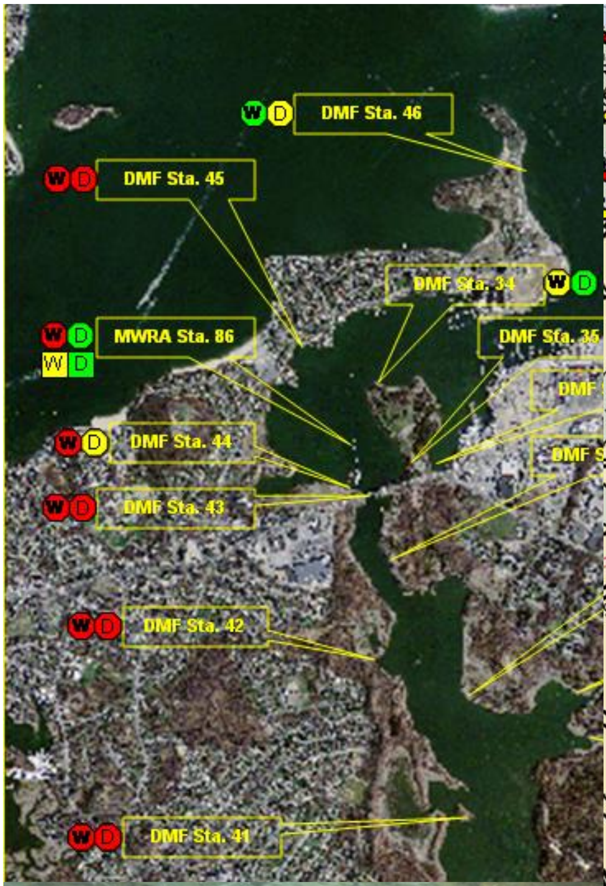
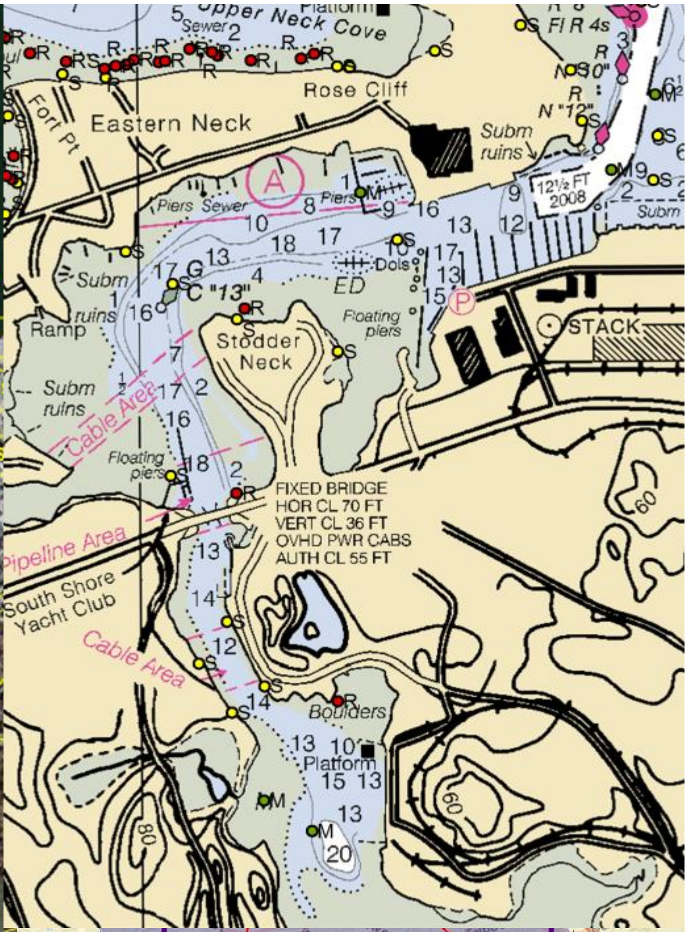
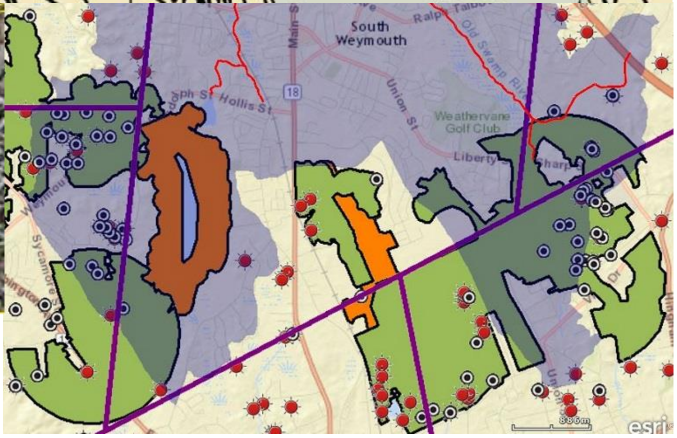
The Ecology of the Weymouth Back River

A Monograph







The Ecology of the Weymouth Back River

A Monograph

Prepared for

Town of Weymouth
Back River Watershed Association

Prepared By

Ed Eichner, Senior Water Scientist/Project Manager
David White, Senior Research Associate
Brian Howes, Director/Professor
COASTAL SYSTEMS GROUP
SCHOOL FOR MARINE SCIENCE AND TECHNOLOGY
UNIVERSITY OF MASSACHUSETTS DARTMOUTH
706 South Rodney French Blvd., New Bedford, MA 02744-1221

Foreword

The following treatise is just one of the continuing legacies of countless peoples' time and energy to clean up, restore and forever protect the area known as the Back River Watershed. As is expressed in the following chapters, the Back River environment has played an important part in the lives of both Weymouth and Hingham residents for millennia.

Although there have been many participants in this half century long effort, it goes without saying that two Marys were the instigators and one Mary was the continuing, vital source of inspiration and energy. These two were Mary Sears, PhD, from Woods Hole Oceanographic Institution and her good friend, Mary Toomey. Mary Sears gave Mary Toomey the vision to embark on the long journey to protect the Back River and its environs. Along the way, Mary enlisted the support of virtually every federal and state governmental agency, every person who could help on the municipal side and essentially every expert who might be able to assist in her quest. She never shied from this monumental task even when serious contamination was discovered on Weymouth Neck. Due to her untiring efforts, Mary was able to protect and preserve for future generations of people as well as aquatic biota, almost the entire Back River. The people of Weymouth and Hingham, as well as the Commonwealth of Massachusetts have kept a gem from becoming just another polluted waterway!

