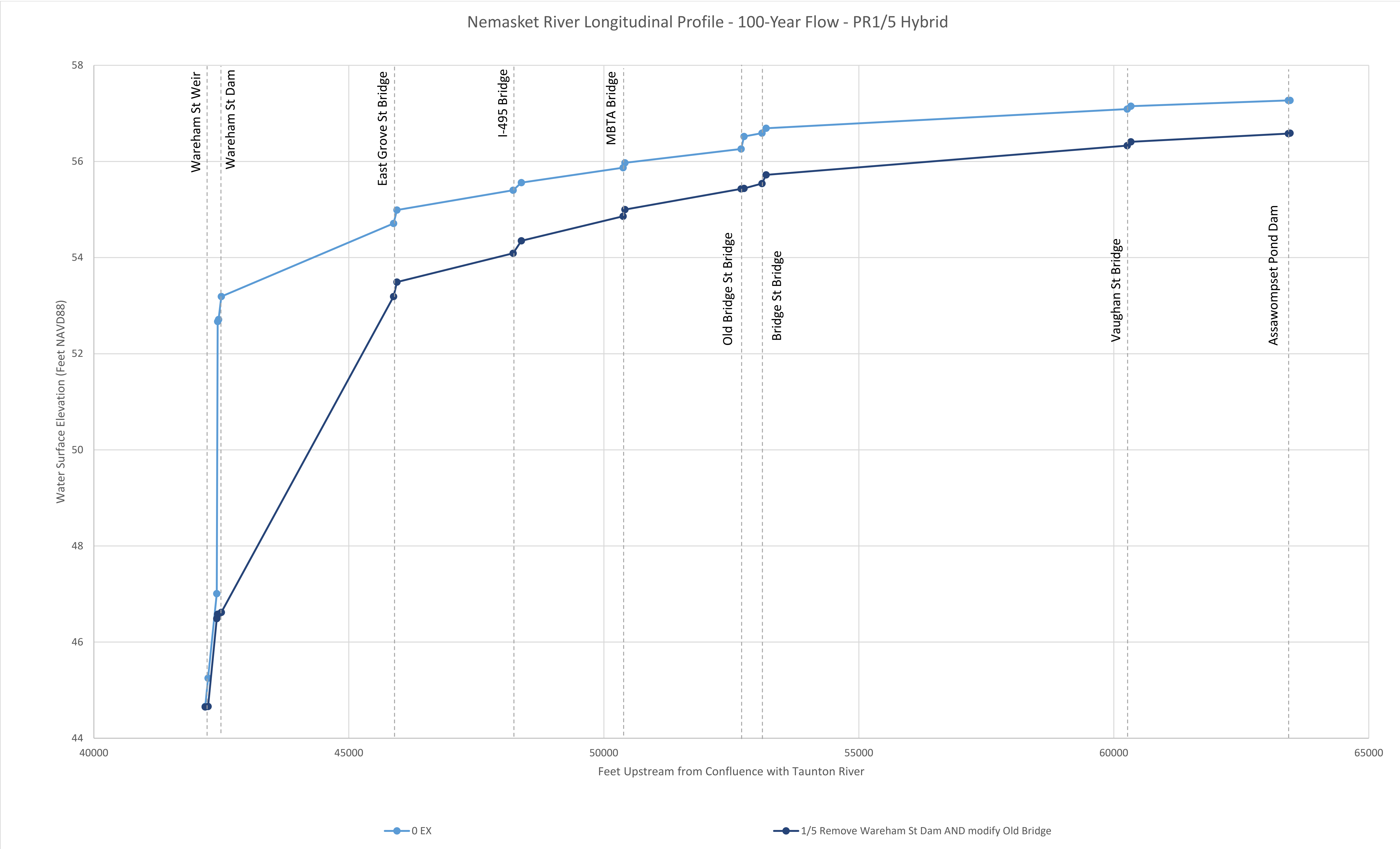

Nemasket River Longitudinal Profile - 100-Year Flow - PR7: Sediment Trap and Dredge
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
44
46
48
50
52
54
56
58
50000
52000
54000
56000
58000
60000
62000
64000
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
7 Sediment trap and Dredge to 1908 dimensions DS of APC Dam



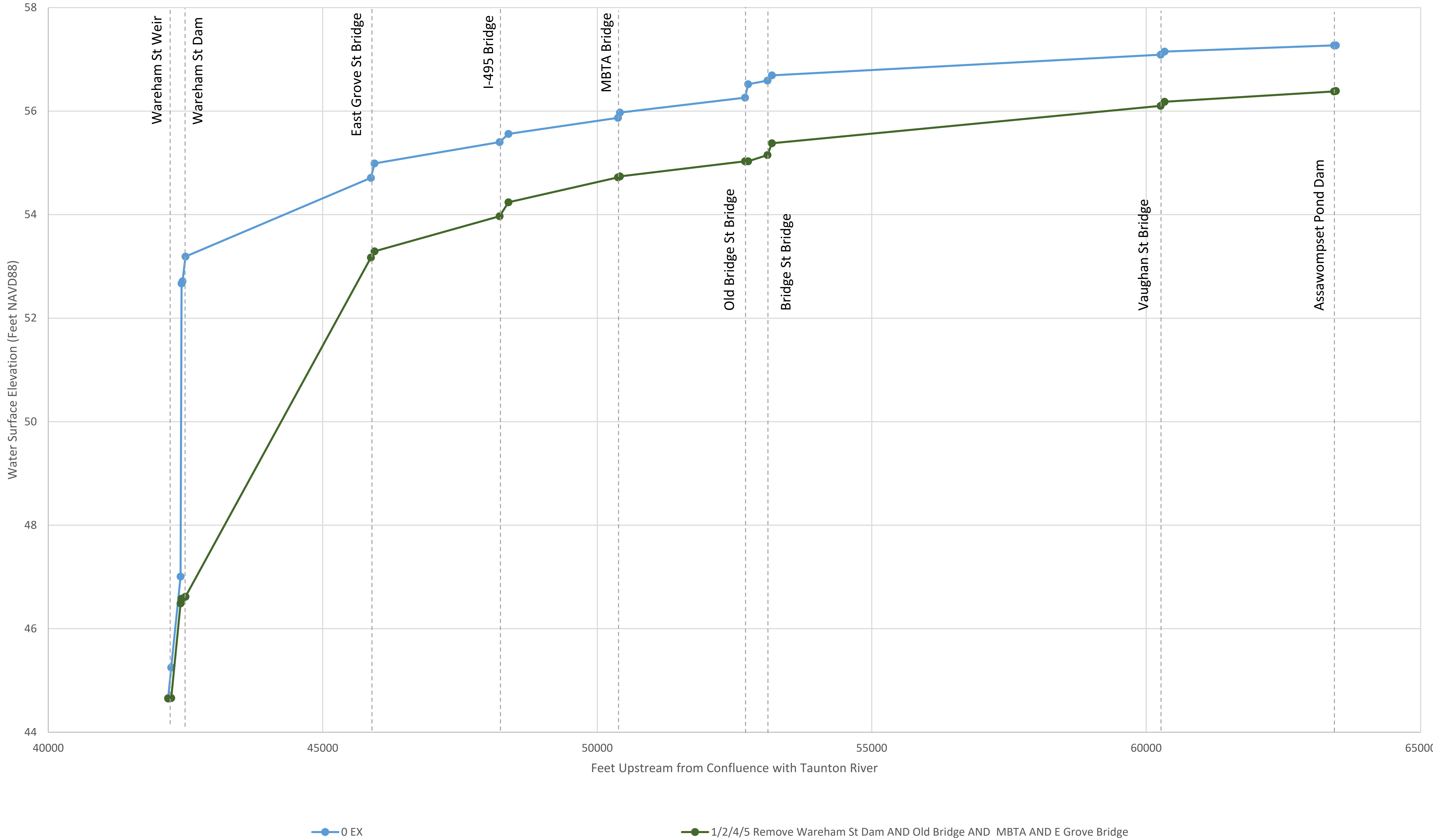
Nemasket River Longitudinal Profile - 100-Year Flow - PR1/2 Hybrid
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
1/2 Remove Wareham St Dam AND modify E Grove Bridge

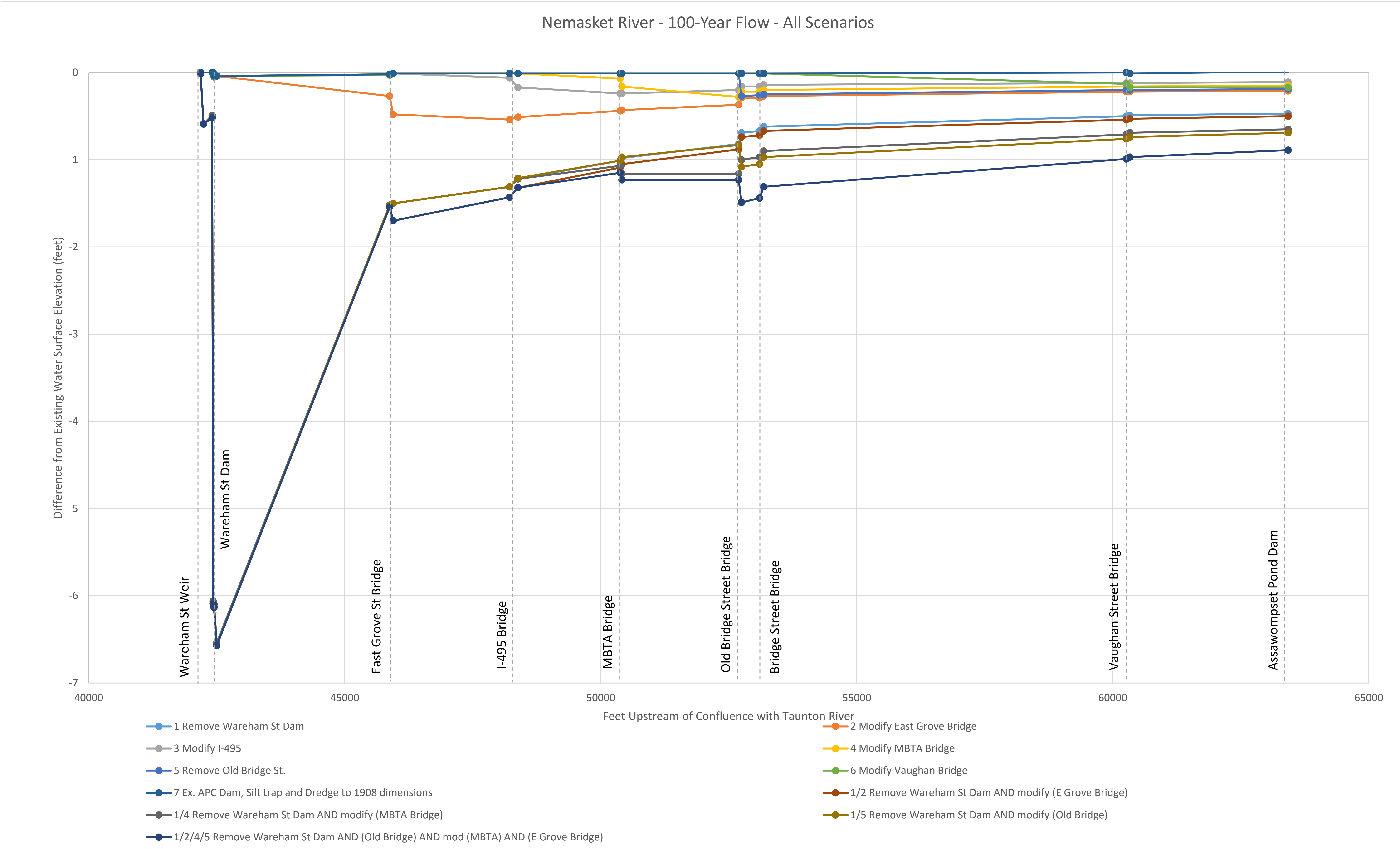


Nemasket River Longitudinal Profile - 100-Year Flow - PR1/4 Hybrid
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Water Surface Elevation (Feet NAVD88)
58
56
54
52
50
48
46
44
40000
45000
50000
55000
60000
65000
Feet Upstream from Confluence with Taunton River
0 EX
1/4 Remove Wareham St Dam AND modify MBTA Bridge

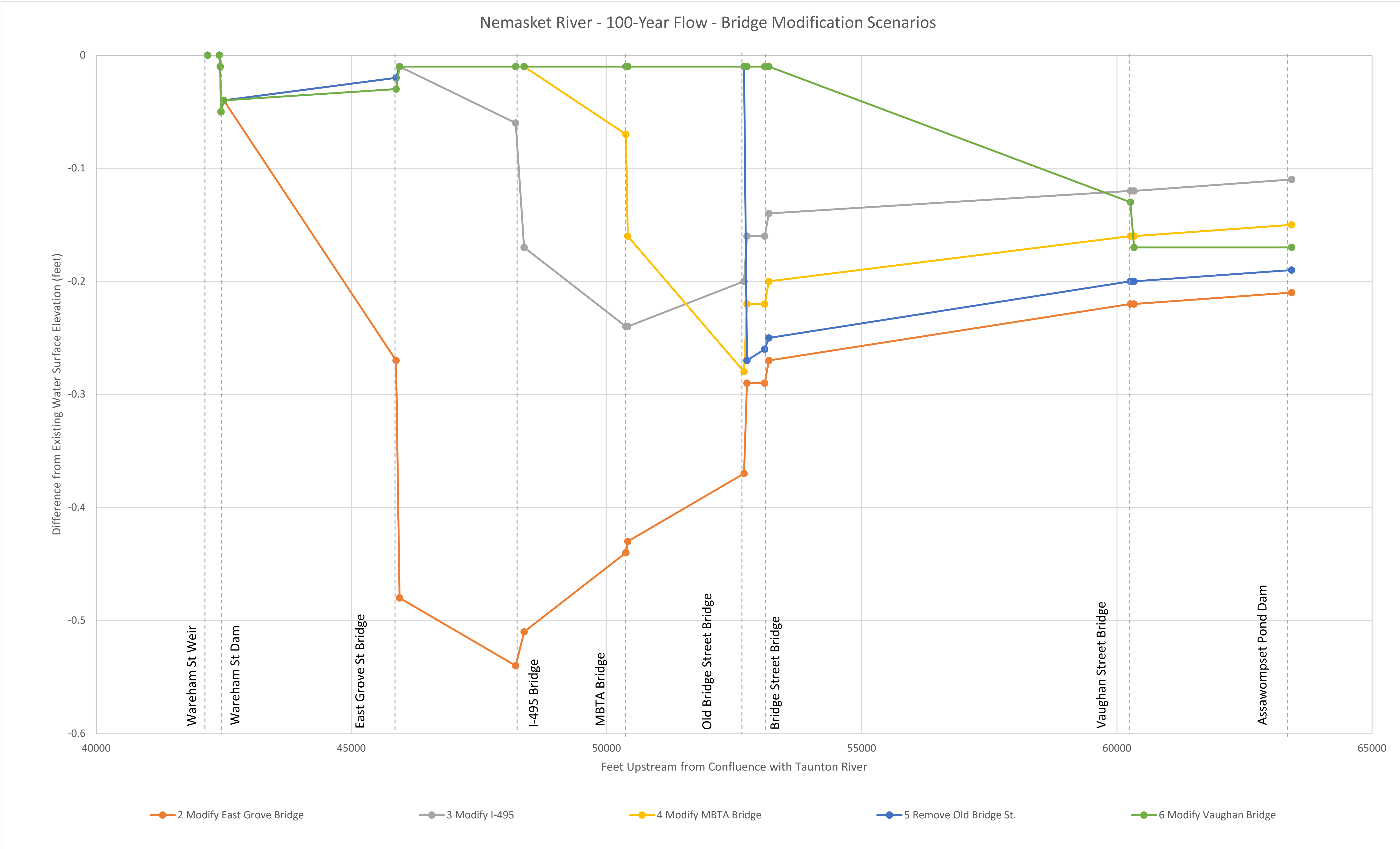

Nemasket River Longitudinal Profile - 100-Year Flow - PR1/5 Hybrid
Water Surface Elevation (Feet NAVD88)
Feet Upstream from Confluence with Taunton River
44
46
48
50
52
54
56
58
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0 EX
1/5 Remove Wareham St Dam AND modify Old Bridge

Nemasket River Longitudinal Profile - 100-Year Flow - PR1/2/4/5 Hybrid

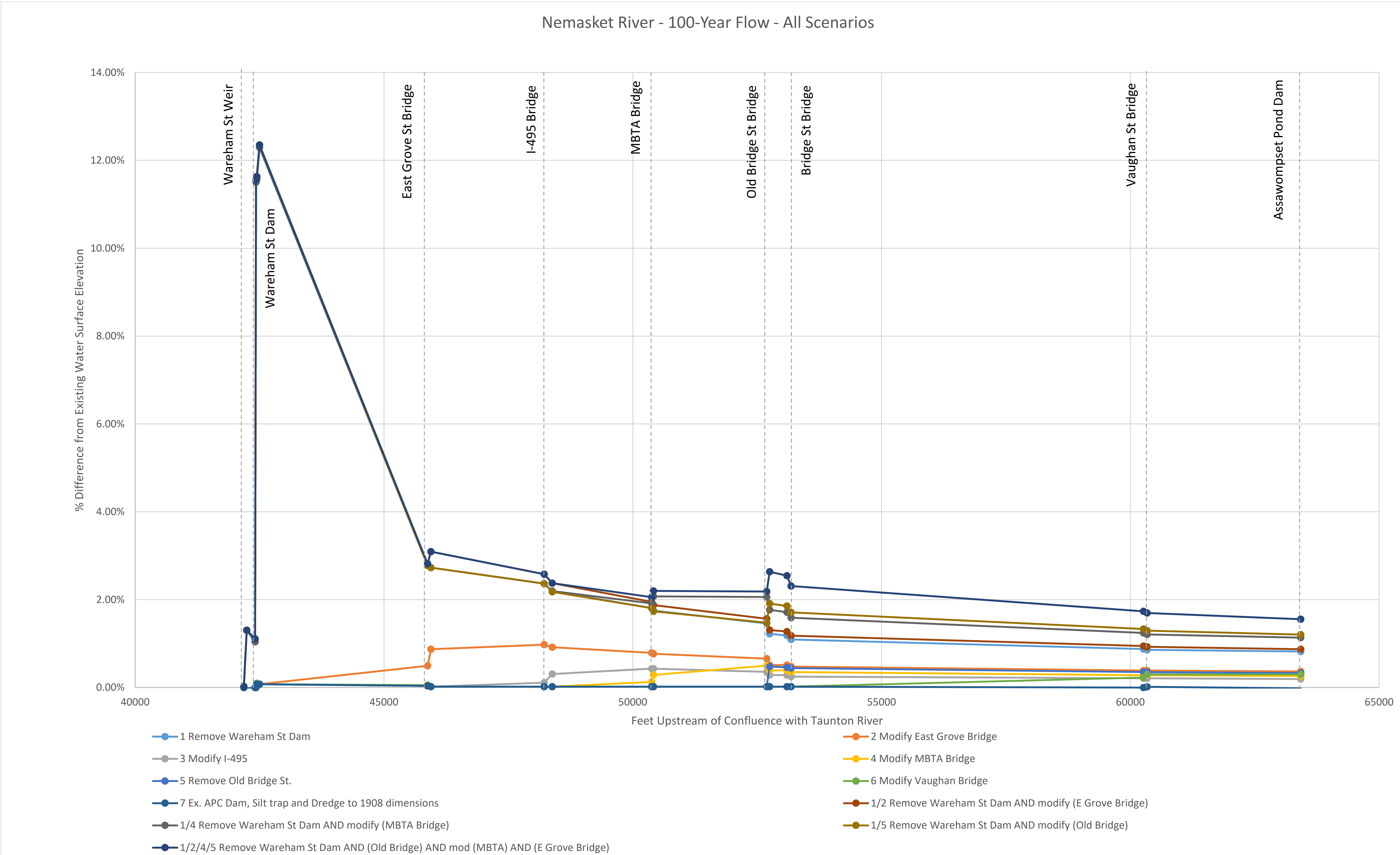




Nemasket River - 100-Year Flow - All Scenarios
Difference from Existing Water Surface Elevation (feet)
Feet Upstream of Confluence with Taunton River
0
-1
-2
-3
-4
-5
-6
-7
40000
45000
50000
55000
60000
65000
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge Street Bridge
Bridge Street Bridge
Vaughan Street Bridge
Assawompset Pond Dam
1 Remove Wareham St Dam
2 Modify East Grove Bridge
3 Modify I-495
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge
7 Ex. APC Dam, Silt trap and Dredge to 1908 dimensions
1/2 Remove Wareham St Dam AND modify (E Grove Bridge)
1/4 Remove Wareham St Dam AND modify (MBTA Bridge)
1/5 Remove Wareham St Dam AND modify (Old Bridge)
1/2/4/5 Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Bridge)

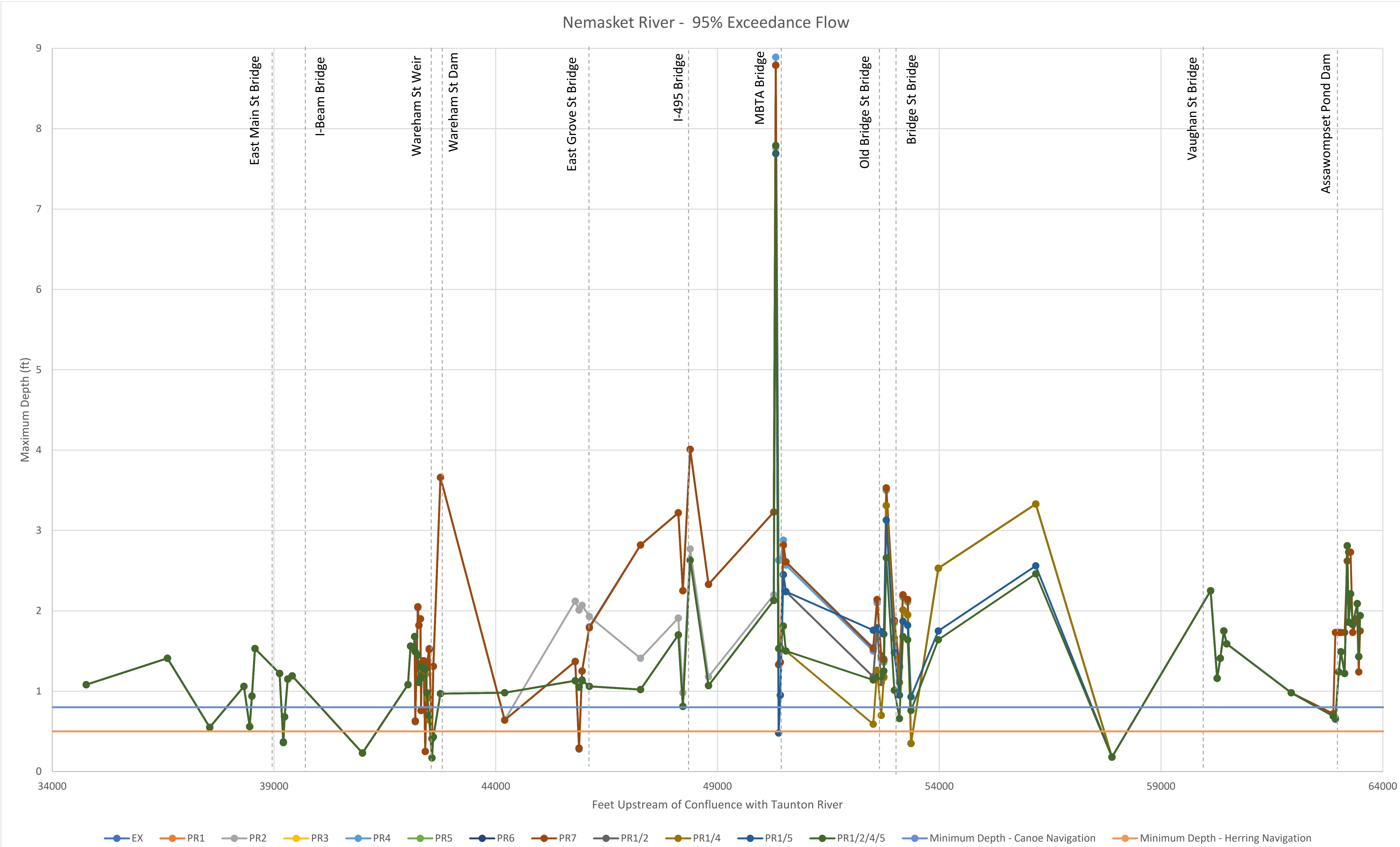


Nemasket River - 100-Year Flow - Bridge Modification Scenarios
Difference from Existing Water Surface Elevation (feet)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
40000
45000
50000
55000
60000
65000
Feet Upstream from Confluence with Taunton River
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge Street Bridge
Bridge Street Bridge
Vaughan Street Bridge
Assawompset Pond Dam
2 Modify East Grove Bridge
3 Modify I-495
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge

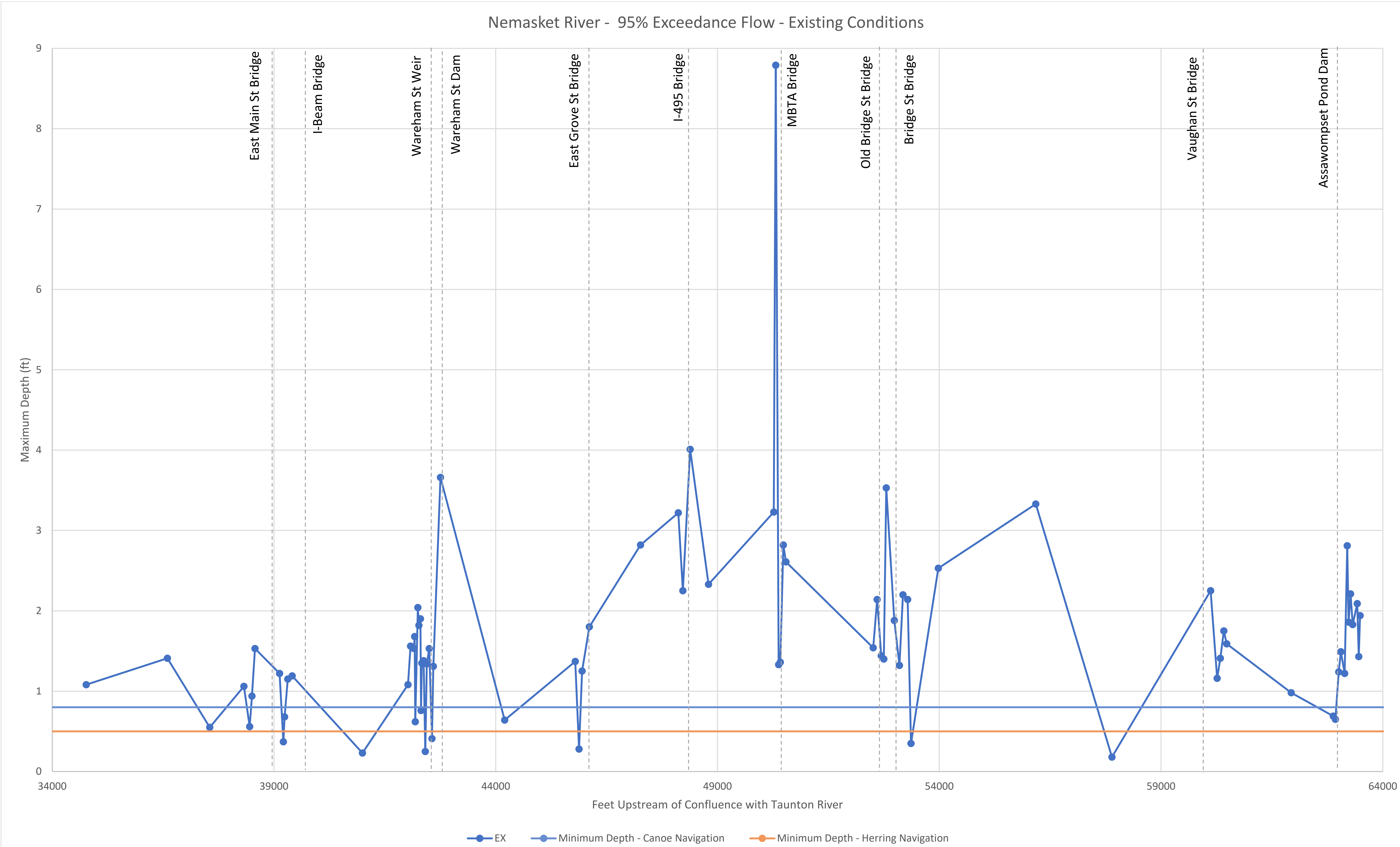


Nemasket River - 100-Year Flow - All Scenarios
14.00%
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
% Difference from Existing Water Surface Elevation
40000
45000
50000
55000
60000
65000
Feet Upstream of Confluence with Taunton River
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
1 Remove Wareham St Dam
2 Modify East Grove Bridge
3 Modify I-495
4 Modify MBTA Bridge
5 Remove Old Bridge St.
6 Modify Vaughan Bridge
7 Ex. APC Dam, Silt trap and Dredge to 1908 dimensions
1/2 Remove Wareham St Dam AND modify (E Grove Bridge)
1/4 Remove Wareham St Dam AND modify (MBTA Bridge)
1/5 Remove Wareham St Dam AND modify (Old Bridge)
1/2/4/5 Remove Wareham St Dam AND (Old Bridge) AND mod (MBTA) AND (E Grove Bridge)

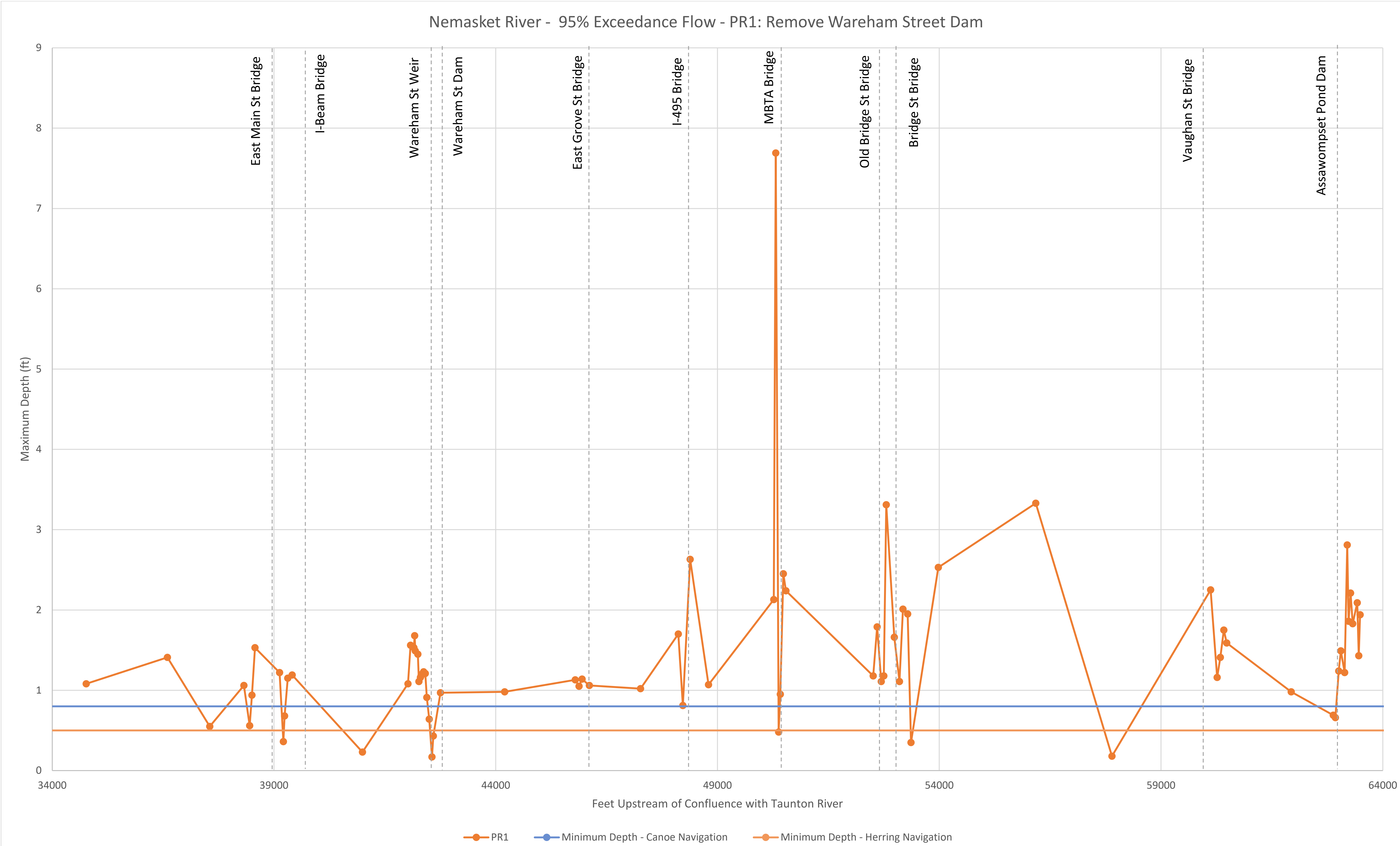
ATTACHMENT C – EXISTING AND PROPOSED MAXIMUM DEPTH LONGITUDINAL PROFILES



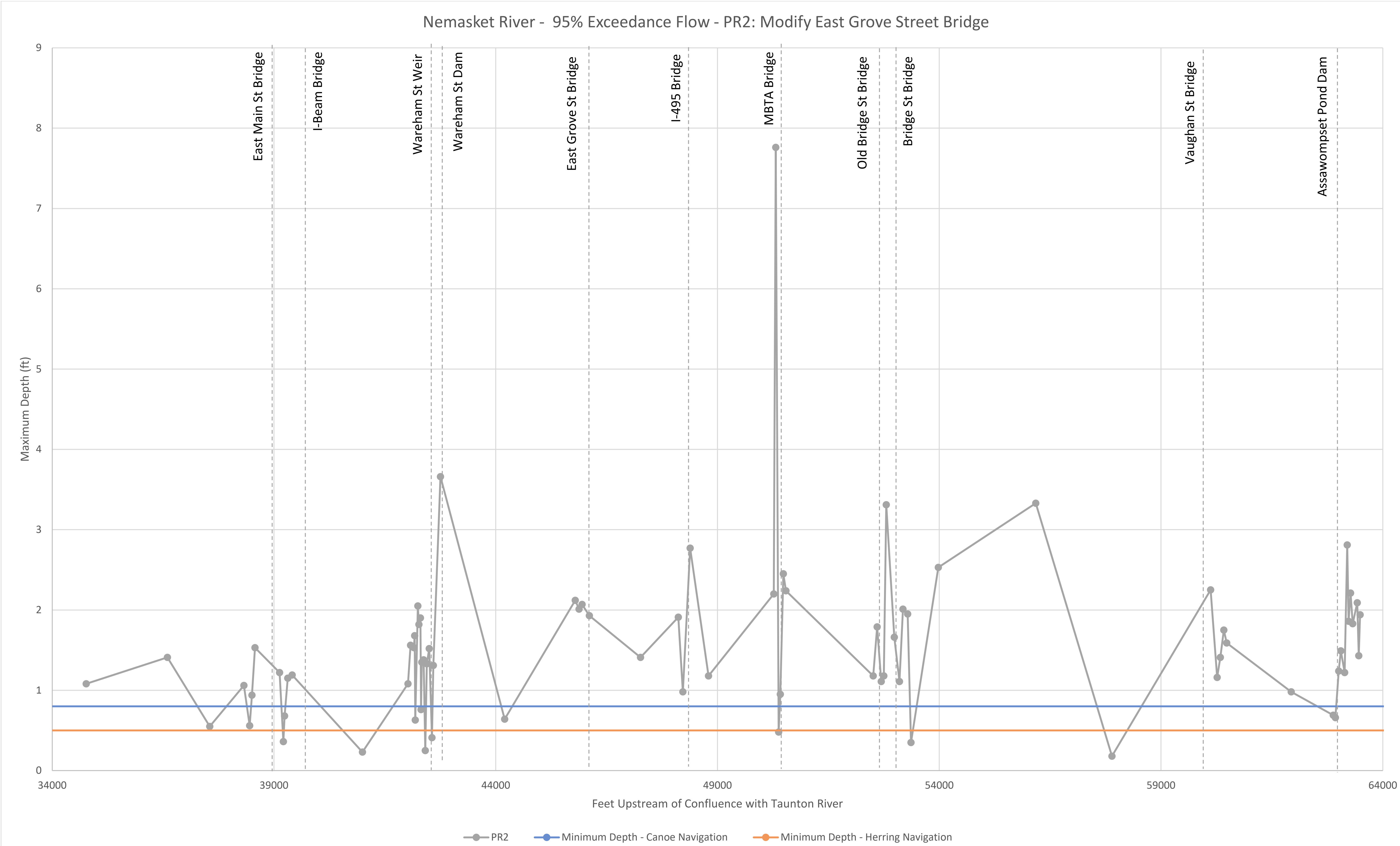
Nemasket River - 95% Exceedance Flow
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
EX
PR1
PR2
PR3
PR4
PR5
PR6
PR7
PR1/2
PR1/4
PR1/5
PR1/2/4/5
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



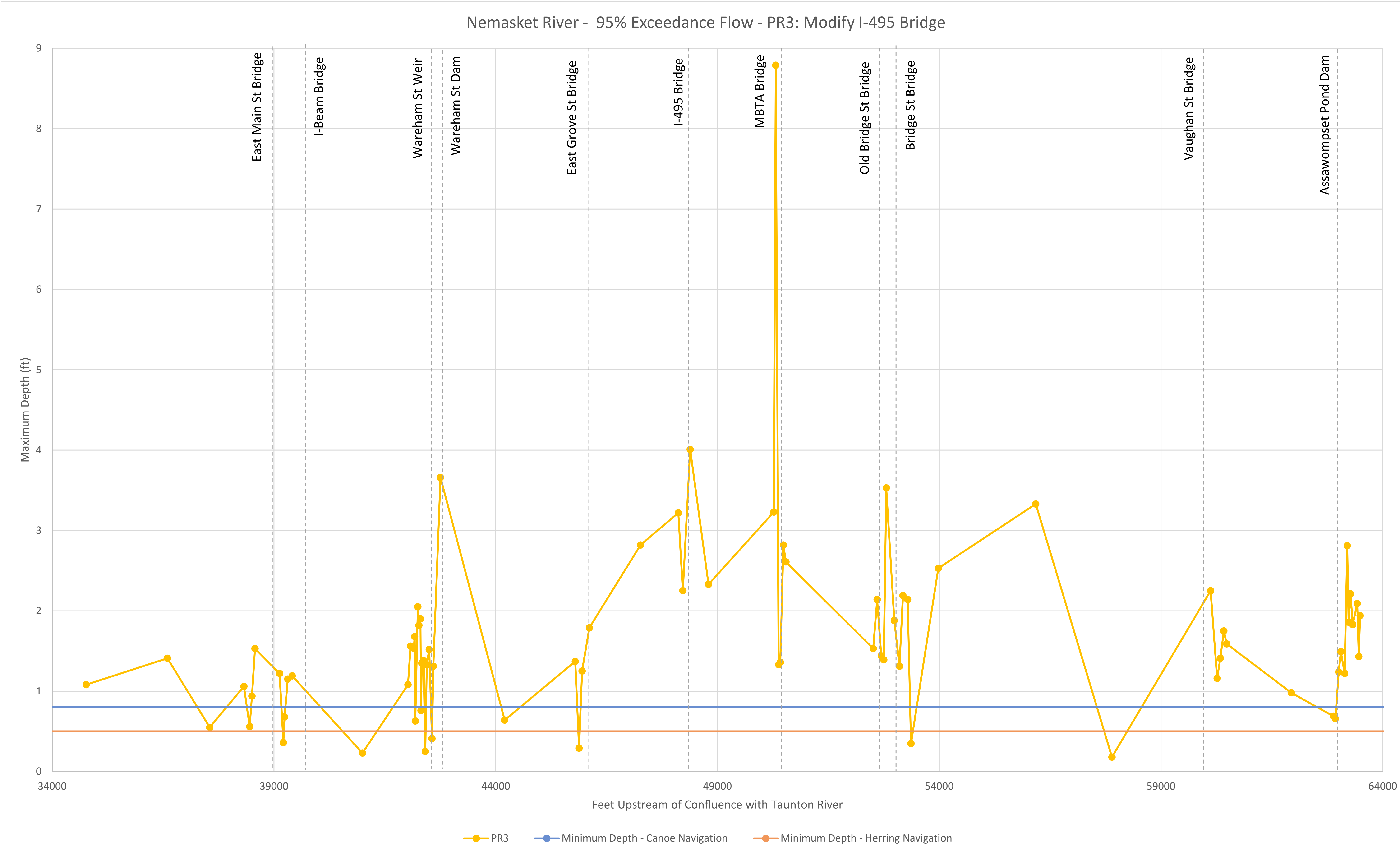
Nemasket River - 95% Exceedance Flow - Existing Conditions
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
EX
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



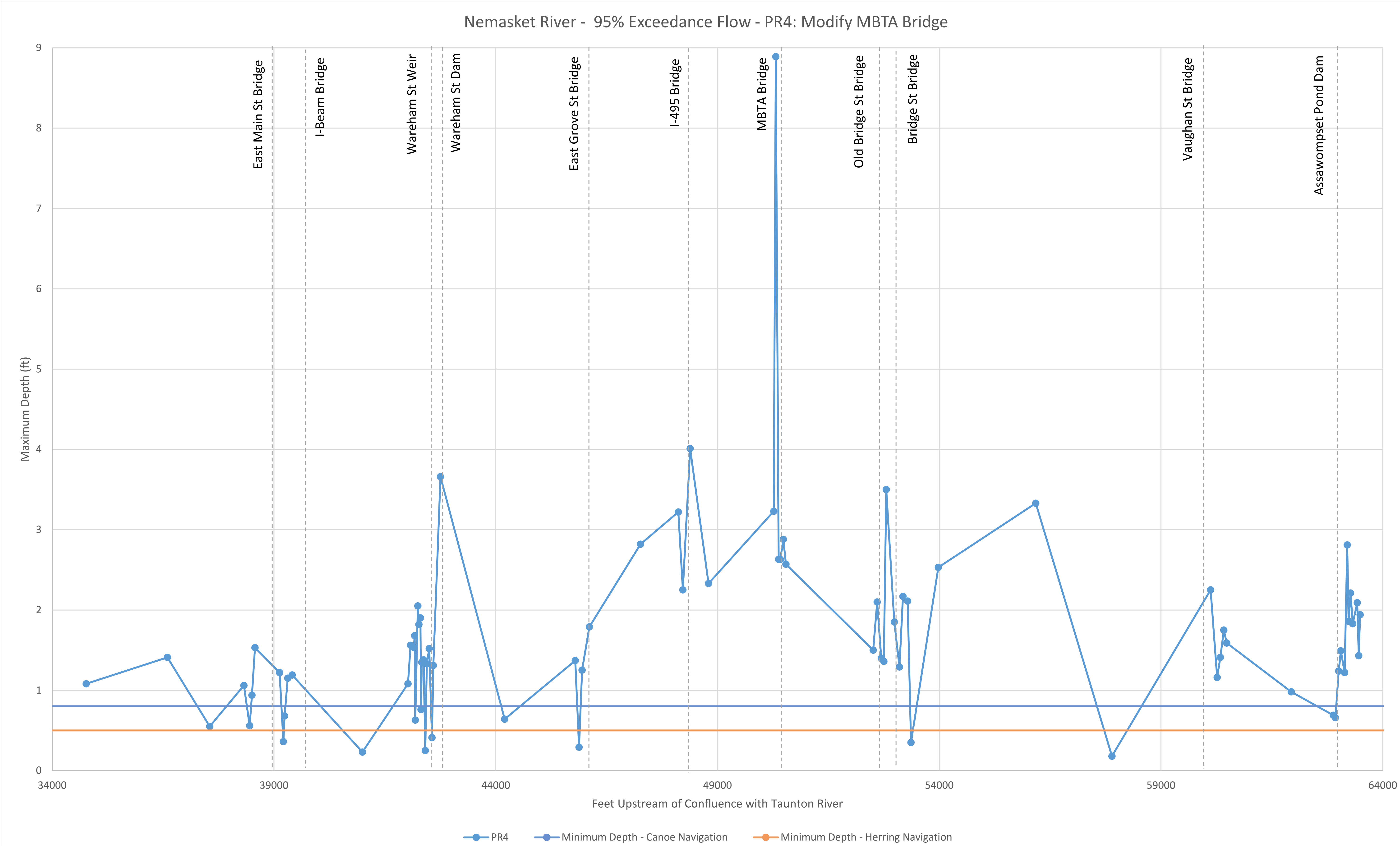
Nemasket River - 95% Exceedance Flow - PR1: Remove Wareham Street Dam
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR1
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation

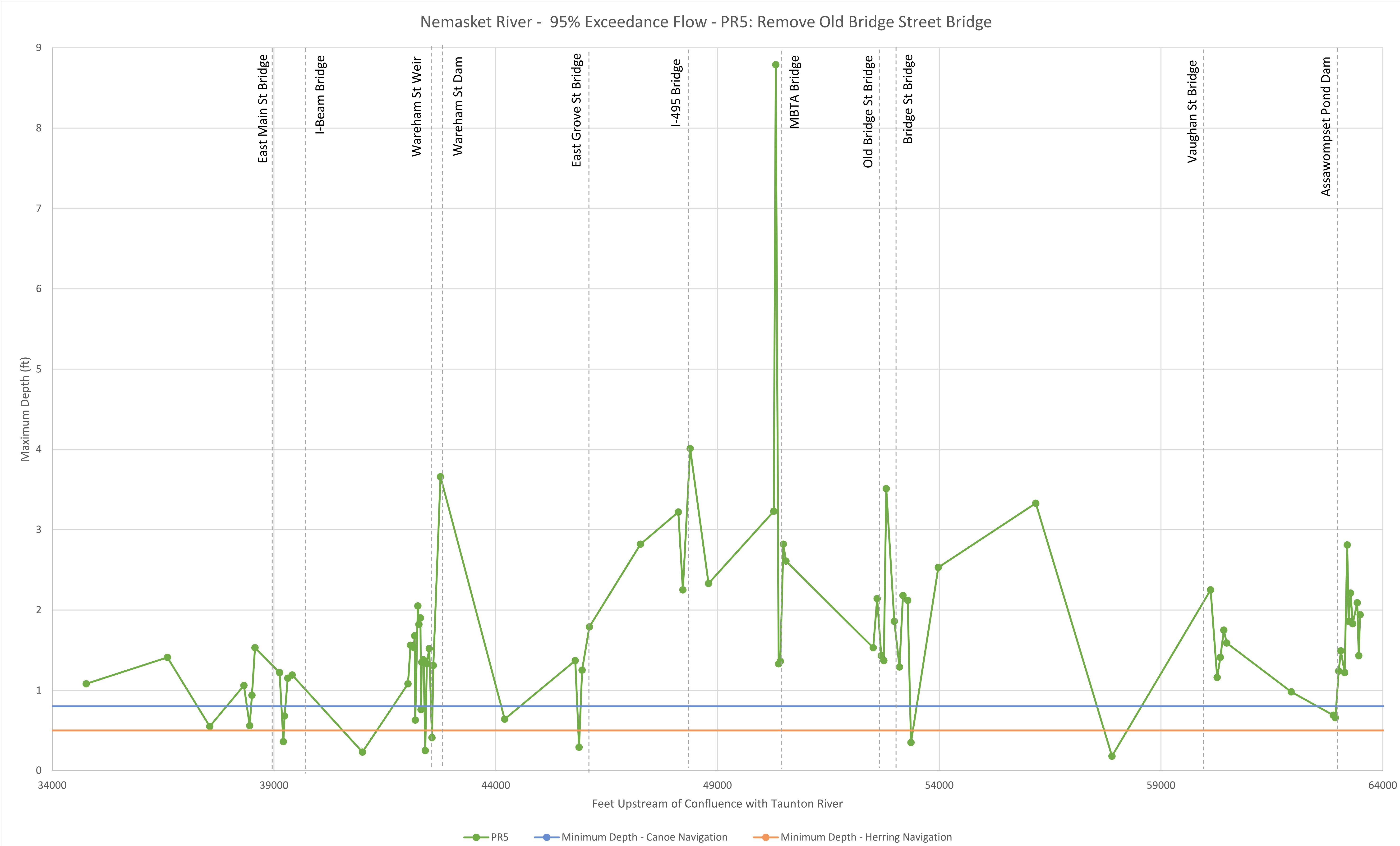


Nemasket River - 95% Exceedance Flow - PR2: Modify East Grove Street Bridge
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Maximum Depth (ft)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR2
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation

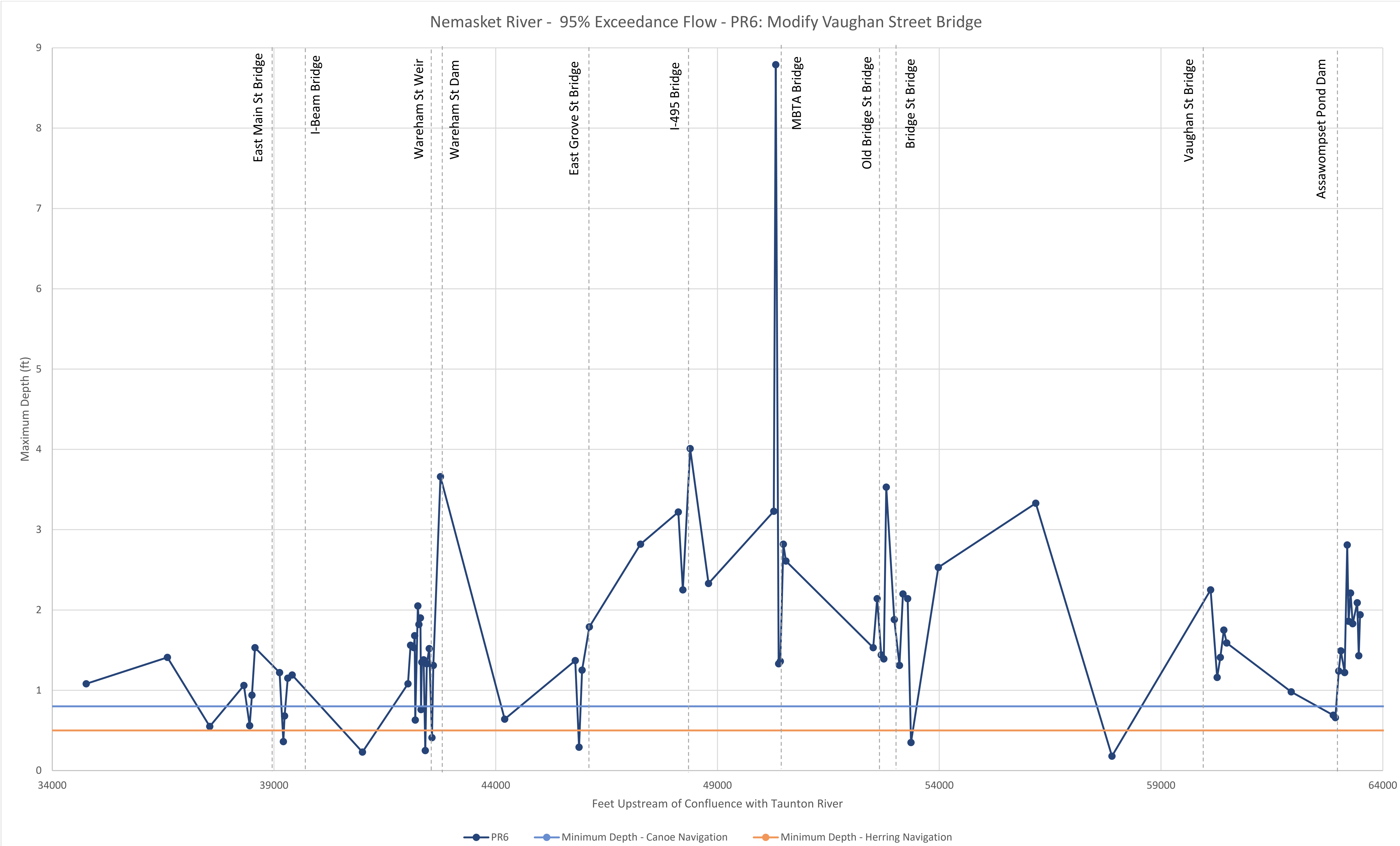


Nemasket River - 95% Exceedance Flow - PR3: Modify I-495 Bridge
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Maximum Depth (ft)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR3
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation

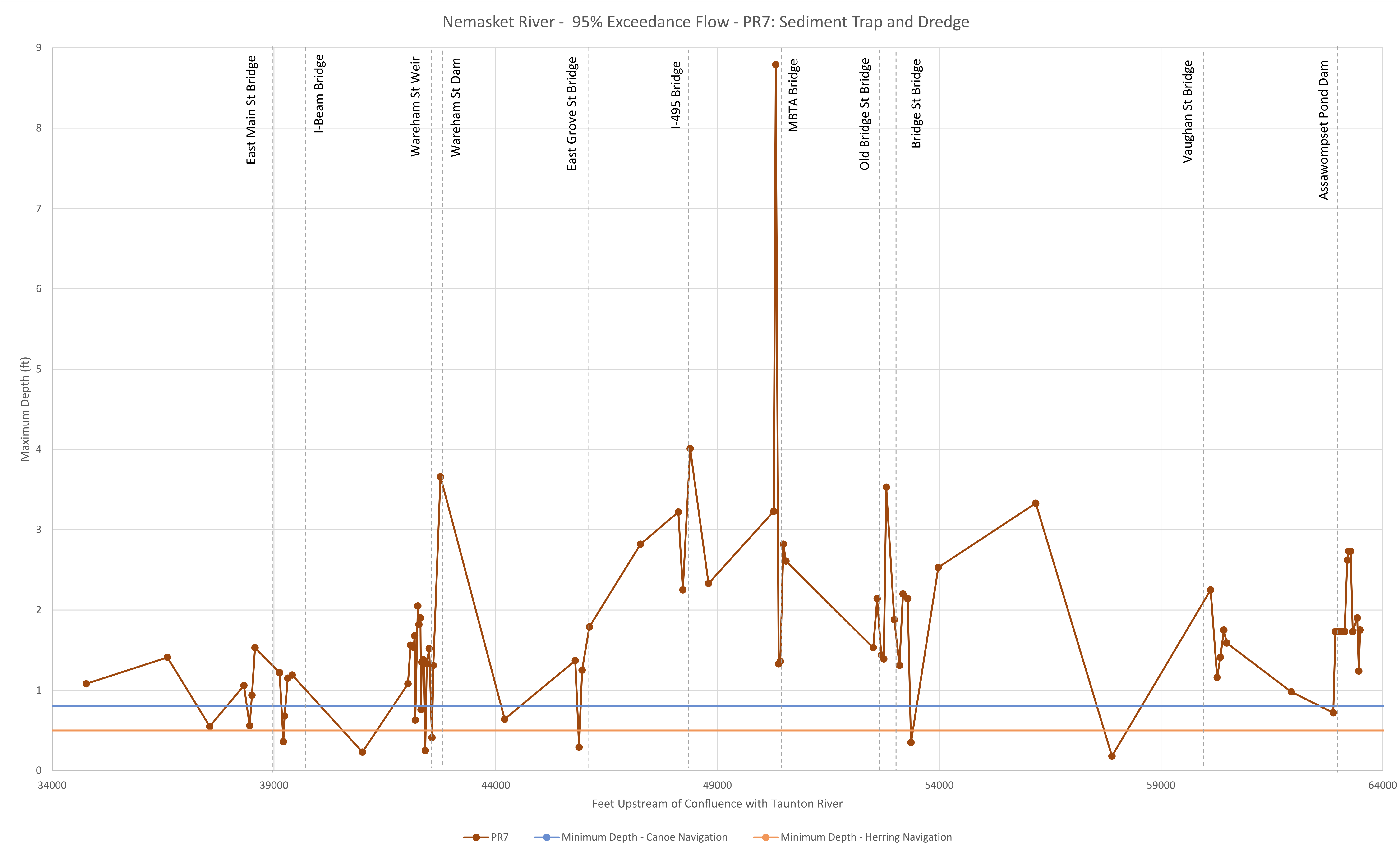

Nemasket River - 95% Exceedance Flow - PR4: Modify MBTA Bridge
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR4
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



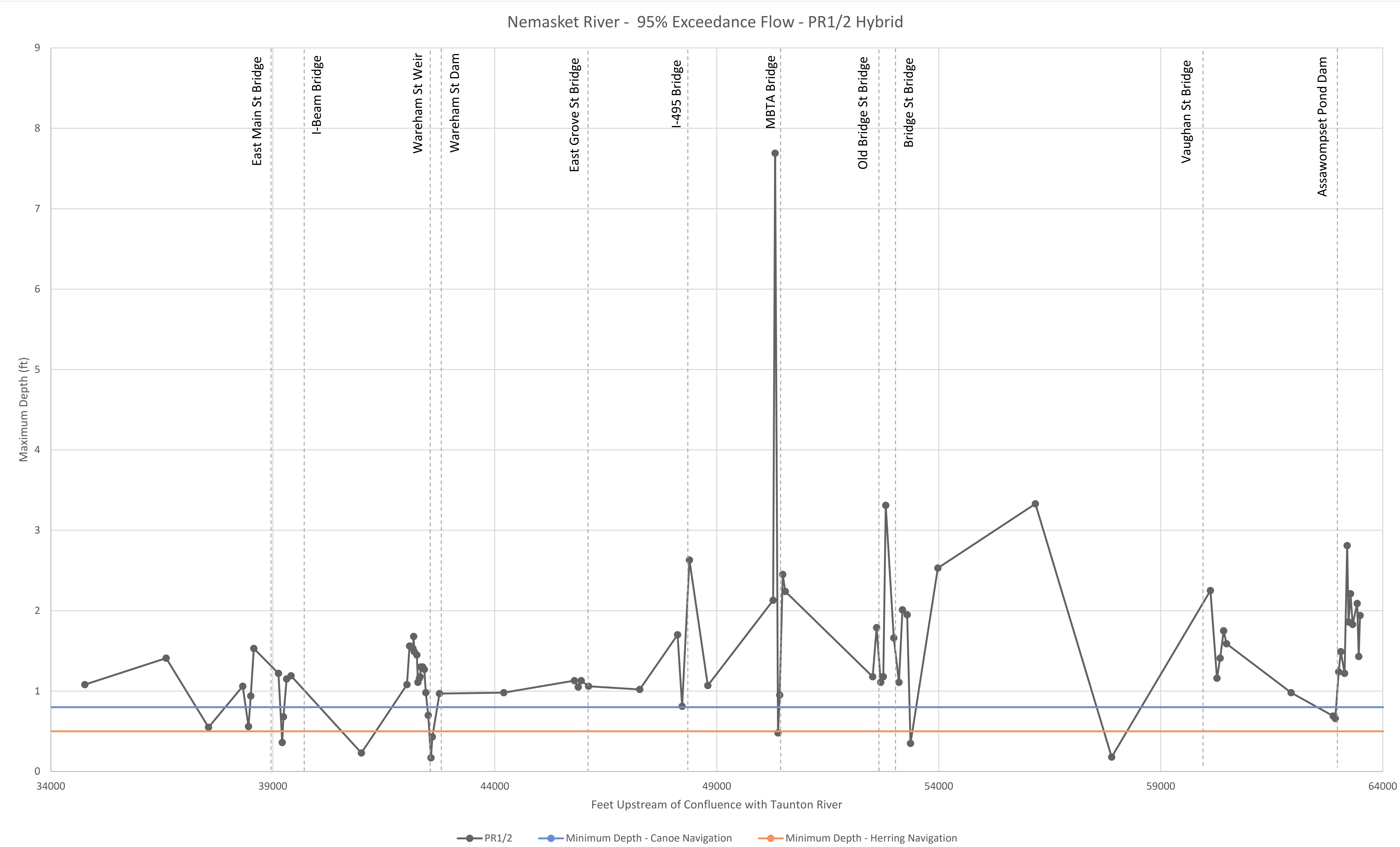
Nemasket River - 95% Exceedance Flow - PR5: Remove Old Bridge Street Bridge
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR5
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



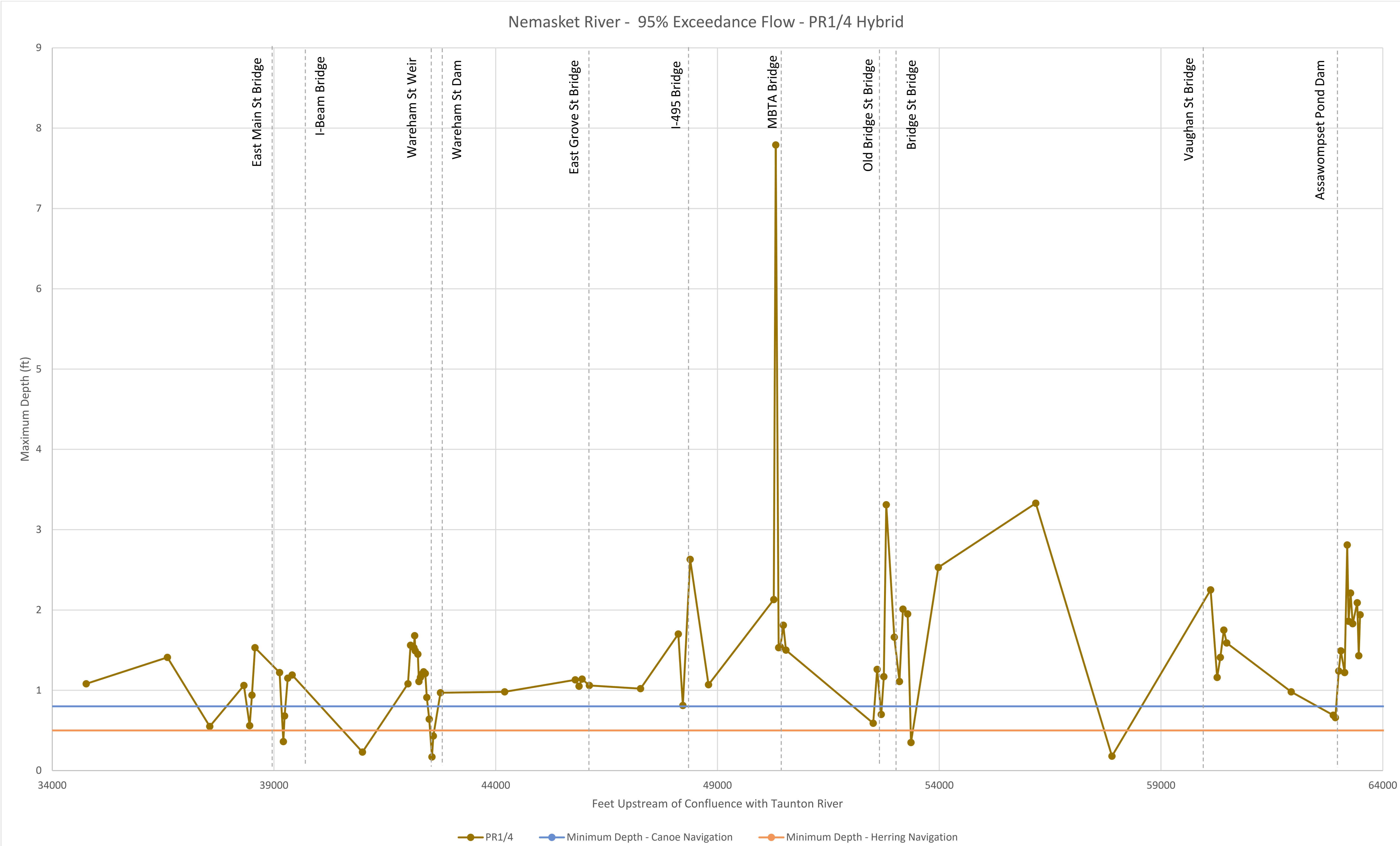
Nemasket River - 95% Exceedance Flow - PR6: Modify Vaughan Street Bridge
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
PR6
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



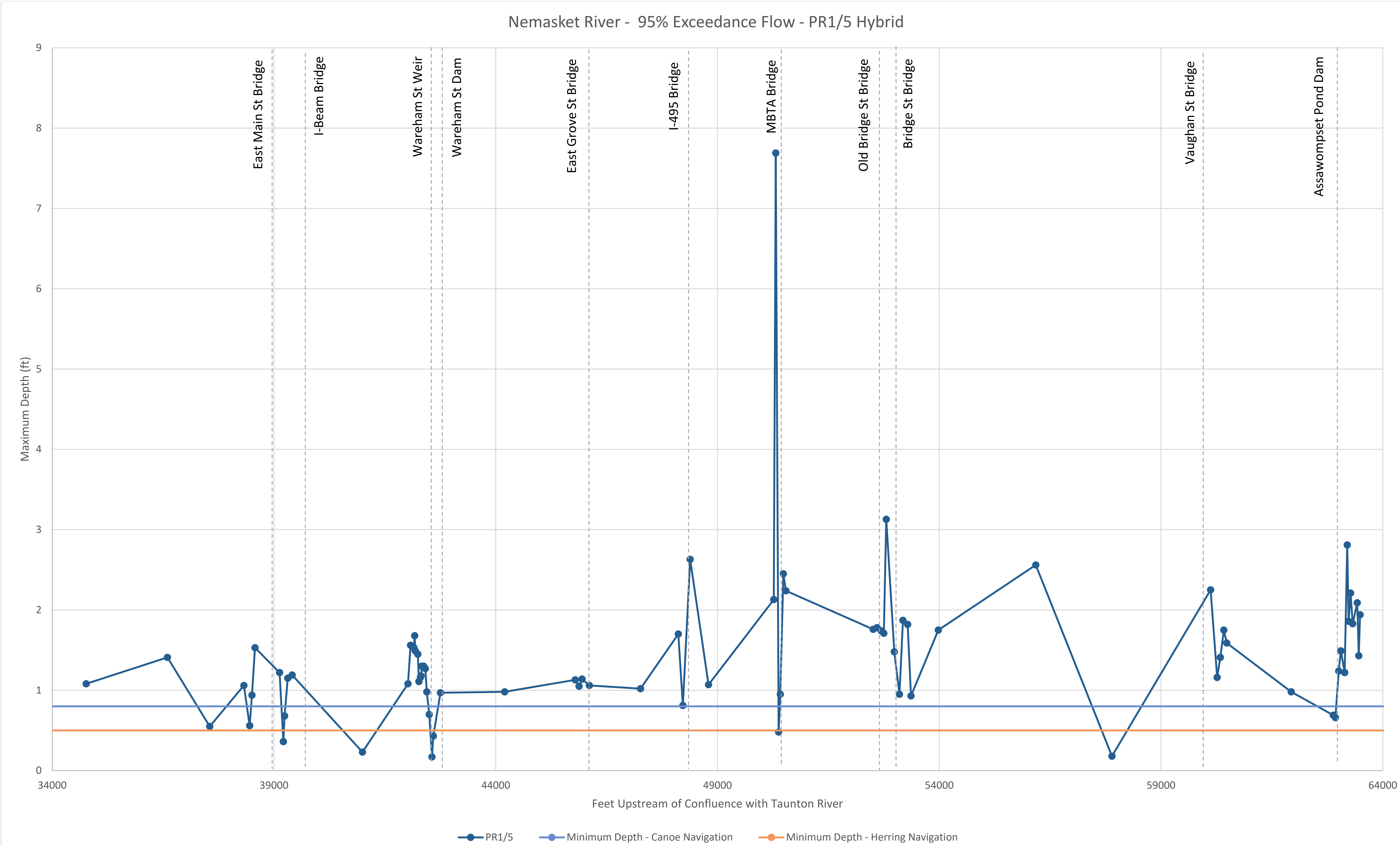
Nemasket River - 95% Exceedance Flow - PR7: Sediment Trap and Dredge
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR7
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



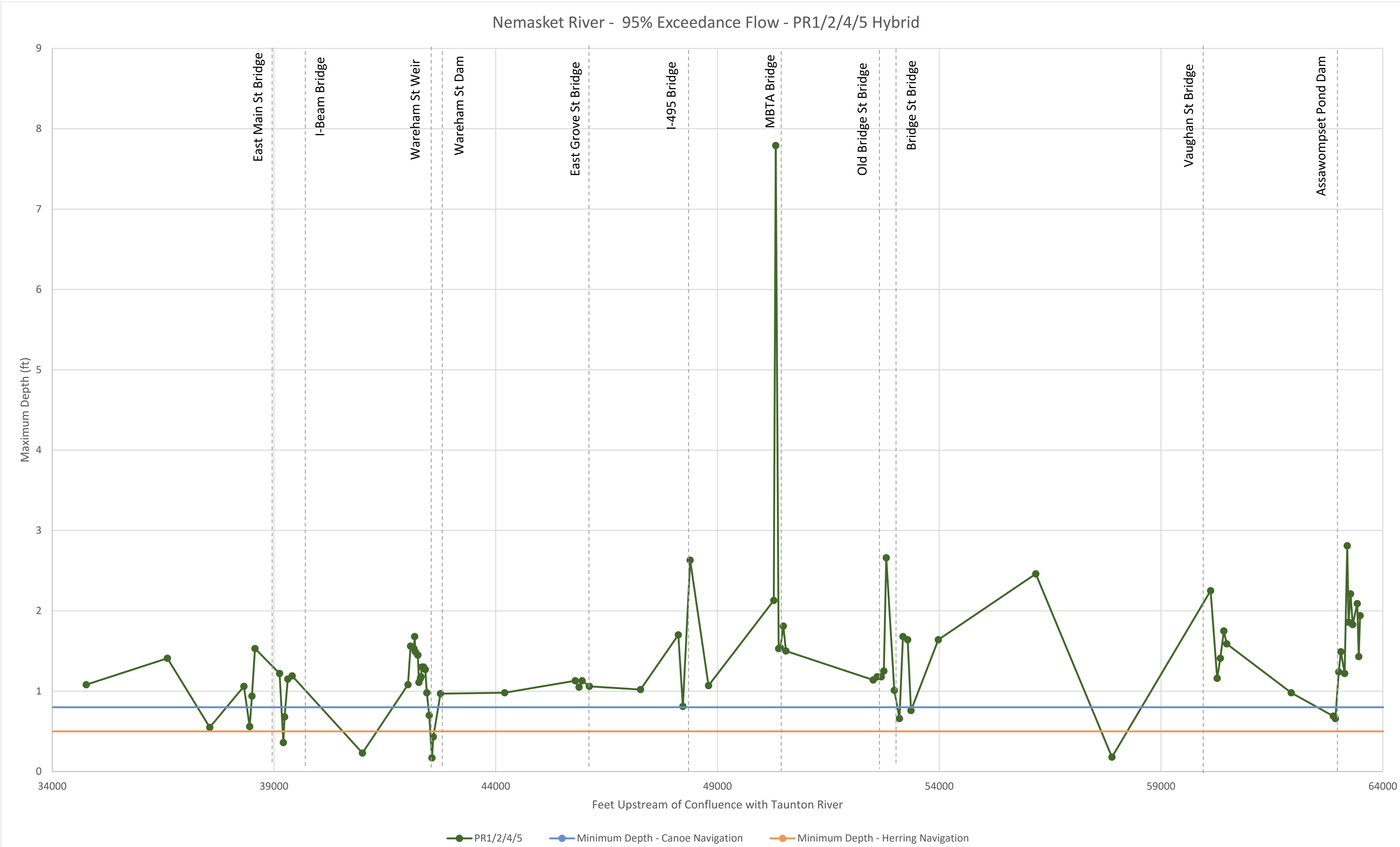
Nemasket River - 95% Exceedance Flow - PR1/2 Hybrid
Maximum Depth (ft)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
PR1/2
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