It is hoped that this monograph can be used as a teaching tool as well as an inspiration to the future generations of students and leaders about the importance one estuary has for us all.

Bob Bentley
Back River Watershed Association

Mary F. Toomey, Founder BRWA

From the Mayor

As Mayor of the Town of Weymouth I am pleased to present the *Ecology of the Back River* report, prepared by the School of Marine Science and Technology at UMass Dartmouth. The Town of Weymouth, in partnership with the Back River Watershed Association, contributed funding for this important study to support the future management of this vital natural resource because we understand the critical importance of the Back River Watershed and its ecology to Weymouth and surrounding communities.

The Back River Watershed is a sub-basin of Boston Harbor and is located largely in the towns of Weymouth and Hingham, and parts of Abington, Rockland, and Braintree. The Back River is a tidal river running a mile and a half through saltwater marshes and receives fresh water from several sources. These include Weymouth's Mill River, Great Pond, Old Swamp River, Whitman's Pond, Hingham's Fresh River, and the Tucker's Swamp/ Hockley Run Complex, creating a highly productive estuary which empties into Hingham Bay. The Back River is distinguished with four designations: an Area of Critical Environmental Concern, One of Massachusetts Special Places, Local Scenic River, and Wildlife Refuge.

It is important to note that all of Weymouth's drinking water, whether from Great Pond, Whitman's Pond or wells, originates within the boundaries of the Back River Watershed. Whitman's Pond, our secondary water source, is also the destination spawning ground for thousands of river herring, also known as alewives, every spring. River herring are a keystone species and play a vital role in a larger effort to restore and sustain New England's Fisheries. Our Weymouth Herring Run, one of the State's most productive, is a prized feature of Weymouth's Natural History. We are committed to ensuring preservation of the Weymouth Herring Run, and recently secured over a half million dollars to make much needed improvements to the herring passage in lower Jackson Square.

The Back River hosts numerous beautiful open space parks with panoramic views for public enjoyment. Great Esker Park, Herring Run Park, and the newly added Osprey Overlook Park, on the town's former landfill, are all managed by Weymouth. Bare Cove Park, Back River Wildlife Sanctuary, More-Brewer Reservation, and Bouve Conservation Land are maintained by the Town of Hingham. The Massachusetts Department of Conservation and Recreation (DCR) manages Webb Memorial State Park, Abigail Adams State Park, and Stodder's Neck State Park. DCR and Weymouth jointly manage the Kibby Property extension to the Abigail Adams Park.

Looking forward, the Back River offers enormous opportunities for passive recreation as envisioned in Weymouth's Back River Trail Master Plan. Improvements to the trails and recent additions to town parks and open space along the river, like Osprey Overlook Park and Lovell Field, in lower Jackson Square, are part of this master plan. Weymouth will continue working to implement more of this master plan and expand the trail system, with the goal of connecting the parks, in the coming years.

Many people and organizations deserve our most sincere thanks and appreciation for preserving the Back River and its surrounding watershed. The late, Mary F. Toomey, who had vision and worked for decades toward saving the Back River and surrounding lands. Weymouth Mayors David M. Madden, Susan Kay, Robert L. Hedlund and their administrations. Our Conservation Commission and Administrator, Mary Ellen Schloss. The Herring Wardens, who work tirelessly each year to ensure safe passage for migrating herring. Our friends in the Massachusetts State Legislature and Division of Marine Fisheries, who understand the importance of the Back River systems to the region's ecology and who have helped financially and technically. The Back River Watershed Association, specifically Robert Bentley, Linda Tringale-DiAngelo, Patricia Pries, who helped edit this final report. The School of Marine Science and Technology at UMass Dartmouth, Professors Dr. Brian Howes, Dr. David White, Dr. Eduard Eichner. And, thank you to all of the volunteers who come out each year to help with the Weymouth Herring Run and Community Clean-Up Days and other community events.

We in Weymouth encourage active stewardship to utilize the Back River Watershed for educational purposes to promote an understanding, appreciation, and enjoyment of the many wonders of the natural world and the importance of its protection and preservation as one of our greatest legacies to future generations.

Thank you,

Robert L. Hedlund, Mayor

June 2003 Dedication of the Abigail Adams State Park on the banks of the Back River

Standing left to right: State Rep. James Murphy, Federal Rep. William Delahunt, Former State Rep. Paul Haley, Mayor Robert L. Hedlund, Former Mayor David Madden, BRWA President Linda Tringale-DiAngelo, BRWA Founder Mary F. Toomey, Secretary of Energy & Environmental Affairs Ellen Roy Herzfelder, Rep. Ron Mariano, & MDC Commissioner William McKinney.

Acknowledgements:
The authors acknowledge the efforts and contributions of the many individuals who worked to ensure the completion of this project. They freely gave of their time and insights to improve and complete this monograph and are strong advocates of effective management within the Back River watershed and estuary.

The authors specifically recognize and applaud the generosity of time and effort spent by Mary Ellen Schloss, Conservation Administrator, Town of Weymouth and Bob Bentley, Back River Watershed Association. These individuals helped edit each of the chapters and provided extensive background documents and historical insights.

We also acknowledge the funding for this project that was provided by Town of Weymouth and Conoco Phillips.

Special thanks to Back River Watershed President Linda DiAngelo and Board Member Tricia Pries for finalizing this important document.

Cover photos: portion of MassCZM sediment map, Mary Toomey (from Town of Weymouth Recreation Department blog site), portion of map (generated for this report) of Natural Heritage & Endangered Species Program priority and estimated habitats, herring underwater, and portion of bacterial testing results map (combined MWRA and MassCZM results, included in this report).

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CHAPTER 1: Introduction

The Weymouth Back River is a primarily tidal river located approximately 10 miles south of Boston. It is an unusual natural areas in the midst of an urban/suburban environment, uniquely preserved considering its proximity to Boston (Figure 1-1).

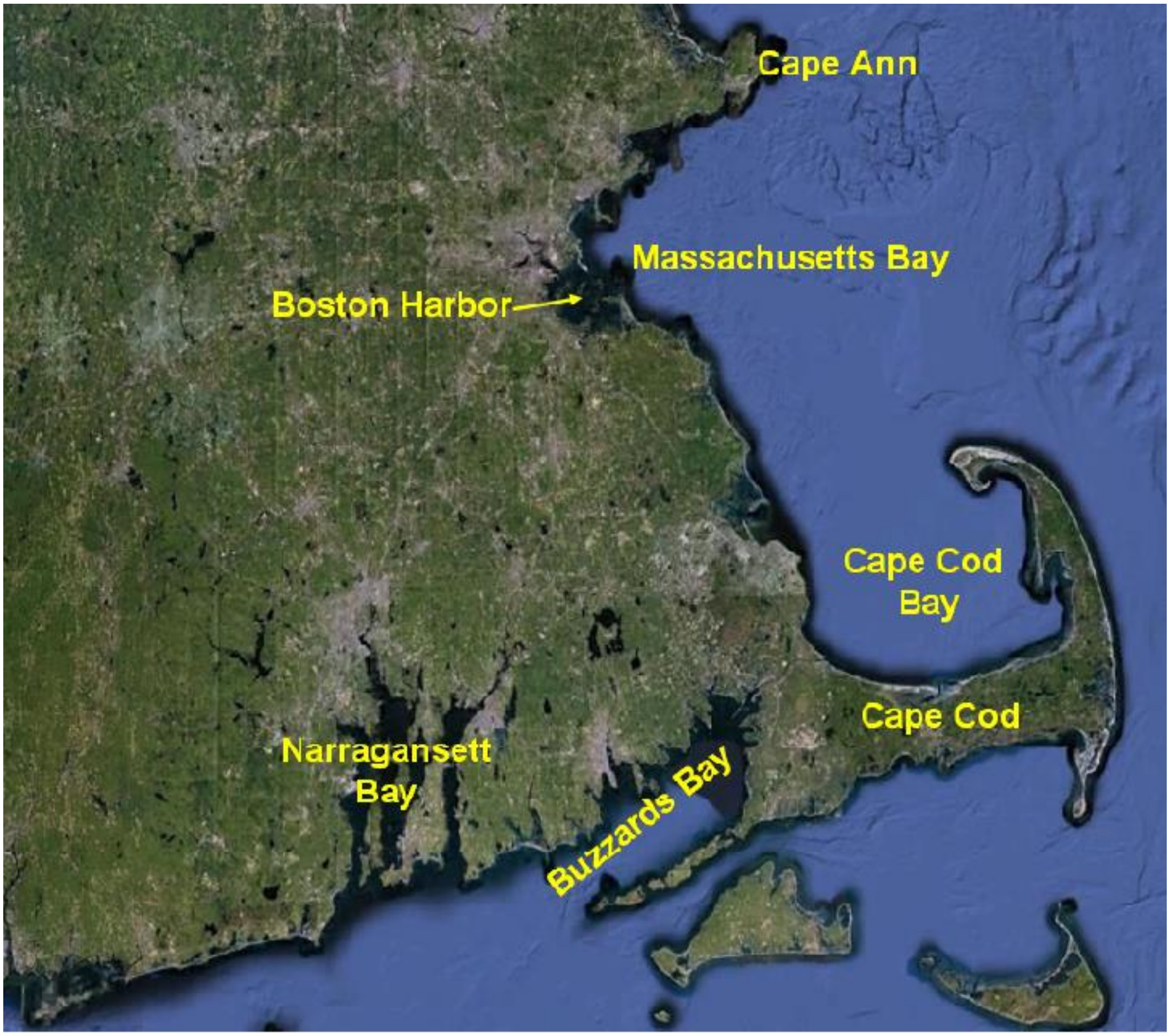


Figure 1-1. Boston Harbor and the surrounding geography of the Massachusetts coastline.

The Weymouth Back River is one of six rivers that make up the greater Boston Harbor region and feed into Boston Harbor (Figure1-2).

1. Mystic
2. Charles River
3. Neponset River
4. Fore River
5. Back River
6. Weir River

The Charles River watershed is the largest of the Boston Harbor subwatersheds, covering 308 square miles with portions of 35 cities and towns within its boundaries.

Figure 1-2. The primary river system watersheds to Boston Harbor. Based on MassGIS Drainage Subbasin coverage (2007).

The Back River watershed is bounded on the west by the Fore River watershed and on the east by the Weir River watershed (Figure 1-3). These three rivers comprise the Weymouth Sub-Basin and drain into Hingham Bay in the southern portion of the Boston Harbor.