Nemasket River - 95% Exceedance Flow - PR1/4 Hybrid
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
PR1/4
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation

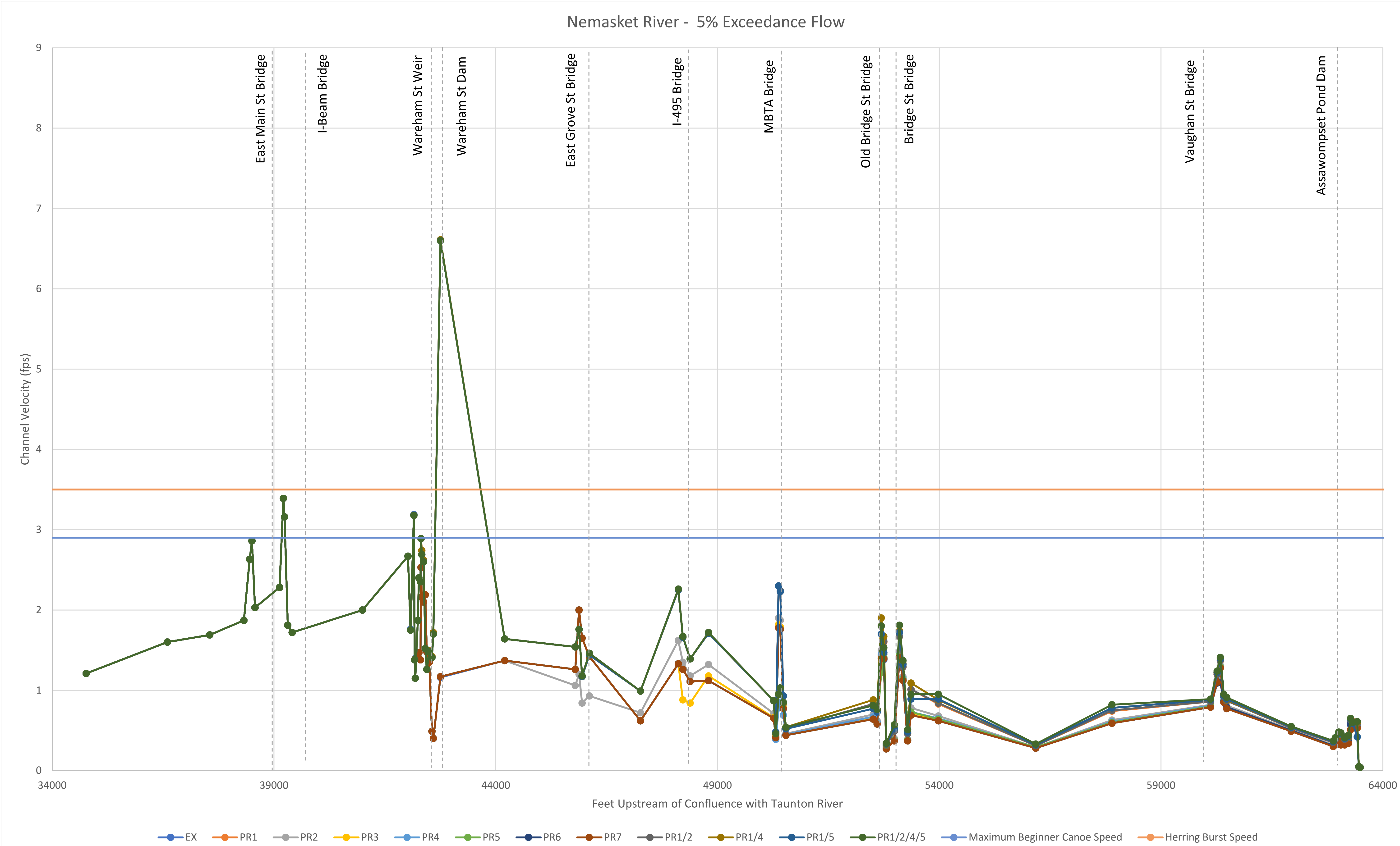


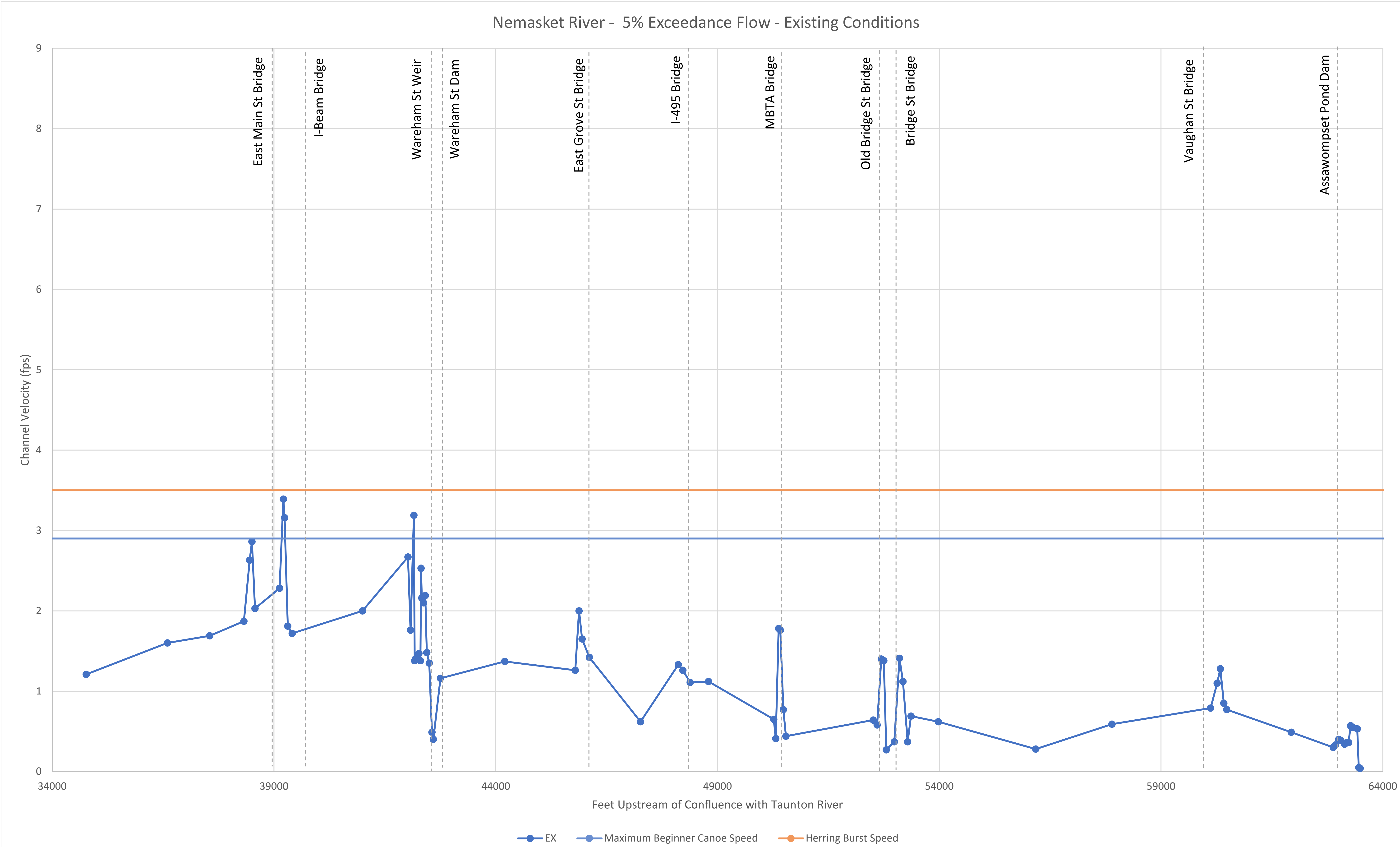
Nemasket River - 95% Exceedance Flow - PR1/5 Hybrid
Maximum Depth (ft)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR1/5
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation



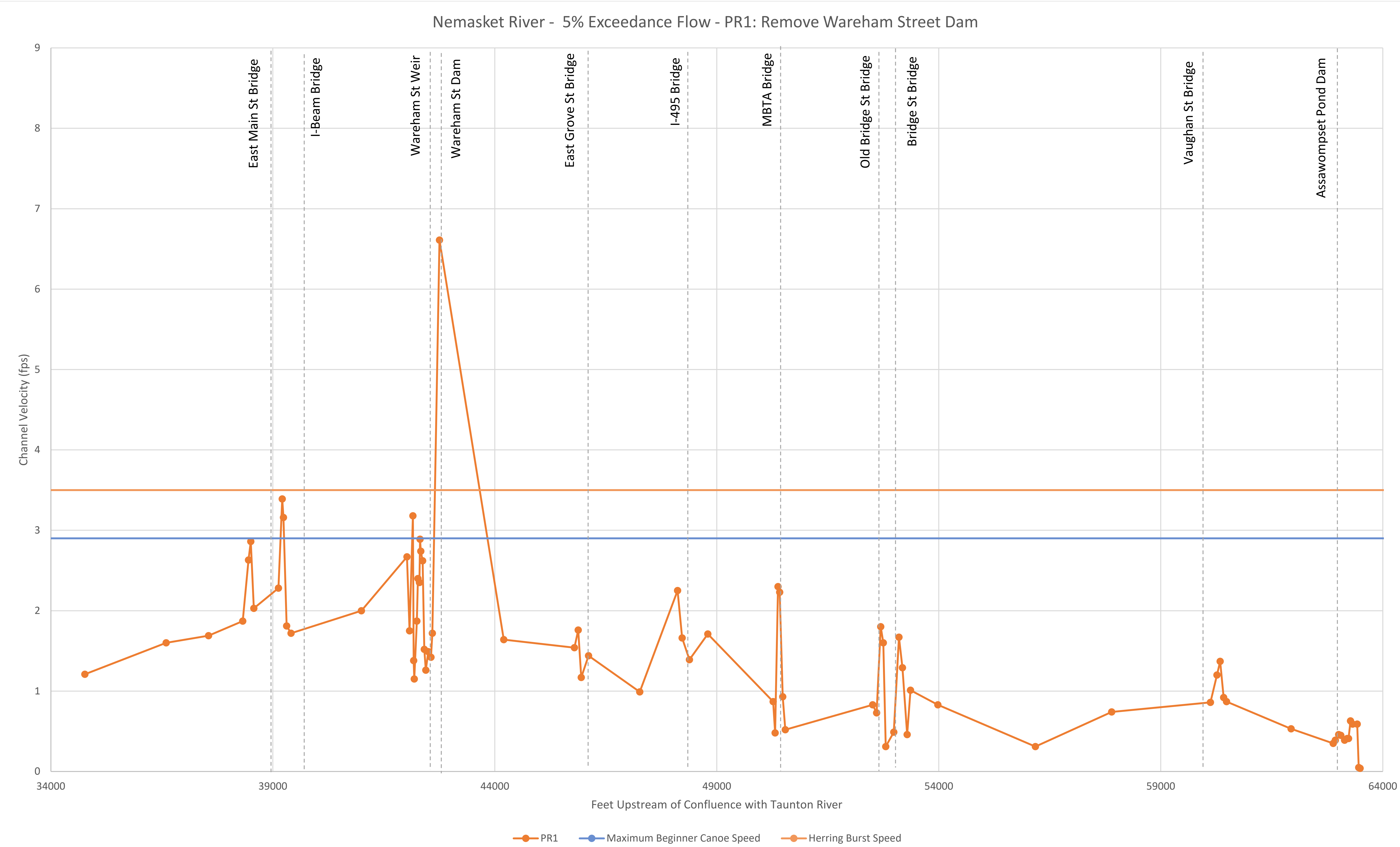
Nemasket River - 95% Exceedance Flow - PR1/2/4/5 Hybrid
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Maximum Depth (ft)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR1/2/4/5
Minimum Depth - Canoe Navigation
Minimum Depth - Herring Navigation

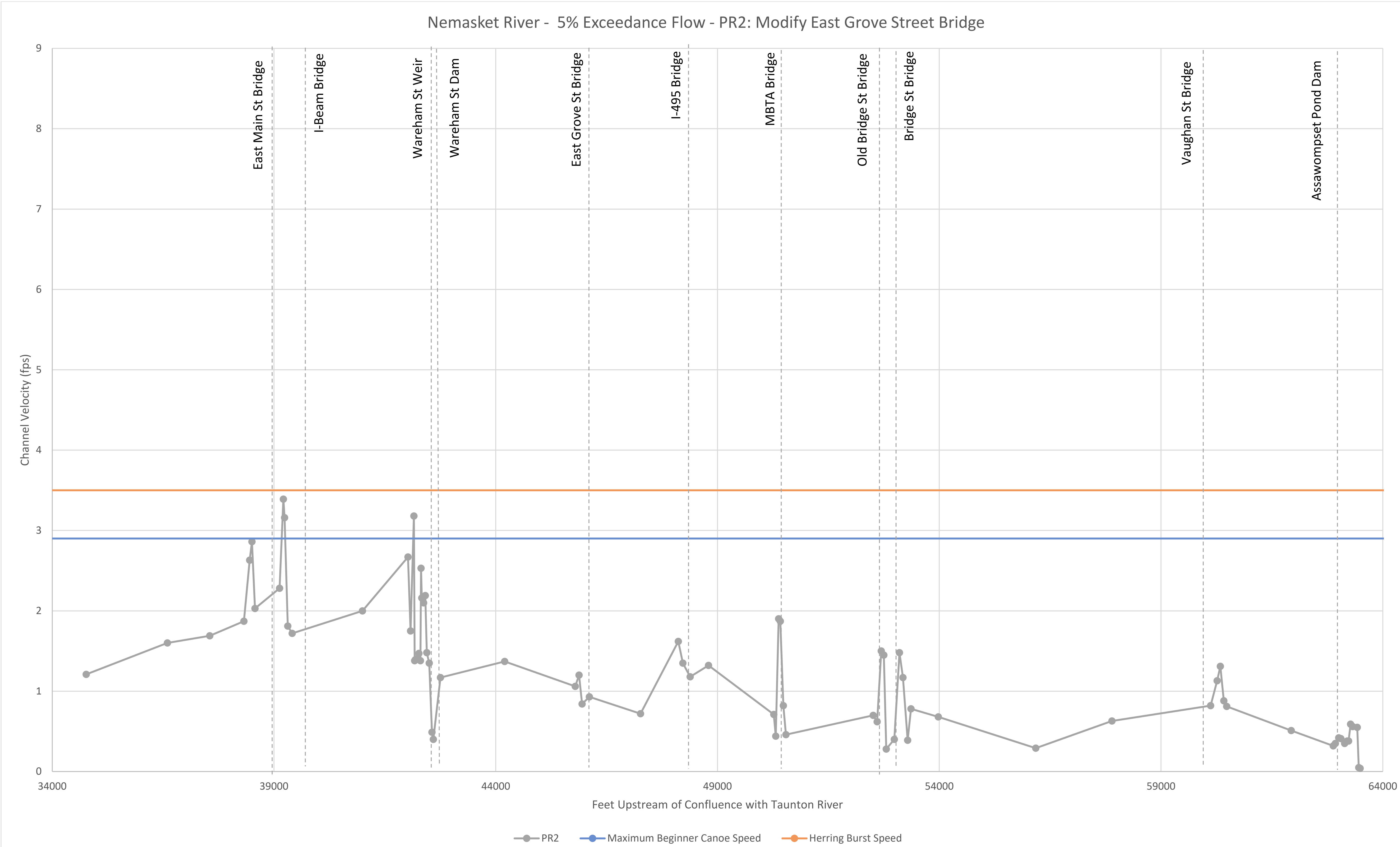
ATTACHMENT D – EXISTING AND PROPOSED CHANNEL VELOCITY LONGITUDINAL PROFILES


Nemasket River - 5% Exceedance Flow
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
EX
PR1
PR2
PR3
PR4
PR5
PR6
PR7
PR1/2
PR1/4
PR1/5
PR1/2/4/5
Maximum Beginner Canoe Speed
Herring Burst Speed

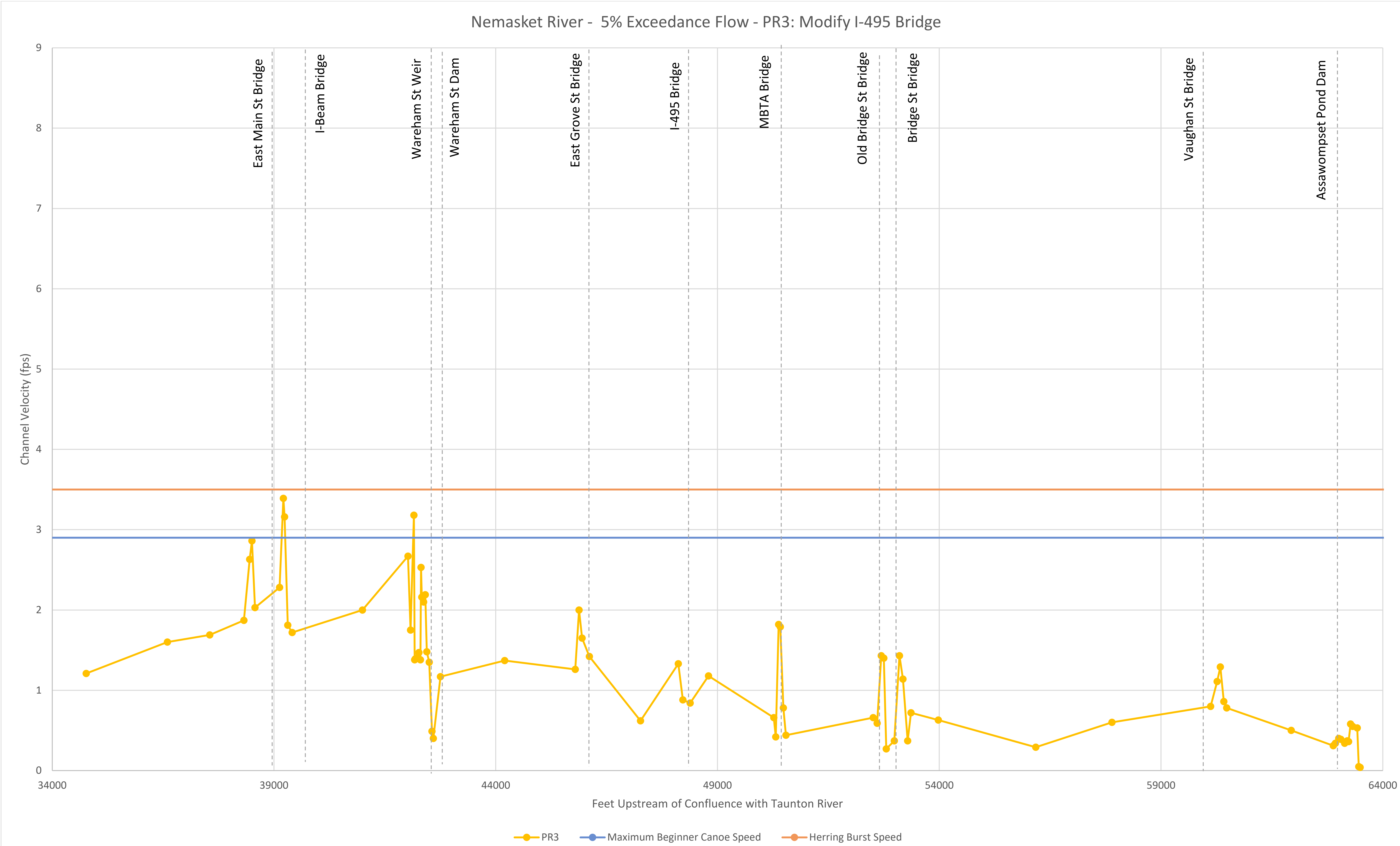


Nemasket River - 5% Exceedance Flow - Existing Conditions
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Channel Velocity (fps)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
EX
Maximum Beginner Canoe Speed
Herring Burst Speed

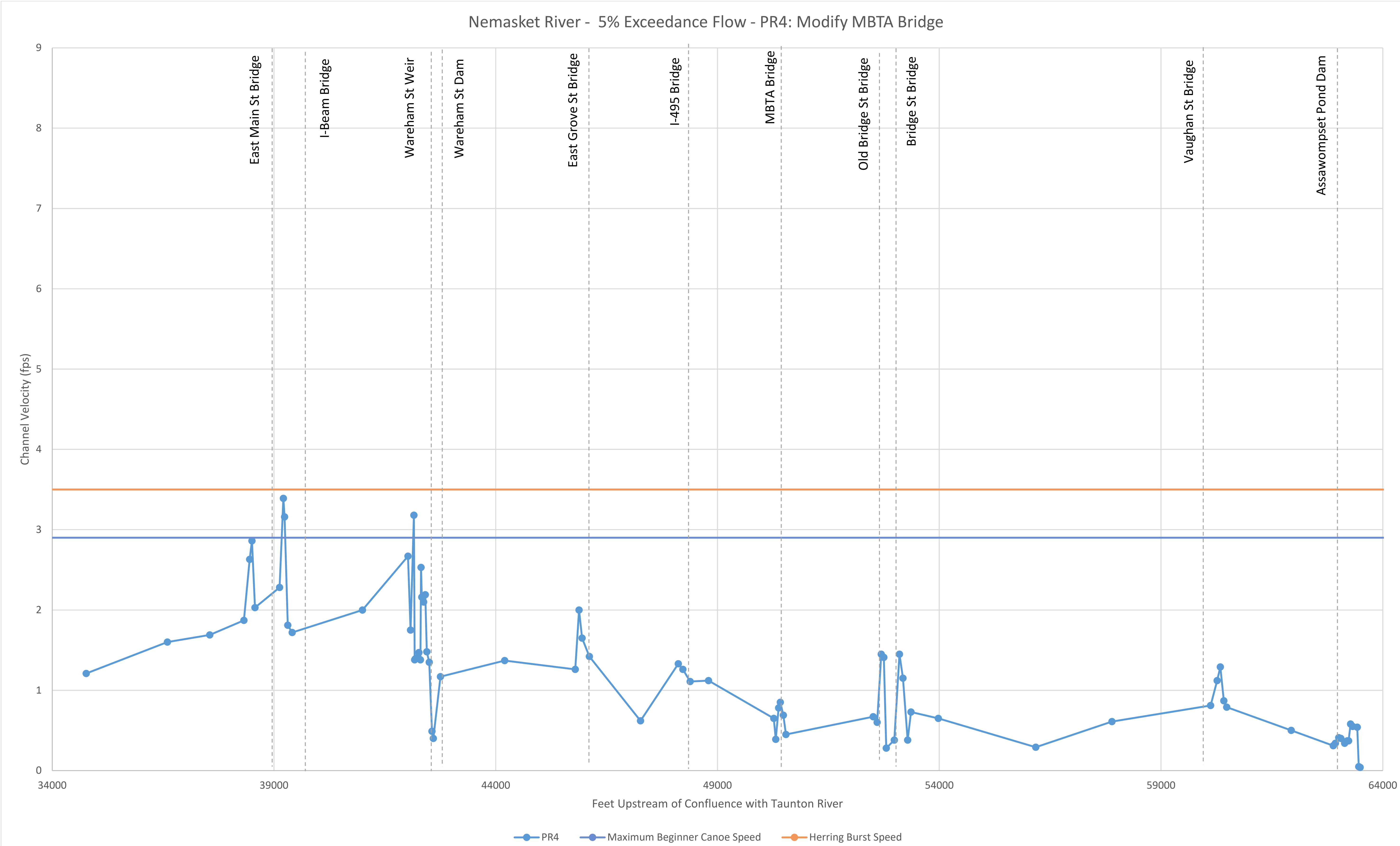

Nemasket River - 5% Exceedance Flow - PR1: Remove Wareham Street Dam
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
PR1
Maximum Beginner Canoe Speed
Herring Burst Speed



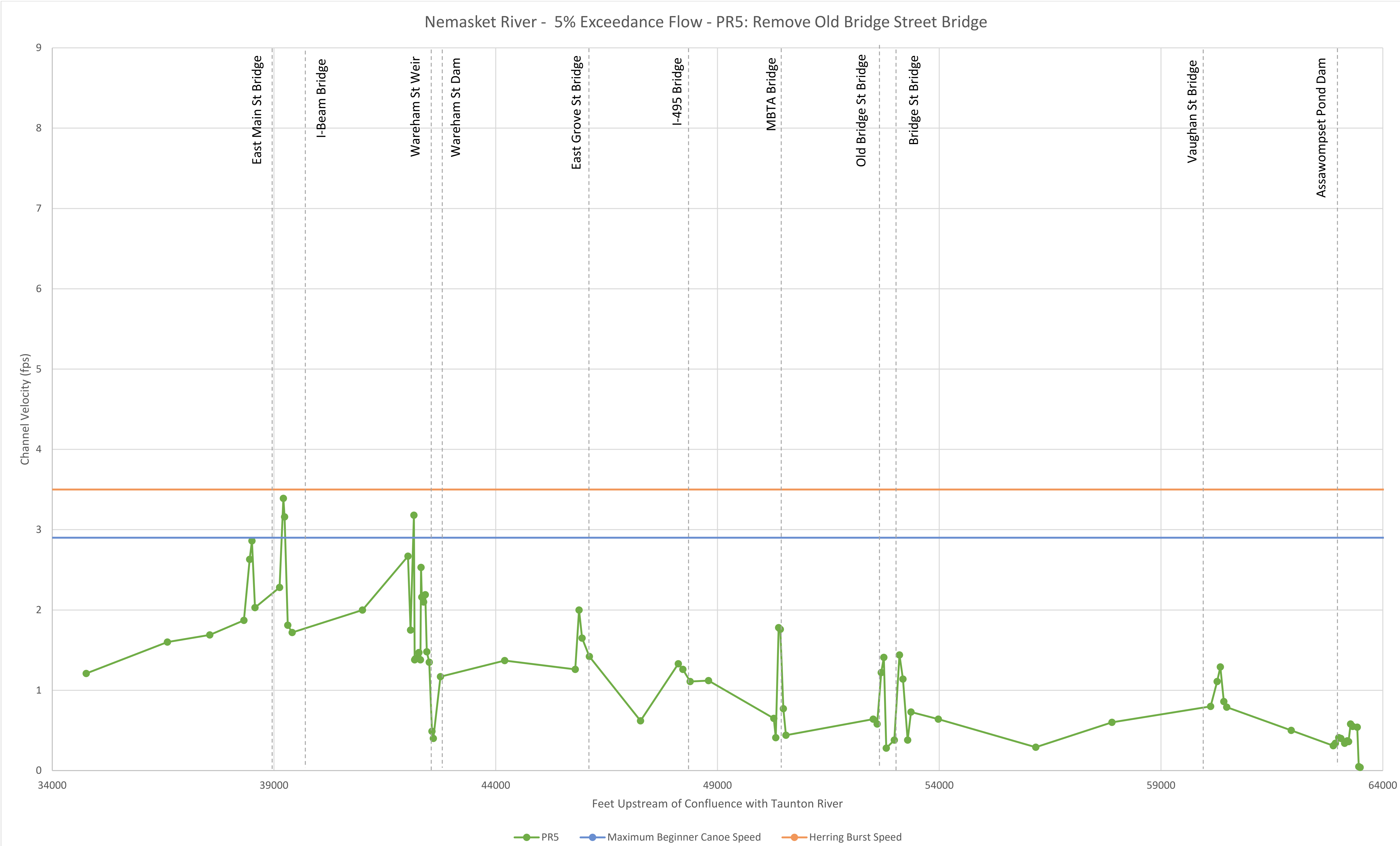
Nemasket River - 5% Exceedance Flow - PR2: Modify East Grove Street Bridge
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR2
Maximum Beginner Canoe Speed
Herring Burst Speed



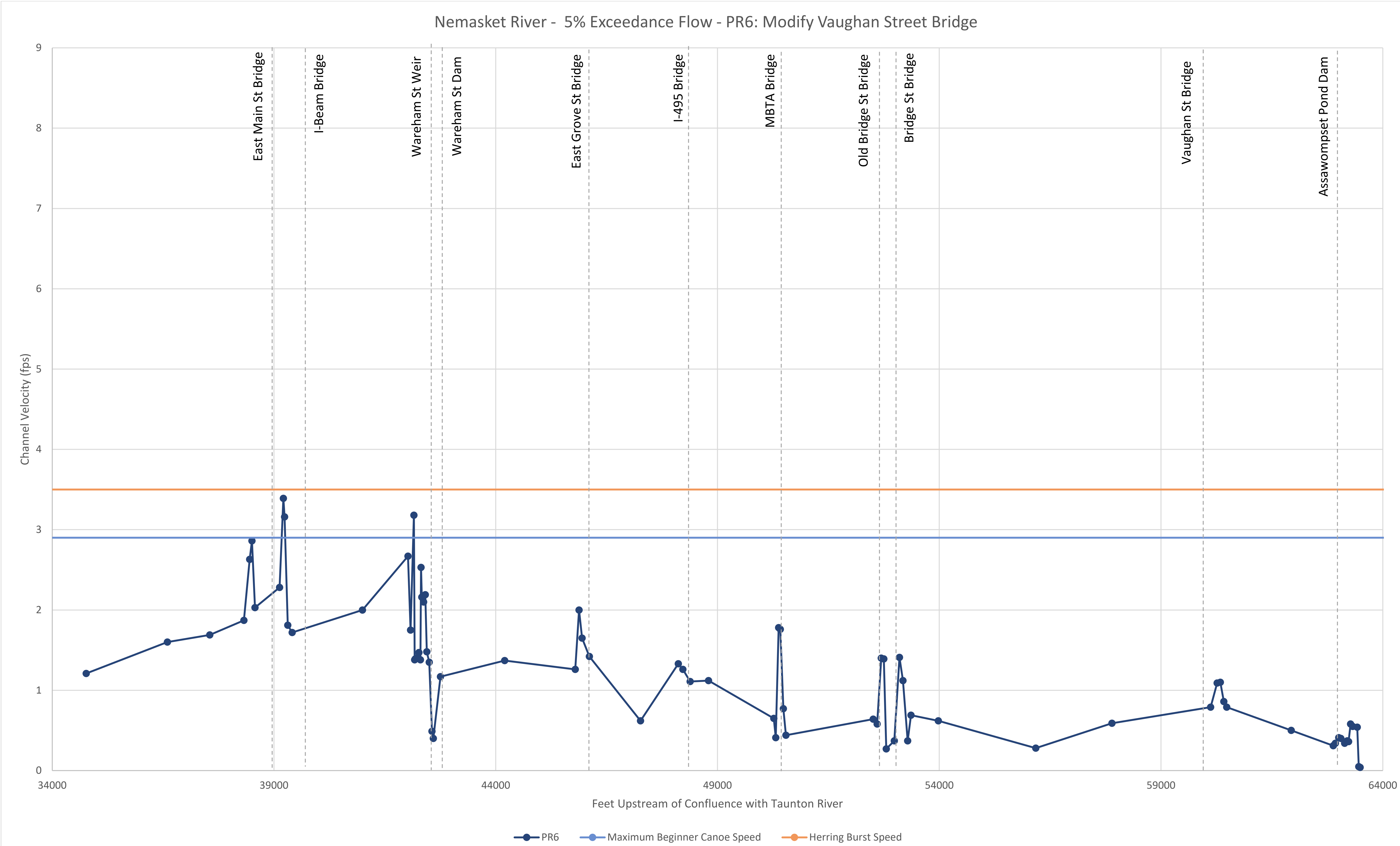
Nemasket River - 5% Exceedance Flow - PR3: Modify I-495 Bridge
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Channel Velocity (fps)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR3
Maximum Beginner Canoe Speed
Herring Burst Speed



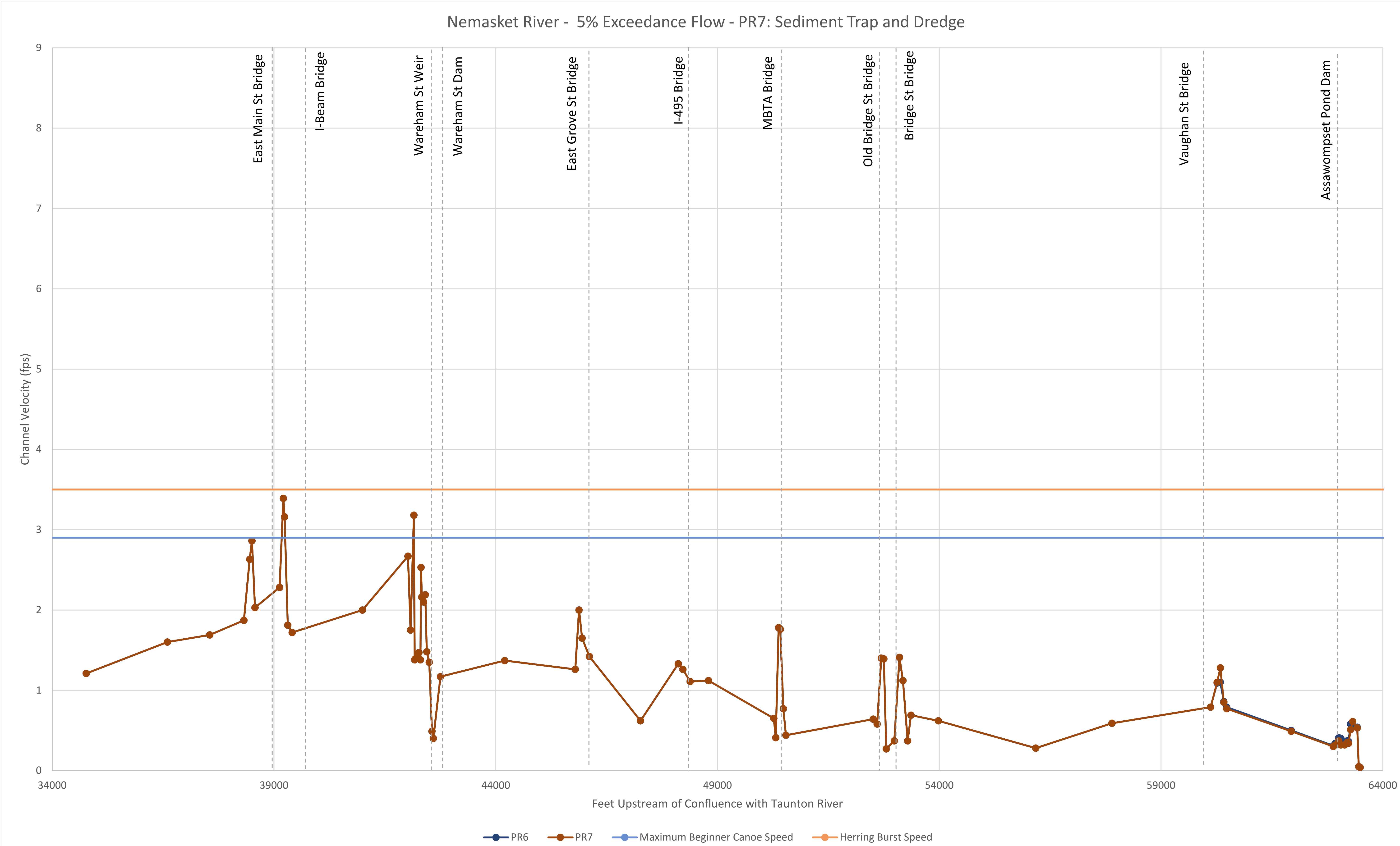
Nemasket River - 5% Exceedance Flow - PR4: Modify MBTA Bridge
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR4
Maximum Beginner Canoe Speed
Herring Burst Speed