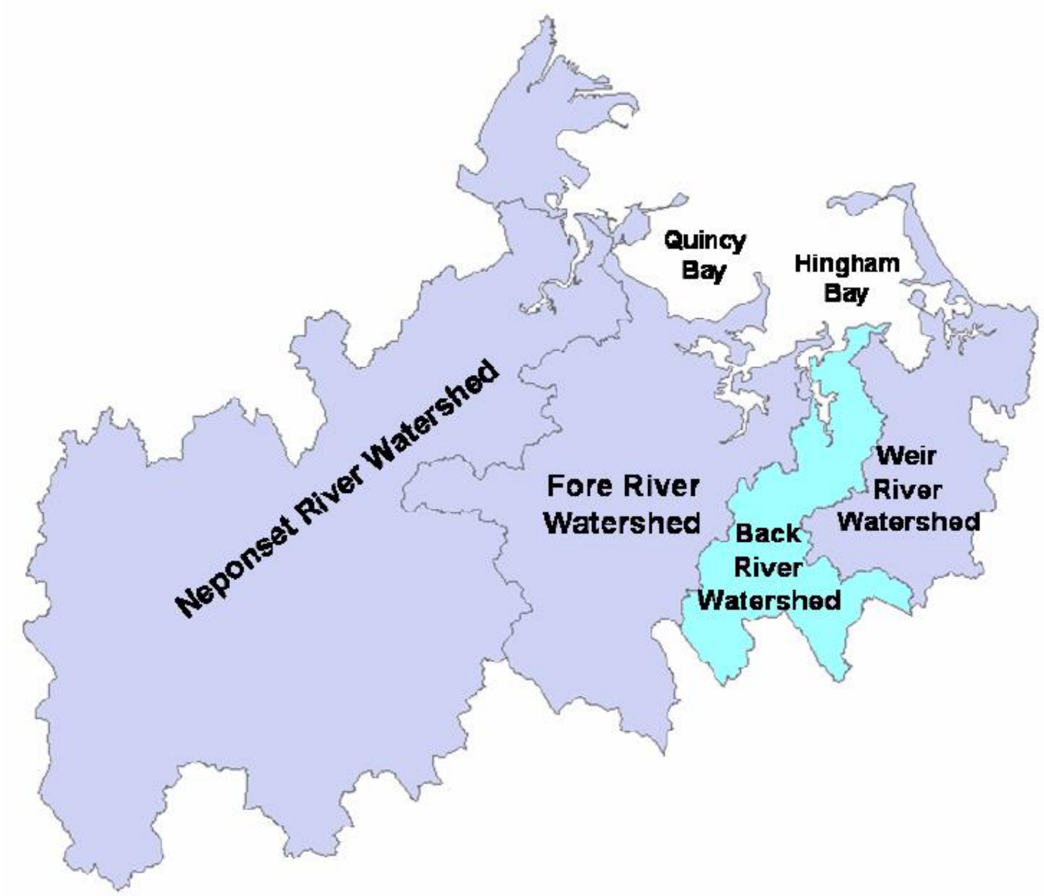


Figure 1-3. Major watershed sub basins of the South Boston Harbor region (source: Town of Weymouth GIS).

The Back River watershed is the smallest of the major Boston Harbor watersheds, draining approximately 18.7 square miles of land. The watershed includes portions of seven towns (Table 1-1).

Table 1-1. Comparison of the area and number of municipalities within the six major watersheds to Boston Harbor.

River Watershed	Area in square miles	# of Cities/Towns in watershed
Mystic	76	22
Charles	308	35
Neponset	130	14
Fore	44	11
Back	19	7
Weir	23	5

By comparison, the adjacent Weir River and Fore River watersheds are 23 and 44 square miles, respectively.

Within the Back River watershed, Weymouth (60%) and Hingham (26%) together occupy 86% of the total watershed area with Rockland, Holbrook and Braintree occupying between 3% and 6% and Norwell and Abington each less than 1% (Table 1-2).

Table 1-2. Areas of the towns within the Back River watershed (Mass DEP and Boston Harbor South Watersheds Assessment Report, 2004).

Town	Town area In sq miles	Portion in watershed In acres	% of Town in watershed	% of watershed area
Abington	10.2	3	0.05%	0.03%
Braintree	14.5	376	4.04%	3.14%
Hingham	25.0	3,087	19.26%	25.84%
Holbrook	7.4	534	11.28%	4.47%
Norwell	21.2	85	0.63%	0.71%
Rockland	10.1	665	10.28%	5.56%
Weymouth	21.6	7,198	52.07%	60.24%
TOTAL		11,947		100.00%

The watershed occupies more than 50% of Weymouth, 19% of Hingham, 11% of Holbrook, 10% of Rockland, and 4% or less of Braintree, Norwell, and Abington.

The Back River watershed, like all those of the greater Boston Harbor region was formed from the glaciation of North America during the last ice age which ended about 10,000-12,000 years ago. The retreating continental glaciers deposited a variety of materials on top of a bedrock foundation, including large hills of sand and gravel deposits, called moraines.

Glacial melt water washed sands and gravels off the face of the glaciers and deposited it in large diffuse areas called outwash plains. Some melt water was concentrated in glacial streams that created river valleys. These features were reworked by the continental glaciers as the climate warmed and cooled until sustained warming moved the glaciers further north.

As sea levels rose during the post-glacial warming, oceanic waters inundated the coastal plain, including these river valleys, creating estuaries where the fresh river waters mixed with salt water flowing in from Massachusetts Bay, thus giving the present day coastline of the harbor its familiar shape (See Chapter 2, Geology for more details).

The estuarine portion of the Back River watershed is the largest feature of the system and extends from the base of the fish ladder off Commercial Street to the mouth of the estuary at Lower Neck, about 2.9 miles in length, encompassing an area of almost two square miles.

The surface freshwater inflow to the estuary is fed by Whitman's Pond, which is 178 acres in area. Within the Whitman's Pond watershed are:

1. Weymouth Great Pond (515 acres) at the headwaters
2. Old Swamp River (4.4 miles long) which originates in Rockland, and
3. Mill River (3.5 miles long).

Two smaller streams, Fresh River and Hockley Run, both in the Town of Hingham, directly empty into Back River estuary at Bare Cove. In addition to these surface water inflows, there is groundwater discharge along the estuarine margin, as in all of the estuaries along the coast of the Commonwealth (See Chapter 3, Physical Environment for more details).

The diverse mix of fresh and salt water systems and varied geology produced a diverse set of habitats in the Back River. With over 200 acres of open water, several salt ponds and over 100 acres each of salt marsh and tidal flats, the system supports a wide variety of habitat for various finfish, shellfish, birds and other species.

Anadromous and catadromous fish runs exist within the system with thousands of alewives and smelt passing through the estuary to spawn in its tributaries and headwaters. As an example, the Back River contains one of the largest river herring populations north of Cape Cod with population estimates ranging from 31,000 in 1978 to as high as 859,000 in 1995.

Tidal exchange through Hingham Bay supports the existence of a productive clam fishery (See Chapter 4, Natural Resources for more details).

Current predominant land use within the Back River watershed is:

- forest (37% of the total area) or
- residential (36%).[1]

The remaining land use within the Back River watershed is:

- About 646 acres of the watershed are open water,
- 69 acres are freshwater wetlands,
- and over 100 acres are salt marsh.
- Only 7.7% (915 acres) of the watershed area is developed in industrial and commercial uses.
- Agricultural lands have dwindled over the past 300 years to be <1% of the land use in the watershed.
- 19% of the watershed is classified as supporting transportation, recreation or open space uses.

---

[1] Norfolk and Plymouth county 2005 land use coverage from MassGIS.

These current watershed land uses are a reflection of a long history of economic activities within the watershed. Initial human uses focused on utilization of the natural resources, including fish and shellfish and agriculture.

European colonization during the early 1600’s gradually expanded agricultural uses, which were eventually accompanied by commercial mills along the rivers.

Economic activities diversified to include ship building, tanning and textiles during the 1700’s and metalworks during the 1800’s, which also saw the construction of railroads for the transport of manufactured goods outside of the watershed.

These economic activities created land use changes within the watershed well into the 1900’s, with the transition from predominantly agricultural use to commercial, then industrial, and finally to the current prevailing residential use. These changes in many ways reflect similar changes throughout Massachusetts, but with unique features characteristic of the Back River watershed area (See Chapter 5, Land Use and Economics for more details).

As the land uses and economic activities changed, the impacts on the Back River water quality, habitats, and natural resources have changed too. Increased development density naturally led to increased nutrients and pollutants added to the estuary, rivers, and ponds, which in turn impacted fish and shellfish living and spawning in these habitats.

Addition of industrial development added discharges of metals and organic chemicals. Current residential development predominantly adds nutrients and residual organics (*e.g.*, oils, gas) from lawns and roads via both percolation through soils and stormwater runoff.

Changes in how water and how wastes were handled within the watershed also altered:

1. where accompanying contaminants impacted resources,
2. and how various species populations were altered.

For example, initially septage pits were used to dispose of human wastes, but in 1947, the Town of Weymouth began building a sewer system. The sewer system collected and removed nutrients and bacteria that previously reached the water resources within the town’s portion of the Back River watershed, but also removed some of the water.

These types of changes alter how various ecosystems function and accentuate certain nutrient sources’ (such as stormwater) impact water quality.

Towns within the watershed have implemented many infrastructure changes to mitigate these impacts and work toward restoring water quality throughout the Back River watershed (See Chapter 6, Changes in the Back River System for more details).

Understanding how all of these changes impact water quality, land use, economic development, and habitats has led to a better understanding of management options within the watershed. Measurements of a host of factors, including bacterial contamination, nutrient loads, drinking water quality and quantity, and wetland impacts, as well as national and state regulatory goals, have combined to create a better understanding of how the Back River resources interact and how to provide standards that can assist in developing a more resilient ecosystem and more informed stewardship (See Chapter 7, Management for more details).

The Ecology of Weymouth Back River combines available information on the current status of the Back River watershed with the history of how that status developed and how it might be managed in the future. Each of the following chapters looks at various components of that relationship and, hopefully, provides some insights that will help the communities of the Back River watershed.

The Ecology of the Weymouth Back River

CHAPTER 2: Geology

2.1 Introduction

The Boston Harbor region, including the Back River basin and its surrounding uplands are a relatively young geologic feature in New England.

The basic structure and shape of the region was created by glacial transport and subsequent erosion of sediments during glacial melting and retreat.

These features were then reworked and adjusted by relative sea level rise, post-glacial rebound of the land mass, wave and tidal erosion and sorting and transport of sediments.

The resulting topography of the Boston Harbor region had important influences on the early history of the area, including settlement and the local economy of Native Americans, and European colonists who migrated to the area beginning in the 17th century. They continue to influence the region today.

The Boston Harbor basin is a drowned coastal basin formed by the confluence of multiple drowned river valleys, including the:

- Charles River,
- Neponset River,
- Mystic River, and
- Back River

The Back River is a moderately sized river feeding into this regional basin. The region is also called the Boston Lowland or Boston Basin with each of the rivers forming an estuary where ocean and river water mix.

Within each estuary, including the Back River, the tides penetrate upstream for several miles forming large navigable estuarine waters, with large expanses of fringing salt marsh along each of the shorelines.

The radial nature of this pattern of river systems and the peninsulas of land between them created an ideal physical setting for the area as an early major port and center of commerce in the New World (La Forge, 1932).

2.2 Formation Geology

Most of the present day geology of the Boston Harbor region is due to the impact of the Pleistocene Epoch glaciations (2.5 million to 12,000 years ago).

Prior to the glaciation (Pre-Pleistocene), what is now the low-lying Boston Harbor basin and its surrounding higher upland masses were composed of largely Pre-Cambrian rocks of volcanic origin that are older than 500 million years (Figure 2-1).