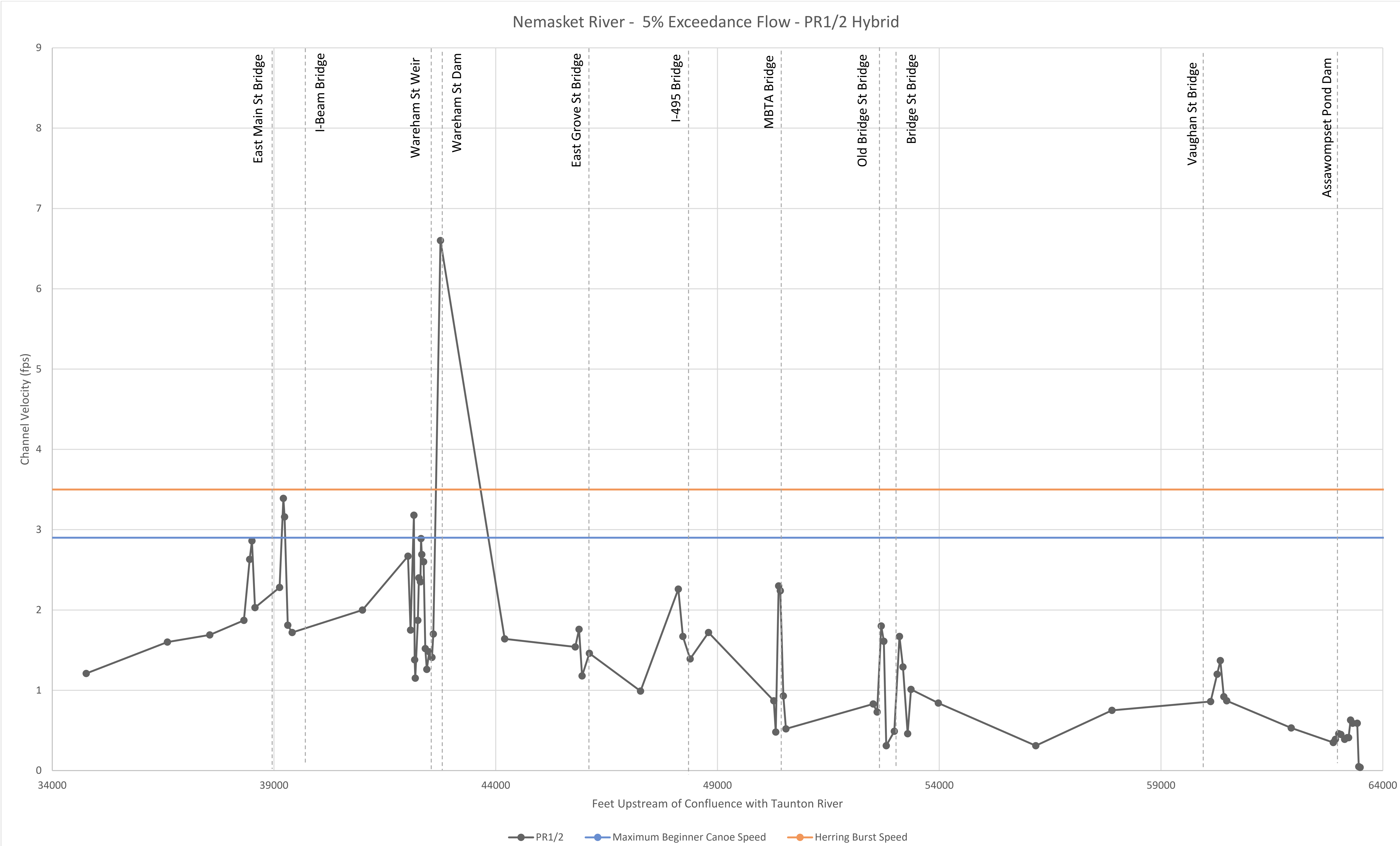


Nemasket River - 5% Exceedance Flow - PR5: Remove Old Bridge Street Bridge
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR5
Maximum Beginner Canoe Speed
Herring Burst Speed

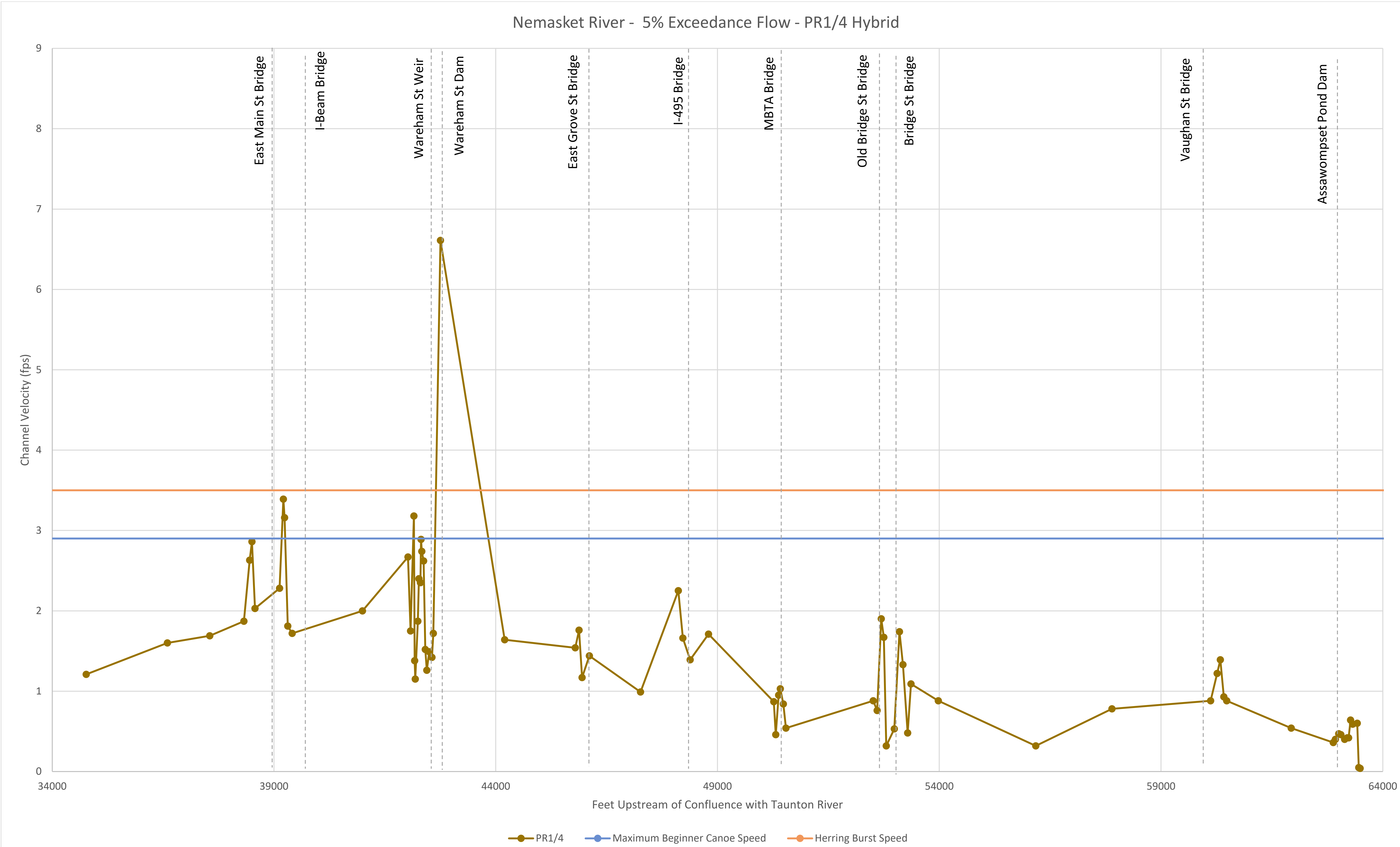


Nemasket River - 5% Exceedance Flow - PR6: Modify Vaughan Street Bridge
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR6
Maximum Beginner Canoe Speed
Herring Burst Speed

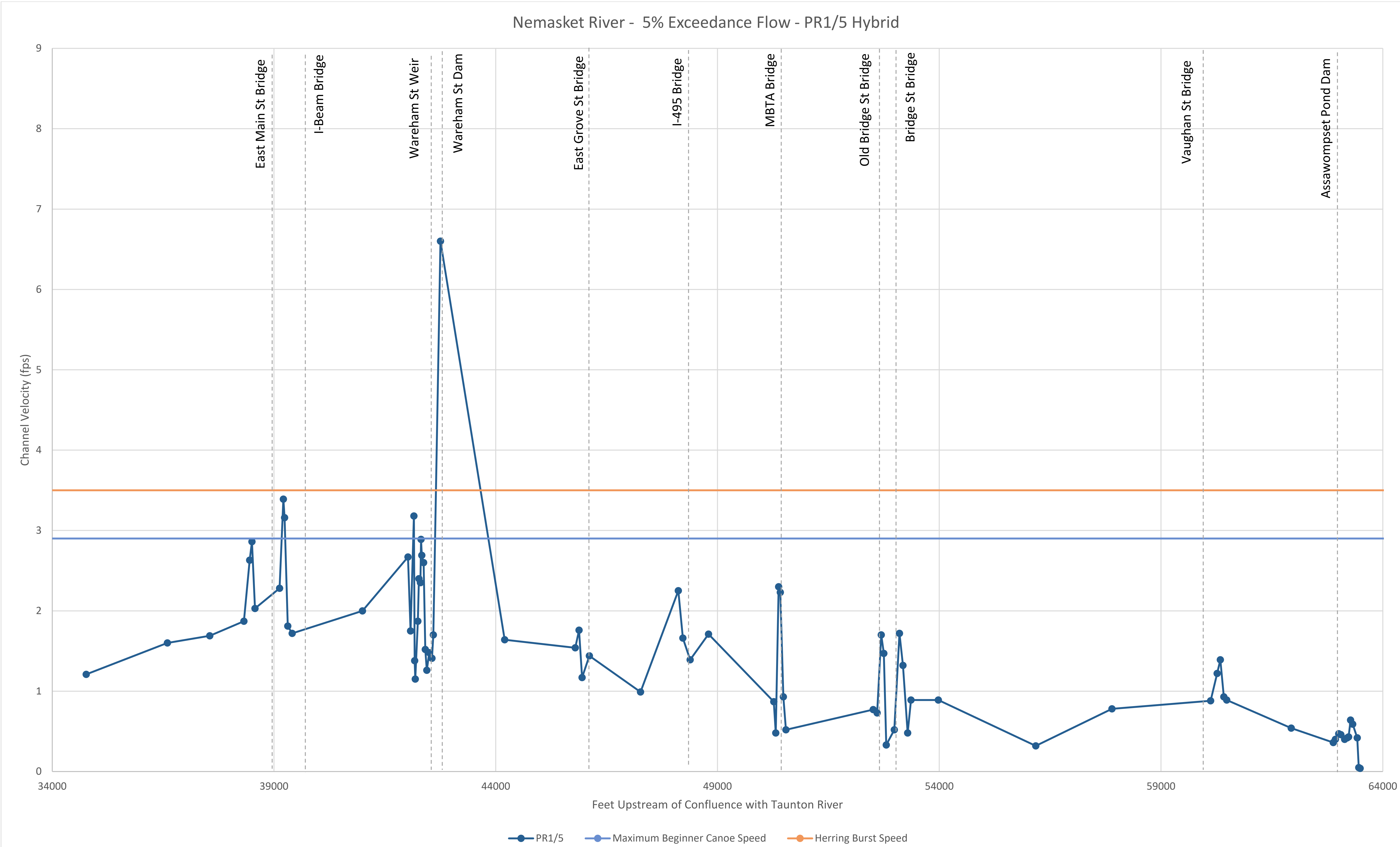

Nemasket River - 5% Exceedance Flow - PR7: Sediment Trap and Dredge
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR6
PR7
Maximum Beginner Canoe Speed
Herring Burst Speed

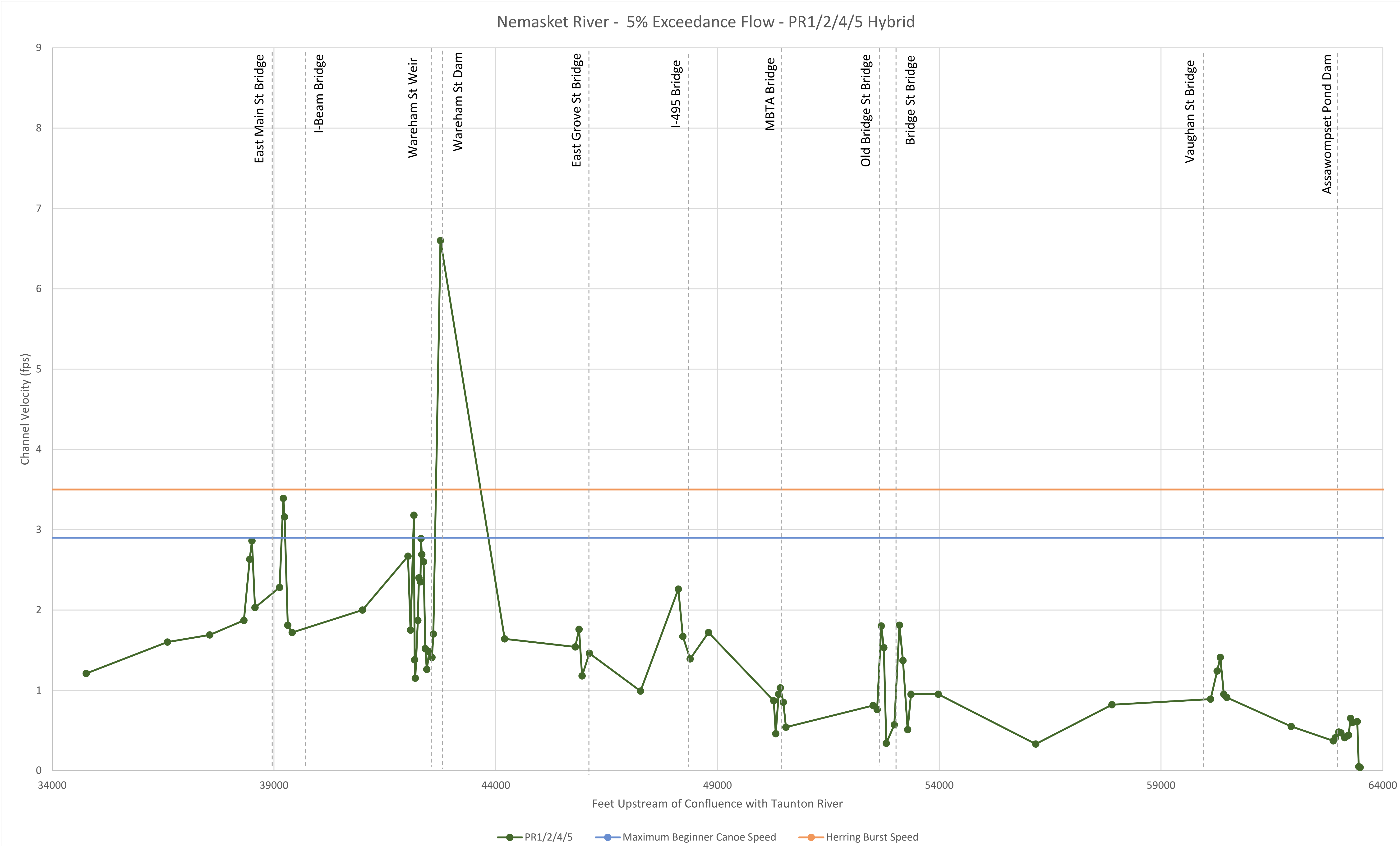


Nemasket River - 5% Exceedance Flow - PR1/2 Hybrid
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
PR1/2
Maximum Beginner Canoe Speed
Herring Burst Speed



Nemasket River - 5% Exceedance Flow - PR1/4 Hybrid
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Channel Velocity (fps)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR1/4
Maximum Beginner Canoe Speed
Herring Burst Speed


Nemasket River - 5% Exceedance Flow - PR1/5 Hybrid
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
Channel Velocity (fps)
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
Feet Upstream of Confluence with Taunton River
PR1/5
Maximum Beginner Canoe Speed
Herring Burst Speed



Nemasket River - 5% Exceedance Flow - PR1/2/4/5 Hybrid
Channel Velocity (fps)
Feet Upstream of Confluence with Taunton River
East Main St Bridge
I-Beam Bridge
Wareham St Weir
Wareham St Dam
East Grove St Bridge
I-495 Bridge
MBTA Bridge
Old Bridge St Bridge
Bridge St Bridge
Vaughan St Bridge
Assawompset Pond Dam
0
1
2
3
4
5
6
7
8
9
34000
39000
44000
49000
54000
59000
64000
PR1/2/4/5
Maximum Beginner Canoe Speed
Herring Burst Speed

APPENDIX A – ANALYTICAL REPORT – WAREHAM STREET, NEMASKET RIVER

ANALYTICAL REPORT

Lab Number:	L2131509
Client:	Outback Engineering, Inc. 165 East Grove St Middleboro, MA 02346
ATTN:	Matthew Grosschedl
Phone:	(508) 946-9231
Project Name:	WAREHAM STREET NEMASKET RIVER
Project Number:	OE-3676A
Report Date:	07/23/21

Certifications & Approvals: MA (M-MA086), NH NELAP (2064), CT (PH-0574), IL (200077), ME (MA00086), MD (348), NJ (MA935), NY (11148), NC (25700/666), PA (68-03671), RI (LAO00065), TX (T104704476), VT (VT-0935), VA (460195), USDA (Permit #P330-17-00196).

Eight Walkup Drive, Westborough, MA 01581-1019
508-898-9220 (Fax) 508-898-9193 800-624-9220 - www.alphalab.com

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

Alpha Sample ID	Client ID	Matrix	Sample Location	Collection Date/Time	Receive Date
L2131509-01	SAMPLE # 1	SOIL	MIDDLEBORO, MA	06/10/21 10:30	06/11/21
L2131509-02	SAMPLE # 2	SOIL	MIDDLEBORO, MA	06/10/21 11:30	06/11/21

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

MADEP MCP Response Action Analytical Report Certification

This form provides certifications for all samples performed by MCP methods. Please refer to the Sample Results and Container Information sections of this report for specification of MCP methods used for each analysis. The following questions pertain only to MCP Analytical Methods.

An affirmative response to questions A through F is required for "Presumptive Certainty" status		
A	Were all samples received in a condition consistent with those described on the Chain-of-Custody, properly preserved (including temperature) in the field or laboratory, and prepared/analyzed within method holding times?	YES
B	Were the analytical method(s) and all associated QC requirements specified in the selected CAM protocol(s) followed?	YES
C	Were all required corrective actions and analytical response actions specified in the selected CAM protocol(s) implemented for all identified performance standard non-conformances?	YES
D	Does the laboratory report comply with all the reporting requirements specified in CAM VII A, "Quality Assurance and Quality Control Guidelines for the Acquisition and Reporting of Analytical Data?"	YES
E a.	VPH, EPH, and APH Methods only: Was each method conducted without significant modification(s)? (Refer to the individual method(s) for a list of significant modifications).	YES
E b.	APH and TO-15 Methods only: Was the complete analyte list reported for each method?	N/A
F	Were all applicable CAM protocol QC and performance standard non-conformances identified and evaluated in a laboratory narrative (including all "No" responses to Questions A through E)?	YES

A response to questions G, H and I is required for "Presumptive Certainty" status		
G	Were the reporting limits at or below all CAM reporting limits specified in the selected CAM protocol(s)?	YES
H	Were all QC performance standards specified in the CAM protocol(s) achieved?	NO
I	Were results reported for the complete analyte list specified in the selected CAM protocol(s)?	NO

For any questions answered "No", please refer to the case narrative section on the following page(s).

Please note that sample matrix information is located in the Sample Results section of this report.

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

Case Narrative

The samples were received in accordance with the Chain of Custody and no significant deviations were encountered during the preparation or analysis unless otherwise noted. Sample Receipt, Container Information, and the Chain of Custody are located at the back of the report.

Results contained within this report relate only to the samples submitted under this Alpha Lab Number and meet NELAP requirements for all NELAP accredited parameters unless otherwise noted in the following narrative. The data presented in this report is organized by parameter (i.e. VOC, SVOC, etc.). Sample specific Quality Control data (i.e. Surrogate Spike Recovery) is reported at the end of the target analyte list for each individual sample, followed by the Laboratory Batch Quality Control at the end of each parameter. Tentatively Identified Compounds (TICs), if requested, are reported for compounds identified to be present and are not part of the method/program Target Compound List, even if only a subset of the TCL are being reported. If a sample was re-analyzed or re-extracted due to a required quality control corrective action and if both sets of data are reported, the Laboratory ID of the re-analysis or re-extraction is designated with an "R" or "RE", respectively.

When multiple Batch Quality Control elements are reported (e.g. more than one LCS), the associated samples for each element are noted in the grey shaded header line of each data table. Any Laboratory Batch, Sample Specific % recovery or RPD value that is outside the listed Acceptance Criteria is bolded in the report. In reference to questions H (CAM) or 4 (RCP) when "NO" is checked, the performance criteria for CAM and RCP methods allow for some quality control failures to occur and still be within method compliance. In these instances, the specific failure is not narrated but noted in the associated QC Outlier Summary Report, located directly after the Case Narrative. QC information is also incorporated in the Data Usability Assessment table (Format 11) of our Data Merger tool, where it can be reviewed in conjunction with the sample result, associated regulatory criteria and any associated data usability implications.

Soil/sediments, solids and tissues are reported on a dry weight basis unless otherwise noted. Definitions of all data qualifiers and acronyms used in this report are provided in the Glossary located at the back of the report.

HOLD POLICY - For samples submitted on hold, Alpha's policy is to hold samples (with the exception of Air canisters) free of charge for 21 calendar days from the date the project is completed. After 21 calendar days, we will dispose of all samples submitted including those put on hold unless you have contacted your Alpha Project Manager and made arrangements for Alpha to continue to hold the samples. Air canisters will be disposed after 3 business days from the date the project is completed.

Please contact Project Management at 800-624-9220 with any questions.

Case Narrative (continued)

MCP Related Narratives

Sample Receipt

In reference to question H:

A Matrix Spike was not submitted for the analysis of Total Metals.

Volatile Organics

In reference to question H:

L2131509-01 and -02: Initial Calibration did not meet:

Lowest Calibration Standard Minimum Response Factor: 1,4-dioxane (0.0020)

Average Response Factor: 1,4-dioxane

L2131509-01 and -02: The associated continuing calibration standard is outside the acceptance criteria for several compounds; however, it is within overall method allowances. A copy of the continuing calibration standard is included as an addendum to this report.

EPH

In reference to question I:

All samples were analyzed for a subset of MCP analytes per client request.

Total Metals

In reference to question I:

All samples were analyzed for a subset of MCP analytes per client request.

Non-MCP Related Narratives

Petroleum Hydrocarbon Quantitation

WG1515332: A Laboratory Duplicate was prepared with the sample batch, however, the native sample was not available for reporting; therefore, the results could not be reported.

Case Narrative (continued)

Grain Size Analysis

The WG1514863-1 Laboratory Duplicate RPD for % total fines (32%), performed on L2131509-02, is outside the acceptance criteria. The elevated RPD has been attributed to the non-homogeneous nature of the native sample.

I, the undersigned, attest under the pains and penalties of perjury that, to the best of my knowledge and belief and based upon my personal inquiry of those responsible for providing the information contained in this analytical report, such information is accurate and complete. This certificate of analysis is not complete unless this page accompanies any and all pages of this report.

Authorized Signature: Kelly Stenstrom

Title: Technical Director/Representative Date: 07/23/21

QC OUTLIER SUMMARY REPORT

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

Method	Client ID (Native ID)	Lab ID	Parameter	QC Type	Recovery/RPD (%)	QC Limits (%)	Associated Samples	Data Quality Assessment
MCP Semivolatile Organics - Westborough Lab								
8270D	SAMPLE # 1	L2131509-01	4-Terphenyl-d14	Surrogate	28	30-130	-	potential low bias
Grain Size Analysis - Mansfield Lab								
D6913/D7928	Batch QC (L2131509-02)	WG1514863-1	% Total Fines	Duplicate	32	20	01-02	non-directional bias

ORGANICS

VOLATILES

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA
Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 97,8260C
Analytical Date: 06/23/21 07:37
Analyst: MV
Percent Solids: 31%

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
Methylene chloride	ND		ug/kg	9.8	--	1
1,1-Dichloroethane	ND		ug/kg	2.0	--	1
Chloroform	ND		ug/kg	3.0	--	1
Carbon tetrachloride	ND		ug/kg	2.0	--	1
1,2-Dichloropropane	ND		ug/kg	2.0	--	1
Dibromochloromethane	ND		ug/kg	2.0	--	1
1,1,2-Trichloroethane	ND		ug/kg	2.0	--	1
Tetrachloroethene	ND		ug/kg	0.98	--	1
Chlorobenzene	ND		ug/kg	0.98	--	1
Trichlorofluoromethane	ND		ug/kg	7.9	--	1
1,2-Dichloroethane	ND		ug/kg	2.0	--	1
1,1,1-Trichloroethane	ND		ug/kg	0.98	--	1
Bromodichloromethane	ND		ug/kg	0.98	--	1
trans-1,3-Dichloropropene	ND		ug/kg	2.0	--	1
cis-1,3-Dichloropropene	ND		ug/kg	0.98	--	1
1,3-Dichloropropene, Total	ND		ug/kg	0.98	--	1
1,1-Dichloropropene	ND		ug/kg	0.98	--	1
Bromoform	ND		ug/kg	7.9	--	1
1,1,2,2-Tetrachloroethane	ND		ug/kg	0.98	--	1
Benzene	ND		ug/kg	0.98	--	1
Toluene	ND		ug/kg	2.0	--	1
Ethylbenzene	ND		ug/kg	2.0	--	1
Chloromethane	ND		ug/kg	7.9	--	1
Bromomethane	ND		ug/kg	3.9	--	1
Vinyl chloride	ND		ug/kg	2.0	--	1
Chloroethane	ND		ug/kg	3.9	--	1
1,1-Dichloroethene	ND		ug/kg	2.0	--	1
trans-1,2-Dichloroethene	ND		ug/kg	3.0	--	1

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
Trichloroethene	ND		ug/kg	0.98	--	1
1,2-Dichlorobenzene	ND		ug/kg	3.9	--	1
1,3-Dichlorobenzene	ND		ug/kg	3.9	--	1
1,4-Dichlorobenzene	ND		ug/kg	3.9	--	1
Methyl tert butyl ether	ND		ug/kg	3.9	--	1
p/m-Xylene	ND		ug/kg	3.9	--	1
o-Xylene	ND		ug/kg	2.0	--	1
Xylenes, Total	ND		ug/kg	2.0	--	1
cis-1,2-Dichloroethene	ND		ug/kg	2.0	--	1
1,2-Dichloroethene, Total	ND		ug/kg	2.0	--	1
Dibromomethane	ND		ug/kg	3.9	--	1
1,2,3-Trichloropropane	ND		ug/kg	3.9	--	1
Styrene	ND		ug/kg	2.0	--	1
Dichlorodifluoromethane	ND		ug/kg	20	--	1
Acetone	150		ug/kg	49	--	1
Carbon disulfide	ND		ug/kg	20	--	1
Methyl ethyl ketone	33		ug/kg	20	--	1
Methyl isobutyl ketone	ND		ug/kg	20	--	1
2-Hexanone	ND		ug/kg	20	--	1
Bromochloromethane	ND		ug/kg	3.9	--	1
Tetrahydrofuran	ND		ug/kg	7.9	--	1
2,2-Dichloropropane	ND		ug/kg	3.9	--	1
1,2-Dibromoethane	ND		ug/kg	2.0	--	1
1,3-Dichloropropane	ND		ug/kg	3.9	--	1
1,1,1,2-Tetrachloroethane	ND		ug/kg	0.98	--	1
Bromobenzene	ND		ug/kg	3.9	--	1
n-Butylbenzene	ND		ug/kg	2.0	--	1
sec-Butylbenzene	ND		ug/kg	2.0	--	1
tert-Butylbenzene	ND		ug/kg	3.9	--	1
o-Chlorotoluene	ND		ug/kg	3.9	--	1
p-Chlorotoluene	ND		ug/kg	3.9	--	1
1,2-Dibromo-3-chloropropane	ND		ug/kg	5.9	--	1
Hexachlorobutadiene	ND		ug/kg	7.9	--	1
Isopropylbenzene	ND		ug/kg	2.0	--	1
p-Isopropyltoluene	ND		ug/kg	2.0	--	1
Naphthalene	ND		ug/kg	7.9	--	1
n-Propylbenzene	ND		ug/kg	2.0	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509

Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
1,2,3-Trichlorobenzene	ND		ug/kg	3.9	--	1
1,2,4-Trichlorobenzene	ND		ug/kg	3.9	--	1
1,3,5-Trimethylbenzene	ND		ug/kg	3.9	--	1
1,2,4-Trimethylbenzene	ND		ug/kg	3.9	--	1
Diethyl ether	ND		ug/kg	3.9	--	1
Diisopropyl Ether	ND		ug/kg	3.9	--	1
Ethyl-Tert-Butyl-Ether	ND		ug/kg	3.9	--	1
Tertiary-Amyl Methyl Ether	ND		ug/kg	3.9	--	1
1,4-Dioxane	ND		ug/kg	160	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
1,2-Dichloroethane-d4	105		70-130
Toluene-d8	97		70-130
4-Bromofluorobenzene	99		70-130
Dibromofluoromethane	111		70-130

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-02	Date Collected:	06/10/21 11:30
Client ID:	SAMPLE # 2	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 97,8260C
Analytical Date: 06/23/21 08:02
Analyst: MV
Percent Solids: 80%

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
Methylene chloride	ND		ug/kg	3.0	--	1
1,1-Dichloroethane	ND		ug/kg	0.60	--	1
Chloroform	ND		ug/kg	0.90	--	1
Carbon tetrachloride	ND		ug/kg	0.60	--	1
1,2-Dichloropropane	ND		ug/kg	0.60	--	1
Dibromochloromethane	ND		ug/kg	0.60	--	1
1,1,2-Trichloroethane	ND		ug/kg	0.60	--	1
Tetrachloroethene	ND		ug/kg	0.30	--	1
Chlorobenzene	ND		ug/kg	0.30	--	1
Trichlorofluoromethane	ND		ug/kg	2.4	--	1
1,2-Dichloroethane	ND		ug/kg	0.60	--	1
1,1,1-Trichloroethane	ND		ug/kg	0.30	--	1
Bromodichloromethane	ND		ug/kg	0.30	--	1
trans-1,3-Dichloropropene	ND		ug/kg	0.60	--	1
cis-1,3-Dichloropropene	ND		ug/kg	0.30	--	1
1,3-Dichloropropene, Total	ND		ug/kg	0.30	--	1
1,1-Dichloropropene	ND		ug/kg	0.30	--	1
Bromoform	ND		ug/kg	2.4	--	1
1,1,2,2-Tetrachloroethane	ND		ug/kg	0.30	--	1
Benzene	ND		ug/kg	0.30	--	1
Toluene	ND		ug/kg	0.60	--	1
Ethylbenzene	ND		ug/kg	0.60	--	1
Chloromethane	ND		ug/kg	2.4	--	1
Bromomethane	ND		ug/kg	1.2	--	1
Vinyl chloride	ND		ug/kg	0.60	--	1
Chloroethane	ND		ug/kg	1.2	--	1
1,1-Dichloroethene	ND		ug/kg	0.60	--	1
trans-1,2-Dichloroethene	ND		ug/kg	0.90	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509

Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02 Date Collected: 06/10/21 11:30
Client ID: SAMPLE # 2 Date Received: 06/11/21
Sample Location: MIDDLEBORO, MA Field Prep: Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
Trichloroethene	ND		ug/kg	0.30	--	1
1,2-Dichlorobenzene	ND		ug/kg	1.2	--	1
1,3-Dichlorobenzene	ND		ug/kg	1.2	--	1
1,4-Dichlorobenzene	ND		ug/kg	1.2	--	1
Methyl tert butyl ether	ND		ug/kg	1.2	--	1
p/m-Xylene	ND		ug/kg	1.2	--	1
o-Xylene	ND		ug/kg	0.60	--	1
Xylenes, Total	ND		ug/kg	0.60	--	1
cis-1,2-Dichloroethene	ND		ug/kg	0.60	--	1
1,2-Dichloroethene, Total	ND		ug/kg	0.60	--	1
Dibromomethane	ND		ug/kg	1.2	--	1
1,2,3-Trichloropropane	ND		ug/kg	1.2	--	1
Styrene	ND		ug/kg	0.60	--	1
Dichlorodifluoromethane	ND		ug/kg	6.0	--	1
Acetone	81		ug/kg	15	--	1
Carbon disulfide	ND		ug/kg	6.0	--	1
Methyl ethyl ketone	17		ug/kg	6.0	--	1
Methyl isobutyl ketone	ND		ug/kg	6.0	--	1
2-Hexanone	ND		ug/kg	6.0	--	1
Bromochloromethane	ND		ug/kg	1.2	--	1
Tetrahydrofuran	ND		ug/kg	2.4	--	1
2,2-Dichloropropane	ND		ug/kg	1.2	--	1
1,2-Dibromoethane	ND		ug/kg	0.60	--	1
1,3-Dichloropropane	ND		ug/kg	1.2	--	1
1,1,1,2-Tetrachloroethane	ND		ug/kg	0.30	--	1
Bromobenzene	ND		ug/kg	1.2	--	1
n-Butylbenzene	ND		ug/kg	0.60	--	1
sec-Butylbenzene	ND		ug/kg	0.60	--	1
tert-Butylbenzene	ND		ug/kg	1.2	--	1
o-Chlorotoluene	ND		ug/kg	1.2	--	1
p-Chlorotoluene	ND		ug/kg	1.2	--	1
1,2-Dibromo-3-chloropropane	ND		ug/kg	1.8	--	1
Hexachlorobutadiene	ND		ug/kg	2.4	--	1
Isopropylbenzene	ND		ug/kg	0.60	--	1
p-Isopropyltoluene	ND		ug/kg	0.60	--	1
Naphthalene	ND		ug/kg	2.4	--	1
n-Propylbenzene	ND		ug/kg	0.60	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-02	Date Collected:	06/10/21 11:30
Client ID:	SAMPLE # 2	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Volatile Organics by EPA 5035 Low - Westborough Lab						
1,2,3-Trichlorobenzene	ND		ug/kg	1.2	--	1
1,2,4-Trichlorobenzene	ND		ug/kg	1.2	--	1
1,3,5-Trimethylbenzene	ND		ug/kg	1.2	--	1
1,2,4-Trimethylbenzene	ND		ug/kg	1.2	--	1
Diethyl ether	ND		ug/kg	1.2	--	1
Diisopropyl Ether	ND		ug/kg	1.2	--	1
Ethyl-Tert-Butyl-Ether	ND		ug/kg	1.2	--	1
Tertiary-Amyl Methyl Ether	ND		ug/kg	1.2	--	1
1,4-Dioxane	ND		ug/kg	48	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
1,2-Dichloroethane-d4	112		70-130
Toluene-d8	94		70-130
4-Bromofluorobenzene	97		70-130
Dibromofluoromethane	115		70-130

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 97,8260C
Analytical Date: 06/23/21 06:21
Analyst: MV

Parameter	Result	Qualifier	Units	RL	MDL
MCP Volatile Organics by EPA 5035 Low - Westborough Lab for sample(s): 01-02 Batch: WG1515882-5					
Methylene chloride	ND		ug/kg	5.0	--
1,1-Dichloroethane	ND		ug/kg	1.0	--
Chloroform	ND		ug/kg	1.5	--
Carbon tetrachloride	ND		ug/kg	1.0	--
1,2-Dichloropropane	ND		ug/kg	1.0	--
Dibromochloromethane	ND		ug/kg	1.0	--
1,1,2-Trichloroethane	ND		ug/kg	1.0	--
Tetrachloroethene	ND		ug/kg	0.50	--
Chlorobenzene	ND		ug/kg	0.50	--
Trichlorofluoromethane	ND		ug/kg	4.0	--
1,2-Dichloroethane	ND		ug/kg	1.0	--
1,1,1-Trichloroethane	ND		ug/kg	0.50	--
Bromodichloromethane	ND		ug/kg	0.50	--
trans-1,3-Dichloropropene	ND		ug/kg	1.0	--
cis-1,3-Dichloropropene	ND		ug/kg	0.50	--
1,3-Dichloropropene, Total	ND		ug/kg	0.50	--
1,1-Dichloropropene	ND		ug/kg	0.50	--
Bromoform	ND		ug/kg	4.0	--
1,1,2,2-Tetrachloroethane	ND		ug/kg	0.50	--
Benzene	ND		ug/kg	0.50	--
Toluene	ND		ug/kg	1.0	--
Ethylbenzene	ND		ug/kg	1.0	--
Chloromethane	ND		ug/kg	4.0	--
Bromomethane	ND		ug/kg	2.0	--
Vinyl chloride	ND		ug/kg	1.0	--
Chloroethane	ND		ug/kg	2.0	--
1,1-Dichloroethene	ND		ug/kg	1.0	--
trans-1,2-Dichloroethene	ND		ug/kg	1.5	--
Trichloroethene	ND		ug/kg	0.50	--

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 97,8260C
Analytical Date: 06/23/21 06:21
Analyst: MV

Parameter	Result	Qualifier	Units	RL	MDL
MCP Volatile Organics by EPA 5035 Low - Westborough Lab for sample(s): 01-02 Batch: WG1515882-5					
1,2-Dichlorobenzene	ND		ug/kg	2.0	--
1,3-Dichlorobenzene	ND		ug/kg	2.0	--
1,4-Dichlorobenzene	ND		ug/kg	2.0	--
Methyl tert butyl ether	ND		ug/kg	2.0	--
p/m-Xylene	ND		ug/kg	2.0	--
o-Xylene	ND		ug/kg	1.0	--
Xylenes, Total	ND		ug/kg	1.0	--
cis-1,2-Dichloroethene	ND		ug/kg	1.0	--
1,2-Dichloroethene, Total	ND		ug/kg	1.0	--
Dibromomethane	ND		ug/kg	2.0	--
1,2,3-Trichloropropane	ND		ug/kg	2.0	--
Styrene	ND		ug/kg	1.0	--
Dichlorodifluoromethane	ND		ug/kg	10	--
Acetone	ND		ug/kg	25	--
Carbon disulfide	ND		ug/kg	10	--
Methyl ethyl ketone	ND		ug/kg	10	--
Methyl isobutyl ketone	ND		ug/kg	10	--
2-Hexanone	ND		ug/kg	10	--
Bromochloromethane	ND		ug/kg	2.0	--
Tetrahydrofuran	ND		ug/kg	4.0	--
2,2-Dichloropropane	ND		ug/kg	2.0	--
1,2-Dibromoethane	ND		ug/kg	1.0	--
1,3-Dichloropropane	ND		ug/kg	2.0	--
1,1,1,2-Tetrachloroethane	ND		ug/kg	0.50	--
Bromobenzene	ND		ug/kg	2.0	--
n-Butylbenzene	ND		ug/kg	1.0	--
sec-Butylbenzene	ND		ug/kg	1.0	--
tert-Butylbenzene	ND		ug/kg	2.0	--
o-Chlorotoluene	ND		ug/kg	2.0	--

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 97,8260C
Analytical Date: 06/23/21 06:21
Analyst: MV

Parameter	Result	Qualifier	Units	RL	MDL
MCP Volatile Organics by EPA 5035 Low - Westborough Lab for sample(s): 01-02 Batch: WG1515882-5					
p-Chlorotoluene	ND		ug/kg	2.0	--
1,2-Dibromo-3-chloropropane	ND		ug/kg	3.0	--
Hexachlorobutadiene	ND		ug/kg	4.0	--
Isopropylbenzene	ND		ug/kg	1.0	--
p-Isopropyltoluene	ND		ug/kg	1.0	--
Naphthalene	ND		ug/kg	4.0	--
n-Propylbenzene	ND		ug/kg	1.0	--
1,2,3-Trichlorobenzene	ND		ug/kg	2.0	--
1,2,4-Trichlorobenzene	ND		ug/kg	2.0	--
1,3,5-Trimethylbenzene	ND		ug/kg	2.0	--
1,2,4-Trimethylbenzene	ND		ug/kg	2.0	--
Diethyl ether	ND		ug/kg	2.0	--
Diisopropyl Ether	ND		ug/kg	2.0	--
Ethyl-Tert-Butyl-Ether	ND		ug/kg	2.0	--
Tertiary-Amyl Methyl Ether	ND		ug/kg	2.0	--
1,4-Dioxane	ND		ug/kg	80	--

Surrogate	%Recovery	Qualifier	Acceptance Criteria
1,2-Dichloroethane-d4	107		70-130
Toluene-d8	92		70-130
4-Bromofluorobenzene	94		70-130
Dibromofluoromethane	105		70-130

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER

Project Number: OE-3676A

Lab Number: L2131509

Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Volatile Organics by EPA 5035 Low - Westborough Lab Associated sample(s): 01-02 Batch: WG1515882-3 WG1515882-4								
Methylene chloride	100		95		70-130	5		20
1,1-Dichloroethane	106		102		70-130	4		20
Chloroform	102		98		70-130	4		20
Carbon tetrachloride	120		116		70-130	3		20
1,2-Dichloropropane	101		99		70-130	2		20
Dibromochloromethane	95		94		70-130	1		20
1,1,2-Trichloroethane	91		92		70-130	1		20
Tetrachloroethene	114		112		70-130	2		20
Chlorobenzene	96		94		70-130	2		20
Trichlorofluoromethane	126		119		70-130	6		20
1,2-Dichloroethane	97		95		70-130	2		20
1,1,1-Trichloroethane	114		111		70-130	3		20
Bromodichloromethane	98		97		70-130	1		20
trans-1,3-Dichloropropene	99		98		70-130	1		20
cis-1,3-Dichloropropene	102		99		70-130	3		20
1,1-Dichloropropene	116		112		70-130	4		20
Bromoform	92		92		70-130	0		20
1,1,2,2-Tetrachloroethane	86		85		70-130	1		20
Benzene	102		99		70-130	3		20
Toluene	100		98		70-130	2		20
Ethylbenzene	102		100		70-130	2		20
Chloromethane	96		90		70-130	6		20
Bromomethane	128		119		70-130	7		20

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Volatile Organics by EPA 5035 Low - Westborough Lab Associated sample(s): 01-02 Batch: WG1515882-3 WG1515882-4								
Vinyl chloride	109		102		70-130	7		20
Chloroethane	107		90		70-130	17		20
1,1-Dichloroethene	114		109		70-130	4		20
trans-1,2-Dichloroethene	109		104		70-130	5		20
Trichloroethene	107		105		70-130	2		20
1,2-Dichlorobenzene	96		94		70-130	2		20
1,3-Dichlorobenzene	98		97		70-130	1		20
1,4-Dichlorobenzene	96		95		70-130	1		20
Methyl tert butyl ether	96		93		70-130	3		20
p/m-Xylene	99		99		70-130	0		20
o-Xylene	95		95		70-130	0		20
cis-1,2-Dichloroethene	99		97		70-130	2		20
Dibromomethane	97		95		70-130	2		20
1,2,3-Trichloropropane	86		84		70-130	2		20
Styrene	93		92		70-130	1		20
Dichlorodifluoromethane	113		108		70-130	5		20
Acetone	101		88		70-130	14		20
Carbon disulfide	106		102		70-130	4		20
Methyl ethyl ketone	89		82		70-130	8		20
Methyl isobutyl ketone	91		91		70-130	0		20
2-Hexanone	83		82		70-130	1		20
Bromochloromethane	98		96		70-130	2		20
Tetrahydrofuran	97		94		70-130	3		20

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Volatile Organics by EPA 5035 Low - Westborough Lab Associated sample(s): 01-02 Batch: WG1515882-3 WG1515882-4								
2,2-Dichloropropane	116		111		70-130	4		20
1,2-Dibromoethane	96		96		70-130	0		20
1,3-Dichloropropane	93		93		70-130	0		20
1,1,1,2-Tetrachloroethane	100		98		70-130	2		20
Bromobenzene	96		96		70-130	0		20
n-Butylbenzene	107		105		70-130	2		20
sec-Butylbenzene	105		103		70-130	2		20
tert-Butylbenzene	104		102		70-130	2		20
o-Chlorotoluene	99		97		70-130	2		20
p-Chlorotoluene	98		96		70-130	2		20
1,2-Dibromo-3-chloropropane	86		89		70-130	3		20
Hexachlorobutadiene	114		111		70-130	3		20
Isopropylbenzene	106		103		70-130	3		20
p-Isopropyltoluene	108		105		70-130	3		20
Naphthalene	86		85		70-130	1		20
n-Propylbenzene	105		103		70-130	2		20
1,2,3-Trichlorobenzene	98		96		70-130	2		20
1,2,4-Trichlorobenzene	102		101		70-130	1		20
1,3,5-Trimethylbenzene	102		100		70-130	2		20
1,2,4-Trimethylbenzene	101		99		70-130	2		20
Diethyl ether	93		89		70-130	4		20
Diisopropyl Ether	104		101		70-130	3		20
Ethyl-Tert-Butyl-Ether	102		100		70-130	2		20

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Volatile Organics by EPA 5035 Low - Westborough Lab Associated sample(s): 01-02 Batch: WG1515882-3 WG1515882-4								
Tertiary-Amyl Methyl Ether	97		96		70-130	1		20
1,4-Dioxane	119		114		70-130	4		20

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria
1,2-Dichloroethane-d4	95		95		70-130
Toluene-d8	97		97		70-130
4-Bromofluorobenzene	99		99		70-130
Dibromofluoromethane	98		97		70-130

SEMIVOLATILES

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 105,8270D-SIM/680(M)
Analytical Date: 06/28/21 16:13
Analyst: GP
Percent Solids: 31%

Extraction Method: EPA 3570
Extraction Date: 06/17/21 23:46
Cleanup Method: EPA 3630
Cleanup Date: 06/18/21

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
PAHs/PCB Congeners by GC/MS - Mansfield Lab						
Naphthalene	127		ug/kg	12.0	--	1
Acenaphthylene	469		ug/kg	12.0	--	1
Acenaphthene	222		ug/kg	12.0	--	1
Fluorene	253		ug/kg	12.0	--	1
Phenanthrene	2920	E	ug/kg	12.0	--	1
Anthracene	572		ug/kg	12.0	--	1
Fluoranthene	6000	E	ug/kg	12.0	--	1
Pyrene	5170	E	ug/kg	12.0	--	1
Benz(a)anthracene	3190	E	ug/kg	12.0	--	1
Chrysene	2960	E	ug/kg	12.0	--	1
Benzo(b)fluoranthene	3580	E	ug/kg	12.0	--	1
Benzo(k)fluoranthene	2320		ug/kg	12.0	--	1
Benzo(a)pyrene	2880	E	ug/kg	12.0	--	1
Indeno(1,2,3-cd)Pyrene	2100		ug/kg	12.0	--	1
Dibenz(a,h)anthracene	677		ug/kg	12.0	--	1
Benzo(ghi)perylene	2100		ug/kg	12.0	--	1
Cl4-BZ#44	1.37		ug/kg	1.20	--	1
Cl4-BZ#52	ND		ug/kg	1.20	--	1
Cl4-BZ#66	ND		ug/kg	1.20	--	1
Cl5-BZ#101	1.82		ug/kg	1.20	--	1
Cl5-BZ#118	1.99		ug/kg	1.20	--	1
Cl6-BZ#138	3.09		ug/kg	1.20	--	1
Cl6-BZ#153	2.70		ug/kg	1.20	--	1
Cl7-BZ#170	2.57		ug/kg	1.20	--	1
Cl7-BZ#180	3.04		ug/kg	1.20	--	1
Cl7-BZ#183	ND		ug/kg	1.20	--	1
Cl7-BZ#187	ND		ug/kg	1.20	--	1
Cl9-BZ#206	ND		ug/kg	1.20	--	1

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
PAHs/PCB Congeners by GC/MS - Mansfield Lab						
Cl10-BZ#209	1.84		ug/kg	1.20	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
2-Methylnaphthalene-d10	81		30-150
Pyrene-d10	80		30-150
Benzo(b)fluoranthene-d12	73		30-150
DBOB	105		50-125
BZ 198	82		50-125

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 97,8270D
Analytical Date: 06/23/21 10:58
Analyst: JRW
Percent Solids: 31%

Extraction Method: EPA 3546
Extraction Date: 06/22/21 15:07

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						
Acenaphthene	ND		ug/kg	430	--	1
1,2,4-Trichlorobenzene	ND		ug/kg	530	--	1
Hexachlorobenzene	ND		ug/kg	220	--	1
Bis(2-chloroethyl)ether	ND		ug/kg	220	--	1
2-Chloronaphthalene	ND		ug/kg	530	--	1
1,2-Dichlorobenzene	ND		ug/kg	530	--	1
1,3-Dichlorobenzene	ND		ug/kg	530	--	1
1,4-Dichlorobenzene	ND		ug/kg	220	--	1
3,3'-Dichlorobenzidine	ND		ug/kg	530	--	1
2,4-Dinitrotoluene	ND		ug/kg	220	--	1
2,6-Dinitrotoluene	ND		ug/kg	530	--	1
Azobenzene	ND		ug/kg	530	--	1
Fluoranthene	3600		ug/kg	320	--	1
4-Bromophenyl phenyl ether	ND		ug/kg	530	--	1
Bis(2-chloroisopropyl)ether	ND		ug/kg	220	--	1
Bis(2-chloroethoxy)methane	ND		ug/kg	580	--	1
Hexachlorobutadiene	ND		ug/kg	530	--	1
Hexachloroethane	ND		ug/kg	220	--	1
Isophorone	ND		ug/kg	480	--	1
Naphthalene	ND		ug/kg	530	--	1
Nitrobenzene	ND		ug/kg	480	--	1
Bis(2-ethylhexyl)phthalate	ND		ug/kg	530	--	1
Butyl benzyl phthalate	ND		ug/kg	530	--	1
Di-n-butylphthalate	ND		ug/kg	530	--	1
Di-n-octylphthalate	ND		ug/kg	530	--	1
Diethyl phthalate	ND		ug/kg	530	--	1
Dimethyl phthalate	ND		ug/kg	220	--	1
Benzo(a)anthracene	1700		ug/kg	320	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509

Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						
Benzo(a)pyrene	2000		ug/kg	430	--	1
Benzo(b)fluoranthene	2400		ug/kg	320	--	1
Benzo(k)fluoranthene	960		ug/kg	320	--	1
Chrysene	2000		ug/kg	320	--	1
Acenaphthylene	ND		ug/kg	430	--	1
Anthracene	480		ug/kg	320	--	1
Benzo(ghi)perylene	1200		ug/kg	430	--	1
Fluorene	ND		ug/kg	530	--	1
Phenanthrene	2000		ug/kg	320	--	1
Dibenzo(a,h)anthracene	290		ug/kg	220	--	1
Indeno(1,2,3-cd)pyrene	1300		ug/kg	430	--	1
Pyrene	3100		ug/kg	320	--	1
Aniline	ND		ug/kg	640	--	1
4-Chloroaniline	ND		ug/kg	530	--	1
Dibenzofuran	ND		ug/kg	530	--	1
2-Methylnaphthalene	ND		ug/kg	220	--	1
Acetophenone	ND		ug/kg	530	--	1
2,4,6-Trichlorophenol	ND		ug/kg	220	--	1
2-Chlorophenol	ND		ug/kg	220	--	1
2,4-Dichlorophenol	ND		ug/kg	220	--	1
2,4-Dimethylphenol	ND		ug/kg	220	--	1
2-Nitrophenol	ND		ug/kg	1200	--	1
4-Nitrophenol	ND		ug/kg	750	--	1
2,4-Dinitrophenol	ND		ug/kg	2600	--	1
Pentachlorophenol	ND		ug/kg	1100	--	1
Phenol	ND		ug/kg	530	--	1
2-Methylphenol	ND		ug/kg	530	--	1
3-Methylphenol/4-Methylphenol	ND		ug/kg	770	--	1
2,4,5-Trichlorophenol	ND		ug/kg	530	--	1

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						

Surrogate	% Recovery	Qualifier	Acceptance Criteria
2-Fluorophenol	73		30-130
Phenol-d6	70		30-130
Nitrobenzene-d5	60		30-130
2-Fluorobiphenyl	42		30-130
2,4,6-Tribromophenol	52		30-130
4-Terphenyl-d14	**28**	Q	30-130

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01 D	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified
Sample Depth:			
Matrix:	Soil	Extraction Method:	EPA 3570
Analytical Method:	105,8270D-SIM/680(M)	Extraction Date:	06/17/21 23:46
Analytical Date:	06/29/21 11:42	Cleanup Method:	EPA 3630
Analyst:	GP	Cleanup Date:	06/18/21
Percent Solids:	31%		

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
PAHs/PCB Congeners by GC/MS - Mansfield Lab						
Phenanthrene	2660		ug/kg	60.0	--	5
Fluoranthene	5690		ug/kg	60.0	--	5
Pyrene	5150		ug/kg	60.0	--	5
Benz(a)anthracene	2870		ug/kg	60.0	--	5
Chrysene	3060		ug/kg	60.0	--	5
Benzo(b)fluoranthene	3720		ug/kg	60.0	--	5
Benzo(a)pyrene	2960		ug/kg	60.0	--	5

Surrogate	% Recovery	Qualifier	Acceptance Criteria
2-Methylnaphthalene-d10	77		30-150
Pyrene-d10	78		30-150
Benzo(b)fluoranthene-d12	71		30-150
DBOB	100		50-125
BZ 198	72		50-125

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Client ID: SAMPLE # 2
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 11:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 105,8270D-SIM/680(M)
Analytical Date: 06/28/21 16:50
Analyst: GP
Percent Solids: 80%

Extraction Method: EPA 3570
Extraction Date: 06/17/21 23:46
Cleanup Method: EPA 3630
Cleanup Date: 06/18/21

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
PAHs/PCB Congeners by GC/MS - Mansfield Lab						
Naphthalene	17.2		ug/kg	4.67	--	1
Acenaphthylene	95.2		ug/kg	4.67	--	1
Acenaphthene	14.6		ug/kg	4.67	--	1
Fluorene	22.6		ug/kg	4.67	--	1
Phenanthrene	343		ug/kg	4.67	--	1
Anthracene	97.4		ug/kg	4.67	--	1
Fluoranthene	800		ug/kg	4.67	--	1
Pyrene	778		ug/kg	4.67	--	1
Benz(a)anthracene	487		ug/kg	4.67	--	1
Chrysene	470		ug/kg	4.67	--	1
Benzo(b)fluoranthene	512		ug/kg	4.67	--	1
Benzo(k)fluoranthene	299		ug/kg	4.67	--	1
Benzo(a)pyrene	447		ug/kg	4.67	--	1
Indeno(1,2,3-cd)Pyrene	294		ug/kg	4.67	--	1
Dibenz(a,h)anthracene	93.5		ug/kg	4.67	--	1
Benzo(ghi)perylene	289		ug/kg	4.67	--	1
Cl2-BZ#8	ND		ug/kg	0.467	--	1
Cl3-BZ#18	ND		ug/kg	0.467	--	1
Cl3-BZ#28	ND		ug/kg	0.467	--	1
Cl4-BZ#44	ND		ug/kg	0.467	--	1
Cl4-BZ#49	ND		ug/kg	0.467	--	1
Cl4-BZ#52	ND		ug/kg	0.467	--	1
Cl4-BZ#66	ND		ug/kg	0.467	--	1
Cl5-BZ#87	ND		ug/kg	0.467	--	1
Cl5-BZ#101	ND		ug/kg	0.467	--	1
Cl5-BZ#105	ND		ug/kg	0.467	--	1
Cl5-BZ#118	ND		ug/kg	0.467	--	1
Cl6-BZ#128	ND		ug/kg	0.467	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509

Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-02	Date Collected:	06/10/21 11:30
Client ID:	SAMPLE # 2	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
PAHs/PCB Congeners by GC/MS - Mansfield Lab						
Cl6-BZ#138	ND		ug/kg	0.467	--	1
Cl6-BZ#153	ND		ug/kg	0.467	--	1
Cl7-BZ#170	ND		ug/kg	0.467	--	1
Cl7-BZ#180	ND		ug/kg	0.467	--	1
Cl7-BZ#183	ND		ug/kg	0.467	--	1
Cl7-BZ#184	ND		ug/kg	0.467	--	1
Cl7-BZ#187	ND		ug/kg	0.467	--	1
Cl8-BZ#195	ND		ug/kg	0.467	--	1
Cl9-BZ#206	ND		ug/kg	0.467	--	1
Cl10-BZ#209	ND		ug/kg	0.467	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
2-Methylnaphthalene-d10	68		30-150
Pyrene-d10	72		30-150
Benzo(b)fluoranthene-d12	72		30-150
DBOB	94		50-125
BZ 198	77		50-125

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509

Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Client ID: SAMPLE # 2
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 11:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 97,8270D
Analytical Date: 06/23/21 11:21
Analyst: JRW
Percent Solids: 80%

Extraction Method: EPA 3546
Extraction Date: 06/22/21 15:07

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						
Acenaphthene	ND		ug/kg	160	--	1
1,2,4-Trichlorobenzene	ND		ug/kg	200	--	1
Hexachlorobenzene	ND		ug/kg	86	--	1
Bis(2-chloroethyl)ether	ND		ug/kg	86	--	1
2-Chloronaphthalene	ND		ug/kg	200	--	1
1,2-Dichlorobenzene	ND		ug/kg	200	--	1
1,3-Dichlorobenzene	ND		ug/kg	200	--	1
1,4-Dichlorobenzene	ND		ug/kg	86	--	1
3,3'-Dichlorobenzidine	ND		ug/kg	200	--	1
2,4-Dinitrotoluene	ND		ug/kg	86	--	1
2,6-Dinitrotoluene	ND		ug/kg	200	--	1
Azobenzene	ND		ug/kg	200	--	1
Fluoranthene	1300		ug/kg	120	--	1
4-Bromophenyl phenyl ether	ND		ug/kg	200	--	1
Bis(2-chloroisopropyl)ether	ND		ug/kg	86	--	1
Bis(2-chloroethoxy)methane	ND		ug/kg	220	--	1
Hexachlorobutadiene	ND		ug/kg	200	--	1
Hexachloroethane	ND		ug/kg	86	--	1
Isophorone	ND		ug/kg	180	--	1
Naphthalene	ND		ug/kg	200	--	1
Nitrobenzene	ND		ug/kg	180	--	1
Bis(2-ethylhexyl)phthalate	ND		ug/kg	200	--	1
Butyl benzyl phthalate	ND		ug/kg	200	--	1
Di-n-butylphthalate	ND		ug/kg	200	--	1
Di-n-octylphthalate	ND		ug/kg	200	--	1
Diethyl phthalate	ND		ug/kg	200	--	1
Dimethyl phthalate	ND		ug/kg	86	--	1
Benzo(a)anthracene	740		ug/kg	120	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02 Date Collected: 06/10/21 11:30
Client ID: SAMPLE # 2 Date Received: 06/11/21
Sample Location: MIDDLEBORO, MA Field Prep: Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						
Benzo(a)pyrene	680		ug/kg	160	--	1
Benzo(b)fluoranthene	900		ug/kg	120	--	1
Benzo(k)fluoranthene	300		ug/kg	120	--	1
Chrysene	820		ug/kg	120	--	1
Acenaphthylene	ND		ug/kg	160	--	1
Anthracene	190		ug/kg	120	--	1
Benzo(ghi)perylene	350		ug/kg	160	--	1
Fluorene	ND		ug/kg	200	--	1
Phenanthrene	540		ug/kg	120	--	1
Dibenzo(a,h)anthracene	100		ug/kg	86	--	1
Indeno(1,2,3-cd)pyrene	400		ug/kg	160	--	1
Pyrene	1100		ug/kg	120	--	1
Aniline	ND		ug/kg	250	--	1
4-Chloroaniline	ND		ug/kg	200	--	1
Dibenzofuran	ND		ug/kg	200	--	1
2-Methylnaphthalene	ND		ug/kg	86	--	1
Acetophenone	ND		ug/kg	200	--	1
2,4,6-Trichlorophenol	ND		ug/kg	86	--	1
2-Chlorophenol	ND		ug/kg	86	--	1
2,4-Dichlorophenol	ND		ug/kg	86	--	1
2,4-Dimethylphenol	ND		ug/kg	86	--	1
2-Nitrophenol	ND		ug/kg	440	--	1
4-Nitrophenol	ND		ug/kg	290	--	1
2,4-Dinitrophenol	ND		ug/kg	990	--	1
Pentachlorophenol	ND		ug/kg	410	--	1
Phenol	ND		ug/kg	200	--	1
2-Methylphenol	ND		ug/kg	200	--	1
3-Methylphenol/4-Methylphenol	ND		ug/kg	300	--	1
2,4,5-Trichlorophenol	ND		ug/kg	200	--	1

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Client ID: SAMPLE # 2
Sample Location: MIDDLEBORO, MA
Date Collected: 06/10/21 11:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
MCP Semivolatile Organics - Westborough Lab						

Surrogate	% Recovery	Qualifier	Acceptance Criteria
2-Fluorophenol	92		30-130
Phenol-d6	90		30-130
Nitrobenzene-d5	85		30-130
2-Fluorobiphenyl	72		30-130
2,4,6-Tribromophenol	77		30-130
4-Terphenyl-d14	55		30-130

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 105,8270D-SIM/680(M)
Analytical Date: 06/23/21 13:12
Analyst: GP

Extraction Method: EPA 3570
Extraction Date: 06/17/21 23:46
Cleanup Method: EPA 3630
Cleanup Date: 06/18/21

Parameter	Result	Qualifier	Units	RL	MDL
PAHs/PCB Congeners by GC/MS - Mansfield Lab for sample(s): 01-02 Batch: WG1513579-1					
Naphthalene	ND		ug/kg	4.00	--
Acenaphthylene	ND		ug/kg	4.00	--
Acenaphthene	ND		ug/kg	4.00	--
Fluorene	ND		ug/kg	4.00	--
Phenanthrene	ND		ug/kg	4.00	--
Anthracene	ND		ug/kg	4.00	--
Fluoranthene	ND		ug/kg	4.00	--
Pyrene	ND		ug/kg	4.00	--
Benz(a)anthracene	ND		ug/kg	4.00	--
Chrysene	ND		ug/kg	4.00	--
Benzo(b)fluoranthene	ND		ug/kg	4.00	--
Benzo(k)fluoranthene	ND		ug/kg	4.00	--
Benzo(a)pyrene	ND		ug/kg	4.00	--
Indeno(1,2,3-cd)Pyrene	ND		ug/kg	4.00	--
Dibenz(a,h)anthracene	ND		ug/kg	4.00	--
Benzo(ghi)perylene	ND		ug/kg	4.00	--
Cl2-BZ#8	ND		ug/kg	0.400	--
Cl3-BZ#18	ND		ug/kg	0.400	--
Cl3-BZ#28	ND		ug/kg	0.400	--
Cl4-BZ#44	ND		ug/kg	0.400	--
Cl4-BZ#49	ND		ug/kg	0.400	--
Cl4-BZ#52	ND		ug/kg	0.400	--
Cl4-BZ#66	ND		ug/kg	0.400	--
Cl5-BZ#87	ND		ug/kg	0.400	--
Cl5-BZ#101	ND		ug/kg	0.400	--
Cl5-BZ#105	ND		ug/kg	0.400	--
Cl5-BZ#118	ND		ug/kg	0.400	--
Cl6-BZ#128	ND		ug/kg	0.400	--
Cl6-BZ#138	ND		ug/kg	0.400	--

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 105,8270D-SIM/680(M)
Analytical Date: 06/23/21 13:12
Analyst: GP

Extraction Method: EPA 3570
Extraction Date: 06/17/21 23:46
Cleanup Method: EPA 3630
Cleanup Date: 06/18/21

Parameter	Result	Qualifier	Units	RL	MDL
PAHs/PCB Congeners by GC/MS - Mansfield Lab for sample(s): 01-02 Batch: WG1513579-1					
Cl6-BZ#153	ND		ug/kg	0.400	--
Cl7-BZ#170	ND		ug/kg	0.400	--
Cl7-BZ#180	ND		ug/kg	0.400	--
Cl7-BZ#183	ND		ug/kg	0.400	--
Cl7-BZ#184	ND		ug/kg	0.400	--
Cl7-BZ#187	ND		ug/kg	0.400	--
Cl8-BZ#195	ND		ug/kg	0.400	--
Cl9-BZ#206	ND		ug/kg	0.400	--
Cl10-BZ#209	ND		ug/kg	0.400	--

Surrogate	%Recovery	Qualifier	Acceptance Criteria
2-Methylnaphthalene-d10	81		30-150
Pyrene-d10	87		30-150
Benzo(b)fluoranthene-d12	88		30-150
DBOB	110		50-125
BZ 198	98		50-125

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method:	97,8270D	Extraction Method:	EPA 3546
Analytical Date:	06/22/21 22:07	Extraction Date:	06/21/21 17:18
Analyst:	WR		

Parameter	Result	Qualifier	Units	RL	MDL
MCP Semivolatile Organics - Westborough Lab for sample(s): 01-02 Batch: WG1515031-1					
Acenaphthene	ND		ug/kg	130	--
1,2,4-Trichlorobenzene	ND		ug/kg	160	--
Hexachlorobenzene	ND		ug/kg	70	--
Bis(2-chloroethyl)ether	ND		ug/kg	70	--
2-Chloronaphthalene	ND		ug/kg	160	--
1,2-Dichlorobenzene	ND		ug/kg	160	--
1,3-Dichlorobenzene	ND		ug/kg	160	--
1,4-Dichlorobenzene	ND		ug/kg	70	--
3,3'-Dichlorobenzidine	ND		ug/kg	160	--
2,4-Dinitrotoluene	ND		ug/kg	70	--
2,6-Dinitrotoluene	ND		ug/kg	160	--
Azobenzene	ND		ug/kg	160	--
Fluoranthene	ND		ug/kg	99	--
4-Bromophenyl phenyl ether	ND		ug/kg	160	--
Bis(2-chloroisopropyl)ether	ND		ug/kg	70	--
Bis(2-chloroethoxy)methane	ND		ug/kg	180	--
Hexachlorobutadiene	ND		ug/kg	160	--
Hexachloroethane	ND		ug/kg	70	--
Isophorone	ND		ug/kg	150	--
Naphthalene	ND		ug/kg	160	--
Nitrobenzene	ND		ug/kg	150	--
Bis(2-ethylhexyl)phthalate	ND		ug/kg	160	--
Butyl benzyl phthalate	ND		ug/kg	160	--
Di-n-butylphthalate	ND		ug/kg	160	--
Di-n-octylphthalate	ND		ug/kg	160	--
Diethyl phthalate	ND		ug/kg	160	--
Dimethyl phthalate	ND		ug/kg	70	--
Benzo(a)anthracene	ND		ug/kg	99	--
Benzo(a)pyrene	ND		ug/kg	130	--

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 97,8270D
Analytical Date: 06/22/21 22:07
Analyst: WR

Extraction Method: EPA 3546
Extraction Date: 06/21/21 17:18

Parameter	Result	Qualifier	Units	RL	MDL
MCP Semivolatile Organics - Westborough Lab for sample(s): 01-02 Batch: WG1515031-1					
Benzo(b)fluoranthene	ND		ug/kg	99	--
Benzo(k)fluoranthene	ND		ug/kg	99	--
Chrysene	ND		ug/kg	99	--
Acenaphthylene	ND		ug/kg	130	--
Anthracene	ND		ug/kg	99	--
Benzo(ghi)perylene	ND		ug/kg	130	--
Fluorene	ND		ug/kg	160	--
Phenanthrene	ND		ug/kg	99	--
Dibenzo(a,h)anthracene	ND		ug/kg	70	--
Indeno(1,2,3-cd)pyrene	ND		ug/kg	130	--
Pyrene	ND		ug/kg	99	--
Aniline	ND		ug/kg	200	--
4-Chloroaniline	ND		ug/kg	160	--
Dibenzofuran	ND		ug/kg	160	--
2-Methylnaphthalene	ND		ug/kg	70	--
Acetophenone	ND		ug/kg	160	--
2,4,6-Trichlorophenol	ND		ug/kg	70	--
2-Chlorophenol	ND		ug/kg	70	--
2,4-Dichlorophenol	ND		ug/kg	70	--
2,4-Dimethylphenol	ND		ug/kg	70	--
2-Nitrophenol	ND		ug/kg	360	--
4-Nitrophenol	ND		ug/kg	230	--
2,4-Dinitrophenol	ND		ug/kg	790	--
Pentachlorophenol	ND		ug/kg	330	--
Phenol	ND		ug/kg	160	--
2-Methylphenol	ND		ug/kg	160	--
3-Methylphenol/4-Methylphenol	ND		ug/kg	240	--
2,4,5-Trichlorophenol	ND		ug/kg	160	--

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method:	97,8270D	Extraction Method:	EPA 3546
Analytical Date:	06/22/21 22:07	Extraction Date:	06/21/21 17:18
Analyst:	WR		

Parameter	Result	Qualifier	Units	RL	MDL
MCP Semivolatile Organics - Westborough Lab for sample(s): 01-02 Batch: WG1515031-1					

Surrogate	%Recovery	Qualifier	Acceptance Criteria
2-Fluorophenol	109		30-130
Phenol-d6	112		30-130
Nitrobenzene-d5	101		30-130
2-Fluorobiphenyl	89		30-130
2,4,6-Tribromophenol	89		30-130
4-Terphenyl-d14	88		30-130

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A
Lab Number: L2131509
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
PAHs/PCB Congeners by GC/MS - Mansfield Lab Associated sample(s): 01-02 Batch: WG1513579-2 WG1513579-3								
Naphthalene	65		75		40-140	14		30
Acenaphthylene	71		78		40-140	9		30
Acenaphthene	69		75		40-140	8		30
Fluorene	71		78		40-140	9		30
Phenanthrene	69		76		40-140	10		30
Anthracene	72		77		40-140	7		30
Fluoranthene	75		80		40-140	6		30
Pyrene	77		83		40-140	8		30
Benz(a)anthracene	81		88		40-140	8		30
Chrysene	72		77		40-140	7		30
Benzo(b)fluoranthene	86		93		40-140	8		30
Benzo(k)fluoranthene	77		80		40-140	4		30
Benzo(a)pyrene	81		89		40-140	9		30
Indeno(1,2,3-cd)Pyrene	77		83		40-140	8		30
Dibenz(a,h)anthracene	77		83		40-140	8		30
Benzo(ghi)perylene	82		88		40-140	7		30
Cl2-BZ#8	86		95		40-140	10		50
Cl3-BZ#18	84		92		40-140	9		50
Cl3-BZ#28	87		96		40-140	10		50
Cl4-BZ#44	90		99		40-140	10		50
Cl4-BZ#49	89		95		40-140	7		50
Cl4-BZ#52	88		95		40-140	8		50
Cl4-BZ#66	92		101		40-140	9		50