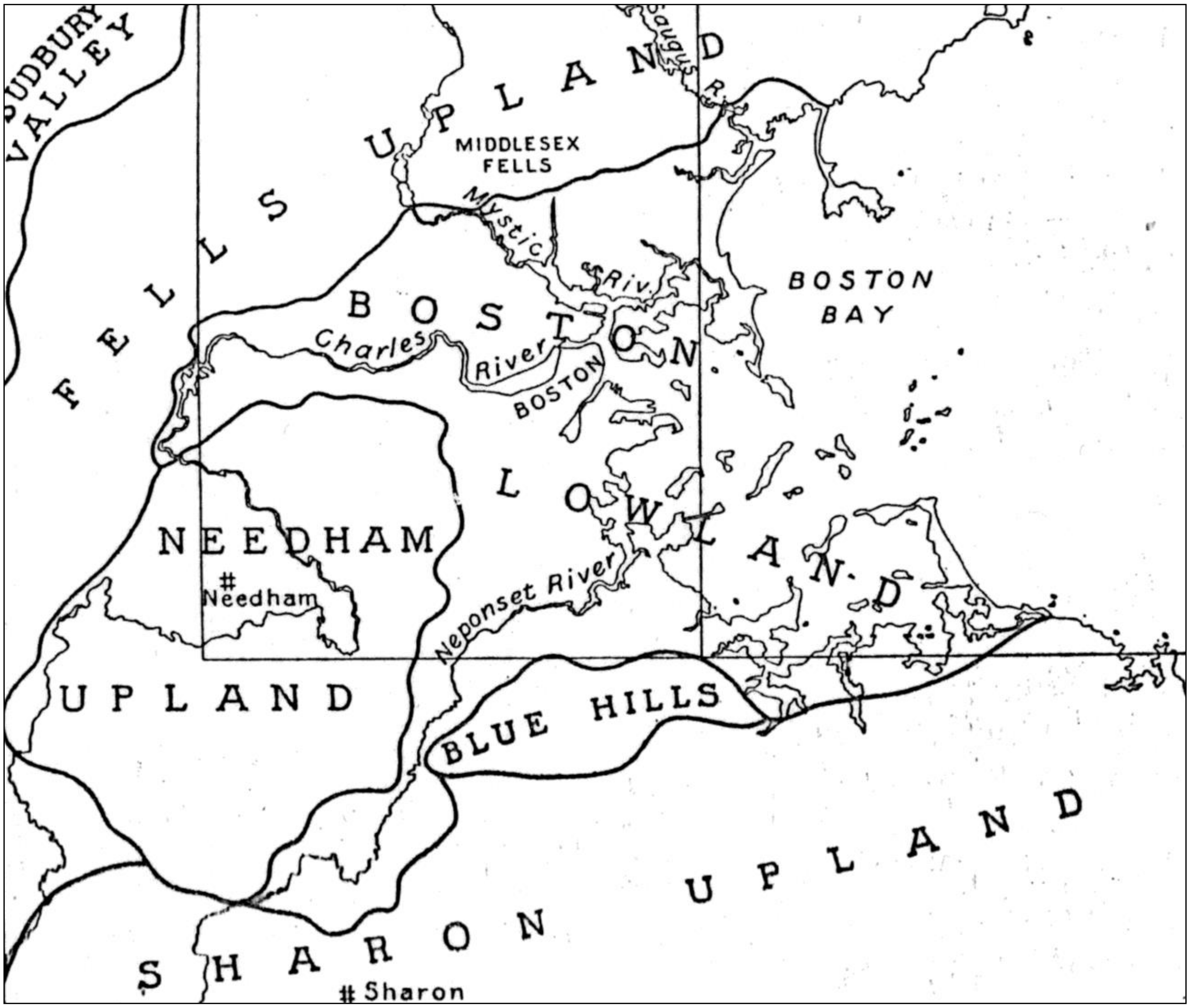


Figure 2-1. Geomorphic subdivisions of the Boston area: Boston Lowland or Boston Basin, Fells Upland to the north, Needham Upland to the west, Blues Hills and Sharon Upland to the south. Modified from La Forge (1932).

Over the millions of years between the Pre-Cambrian and the beginning of the Pleistocene, the basin became overlain by layers of marine sand, clay and marine calcareous "ooze" with the remains of marine organisms including mollusks and crustaceans from periodic incursions by the ocean.

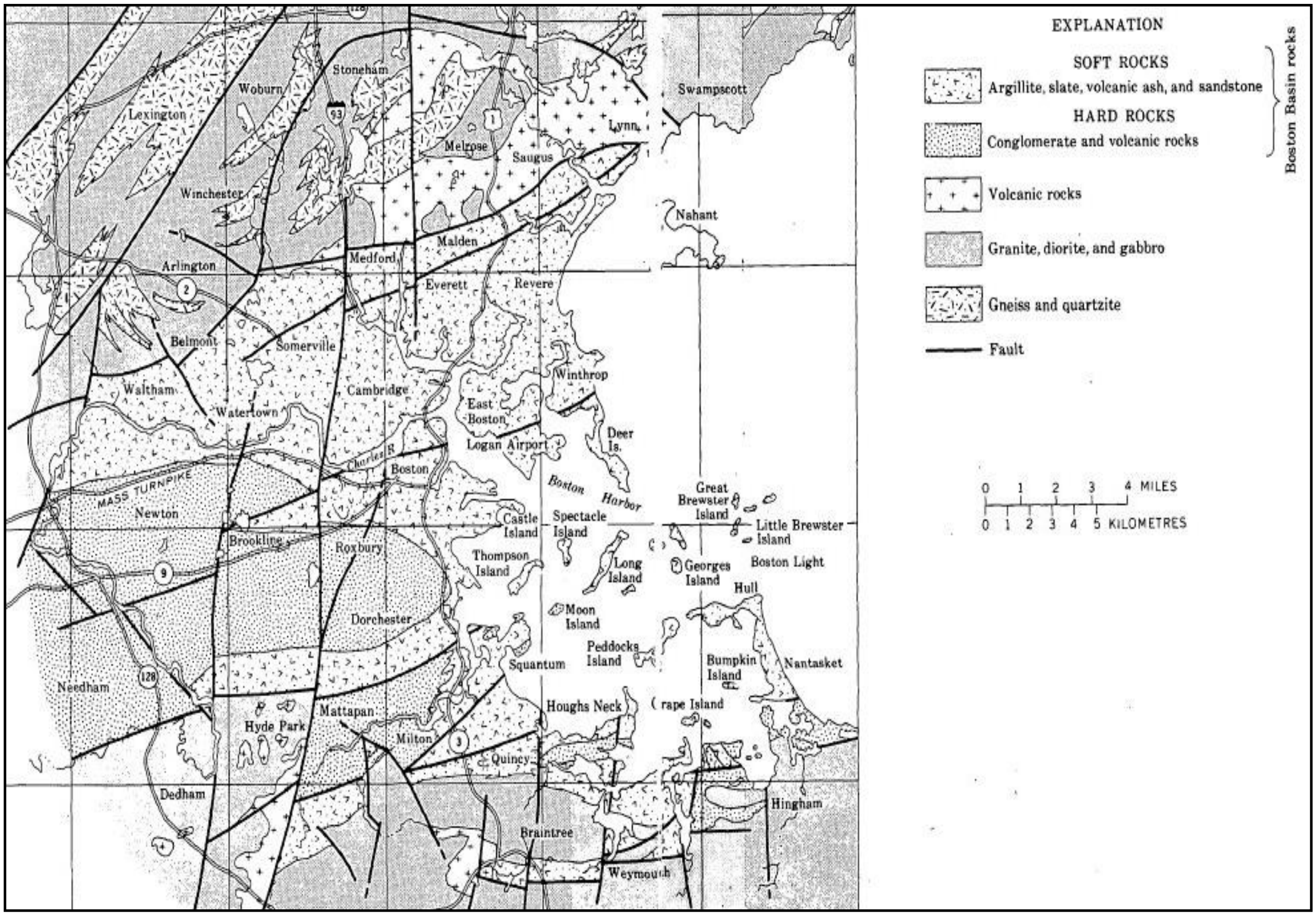


Figure 2-2. Boston area generalized bedrock geology. Modified from Kaye (1976).

Over time, these deposits were compressed and hardened into a substance called Argillite which comprised much of the sedimentary rock of the Boston basin along with volcanic ash and "conglomerate" material of cemented clay and gravel also called "Puddingstone" (Figures 2-2, 2-3).

These rock materials were relatively soft compared to layers of granitic rock which composed most of the upland mass surrounding the Boston Harbor area to the north, west and south (see Figure 2-2).

Figure 2-3. Example of Roxbury Conglomerate stone from Chestnut Hill (photo courtesy J. Share).

The last glaciation left behind the clearest and most complete record of its impact on the geological record of the Boston Harbor region and played a major role in the formation of the present Boston Harbor basin and its tributary river systems, including the Back River.

During this glaciation, the Laurentide Ice sheet covered New England starting some 50,000-70,000 years ago during the Wisconsin Stage of the Pleistocene Epoch and was centered on Labrador and Hudson Bay.

Although the exact number of glaciations that advanced over the Boston Harbor region prior to this is not known, there may have been as many as 10 over a period of 1-2 million years (Kaye, 1976).

The Wisconsin ice sheet moved into the Boston Harbor region from the northwest and advanced over the land toward the southeast (Figure 2-4). Due to the massive weight of the ice sheet, the land subsided (perhaps as much as several hundred feet) and the softer argillite bedrock with the volcanic ash and sand-clay-gravel conglomerate was scoured and eroded away from the area leaving the large depression or valley in the coastline, today recognizable as the Boston Basin.

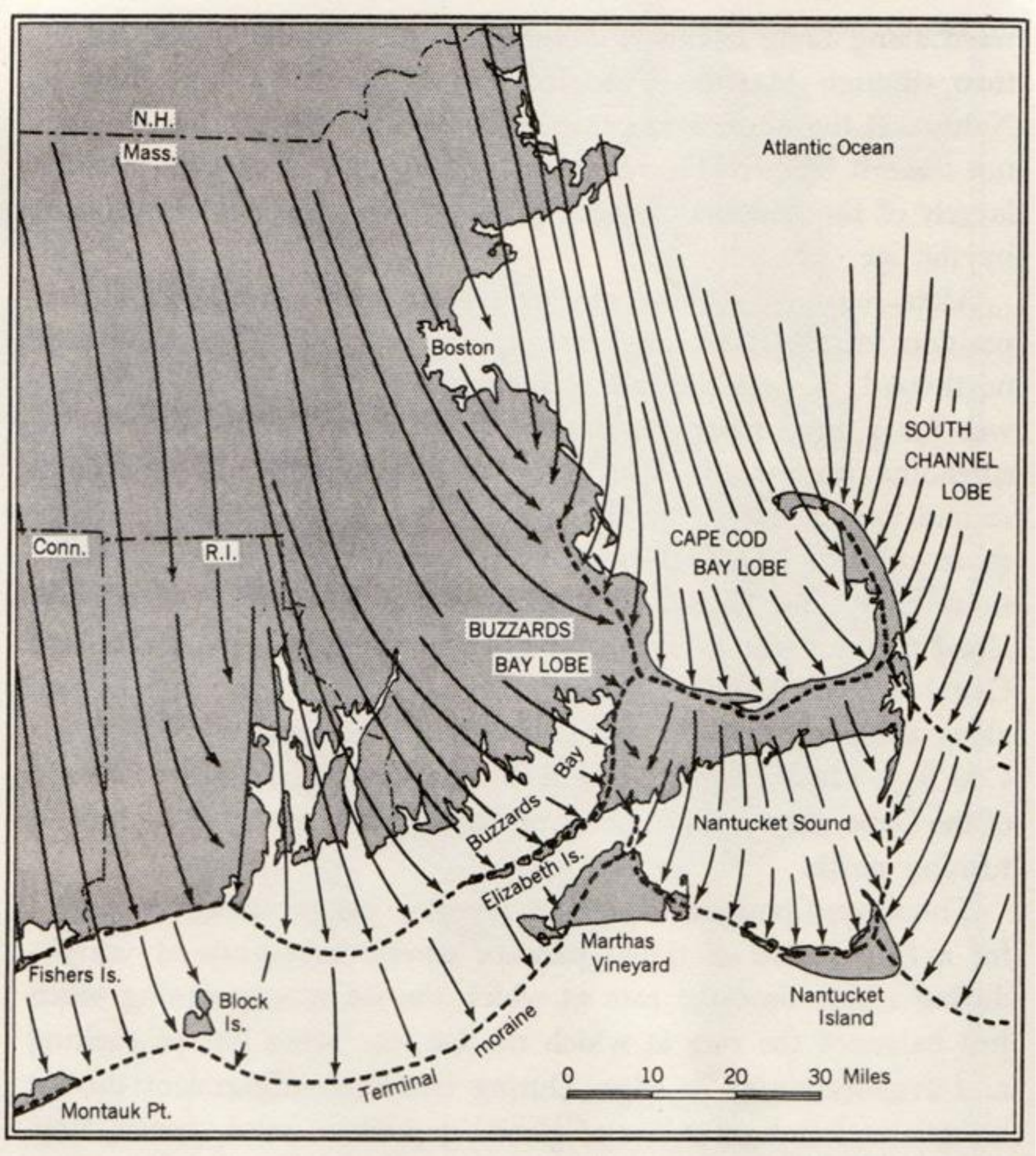


Figure 2-4. Directions of ice flow in Southern New England during the Wisconsin Stage and the two positions of the moraines (dashed lines) (from Strahler 1966).

The edges of the basin are clearly defined by the surrounding highlands or escarpments that stretch continuously in distinct zones (see Figure 2-1): Lynn and Saugus to the north, through Malden, Medford, Arlington and Waltham to the west, and Blues Hills and Sharon Upland to the south (Kaye, 1976).

At its maximum extent, the continental ice sheet advanced as much as 100 miles south of Boston where it formed a series of moraines (ridges of glacial till deposited at glacier's major points of advance and retreat) which are today parts of Cape Cod, Martha's Vineyard and Nantucket (see Figure 2-4).