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
PAHs/PCB Congeners by GC/MS - Mansfield Lab Associated sample(s): 01-02 Batch: WG1513579-2 WG1513579-3								
Cl5-BZ#87	91		98		40-140	7		50
Cl5-BZ#101	96		102		40-140	6		50
Cl5-BZ#105	94		101		40-140	7		50
Cl5-BZ#118	91		99		40-140	8		50
Cl6-BZ#128	96		103		40-140	7		50
Cl6-BZ#138	97		104		40-140	7		50
Cl6-BZ#153	93		105		40-140	12		50
Cl7-BZ#170	99		106		40-140	7		50
Cl7-BZ#180	90		98		40-140	9		50
Cl7-BZ#183	92		98		40-140	6		50
Cl7-BZ#184	94		102		40-140	8		50
Cl7-BZ#187	99		109		40-140	10		50
Cl8-BZ#195	101		109		40-140	8		50
Cl9-BZ#206	97		105		40-140	8		50
Cl10-BZ#209	96		104		40-140	8		50

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria
2-Methylnaphthalene-d10	74		81		30-150
Pyrene-d10	84		88		30-150
Benzo(b)fluoranthene-d12	86		90		30-150
DBOB	109		118		50-125
BZ 198	98		102		50-125

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A
Lab Number: L2131509
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Semivolatile Organics - Westborough Lab Associated sample(s): 01-02 Batch: WG1515031-2 WG1515031-3								
Acenaphthene	83		98		40-140	17		30
1,2,4-Trichlorobenzene	76		83		40-140	9		30
Hexachlorobenzene	68		80		40-140	16		30
Bis(2-chloroethyl)ether	82		91		40-140	10		30
2-Chloronaphthalene	75		86		40-140	14		30
1,2-Dichlorobenzene	78		85		40-140	9		30
1,3-Dichlorobenzene	79		85		40-140	7		30
1,4-Dichlorobenzene	79		85		40-140	7		30
3,3'-Dichlorobenzidine	73		86		40-140	16		30
2,4-Dinitrotoluene	76		90		40-140	17		30
2,6-Dinitrotoluene	76		82		40-140	8		30
Azobenzene	87		103		40-140	17		30
Fluoranthene	82		97		40-140	17		30
4-Bromophenyl phenyl ether	65		76		40-140	16		30
Bis(2-chloroisopropyl)ether	92		99		40-140	7		30
Bis(2-chloroethoxy)methane	81		88		40-140	8		30
Hexachlorobutadiene	65		74		40-140	13		30
Hexachloroethane	84		91		40-140	8		30
Isophorone	85		93		40-140	9		30
Naphthalene	82		92		40-140	11		30
Nitrobenzene	84		94		40-140	11		30
Bis(2-ethylhexyl)phthalate	86		101		40-140	16		30
Butyl benzyl phthalate	88		101		40-140	14		30

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Semivolatile Organics - Westborough Lab Associated sample(s): 01-02 Batch: WG1515031-2 WG1515031-3								
Di-n-butylphthalate	86		102		40-140	17		30
Di-n-octylphthalate	87		102		40-140	16		30
Diethyl phthalate	81		95		40-140	16		30
Dimethyl phthalate	73		82		40-140	12		30
Benzo(a)anthracene	78		93		40-140	18		30
Benzo(a)pyrene	94		108		40-140	14		30
Benzo(b)fluoranthene	85		98		40-140	14		30
Benzo(k)fluoranthene	94		108		40-140	14		30
Chrysene	86		100		40-140	15		30
Acenaphthylene	78		89		40-140	13		30
Anthracene	88		103		40-140	16		30
Benzo(ghi)perylene	88		105		40-140	18		30
Fluorene	81		95		40-140	16		30
Phenanthrene	83		99		40-140	18		30
Dibenzo(a,h)anthracene	89		106		40-140	17		30
Indeno(1,2,3-cd)pyrene	82		100		40-140	20		30
Pyrene	84		98		40-140	15		30
Aniline	66		76		40-140	14		30
4-Chloroaniline	83		101		40-140	20		30
Dibenzofuran	78		92		40-140	16		30
2-Methylnaphthalene	80		91		40-140	13		30
Acetophenone	86		94		40-140	9		30
2,4,6-Trichlorophenol	72		82		30-130	13		30

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A
Lab Number: L2131509
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Semivolatile Organics - Westborough Lab Associated sample(s): 01-02 Batch: WG1515031-2 WG1515031-3								
2-Chlorophenol	91		100		30-130	9		30
2,4-Dichlorophenol	85		94		30-130	10		30
2,4-Dimethylphenol	88		98		30-130	11		30
2-Nitrophenol	80		89		30-130	11		30
4-Nitrophenol	78		93		30-130	18		30
2,4-Dinitrophenol	34		42		30-130	21		30
Pentachlorophenol	73		86		30-130	16		30
Phenol	92		103		30-130	11		30
2-Methylphenol	94		102		30-130	8		30
3-Methylphenol/4-Methylphenol	99		109		30-130	10		30
2,4,5-Trichlorophenol	77		88		30-130	13		30

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria
2-Fluorophenol	91		100		30-130
Phenol-d6	90		97		30-130
Nitrobenzene-d5	82		92		30-130
2-Fluorobiphenyl	73		82		30-130
2,4,6-Tribromophenol	71		85		30-130
4-Terphenyl-d14	74		84		30-130

PETROLEUM HYDROCARBONS

Project Name: WAREHAM STREET NEMASKET RIVER | **Lab Number:** L2131509

Project Number: OE-3676A | **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01 D
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 1,8015D(M)
Analytical Date: 07/02/21 11:41
Analyst: SR
Percent Solids: 31%

Extraction Method: EPA 3546
Extraction Date: 06/23/21 10:47

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
Petroleum Hydrocarbon Quantitation - Westborough Lab						
TPH (C10-C36)	7980000		ug/kg	1040000	--	10

Surrogate	% Recovery	Qualifier	Acceptance Criteria
o-Terphenyl	77		40-140

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Client ID: SAMPLE # 2
Sample Location: MIDDLEBORO, MA
Date Collected: 06/10/21 11:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 1,8015D(M)
Analytical Date: 06/24/21 10:32
Analyst: MEO
Percent Solids: 80%
Extraction Method: EPA 3546
Extraction Date: 06/23/21 10:47

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
Petroleum Hydrocarbon Quantitation - Westborough Lab						
TPH (C10-C36)	61400		ug/kg	39200	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
o-Terphenyl	60		40-140

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 1,8015D(M)
Analytical Date: 06/23/21 07:27
Analyst: JB

Extraction Method: EPA 3546
Extraction Date: 06/22/21 10:59

Parameter	Result	Qualifier	Units	RL	MDL
Petroleum Hydrocarbon Quantitation - Westborough Lab for sample(s): 01-02 Batch: WG1515332-1					
TPH (C10-C36)	ND		ug/kg	33000	--

Surrogate	%Recovery	Qualifier	Acceptance Criteria
o-Terphenyl	95		40-140

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
Petroleum Hydrocarbon Quantitation - Westborough Lab Associated sample(s): 01-02 Batch: WG1515332-2								
TPH (C10-C36)	97		-		40-140	-		40

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria
o-Terphenyl	88				40-140

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified
Sample Depth:			
Matrix:	Soil	Extraction Method:	EPA 3546
Analytical Method:	135,EPH-19-2.1	Extraction Date:	06/23/21 13:41
Analytical Date:	06/24/21 22:05	Cleanup Method1:	EPH-19-2.1
Analyst:	MEO	Cleanup Date1:	06/24/21
Percent Solids:	31%		

Quality Control Information

Condition of sample received:	Satisfactory
Sample Temperature upon receipt:	Received on Ice
Sample Extraction method:	Extracted Per the Method

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
Extractable Petroleum Hydrocarbons - Westborough Lab						
C9-C18 Aliphatics	ND		mg/kg	21.1	--	1
C19-C36 Aliphatics	34.2		mg/kg	21.1	--	1
C11-C22 Aromatics	72.2		mg/kg	21.1	--	1
C11-C22 Aromatics, Adjusted	56.5		mg/kg	21.1	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
Chloro-Octadecane	49		40-140
o-Terphenyl	50		40-140
2-Fluorobiphenyl	80		40-140
2-Bromonaphthalene	79		40-140

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-02	Date Collected:	06/10/21 11:30
Client ID:	SAMPLE # 2	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified
Sample Depth:			
Matrix:	Soil	Extraction Method:	EPA 3546
Analytical Method:	135,EPH-19-2.1	Extraction Date:	06/23/21 13:41
Analytical Date:	06/24/21 21:29	Cleanup Method1:	EPH-19-2.1
Analyst:	MEO	Cleanup Date1:	06/24/21
Percent Solids:	80%		

Quality Control Information

Condition of sample received:	Satisfactory
Sample Temperature upon receipt:	Received on Ice
Sample Extraction method:	Extracted Per the Method

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor
Extractable Petroleum Hydrocarbons - Westborough Lab						
C9-C18 Aliphatics	ND		mg/kg	8.14	--	1
C19-C36 Aliphatics	14.8		mg/kg	8.14	--	1
C11-C22 Aromatics	34.6		mg/kg	8.14	--	1
C11-C22 Aromatics, Adjusted	26.5		mg/kg	8.14	--	1

Surrogate	% Recovery	Qualifier	Acceptance Criteria
Chloro-Octadecane	62		40-140
o-Terphenyl	71		40-140
2-Fluorobiphenyl	90		40-140
2-Bromonaphthalene	92		40-140

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method:	135,EPH-19-2.1	Extraction Method:	EPA 3546
Analytical Date:	06/23/21 17:58	Extraction Date:	06/22/21 21:48
Analyst:	SC	Cleanup Method:	EPH-19-2.1
		Cleanup Date:	06/23/21

Parameter	Result	Qualifier	Units	RL	MDL
Extractable Petroleum Hydrocarbons - Westborough Lab for sample(s): 01-02 Batch: WG1515669-1					
C9-C18 Aliphatics	ND		mg/kg	6.48	--
C19-C36 Aliphatics	ND		mg/kg	6.48	--
C11-C22 Aromatics	ND		mg/kg	6.48	--
C11-C22 Aromatics, Adjusted	ND		mg/kg	6.48	--

Surrogate	%Recovery	Qualifier	Acceptance Criteria
Chloro-Octadecane	74		40-140
o-Terphenyl	66		40-140
2-Fluorobiphenyl	73		40-140
2-Bromonaphthalene	74		40-140

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A
Lab Number: L2131509
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
Extractable Petroleum Hydrocarbons - Westborough Lab Associated sample(s): 01-02 Batch: WG1515669-2 WG1515669-3								
C9-C18 Aliphatics	50		46		40-140	8		25
C19-C36 Aliphatics	82		82		40-140	0		25
C11-C22 Aromatics	76		78		40-140	3		25
Naphthalene	66		63		40-140	5		25
2-Methylnaphthalene	69		66		40-140	4		25
Acenaphthylene	67		66		40-140	2		25
Acenaphthene	72		71		40-140	1		25
Fluorene	72		74		40-140	3		25
Phenanthrene	72		74		40-140	3		25
Anthracene	74		77		40-140	4		25
Fluoranthene	73		76		40-140	4		25
Pyrene	74		78		40-140	5		25
Benzo(a)anthracene	76		79		40-140	4		25
Chrysene	73		76		40-140	4		25
Benzo(b)fluoranthene	71		74		40-140	4		25
Benzo(k)fluoranthene	68		71		40-140	4		25
Benzo(a)pyrene	72		76		40-140	5		25
Indeno(1,2,3-cd)Pyrene	67		71		40-140	6		25
Dibenzo(a,h)anthracene	72		75		40-140	4		25
Benzo(ghi)perylene	66		69		40-140	4		25

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
Extractable Petroleum Hydrocarbons - Westborough Lab Associated sample(s): 01-02 Batch: WG1515669-2 WG1515669-3								

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria
Chloro-Octadecane	70		69		40-140
o-Terphenyl	70		72		40-140
2-Fluorobiphenyl	76		80		40-140
2-Bromonaphthalene	76		80		40-140
% Naphthalene Breakthrough	0		0		
% 2-Methylnaphthalene Breakthrough	0		0		

PCBS

Project Name: WAREHAM STREET NEMASKET RIVER | **Lab Number:** L2131509
Project Number: OE-3676A | **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Analytical Method: 97,8082A
Analytical Date: 06/29/21 10:59
Analyst: JAW
Percent Solids: 31%

Extraction Method: EPA 3546
Extraction Date: 06/28/21 10:16
Cleanup Method: EPA 3665A
Cleanup Date: 06/28/21
Cleanup Method: EPA 3660B
Cleanup Date: 06/29/21

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Column
MCP Polychlorinated Biphenyls - Westborough Lab							
Aroclor 1016	ND		ug/kg	107	--	1	A
Aroclor 1221	ND		ug/kg	107	--	1	A
Aroclor 1232	ND		ug/kg	107	--	1	A
Aroclor 1242	ND		ug/kg	107	--	1	A
Aroclor 1248	ND		ug/kg	107	--	1	A
Aroclor 1254	ND		ug/kg	107	--	1	A
Aroclor 1260	ND		ug/kg	107	--	1	A
Aroclor 1262	ND		ug/kg	107	--	1	A
Aroclor 1268	ND		ug/kg	107	--	1	A
PCBs, Total	ND		ug/kg	107	--	1	A

Surrogate	% Recovery	Qualifier	Acceptance Criteria	Column
2,4,5,6-Tetrachloro-m-xylene	58		30-150	B
Decachlorobiphenyl	54		30-150	B
2,4,5,6-Tetrachloro-m-xylene	54		30-150	A
Decachlorobiphenyl	47		30-150	A

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-02	Date Collected:	06/10/21 11:30
Client ID:	SAMPLE # 2	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified
Sample Depth:			
Matrix:	Soil	Extraction Method:	EPA 3546
Analytical Method:	97,8082A	Extraction Date:	06/28/21 10:16
Analytical Date:	06/29/21 11:07	Cleanup Method:	EPA 3665A
Analyst:	JAW	Cleanup Date:	06/28/21
Percent Solids:	80%	Cleanup Method:	EPA 3660B
		Cleanup Date:	06/29/21

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Column
MCP Polychlorinated Biphenyls - Westborough Lab							
Aroclor 1016	ND		ug/kg	39.5	--	1	A
Aroclor 1221	ND		ug/kg	39.5	--	1	A
Aroclor 1232	ND		ug/kg	39.5	--	1	A
Aroclor 1242	ND		ug/kg	39.5	--	1	A
Aroclor 1248	ND		ug/kg	39.5	--	1	A
Aroclor 1254	ND		ug/kg	39.5	--	1	A
Aroclor 1260	ND		ug/kg	39.5	--	1	A
Aroclor 1262	ND		ug/kg	39.5	--	1	A
Aroclor 1268	ND		ug/kg	39.5	--	1	A
PCBs, Total	ND		ug/kg	39.5	--	1	A

Surrogate	% Recovery	Qualifier	Acceptance Criteria	Column
2,4,5,6-Tetrachloro-m-xylene	62		30-150	B
Decachlorobiphenyl	60		30-150	B
2,4,5,6-Tetrachloro-m-xylene	58		30-150	A
Decachlorobiphenyl	56		30-150	A

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

Method Blank Analysis
Batch Quality Control

Analytical Method: 97,8082A
Analytical Date: 06/29/21 09:53
Analyst: CW

Extraction Method: EPA 3546
Extraction Date: 06/28/21 10:16
Cleanup Method: EPA 3665A
Cleanup Date: 06/28/21
Cleanup Method: EPA 3660B
Cleanup Date: 06/29/21

Parameter	Result	Qualifier	Units	RL	MDL	Column
MCP Polychlorinated Biphenyls - Westborough Lab for sample(s): 01-02 Batch: WG1517695-1						
Aroclor 1016	ND		ug/kg	32.9	--	A
Aroclor 1221	ND		ug/kg	32.9	--	A
Aroclor 1232	ND		ug/kg	32.9	--	A
Aroclor 1242	ND		ug/kg	32.9	--	A
Aroclor 1248	ND		ug/kg	32.9	--	A
Aroclor 1254	ND		ug/kg	32.9	--	A
Aroclor 1260	ND		ug/kg	32.9	--	A
Aroclor 1262	ND		ug/kg	32.9	--	A
Aroclor 1268	ND		ug/kg	32.9	--	A
PCBs, Total	ND		ug/kg	32.9	--	A

Surrogate	%Recovery	Qualifier	Acceptance Criteria	Column
2,4,5,6-Tetrachloro-m-xylene	68		30-150	B
Decachlorobiphenyl	63		30-150	B
2,4,5,6-Tetrachloro-m-xylene	65		30-150	A
Decachlorobiphenyl	58		30-150	A

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits	Column
MCP Polychlorinated Biphenyls - Westborough Lab Associated sample(s): 01-02 Batch: WG1517695-2 WG1517695-3									
Aroclor 1016	70		73		40-140	4		30	A
Aroclor 1260	60		62		40-140	3		30	A

Surrogate	LCS %Recovery	Qual	LCSD %Recovery	Qual	Acceptance Criteria	Column
2,4,5,6-Tetrachloro-m-xylene	68		69		30-150	B
Decachlorobiphenyl	64		62		30-150	B
2,4,5,6-Tetrachloro-m-xylene	66		66		30-150	A
Decachlorobiphenyl	59		57		30-150	A

METALS

Project Name:	WAREHAM STREET NEMASKET RIVER	**Lab Number:**	L2131509
Project Number:	OE-3676A	**Report Date:**	07/23/21

SAMPLE RESULTS

Lab ID:	L2131509-01	Date Collected:	06/10/21 10:30
Client ID:	SAMPLE # 1	Date Received:	06/11/21
Sample Location:	MIDDLEBORO, MA	Field Prep:	Not Specified

Sample Depth:
Matrix: Soil
Percent Solids: 31%

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Prep Method	Analytical Method	Analyst
MCP Total Metals - Mansfield Lab											
Arsenic, Total	6.77		mg/kg	1.27	--	1	06/28/21 07:40	07/15/21 19:28	EPA 3050B	97,6010D	VL
Arsenic, Total	6.24		mg/kg	1.58	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD
Cadmium, Total	0.8649		mg/kg	0.6300	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD
Chromium, Total	12.5		mg/kg	6.30	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD
Copper, Total	63.7		mg/kg	6.30	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD
Lead, Total	143		mg/kg	6.33	--	1	06/28/21 07:40	07/15/21 19:28	EPA 3050B	97,6010D	VL
Mercury, Total	ND		mg/kg	0.245	--	1	06/24/21 12:54	06/24/21 18:39	EPA 7471B	97,7471B	OU
Nickel, Total	12.4		mg/kg	3.15	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD
Zinc, Total	115		mg/kg	31.5	--	10	07/22/21 15:58	07/23/21 10:47	EPA 3050B	97,6020B	CD

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Date Collected: 06/10/21 11:30
Client ID: SAMPLE # 2
Date Received: 06/11/21
Sample Location: MIDDLEBORO, MA
Field Prep: Not Specified

Sample Depth:
Matrix: Soil
Percent Solids: 80%

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Prep Method	Analytical Method	Analyst
MCP Total Metals - Mansfield Lab											
Arsenic, Total	2.24		mg/kg	0.468	--	1	06/28/21 07:40	07/15/21 19:40	EPA 3050B	97,6010D	VL
Arsenic, Total	2.52		mg/kg	0.586	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD
Cadmium, Total	ND		mg/kg	0.2345	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD
Chromium, Total	5.51		mg/kg	2.34	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD
Copper, Total	9.92		mg/kg	2.34	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD
Lead, Total	22.2		mg/kg	2.34	--	1	06/28/21 07:40	07/15/21 19:40	EPA 3050B	97,6010D	VL
Mercury, Total	0.206		mg/kg	0.088	--	1	06/24/21 12:54	06/24/21 18:42	EPA 7471B	97,7471B	OU
Nickel, Total	5.12		mg/kg	1.17	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD
Zinc, Total	39.3		mg/kg	11.7	--	10	07/22/21 15:58	07/23/21 10:52	EPA 3050B	97,6020B	CD

Project Name: WAREHAM STREET NEMASKET RIVER **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

Method Blank Analysis
Batch Quality Control

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
MCP Total Metals - Mansfield Lab for sample(s): 01-02 Batch: WG1515622-1										
Mercury, Total	ND		mg/kg	0.083	--	1	06/24/21 12:54	06/24/21 18:19	97,7471B	OU

Prep Information

Digestion Method: EPA 7471B

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
MCP Total Metals - Mansfield Lab for sample(s): 01-02 Batch: WG1517137-1										
Arsenic, Total	ND		mg/kg	0.400	--	1	06/28/21 07:40	07/15/21 19:15	97,6010D	VL
Lead, Total	ND		mg/kg	2.00	--	1	06/28/21 07:40	07/15/21 19:15	97,6010D	VL

Prep Information

Digestion Method: EPA 3050B

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
MCP Total Metals - Mansfield Lab for sample(s): 01-02 Batch: WG1526850-1										
Arsenic, Total	ND		mg/kg	0.500	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD
Cadmium, Total	ND		mg/kg	0.2000	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD
Chromium, Total	ND		mg/kg	2.00	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD
Copper, Total	ND		mg/kg	2.00	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD
Nickel, Total	ND		mg/kg	1.00	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD
Zinc, Total	ND		mg/kg	10.0	--	10	07/22/21 15:58	07/23/21 11:23	97,6020B	CD

Prep Information

Digestion Method: EPA 3050B

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
MCP Total Metals - Mansfield Lab Associated sample(s): 01-02 Batch: WG1515622-2 WG1515622-3 SRM Lot Number: D109-540								
Mercury, Total	96		96		60-140	0		30
MCP Total Metals - Mansfield Lab Associated sample(s): 01-02 Batch: WG1517137-2 WG1517137-3 SRM Lot Number: D109-540								
Arsenic, Total	99		100		70-130	1		30
Lead, Total	94		96		72-128	2		30
MCP Total Metals - Mansfield Lab Associated sample(s): 01-02 Batch: WG1526850-2 WG1526850-3 SRM Lot Number: D109-540								
Arsenic, Total	101		108		70-130	7		30
Cadmium, Total	98		107		75-125	9		30
Chromium, Total	98		106		70-130	8		30
Copper, Total	105		114		75-125	8		30
Nickel, Total	105		116		70-130	10		30
Zinc, Total	105		109		70-130	4		30

INORGANICS
&
MISCELLANEOUS

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-01
Client ID: SAMPLE # 1
Sample Location: MIDDLEBORO, MA

Date Collected: 06/10/21 10:30
Date Received: 06/11/21
Field Prep: Not Specified

Sample Depth:
Matrix: Soil

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
Total Organic Carbon - Mansfield Lab										
Total Organic Carbon (Rep1)	6.37		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Rep2)	8.35		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Average)	7.36		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Grain Size Analysis - Mansfield Lab										
% Total Gravel	ND		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Coarse Sand	1.40		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Medium Sand	21.8		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Fine Sand	41.2		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Total Fines	35.6		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
General Chemistry - Westborough Lab										
Specific Conductance @ 25 C	24		umhos/cm	10	--	1	-	06/24/21 06:37	1,9050A	KA
General Chemistry - Mansfield Lab										
Solids, Total	31.0		%	0.100	--	1	-	06/16/21 11:43	121,2540G	NG

Project Name: WAREHAM STREET NEMASKET RIVER
Lab Number: L2131509
Project Number: OE-3676A
Report Date: 07/23/21

SAMPLE RESULTS

Lab ID: L2131509-02
Date Collected: 06/10/21 11:30
Client ID: SAMPLE # 2
Date Received: 06/11/21
Sample Location: MIDDLEBORO, MA
Field Prep: Not Specified

Sample Depth:
Matrix: Soil

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
Total Organic Carbon - Mansfield Lab										
Total Organic Carbon (Rep1)	0.340		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Rep2)	0.301		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Average)	0.320		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Grain Size Analysis - Mansfield Lab										
% Total Gravel	3.10		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Coarse Sand	9.50		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Medium Sand	75.3		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Fine Sand	11.3		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
% Total Fines	0.800		%	0.100	NA	1	-	06/21/21 12:35	12,D6913/D7928	DR
General Chemistry - Westborough Lab										
Specific Conductance @ 25 C	23		umhos/cm	10	--	1	-	06/24/21 06:37	1,9050A	KA
General Chemistry - Mansfield Lab										
Solids, Total	80.4		%	0.100	--	1	-	06/16/21 11:43	121,2540G	NG

Project Name: WAREHAM STREET NEMASKET RIVE **Lab Number:** L2131509
Project Number: OE-3676A **Report Date:** 07/23/21

Method Blank Analysis
Batch Quality Control

Parameter	Result	Qualifier	Units	RL	MDL	Dilution Factor	Date Prepared	Date Analyzed	Analytical Method	Analyst
Total Organic Carbon - Mansfield Lab for sample(s): 01-02 Batch: WG1515454-1										
Total Organic Carbon (Rep1)	ND		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Rep2)	ND		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP
Total Organic Carbon (Average)	ND		%	0.010	--	1	-	06/29/21 11:43	1,9060A	SP

Lab Control Sample Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

Parameter	LCS %Recovery	Qual	LCSD %Recovery	Qual	%Recovery Limits	RPD	Qual	RPD Limits
Total Organic Carbon - Mansfield Lab Associated sample(s): 01-02 Batch: WG1515454-2								
Total Organic Carbon (Rep1)	103		-		75-125	-		25
Total Organic Carbon (Rep2)	91		-		75-125	-		25
Total Organic Carbon (Average)	97		-		75-125	-		25
General Chemistry - Westborough Lab Associated sample(s): 01-02 Batch: WG1516363-1								
Specific Conductance	99		-		99-101	-		

Lab Duplicate Analysis
Batch Quality Control

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

Parameter	Native Sample	Duplicate Sample	Units	RPD	Qual	RPD Limits
Grain Size Analysis - Mansfield Lab Associated sample(s): 01-02 QC Batch ID: WG1514863-1 QC Sample: L2131509-02 Client ID: SAMPLE # 2						
% Total Gravel	3.10	3.60	%	15		20
% Coarse Sand	9.50	9.00	%	5		20
% Medium Sand	75.3	73.3	%	3		20
% Fine Sand	11.3	13.0	%	14		20
% Total Fines	0.800	1.10	%	**32**	Q	20

Sample Receipt and Container Information

Were project specific reporting limits specified? YES

Cooler Information

Cooler	Custody Seal
A	Absent

Container Information

Container ID	Container Type	Cooler	Initial pH	Final pH	Temp deg C	Pres	Seal	Frozen Date/Time	Analysis(*)
L2131509-01A	Vial MeOH preserved	A	NA		3.1	Y	Absent		MCP-8260HLW-10(14)
L2131509-01B	Vial water preserved	A	NA		3.1	Y	Absent	11-JUN-21 19:41	MCP-8260HLW-10(14)
L2131509-01C	Vial water preserved	A	NA		3.1	Y	Absent	11-JUN-21 19:41	MCP-8260HLW-10(14)
L2131509-01D	Plastic 2oz unpreserved for TS	A	NA		3.1	Y	Absent		ARCHIVE()
L2131509-01E	Glass 60mL/2oz unpreserved	A	NA		3.1	Y	Absent		MCP-AS-6010T-10(180),A2-CR-MCP6020T-10(180),A2-CD-MCP6020T-10(180),A2-ZN-MCP6020T-10(180),A2-AS-MCP6020T-10(180),A2-TS(7),A2-HG-MCP7471T-10(28),A2-CU-MCP6020T-10(180),A2-NI-MCP6020T-10(180),A2-HGPREP-AF(28),A2-PREP-3050:2T(180),A2-TOC-9060-2REPS(28),MCP-PB-6010T-10(180),A2-PAH/PCBCONG(14)
L2131509-01F	Plastic 8oz unpreserved for Grain Size	A	NA		3.1	Y	Absent		A2-HYDRO-TFINE(),A2-HYDRO-FSAND(),A2-HYDRO-MSAND(),A2-HYDRO-TGRAVEL(),A2-HYDRO-CSAND()
L2131509-01H	Glass 500ml/16oz unpreserved	A	NA		3.1	Y	Absent		MCP-8082-10(365),MCP-8270-10(14),EPH-20(14),TPH-DRO-D(14),COND-9050(28)
L2131509-02A	Vial MeOH preserved	A	NA		3.1	Y	Absent		MCP-8260HLW-10(14)
L2131509-02B	Vial water preserved	A	NA		3.1	Y	Absent	11-JUN-21 19:41	MCP-8260HLW-10(14)
L2131509-02C	Vial water preserved	A	NA		3.1	Y	Absent	11-JUN-21 19:41	MCP-8260HLW-10(14)
L2131509-02D	Plastic 2oz unpreserved for TS	A	NA		3.1	Y	Absent		ARCHIVE()
L2131509-02E	Glass 60mL/2oz unpreserved	A	NA		3.1	Y	Absent		A2-CR-MCP6020T-10(180),MCP-AS-6010T-10(180),A2-TS(7),A2-AS-MCP6020T-10(180),A2-CD-MCP6020T-10(180),A2-ZN-MCP6020T-10(180),A2-HG-MCP7471T-10(28),A2-HGPREP-AF(28),A2-CU-MCP6020T-10(180),A2-NI-MCP6020T-10(180),A2-TOC-9060-2REPS(28),A2-PREP-3050:2T(180),MCP-PB-6010T-10(180),A2-PAH/PCBCONG(14)
L2131509-02F	Plastic 8oz unpreserved for Grain Size	A	NA		3.1	Y	Absent		A2-HYDRO-TFINE(),A2-HYDRO-FSAND(),A2-HYDRO-MSAND(),A2-HYDRO-TGRAVEL(),A2-HYDRO-CSAND()

*Values in parentheses indicate holding time in days

Project Name: WAREHAM STREET NEMASKET RIVER
Project Number: OE-3676A

Lab Number: L2131509
Report Date: 07/23/21

Container Information

Container ID	Container Type	Cooler	Initial pH	Final pH	Temp deg C	Pres	Seal	Frozen Date/Time	Analysis(*)
L2131509-02H	Glass 500ml/16oz unpreserved	A	NA		3.1	Y	Absent		MCP-8082-10(365),MCP-8270-10(14),EPH-20(14),TPH-DRO-D(14),COND-9050(28)

*Values in parentheses indicate holding time in days

GLOSSARY

Acronyms

DL	- Detection Limit: This value represents the level to which target analyte concentrations are reported as estimated values, when those target analyte concentrations are quantified below the limit of quantitation (LOQ). The DL includes any adjustments from dilutions, concentrations or moisture content, where applicable. (DoD report formats only.)
EDL	- Estimated Detection Limit: This value represents the level to which target analyte concentrations are reported as estimated values, when those target analyte concentrations are quantified below the reporting limit (RL). The EDL includes any adjustments from dilutions, concentrations or moisture content, where applicable. The use of EDLs is specific to the analysis of PAHs using Solid-Phase Microextraction (SPME).
EMPC	- Estimated Maximum Possible Concentration: The concentration that results from the signal present at the retention time of an analyte when the ions meet all of the identification criteria except the ion abundance ratio criteria. An EMPC is a worst-case estimate of the concentration.
EPA	- Environmental Protection Agency.
LCS	- Laboratory Control Sample: A sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes.
LCSD	- Laboratory Control Sample Duplicate: Refer to LCS.
LFB	- Laboratory Fortified Blank: A sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes.
LOD	- Limit of Detection: This value represents the level to which a target analyte can reliably be detected for a specific analyte in a specific matrix by a specific method. The LOD includes any adjustments from dilutions, concentrations or moisture content, where applicable. (DoD report formats only.)
LOQ	- Limit of Quantitation: The value at which an instrument can accurately measure an analyte at a specific concentration. The LOQ includes any adjustments from dilutions, concentrations or moisture content, where applicable. (DoD report formats only.) Limit of Quantitation: The value at which an instrument can accurately measure an analyte at a specific concentration. The LOQ includes any adjustments from dilutions, concentrations or moisture content, where applicable. (DoD report formats only.)
MDL	- Method Detection Limit: This value represents the level to which target analyte concentrations are reported as estimated values, when those target analyte concentrations are quantified below the reporting limit (RL). The MDL includes any adjustments from dilutions, concentrations or moisture content, where applicable.
MS	- Matrix Spike Sample: A sample prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. For Method 332.0, the spike recovery is calculated using the native concentration, including estimated values.
MSD	- Matrix Spike Sample Duplicate: Refer to MS.
NA	- Not Applicable.
NC	- Not Calculated: Term is utilized when one or more of the results utilized in the calculation are non-detect at the parameter's reporting unit.
NDPA/DPA	- N-Nitrosodiphenylamine/Diphenylamine.
NI	- Not Ignitable.
NP	- Non-Plastic: Term is utilized for the analysis of Atterberg Limits in soil.
NR	- No Results: Term is utilized when 'No Target Compounds Requested' is reported for the analysis of Volatile or Semivolatile Organic TIC only requests.
RL	- Reporting Limit: The value at which an instrument can accurately measure an analyte at a specific concentration. The RL includes any adjustments from dilutions, concentrations or moisture content, where applicable.
RPD	- Relative Percent Difference: The results from matrix and/or matrix spike duplicates are primarily designed to assess the precision of analytical results in a given matrix and are expressed as relative percent difference (RPD). Values which are less than five times the reporting limit for any individual parameter are evaluated by utilizing the absolute difference between the values; although the RPD value will be provided in the report.
SRM	- Standard Reference Material: A reference sample of a known or certified value that is of the same or similar matrix as the associated field samples.
STLP	- Semi-dynamic Tank Leaching Procedure per EPA Method 1315.
TEF	- Toxic Equivalency Factors: The values assigned to each dioxin and furan to evaluate their toxicity relative to 2,3,7,8-TCDD.
TEQ	- Toxic Equivalent: The measure of a sample's toxicity derived by multiplying each dioxin and furan by its corresponding TEF and then summing the resulting values.
TIC	- Tentatively Identified Compound: A compound that has been identified to be present and is not part of the target compound list (TCL) for the method and/or program. All TICs are qualitatively identified and reported as estimated concentrations.

Report Format: Data Usability Report

Footnotes

1 - The reference for this analyte should be considered modified since this analyte is absent from the target analyte list of the original method.

Terms

Analytical Method: Both the document from which the method originates and the analytical reference method. (Example: EPA 8260B is shown as 1,8260B.) The codes for the reference method documents are provided in the References section of the Addendum.

Difference: With respect to Total Oxidizable Precursor (TOP) Assay analysis, the difference is defined as the Post-Treatment value minus the Pre-Treatment value.

Final pH: As it pertains to Sample Receipt & Container Information section of the report, Final pH reflects pH of container determined after adjustment at the laboratory, if applicable. If no adjustment required, value reflects Initial pH.

Frozen Date/Time: With respect to Volatile Organics in soil, Frozen Date/Time reflects the date/time at which associated Reagent Water-preserved vials were initially frozen. Note: If frozen date/time is beyond 48 hours from sample collection, value will be reflected in 'bold'.

Initial pH: As it pertains to Sample Receipt & Container Information section of the report, Initial pH reflects pH of container determined upon receipt, if applicable.

PAH Total: With respect to Alkylated PAH analyses, the 'PAHs, Total' result is defined as the summation of results for all or a subset of the following compounds: Naphthalene, C1-C4 Naphthalenes, 2-Methylnaphthalene, 1-Methylnaphthalene, Biphenyl, Acenaphthylene, Acenaphthene, Fluorene, C1-C3 Fluorenes, Phenanthrene, C1-C4 Phenanthrenes/Anthracenes, Anthracene, Fluoranthene, Pyrene, C1-C4 Fluoranthenes/Pyrenes, Benz(a)anthracene, Chrysene, C1-C4 Chrysenes, Benzo(b)fluoranthene, Benzo(j)+(k)fluoranthene, Benzo(e)pyrene, Benzo(a)pyrene, Perylene, Indeno(1,2,3-cd)pyrene, Dibenz(ah)+(ac)anthracene, Benzo(g,h,i)perylene. If a 'Total' result is requested, the results of its individual components will also be reported.

PFAS Total: With respect to PFAS analyses, the 'PFAS, Total (5)' result is defined as the summation of results for: PFHpA, PFHxS, PFOA, PFNA and PFOS. In addition, the 'PFAS, Total (6)' result is defined as the summation of results for: PFHpA, PFHxS, PFOA, PFNA, PFDA and PFOS. For MassDEP DW compliance analysis only, the 'PFAS, Total (6)' result is defined as the summation of results at or above the RL. Note: If a 'Total' result is requested, the results of its individual components will also be reported.

The target compound Chlordane (CAS No. 57-74-9) is reported for GC ECD analyses. Per EPA,this compound "refers to a mixture of chlordane isomers, other chlorinated hydrocarbons and numerous other components." (Reference: USEPA Toxicological Review of Chlordane, In Support of Summary Information on the Integrated Risk Information System (IRIS), December 1997.)

Total: With respect to Organic analyses, a 'Total' result is defined as the summation of results for individual isomers or Aroclors. If a 'Total' result is requested, the results of its individual components will also be reported. This is applicable to 'Total' results for methods 8260, 8081 and 8082.

Data Qualifiers

A - Spectra identified as "Aldol Condensates" are byproducts of the extraction/concentration procedures when acetone is introduced in the process.

B - The analyte was detected above the reporting limit in the associated method blank. Flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank. For MCP-related projects, flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank. For DOD-related projects, flag only applies to associated field samples that have detectable concentrations of the analyte at less than ten times (10x) the concentration found in the blank AND the analyte was detected above one-half the reporting limit (or above the reporting limit for common lab contaminants) in the associated method blank. For NJ-Air-related projects, flag only applies to associated field samples that have detectable concentrations of the analyte above the reporting limit. For NJ-related projects (excluding Air), flag only applies to associated field samples that have detectable concentrations of the analyte, which was detected above the reporting limit in the associated method blank or above five times the reporting limit for common lab contaminants (Phthalates, Acetone, Methylene Chloride, 2-Butanone).

C - Co-elution: The target analyte co-elutes with a known lab standard (i.e. surrogate, internal standards, etc.) for co-extracted analyses.

D - Concentration of analyte was quantified from diluted analysis. Flag only applies to field samples that have detectable concentrations of the analyte.

E - Concentration of analyte exceeds the range of the calibration curve and/or linear range of the instrument.

F - The ratio of quantifier ion response to qualifier ion response falls outside of the laboratory criteria. Results are considered to be an estimated maximum concentration.

G - The concentration may be biased high due to matrix interferences (i.e, co-elution) with non-target compound(s). The result should be considered estimated.

H - The analysis of pH was performed beyond the regulatory-required holding time of 15 minutes from the time of sample collection.

I - The lower value for the two columns has been reported due to obvious interference.

J - Estimated value. This represents an estimated concentration for Tentatively Identified Compounds (TICs).

M - Reporting Limit (RL) exceeds the MCP CAM Reporting Limit for this analyte.

ND - Not detected at the reporting limit (RL) for the sample.

NJ - Presumptive evidence of compound. This represents an estimated concentration for Tentatively Identified Compounds (TICs), where

Data Qualifiers

the identification is based on a mass spectral library search.

P - The RPD between the results for the two columns exceeds the method-specified criteria.

Q - The quality control sample exceeds the associated acceptance criteria. For DOD-related projects, LCS and/or Continuing Calibration Standard exceedences are also qualified on all associated sample results. Note: This flag is not applicable for matrix spike recoveries when the sample concentration is greater than 4x the spike added or for batch duplicate RPD when the sample concentrations are less than 5x the RL. (Metals only.)

R - Analytical results are from sample re-analysis.

RE - Analytical results are from sample re-extraction.

S - Analytical results are from modified screening analysis.

REFERENCES

1 Test Methods for Evaluating Solid Waste: Physical/Chemical Methods. EPA SW-846. Third Edition. Updates I - VI, 2018.

12 Annual Book of ASTM Standards. (American Society for Testing and Materials) ASTM International.

97 EPA Test Methods (SW-846) with QC Requirements & Performance Standards for the Analysis of EPA SW-846 Methods under the Massachusetts Contingency Plan, WSC-CAM-IIA, IIB, IIIA, IIIB, IIIC, IIID, VA, VB, VC, VIA, VIB, VIIIA and VIIIB, July 2010.

105 Test Methods for Evaluating Solid Waste: Physical/Chemical Methods. EPA SW-846. Third Edition. Updates I - IIIA, 1997 in conjunction with NOAA Technical Memorandum NMFS-NWFSC-59: Extraction, Cleanup and GC/MS Analysis of Sediments and Tissues for Organic Contaminants, March 2004 and the Determination of Pesticides and PCBs in Water and Oil/Sediment by GC/MS: Method 680, EPA 01A0005295, November 1985.

121 Standard Methods for the Examination of Water and Wastewater. APHA-AWWA-WEF. Standard Methods Online.

135 Method for the Determination of Extractable Petroleum Hydrocarbons (EPH), MassDEP, December 2019, Revision 2.1 with QC Requirements & Performance Standards for the Analysis of EPH under the Massachusetts Contingency Plan, WSC-CAM-IVB, March 1, 2020.

LIMITATION OF LIABILITIES

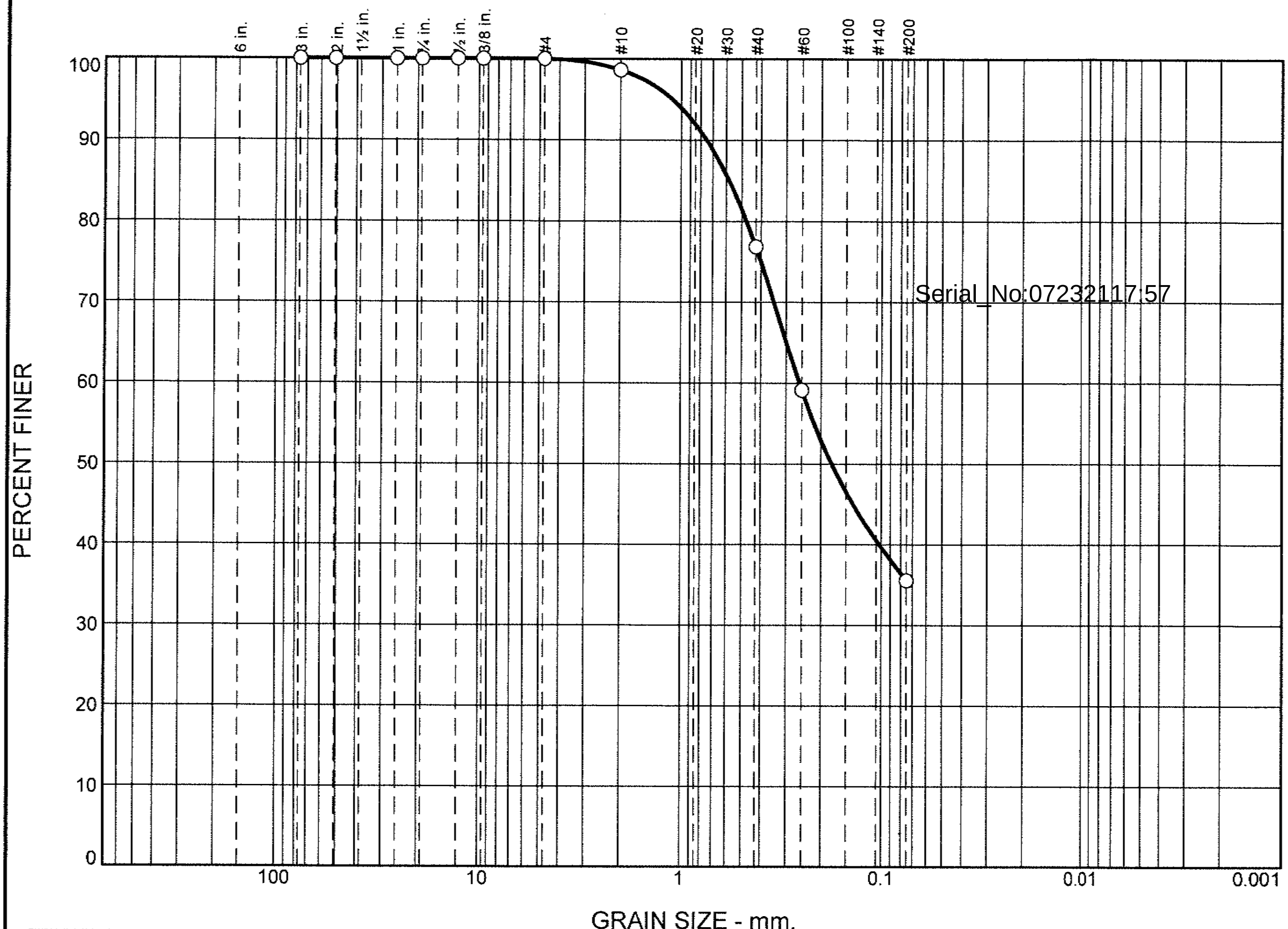
Alpha Analytical performs services with reasonable care and diligence normal to the analytical testing laboratory industry. In the event of an error, the sole and exclusive responsibility of Alpha Analytical shall be to re-perform the work at it's own expense. In no event shall Alpha Analytical be held liable for any incidental, consequential or special damages, including but not limited to, damages in any way connected with the use of, interpretation of, information or analysis provided by Alpha Analytical.

We strongly urge our clients to comply with EPA protocol regarding sample volume, preservation, cooling, containers, sampling procedures, holding time and splitting of samples in the field.

ASTM D6913/D7928

GRAIN SIZE ANALYSIS

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	0.0	1.4	21.8	41.2	35.6	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			0.5786	0.2570	0.1772					

	Material Description	USCS	AASHTO
○			

Project No. **Client:**

Project:

○ **Source of Sample:** SAMPLE 1 **Sample Number:** L2131509-01

Remarks:

Alpha Analytical

Mansfield, MA

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

6/24/2021

Location: SAMPLE 1

Sample Number: L2131509-01

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 49.97
Tare Wt. = 0.00
Minus #200 from wash = 0.0%

Serial_No:07232117:57

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
49.97	0.00	3"	0.00	0.00	100.0
		2"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		3/4"	0.00	0.00	100.0
		1/2"	0.00	0.00	100.0
		3/8"	0.00	0.00	100.0
		#4	0.00	0.00	100.0
		#10	0.68	0.00	98.6
		#40	10.89	0.00	76.8
		#60	8.85	0.00	59.1
		#200	11.78	0.00	35.6

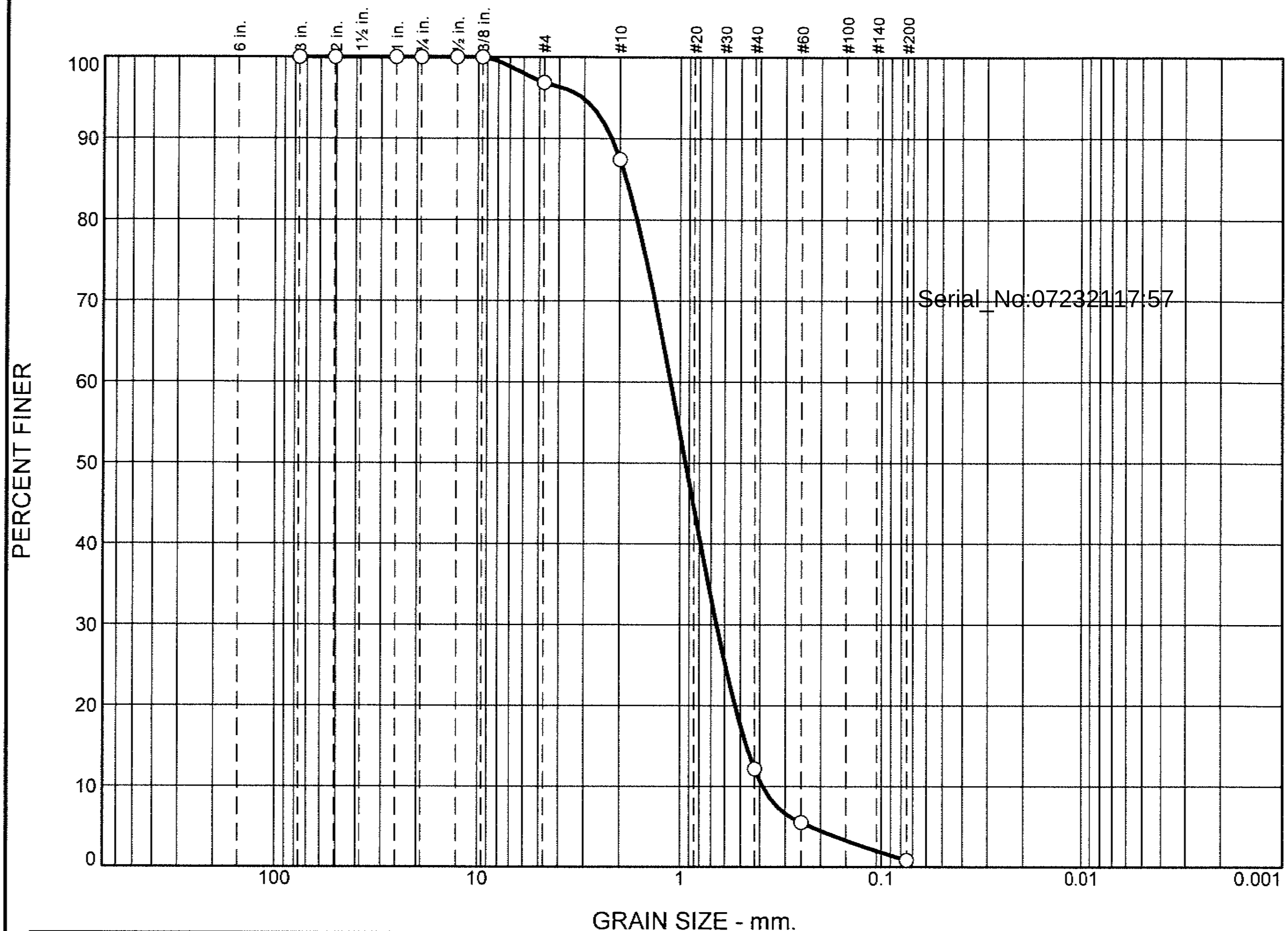
Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	0.0	0.0	1.4	21.8	41.2	64.4			35.6

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
					0.1024	0.1772	0.2570	0.4736	0.5786	0.7489	1.1034

Fineness Modulus
1.08

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	3.1	9.5	75.3	11.3	0.8	

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.8608	1.1136	0.9376	0.6573	0.4669	0.3876	1.00	2.87

	Material Description	USCS	AASHTO
○		SP	

Project No. **Client:**

Project:

○ **Source of Sample:** SAMPLE 2 **Sample Number:** L2131509-02

Alpha Analytical

Mansfield, MA

Remarks:

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

6/24/2021

Location: SAMPLE 2
Sample Number: L2131509-02
USCS Classification: SP

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 75.08
Tare Wt. = 0.00
Minus #200 from wash = 0.0%

Serial_No:07232117:57

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
75.08	0.00	3"	0.00	0.00	100.0
		2"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		3/4"	0.00	0.00	100.0
		1/2"	0.00	0.00	100.0
		3/8"	0.00	0.00	100.0
		#4	2.33	0.00	96.9
		#10	7.13	0.00	87.4
		#40	56.50	0.00	12.1
		#60	4.97	0.00	5.5
		#200	3.53	0.00	0.8

Fractional Components

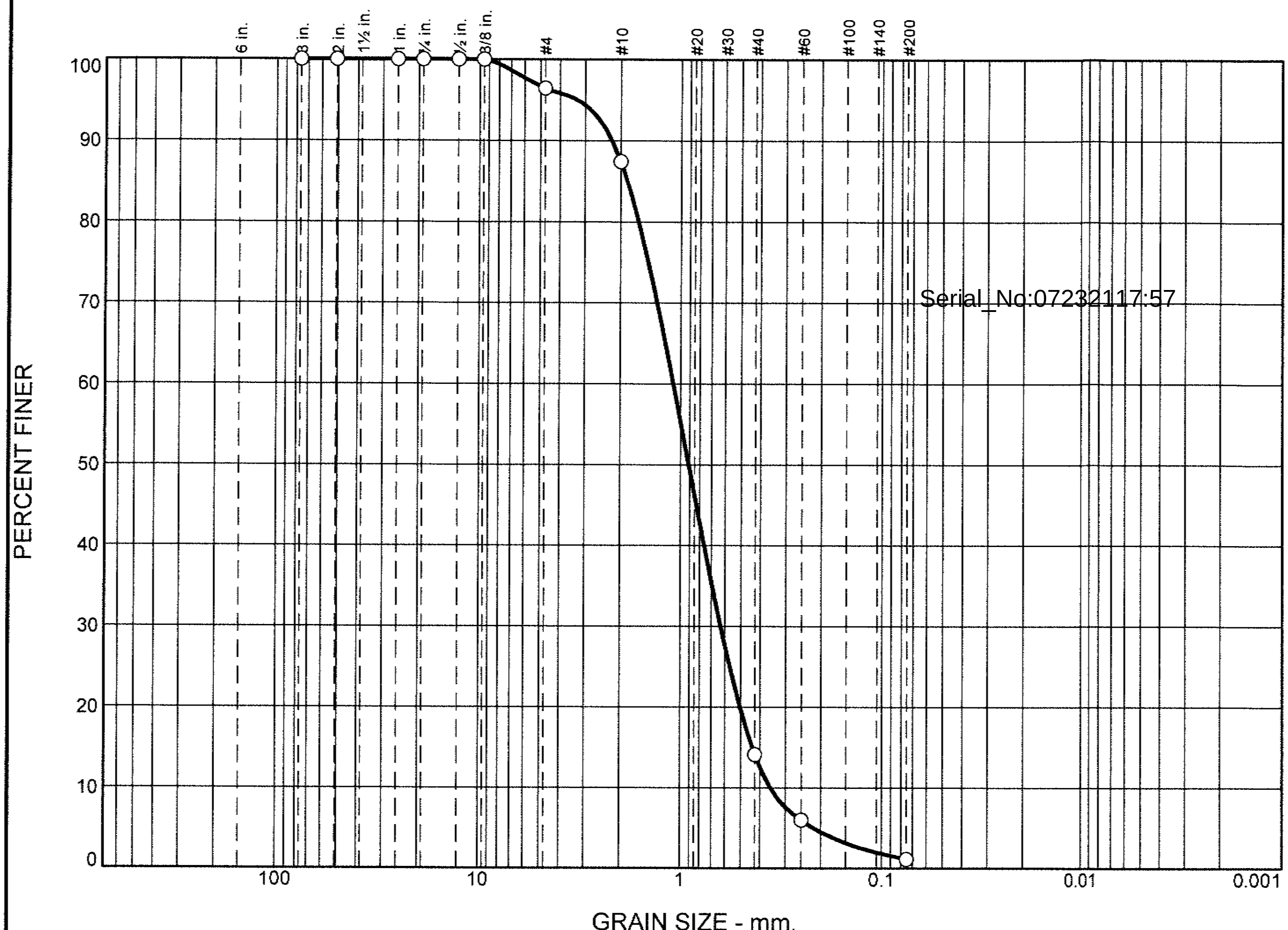
Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	3.1	3.1	9.5	75.3	11.3	96.1			0.8

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.2242	0.3876	0.4669	0.5323	0.6573	0.7890	0.9376	1.1136	1.6409	1.8608	2.2000	3.0602

Fineness Modulus	C_u	C_c
3.13	2.87	1.00

Alpha Analytical

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0.0	0.0	3.6	9.0	73.3	13.0	1.1	

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.8517	1.0870	0.9098	0.6292	0.4377	0.3553	1.03	3.06

	Material Description	USCS	AASHTO
○		SP	

Project No. **Client:**

Project:

○ **Source of Sample:** SAMPLE 2 **Sample Number:** WG1514863-1

Remarks:

Alpha Analytical

Mansfield, MA

Figure

GRAIN SIZE DISTRIBUTION TEST DATA

6/24/2021

Location: SAMPLE 2

Sample Number: WG1514863-1

USCS Classification: SP

Sieve Test Data

Post #200 Wash Test Weights (grams): **Dry Sample and Tare =** 74.57
Tare Wt. = 0.00
Minus #200 from wash = 0.0%

Serial_No:07232117:57

Dry Sample and Tare (grams)	Tare (grams)	Sieve Opening Size	Weight Retained (grams)	Sieve Weight (grams)	Percent Finer
74.57	0.00	3"	0.00	0.00	100.0
		2"	0.00	0.00	100.0
		1"	0.00	0.00	100.0
		3/4"	0.00	0.00	100.0
		1/2"	0.00	0.00	100.0
		3/8"	0.00	0.00	100.0
		#4	2.66	0.00	96.4
		#10	6.71	0.00	87.4
		#40	54.67	0.00	14.1
		#60	6.07	0.00	6.0
		#200	3.61	0.00	1.1

Fractional Components

Cobbles	Gravel			Sand				Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	3.6	3.6	9.0	73.3	13.0	95.3			1.1

D_5	D_{10}	D_{15}	D_{20}	D_{30}	D_{40}	D_{50}	D_{60}	D_{80}	D_{85}	D_{90}	D_{95}
0.2168	0.3553	0.4377	0.5041	0.6292	0.7609	0.9098	1.0870	1.6241	1.8517	2.2116	3.2776

Fineness Modulus	C_u	C_c
3.09	3.06	1.03

Certification Information

The following analytes are not included in our Primary NELAP Scope of Accreditation:

Westborough Facility
EPA 624/624.1: m/p-xylene, o-xylene, Naphthalene
EPA 625/625.1: alpha-Terpineol
EPA 8260C/8260D: NPW: 1,2,4,5-Tetramethylbenzene; 4-Ethyltoluene, Azobenzene; SCM: Iodomethane (methyl iodide), 1,2,4,5-Tetramethylbenzene; 4-Ethyltoluene.
EPA 8270D/8270E: NPW: Dimethylnaphthalene,1,4-Diphenylhydrazine, alpha-Terpineol; SCM: Dimethylnaphthalene,1,4-Diphenylhydrazine.
SM4500: NPW: Amenable Cyanide; SCM: Total Phosphorus, TKN, NO2, NO3.

Mansfield Facility
SM 2540D: TSS
EPA 8082A: NPW: PCB: 1, 5, 31, 87,101, 110, 141, 151, 153, 180, 183, 187.
EPA TO-15: Halothane, 2,4,4-Trimethyl-2-pentene, 2,4,4-Trimethyl-1-pentene, Thiophene, 2-Methylthiophene, 3-Methylthiophene, 2-Ethylthiophene, 1,2,3-Trimethylbenzene, Indan, Indene, 1,2,4,5-Tetramethylbenzene, Benzothiophene, 1-Methylnaphthalene.
Biological Tissue Matrix: EPA 3050B

The following analytes are included in our Massachusetts DEP Scope of Accreditation

Westborough Facility:

Drinking Water
EPA 300.0: Chloride, Nitrate-N, Fluoride, Sulfate; **EPA 353.2**: Nitrate-N, Nitrite-N; **SM4500NO3-F**: Nitrate-N, Nitrite-N; **SM4500F-C, SM4500CN-CE, EPA 180.1, SM2130B, SM4500Cl-D, SM2320B, SM2540C, SM4500H-B, SM4500NO2-B**
EPA 332: Perchlorate; **EPA 524.2:** THMs and VOCs; **EPA 504.1:** EDB, DBCP.
Microbiology: **SM9215B; SM9223-P/A, SM9223B-Colilert-QT,SM9222D**.

Non-Potable Water
SM4500H,B, EPA 120.1, SM2510B, SM2540C, SM2320B, SM4500CL-E, SM4500F-BC, SM4500NH3-BH: Ammonia-N and Kjeldahl-N, **EPA 350.1**: Ammonia-N, **LACHAT 10-107-06-1-B**: Ammonia-N, **EPA 351.1, SM4500NO3-F, EPA 353.2**: Nitrate-N**, SM4500P-E, SM4500P-B, E, SM4500SO4-E, SM5220D, EPA 410.4, SM5210B, SM5310C, SM4500CL-D, EPA 1664, EPA 420.1, SM4500-CN-CE, SM2540D, EPA 300: Chloride, Sulfate, Nitrate.**
EPA 624.1: Volatile Halocarbons & Aromatics,
EPA 608.3: Chlordane, Toxaphene, Aldrin, alpha-BHC, beta-BHC, gamma-BHC, delta-BHC, Dieldrin, DDD, DDE, DDT, Endosulfan I, Endosulfan II, Endosulfan sulfate, Endrin, Endrin Aldehyde, Heptachlor, Heptachlor Epoxide, PCBs
EPA 625.1: SVOC (Acid/Base/Neutral Extractables), **EPA 600/4-81-045**: PCB-Oil.
Microbiology: **SM9223B-Colilert-QT; Enterolert-QT, SM9221E, EPA 1600, EPA 1603, SM9222D.**

Mansfield Facility:

Drinking Water
EPA 200.7: Al, Ba, Cd, Cr, Cu, Fe, Mn, Ni, Na, Ag, Ca, Zn. **EPA 200.8:** Al, Sb, As, Ba, Be, Cd, Cr, Cu, Pb, Mn, Ni, Se, Ag, TL, Zn. **EPA 245.1** Hg.
EPA 522, EPA 537.1.

Non-Potable Water
EPA 200.7: Al, Sb, As, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Sr, TL, Ti, V, Zn.
EPA 200.8: Al, Sb**,** As, Be, Cd, Cr, Cu, Fe, Pb, Mn, Ni, K, Se, Ag, Na, TL, Zn.
EPA 245.1 Hg.
SM2340B

For a complete listing of analytes and methods, please contact your Alpha Project Manager.

Serial_No:07232117:57

CHAIN OF CUSTODY

PAGE 1 OF 1

ALPHA ANALYTICAL

8 Walkup Drive, Westboro, MA 01581, Tel: 508-898-9220
320 Forbes Blvd, Mansfield, MA 02048, Tel: 508-822-9300

Date Rec'd in Lab: 06/11/21

ALPHA Job #: L2131509

Project Information

Project Name: WAREHAM STREET NEMASKET RIVER
Project Location: MIDDLEBORO, MA
Project #: OE-3676A
Project Manager: MAG
ALPHA Quote #: 11427

Report Information - Data Deliverables

☐ ADEx ☒ EMAIL

Billing Information

☒ Same as Client info PO #:

Client Information

Client: OUTBACK ENGINEERING
Address: 165 EAST GROVE ST. MIDDLEBORO, MA 02346
Phone: 508-946-0928
Email: matt@outback-eng.com

Regulatory Requirements & Project Information Requirements

☒ Yes ☐ No MA MCP Analytical Methods ☐ Yes ☐ No CT RCP Analytical Methods
☐ Yes ☐ No Matrix Spike Required on this SDG? (Required for MCP Inorganics)
☐ Yes ☐ No GW1 Standards (Info Required for Metals & EPH with Targets)
☐ Yes ☐ No NPDES RGP
☒ Other State /Fed Program MA 401 WQ COMM-97 Criteria

Turn-Around Time

☒ Standard ☐ RUSH (only confirmed if pre-approved!)

Date Due:

Additional Project Information:

ANALYSIS: VOC: ☐ 8260 ☐ 624 ☐ 524.2; SVOC: ☐ ABN ☐ PAH; METALS: ☐ MCP 13 ☐ MCP 14 ☐ RCP 15; METALS: ☐ RCRA5 ☐ RCRA8 ☐ PP13; EPH: ☐ Ranges & Targets ☐ Ranges Only; VPH: ☐ Ranges & Targets ☐ Ranges Only; ☐ PCB ☐ PEST; TPH: ☐ Quant Only ☐ Fingerprint

SAMPLE INFO — Filtration: ☐ Field ☐ Lab to do; Preservation: ☐ Lab to do

ALPHA Lab ID (Lab Use Only)	Sample ID	Collection Date	Collection Time	Sample Matrix	Sampler Initials	VOC	SVOC	METALS (MCP)	METALS (RCRA)	EPH	VPH	PCB/PEST	TPH	COND	8270 PCB	TOTAL METALS	GRAIN SIZE	TS	8260 HLW (HIGH)	8260 HLW (LOW)	Sample Comments	TOTAL # BOTTLES
31509 -01	SAMPLE #1	6/10/21	1030	S	MAG									1	1	1	1	1	2			
-02	SAMPLE #2	6/10/21	1130	S	MAG									1	1	1	1	1	2			
Container Type														G	G	P	P	✓	✓			
Preservative														A	A	A	A	F	O			

Container Type
P= Plastic
A= Amber glass
V= Vial
G= Glass
B= Bacteria cup
C= Cube
O= Other
E= Encore
D= BOD Bottle

Preservative
A= None
B= HCl
C= HNO_3
D= H_2SO_4
E= NaOH
F= MeOH
G= $NaHSO_4$
H = $Na_2S_2O_3$
I= Ascorbic Acid
J = NH_4Cl
K= Zn Acetate
O= Other

Relinquished By:	Date/Time	Received By:	Date/Time
Matt Grosscheidl	6/11/21 0800	[illegible] AAL	6-11-21 1020
[illegible] AAL	6.11.21 1820	[illegible]	6/11/21 1820

FORM NO: 01-01 (rev. 12-Mar-2012)

Method Blank Summary
Form 4
Volatiles

Client	: **Outback Engineering, Inc.**	**Lab Number**	: **L2131509**
Project Name	: **WAREHAM STREET NEMASKET RIVER**	**Project Number**	: **OE-3676A**
Lab Sample ID	: **WG1515882-5**	**Lab File ID**	: **V04210623A04**
Instrument ID	: **VOA104**		
Matrix	: **SOIL**	**Analysis Date**	: **06/23/21 06:21**

Client Sample No.	Lab Sample ID	Analysis Date
WG1515882-3LCS	WG1515882-3	06/23/21 05:05
WG1515882-4LCSD	WG1515882-4	06/23/21 05:30
SAMPLE # 1	L2131509-01	06/23/21 07:37
SAMPLE # 2	L2131509-02	06/23/21 08:02

Calibration Verification Summary
Form 7
Volatiles

Client	: Outback Engineering, Inc.	Lab Number	: L2131509	
Project Name	: WAREHAM STREET NEMASKET RIVER	Project Number	: OE-3676A	
Instrument ID	: VOA104	Calibration Date	: 06/23/21 05:05	
Lab File ID	: V04210623A01	Init. Calib. Date(s)	: 05/26/21	05/26/21
Sample No	: WG1515882-2	Init. Calib. Times	: 04:50	08:11
Channel	:			

Compound	Ave. RRF	RRF	Min RRF	%D	Max %D	Area%	Dev(min)
Fluorobenzene	1	1	-	0	20	77	0
Dichlorodifluoromethane	0.199	0.224	-	-12.6	20	86	0
Chloromethane	0.378	0.363	-	4	20	87	0
Vinyl chloride	0.318	0.347	-	-9.1	20	92	0
Bromomethane	40	51.271	-	-28.2*	20	104	0
Chloroethane	0.145	0.155	-	-6.9	20	95	0
Trichlorofluoromethane	0.34	0.429	-	-26.2*	20	100	0
Ethyl ether	0.133	0.124	-	6.8	20	84	0
1,1-Dichloroethene	0.217	0.248	-	-14.3	20	94	0
Carbon disulfide	0.758	0.807	-	-6.5	20	92	0
Freon-113	0.219	0.271	-	-23.7*	20	97	0
Acrolein	0.027	0.03*	-	-11.1	20	99	0
Methylene chloride	0.281	0.28	-	0.4	20	90	0
Acetone	40	40.501	-	-1.3	20	86	0
trans-1,2-Dichloroethene	0.251	0.274	-	-9.2	20	92	0
Methyl acetate	0.184	0.156	-	15.2	20	80	0
Methyl tert-butyl ether	0.66	0.632	-	4.2	20	84	0
tert-Butyl alcohol	0.034	0.03*	-	11.8	20	81	0
Diisopropyl ether	1.039	1.076	-	-3.6	20	87	0
1,1-Dichloroethane	0.569	0.602	-	-5.8	20	93	0
Halothane	0.198	0.227	-	-14.6	20	93	0
Acrylonitrile	0.087	0.085	-	2.3	20	82	0
Ethyl tert-butyl ether	0.938	0.956	-	-1.9	20	86	0
Vinyl acetate	0.68	0.671	-	1.3	20	84	0
cis-1,2-Dichloroethene	0.296	0.294	-	0.7	20	89	0
2,2-Dichloropropane	0.374	0.434	-	-16	20	99	0
Bromochloromethane	0.143	0.141	-	1.4	20	87	0
Cyclohexane	0.511	0.615	-	-20.4*	20	96	0
Chloroform	0.477	0.485	-	-1.7	20	92	0
Ethyl acetate	0.268	0.234	-	12.7	20	78	0
Carbon tetrachloride	0.337	0.404	-	-19.9	20	96	0
Tetrahydrofuran	0.087	0.084	-	3.4	20	91	0
Dibromofluoromethane	0.284	0.279	-	1.8	20	78	0
1,1,1-Trichloroethane	0.367	0.421	-	-14.7	20	96	0
2-Butanone	0.113	0.1	-	11.5	20	82	0
1,1-Dichloropropene	0.322	0.374	-	-16.1	20	94	0
Benzene	1.004	1.019	-	-1.5	20	90	0
tert-Amyl methyl ether	0.647	0.626	-	3.2	20	84	0
1,2-Dichloroethane-d4	0.27	0.255	-	5.6	20	78	0
1,2-Dichloroethane	0.382	0.371	-	2.9	20	88	0
Methyl cyclohexane	0.384	0.437	-	-13.8	20	94	0
Trichloroethene	0.263	0.281	-	-6.8	20	92	0
Dibromomethane	0.157	0.153	-	2.5	20	85	0

* Value outside of QC limits.

Calibration Verification Summary
Form 7
Volatiles

Client	: Outback Engineering, Inc.	Lab Number	: L2131509	
Project Name	: WAREHAM STREET NEMASKET RIVER	Project Number	: OE-3676A	
Instrument ID	: VOA104	Calibration Date	: 06/23/21 05:05	
Lab File ID	: V04210623A01	Init. Calib. Date(s)	: 05/26/21	05/26/21
Sample No	: WG1515882-2	Init. Calib. Times	: 04:50	08:11
Channel	:			

Compound	Ave. RRF	RRF	Min RRF	%D	Max %D	Area%	Dev(min)
1,2-Dichloropropane	0.336	0.34	-	-1.2	20	88	0
2-Chloroethyl vinyl ether	0.169	0.172	-	-1.8	20	83	0
Bromodichloromethane	0.372	0.366	-	1.6	20	88	0
1,4-Dioxane	0.00232	0.00276*	-	-19	20	90	0
cis-1,3-Dichloropropene	0.425	0.434	-	-2.1	20	88	0
Chlorobenzene-d5	1	1	-	0	20	82	0
Toluene-d8	1.238	1.198	-	3.2	20	79	0
Toluene	0.769	0.765	-	0.5	20	90	0
4-Methyl-2-pentanone	0.133	0.122	-	8.3	20	83	0
Tetrachloroethene	0.353	0.405	-	-14.7	20	95	0
trans-1,3-Dichloropropene	0.445	0.443	-	0.4	20	86	0
Ethyl methacrylate	0.364	0.325	-	10.7	20	82	0
1,1,2-Trichloroethane	0.236	0.216	-	8.5	20	82	0
Chlorodibromomethane	0.358	0.34	-	5	20	85	0
1,3-Dichloropropane	0.459	0.425	-	7.4	20	83	0
1,2-Dibromoethane	0.28	0.27	-	3.6	20	83	0
2-Hexanone	0.244	0.204	-	16.4	20	81	0
Chlorobenzene	0.955	0.914	-	4.3	20	89	0
Ethylbenzene	1.447	1.483	-	-2.5	20	92	0
1,1,1,2-Tetrachloroethane	0.343	0.342	-	0.3	20	89	0
p/m Xylene	0.581	0.577	-	0.7	20	90	0
o Xylene	0.579	0.55	-	5	20	88	0
Styrene	0.991	0.918	-	7.4	20	87	0
1,4-Dichlorobenzene-d4	1	1	-	0	20	83	0
Bromoform	0.396	0.366	-	7.6	20	81	0
Isopropylbenzene	2.614	2.771	-	-6	20	91	0
4-Bromofluorobenzene	0.855	0.843	-	1.4	20	80	0
Bromobenzene	0.76	0.733	-	3.6	20	88	0
n-Propylbenzene	3.015	3.156	-	-4.7	20	91	0
1,4-Dichlorobutane	1.087	0.966	-	11.1	20	83	0
1,1,2,2-Tetrachloroethane	0.64	0.548	-	14.4	20	81	0
4-Ethyltoluene	2.583	2.717	-	-5.2	20	92	0
2-Chlorotoluene	1.84	1.821	-	1	20	90	0
1,3,5-Trimethylbenzene	2.199	2.243	-	-2	20	91	0
1,2,3-Trichloropropane	0.474	0.406	-	14.3	20	82	0
trans-1,4-Dichloro-2-buten	0.196	0.189	-	3.6	20	84	0
4-Chlorotoluene	1.924	1.886	-	2	20	90	0
tert-Butylbenzene	1.891	1.958	-	-3.5	20	91	0
1,2,4-Trimethylbenzene	2.196	2.212	-	-0.7	20	91	0
sec-Butylbenzene	2.857	3.003	-	-5.1	20	92	0
p-Isopropyltoluene	2.422	2.605	-	-7.6	20	94	0
1,3-Dichlorobenzene	1.431	1.4	-	2.2	20	90	0
1,4-Dichlorobenzene	1.461	1.401	-	4.1	20	89	0

* Value outside of QC limits.

Calibration Verification Summary
Form 7
Volatiles

Client	: Outback Engineering, Inc.	**Lab Number**	: L2131509		
Project Name	: WAREHAM STREET NEMASKET RIVER	**Project Number**	: OE-3676A		
Instrument ID	: VOA104	**Calibration Date**	: 06/23/21 05:05		
Lab File ID	: V04210623A01	**Init. Calib. Date(s)**	: 05/26/21	05/26/21	
Sample No	: WG1515882-2	**Init. Calib. Times**	: 04:50	08:11	
Channel	:				

Compound	Ave. RRF	RRF	Min RRF	%D	Max %D	Area%	Dev(min)
p-Diethylbenzene	1.452	1.566	-	-7.9	20	95	0
n-Butylbenzene	2.094	2.242	-	-7.1	20	94	0
1,2-Dichlorobenzene	1.358	1.298	-	4.4	20	88	0
1,2,4,5-Tetramethylbenzene	2.436	2.498	-	-2.5	20	93	0
1,2-Dibromo-3-chloropropan	0.116	0.099	-	14.7	20	78	0
1,3,5-Trichlorobenzene	1.026	1.087	-	-5.9	20	97	0
Hexachlorobutadiene	0.498	0.568	-	-14.1	20	100	0
1,2,4-Trichlorobenzene	0.976	1	-	-2.5	20	95	0
Naphthalene	2.224	1.921	-	13.6	20	82	0
1,2,3-Trichlorobenzene	0.897	0.875	-	2.5	20	90	0

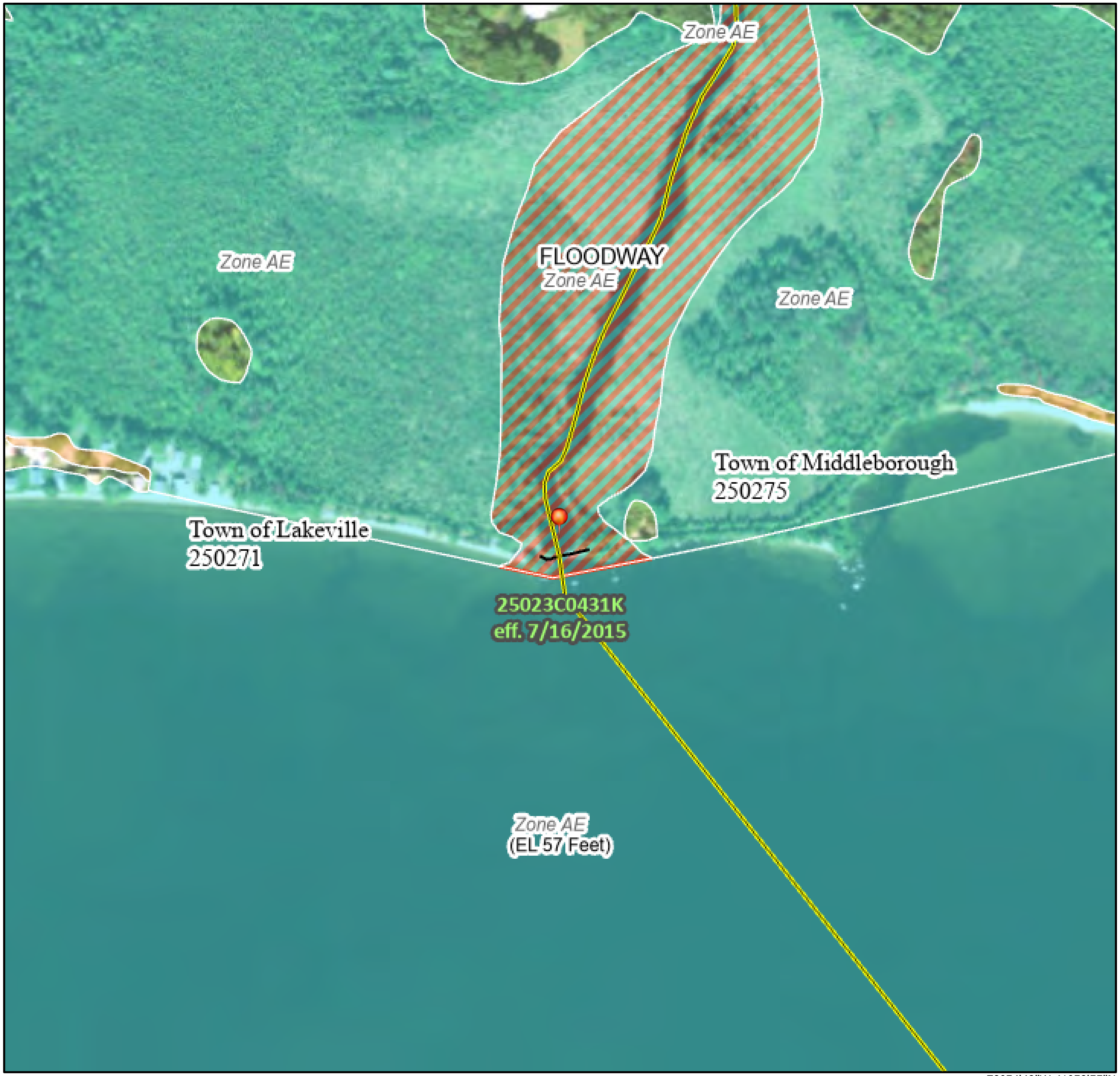
* Value outside of QC limits.

APPENDIX B – FEMA FIRM PANEL 25023C 0431K

National Flood Hazard Layer FIRMette

FEMA

70°55'26"W 41°51'22"N



Feet 0 250 500 1,000 1,500 2,000

1:6,000

70°54'49"W 41°50'55"N

Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 4/22/2022 at 1:56 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

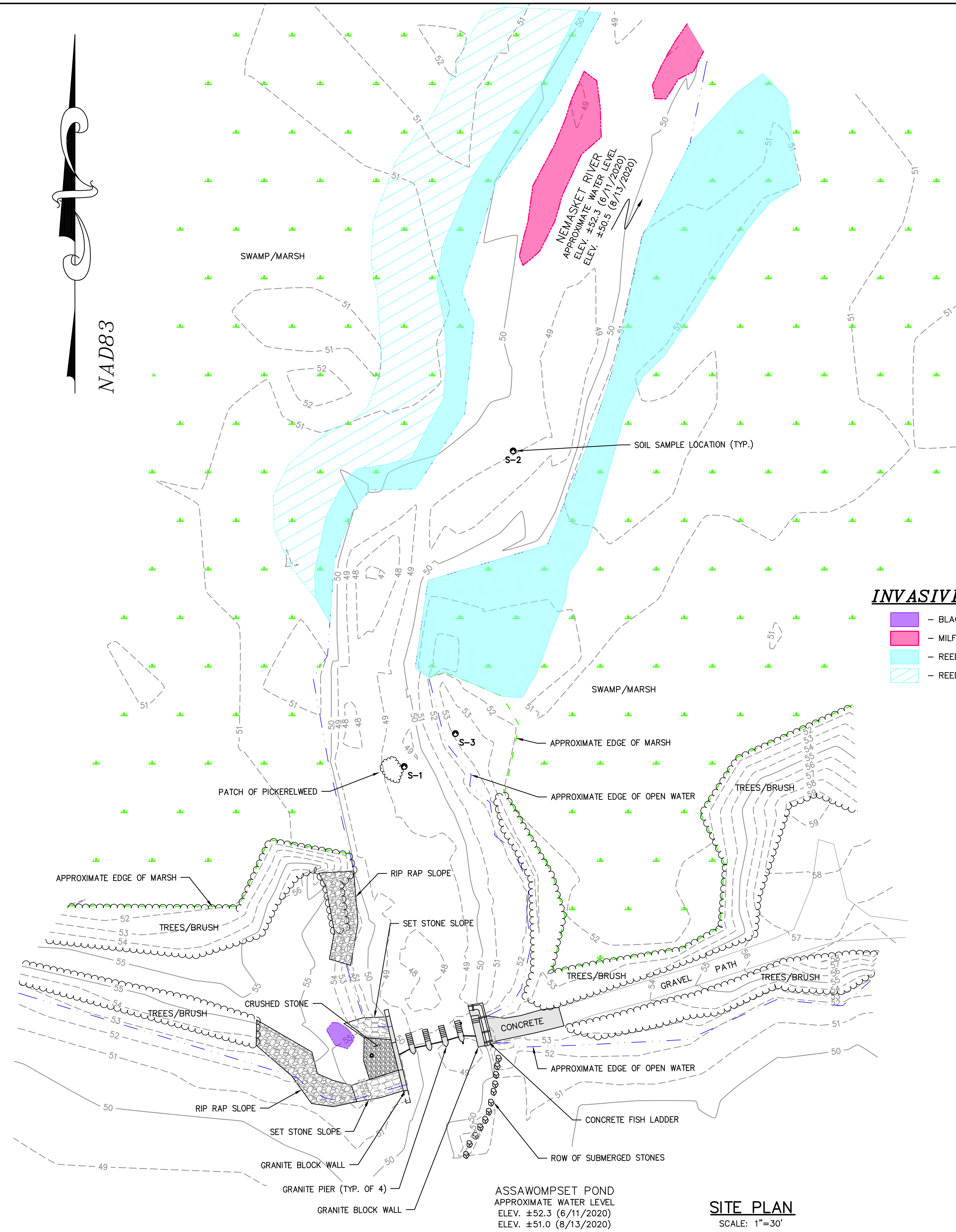
This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

APPENDIX C – EXISTING CONDITIONS AT ASSAWOMPSET POND DAM SPILLWAY AND NEMASKET RIVER

AERIAL IMAGE
NOT TO SCALE

GENERAL NOTES

1. THE TOPOGRAPHIC INFORMATION SHOWN ON THIS PLAN IS THE RESULT OF FIELD SURVEYS PERFORMED BY OUTBACK ENGINEERING, INC. BETWEEN JUNE 11 AND 18, 2020 AND REPRESENT THE CONDITIONS AT THE TIME OF THE SURVEY.
2. VERTICAL DATUM IS NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD 88). SITE BENCHMARK IS HEAD OF A STAINLESS STEEL BOLT FOUND IN THE TOP OF THE GRANITE BLOCKS ON THE SPILLWAY LEFT TRAINING WALL, ELEVATION 57.28 (NAVD 88).
3. HORIZONTAL DATUM IS NORTH AMERICAN DATUM OF 1983 (NAD 83) MASSACHUSETTS STATE PLANE.
4. THE SITE FALLS WITHIN ZONE "AE", WITH BASE FLOOD ELEVATION OF 57 FEET, AS SCALED FROM THE FLOOD INSURANCE RATE MAP (MAP NUMBER: 25023C0431K, EFFECTIVE DATE: JULY 16, 2015). PORTIONS OF THE SITE ALSO FALL WITHIN THE REGULATORY FLOODWAY ASSOCIATED WITH THE NEMASKET RIVER.
5. THE SITE IS LOCATED WITHIN BOTH A ZONE A AND ZONE B SURFACE WATER SUPPLY PROTECTION AREA. THE SITE IS NOT LOCATED WITH IN A ZONE II GROUNDWATER PROTECTION AREA.
6. THE SITE IS LOCATED WITHIN AN ESTIMATED HABITAT FOR RARE SPECIES AND IS LOCATED WITH A PRIORITY HABITAT FOR RARE WILDLIFE ACCORDING TO THE LATEST NATURAL HERITAGE AND ENDANGERED SPECIES PROGRAM ONLINE MAPS.
7. DIGITAL AERIAL ORTHOPHOTOGRAPHY (FROM 2019) INFORMATION SHOWN IS BASED ON ELECTRONIC DATA FILE OBTAINED FROM MassGIS (BUREAU OF GEOGRAPHIC INFORMATION), COMMONWEALTH OF MASSACHUSETTS EOTSS.
8. LOCATIONS AND LIMITS OF INVASIVE SPECIES VEGETATION SHOWN ARE APPROXIMATE AND BASED ON FIELD OBSERVATIONS BY OUTBACK ENGINEERING ON JULY 31, 2020.



SITE PLAN
SCALE: 1"=30'

INVASIVE SPECIES LEGEND

- BLACK LOCUST
- MILFOIL
- REED CANARYGRASS
- REED CANARYGRASS AND SPARSE SHRUBBERY

LOCUS
N.T.S.

REVISIONS

NO.	DATE	DESCRIPTION

PREPARED FOR
MIDDLEBORO-LAKEVILLE HERRING FISHERY COMMISSION
20 CENTER STREET
MIDDLEBORO, MA

EXISTING CONDITIONS
AT
ASSAWOMPSET POND
DAM SPILLWAY AND
NEMASKET RIVER
IN
MIDDLEBORO/LAKEVILLE
MASSACHUSETTS

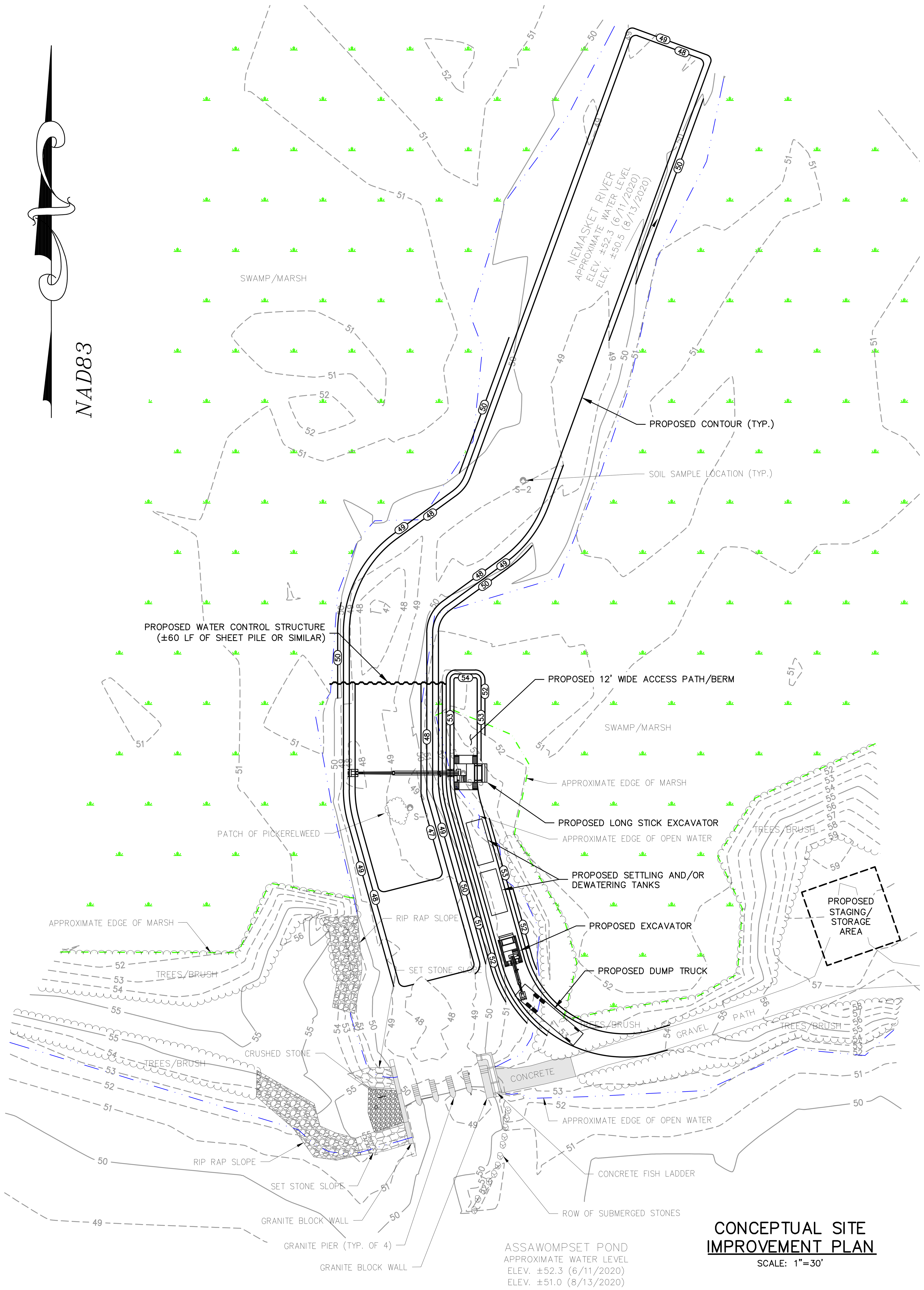
Outback Engineering Incorporated
165 EAST GROVE STREET
MIDDLEBOROUGH, MA 02346
TEL: (508)-946-9231
FAX: (508)-947-8873
www.outback-eng.com

DATE: AUGUST 2020
DRAWN BY: MAG | CHECKED BY: XXX
SCALE: 1"=30' | SHEET 1 OF 4

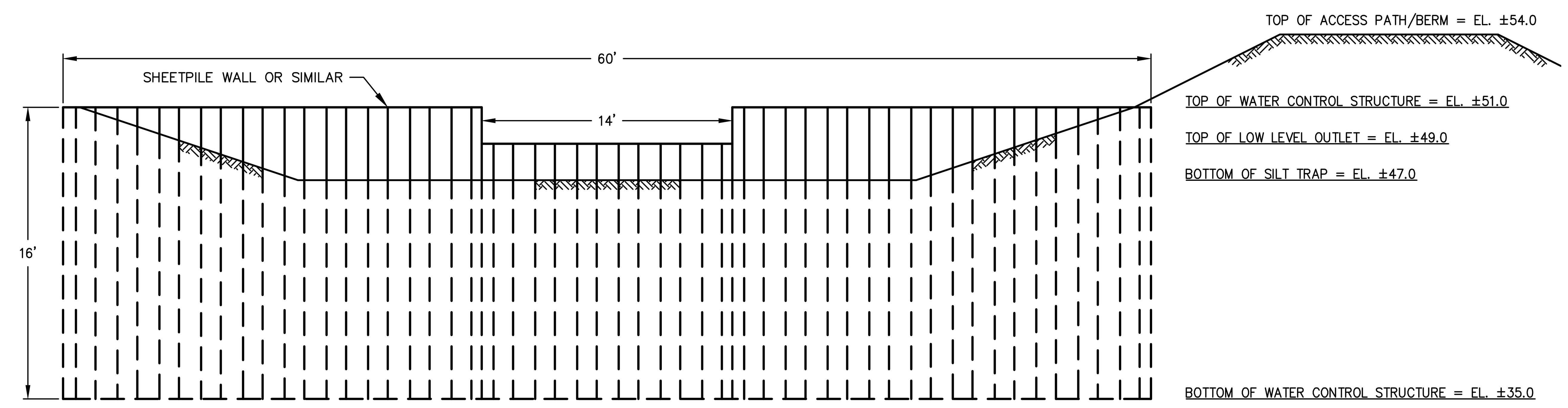
0' 30' 60' 90'

OE-3576

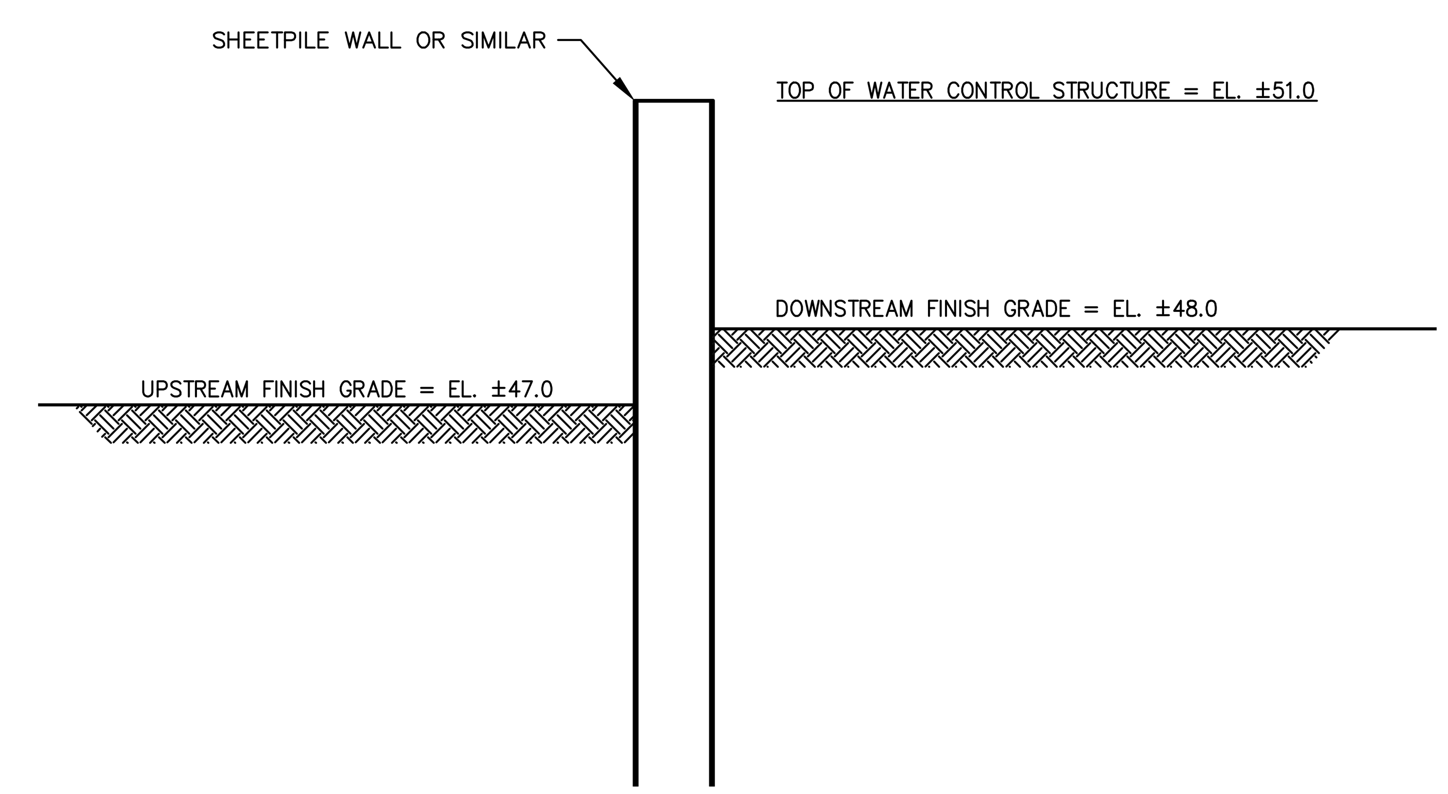
APPENDIX D – PRELIMINARY CONCEPT IMPROVEMENT PLAN AT ASSAWOMPSET POND DAM SPILLWAY AND NEMASKET RIVER



CONCEPTUAL SITE
IMPROVEMENT PLAN
SCALE: 1"=30'



CONCEPTUAL WATER CONTROL STRUCTURE PROFILE (LOOKING DOWN STREAM)
SCALE: 1"=5'



CONCEPTUAL WATER CONTROL STRUCTURE SECTION
SCALE: 1"=2'

NOTES

1. SEE SHEET 1 FOR GENERAL NOTES.
2. IMPROVEMENTS SHOWN ARE CONCEPTUAL ONLY AND SHOULD NOT BE UTILIZED FOR PERMITTING OR CONSTRUCTION PURPOSES.

REVISIONS		
NO.	DATE	DESCRIPTION

PREPARED FOR
MIDDLEBORO–LAKEVILLE HERRING FISHERY COMMISSION
20 CENTER STREET
MIDDLEBORO, MA

PRELIMINARY CONCEPT IMPROVEMENT PLAN AT ASSAWOMPSET POND DAM SPILLWAY AND NEMASKET RIVER IN MIDDLEBORO/LAKEVILLE MASSACHUSETTS

Outback Engineering Incorporated
165 EAST GROVE STREET
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TEL: (508)–946–9231
FAX: (508)–947–8873
www.outback–eng.com

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SCALE: 1"=30' | SHEET 4 OF 4
0' 30' 60' 90'

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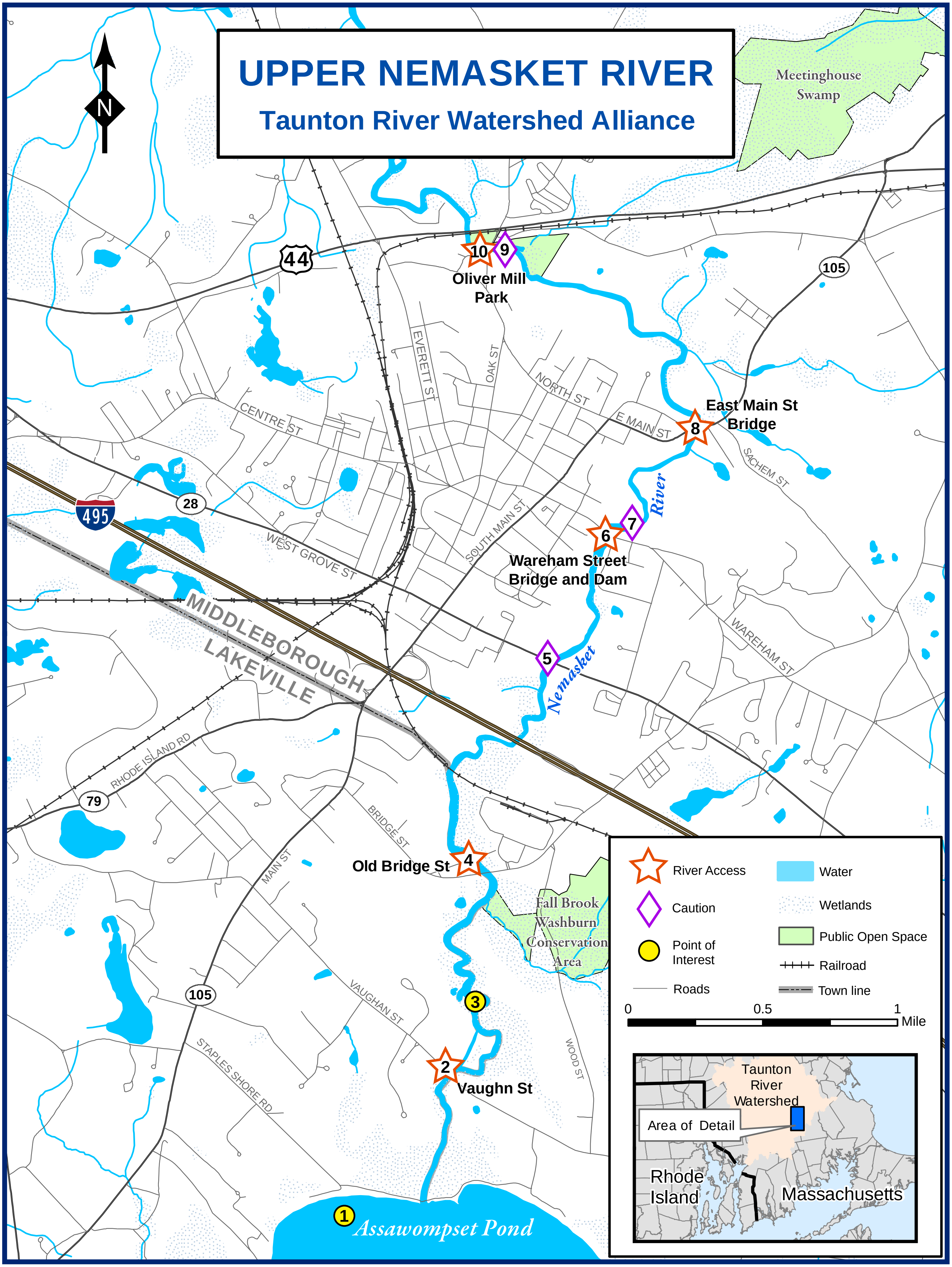
APPENDIX E – TAUNTON RIVER WATERSHED ALLIANCE UPPER NEMASKET RIVER GUIDE



UPPER NEMASKET RIVER
Taunton River Watershed Alliance
N
Meetinghouse Swamp
44
105
10
9
Oliver Mill Park
EVERETT ST
OAK ST
NORTH ST
E MAIN ST
8
East Main St Bridge
SACHEM ST
CENTRE ST
28
495
WEST GROVE ST
SOUTH MAIN ST
6
7
River
Wareham Street Bridge and Dam
MIDDLEBOROUGH
LAKEVILLE
5
Nemasket
WAREHAM ST
RHODE ISLAND RD
79
BRIDGE ST
MAIN ST
Old Bridge St
4
Fall Brook Washburn Conservation Area
3
VAUGHAN ST
105
STAPLES SHORE RD
WOOD ST
2
Vaughn St
1
Assawompset Pond
River Access
Caution
Point of Interest
Roads
Water
Wetlands
Public Open Space
Railroad
Town line
0
0.5
1
Mile
Taunton River Watershed
Area of Detail
Rhode Island
Massachusetts

Upper Nemasket River: Assawompset Pond (Lakeville) To Oliver Mill Park (Middleborough)

The Nemasket River offers a pleasant, meandering trip through forests and meadows. Around every turn in the gently flowing river, birds and other wildlife abound. With its clear water and absence of houses, this segment of the Nemasket offers one of the most enjoyable trips in the Taunton River watershed. There is one section of quickwater and whitewater between Wareham Street and East Main. The Nemasket is passable for canoes and kayaks at all normal water levels. It is the largest alewife run in Massachusetts and one of the state's most productive warm water fisheries. Early settlers used the river to transport shellfish from New Bedford. "Nemasket" is a Wampanoag Indian word for "the fishing place."

Distance: 5.4 miles **Estimated Trip Time:** 3-4 hours

1) **Assawompset Pond** is the largest natural freshwater lake in Massachusetts. A pair of naturally established **Bald Eagles** has been spotted at the south end. The pond has been the water supply for the City of Taunton since 1895 and as a public water supply it is closed to boating. It was formerly noted for abundant bog iron, which was used in colonial times to make iron. **Assawompset** means **"the place of the white stone"** in Wampanoag, probably a reference to its sandy shores. In 1675 the body of John Sassamon, a Harvard-educated Ponkapoag Indian, was found under the Pond's ice. Three men from Metacomet's (King Phillip's) entourage were hung for Sassamon's murder, the spark that began King Phillip's War. **Betty's Neck** (private property), on the southeast side of the Pond, is the former site of Sassamon's home. Here there are two rocks with hand imprints and other marks that are supposed to have been made by Indians, and a foot imprint said to be made by Sassamon's daughter, known to the Puritans as Betty, thus the name Betty's Neck.
2) The **Vaughn Street Bridge** provides the first public access to the river below Assawompset Pond. There is a parking lot with space for about eight cars and a short path leading down to the river below the bridge. When the river is high the path can be a bit muddy. **Mile 0**
3) **The large wetland** below Vaughn Street is a good place to look for birds and other wildlife. Just below the put-in the river forks. You can take either fork as they rejoin not far down the river. The left fork is straighter but may be brushy. The right fork winds through the open marsh.
4) The **Old Bridge Street** landing at the 1.7-acre **Stephen A. Kelly Conservation Area** provides excellent access to the river. There is parking for about 12 cars and a gravel shoreline that is great for launching canoes and kayaks and can also be used to launch trailered boats. **Mile 1.3**
5) The **East Grove Street Bridge** is not recommended as a put-in or take-out due to the poor access to the river, lack of parking and heavy traffic on East Grove Street, but it can be used as a take-out in an emergency. **Mile 2.5**
6) At the **Wareham Street Dam and Bridge** there is river access and parking for 10 cars. Do not go under the bridge! Take out 200 feet to the right of the bridge, next to the fish ladder, for the 50-yard portage. Re-launch below the dam and fish ladder, across the street, in Thomas Memorial Park. To travel upstream, launch from the low bank at the top of the fish ladder next to the Middleborough DPW building. Thomas Memorial Park was built in memory of two local residents and offers picnic tables but no tap water or restrooms. The park and fish ladder are a good place to watch the alewife run in early April. **Mile: 3.2**
7) **CAUTION!** Below Wareham Street there is about ¾ mile of quickwater with a more difficult (Class I) whitewater drop where the river goes through a breached canal wall. At low water a short carry may be necessary at the breached canal wall.
8) At the **East Main Street (Route 105) bridge**, unless the river is quite low, you will have to portage around this low bridge. **CAUTION:** Approach this bridge carefully because the current will want to push you into the bridge! Take out just before the bridge on the left. Carry across the bridge and the road (watch for traffic) and put in down the short steep bank on the right side of the river. Due to the limited parking this is not recommended as the starting or ending point for a trip, but it could be used as an emergency take-out. **Mile 3.9**
9) At the **historic Nemasket Street bridge** use caution when going through the narrow openings under the bridge. **Mile: 5.3**
10) **Oliver Mill Park** is just beyond the bridge. Take out on the right before the dam and fish ladder. Do not attempt to run the fish ladder! There is parking for 50 cars and good access to the river above and below the dam. There are picnic tables but no restrooms or drinking water. In 1740, Peter Oliver, a well known Tory, bought land and water privileges here. Despite objections from many residents, he built a dam, forge and various mills. This area became the center of the town's activities, manufacturing hollowware, heavy ordnance, nails and cotton products. An iron foundry named Oliver's Furnace was located below the dam. Oliver laid out the surrounding area in the manner of an English park or garden. The Nemasket Indian tribe's principle settlement, known as Muttock, was on the west (left) side of the river, across from Oliver Mill Park. Below Oliver Mill the river continues for another 4.75 miles to the Taunton River above Titicut Street and is a nice paddle. **Mile: 5.4**

Always wear your life jacket. Remove what you bring, clean up more if you can. Please respect private property. Report any problems you encounter to TRWA and local authorities if appropriate. Thank you! Enjoy!

This map and guide was created through a partnership between:

Taunton River Watershed Alliance · P.O. Box 1116 · Taunton MA 02780 · The TRWA River Center, Gertrude Boyden Refuge, 1298 Cohannet Street, Taunton, MA · phone: (508) 828-1101 · email: Director@savethetaunton.org · website: savethetaunton.org

Rhode Island Blueways Alliance · P.O. Box 2306 • Providence, RI 02906 · email: info@exploreRI.org · website: exploreRI.org