The ice reached a thickness of several hundred feet, covering the highest hills in the area. It transported many loose boulders and rocks, grinding most into fine materials which became part of the historical record of the advance and retreat of the glacier as it melted and deposited this "drift" material (boulders, rocks, cobbles, sands, and clays) at the moraines. Much of what is known about the Wisconsin glaciation comes from the evidence of these geological "remains" left behind by the retreating ice sheet.

As the glaciers retreated across the landscape, they left a series of what are known as recessional moraines where the ice front was stationary for a time. These moraines included deposits of glacial till (*i.e.* unsorted materials), large ice block holes called kettles and a series of kames which are mounds of glacial till, sand and gravel that have accumulated in some of the kettle holes and other depressions left by the ice.

Kettlehole ponds formed when an ice block was left by a retreating glacier, then was surrounded and eventually covered by glacial outwash materials (*i.e.*, sorted materials deposited by meltwaters flowing off the face of the glacier). When this covered ice block melted, the overlying deposited materials collapsed and created a kettlehole. Whortleberry Pond in Weymouth is an example of a kettlehole pond and is approximately 200 meters in diameter. The area between the moraines contains both glacial till and outwash plain interspersed with kettle holes.

2.3 Drumlin Formation

One of the most notable types of glacial formations in the Boston basin is the extensive drumlins. These small hills are made up of a variety of glacial materials: fluvial sediments, lacustrine sediments, till, and bedrock and were likely formed during a variety of glacial periods.

They generally were formed either under or within the ice sheets, but usually have glacial material deposited on top as the glaciers melted and retreated. They are small round or elliptical hills, smooth and gently sloped, and they occur in groups which are generally oriented in the same direction as glacial flow.

In the Boston basin, however, the drumlins tend to be oriented in a number of different directions which probably reflects the complex glacial history of the region (Figure 2-5). It is clear that not all of the Boston drumlins were formed by the Wisconsin glaciation. Many are remnants of earlier glacial events and simply survived to the present day (Newman and Mickelson, 1994).

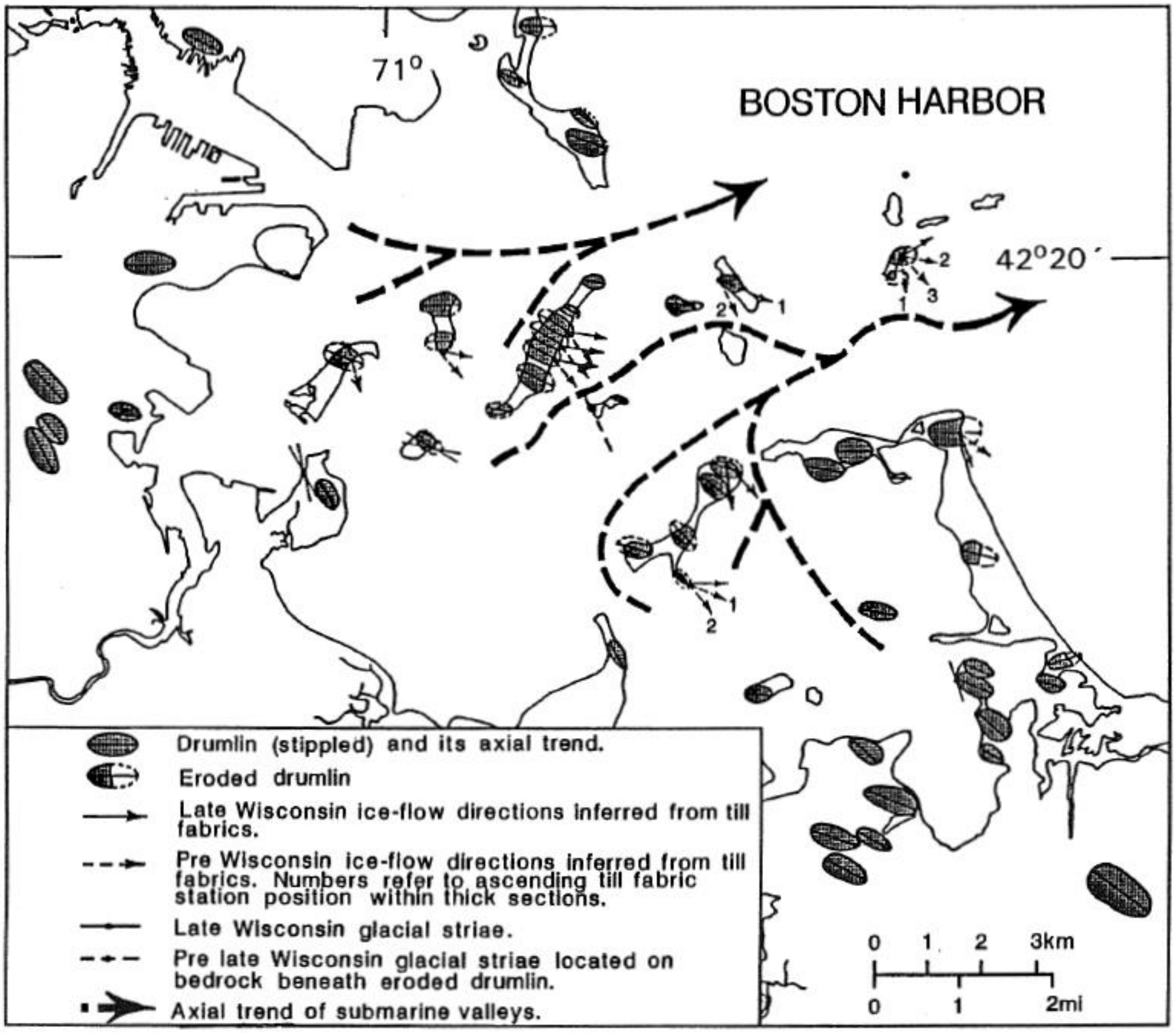


Figure 2-5. Location and orientation of drumlins in Boston Harbor. Postglacial drainage channels, which form modern tidal channels, are also shown (Newman and Mickelson, 1994).

Among the most famous drumlins in the Boston area are Bunker Hill and Breeds Hill in Charlestown, site of the first major battle of the American Revolution. Nahant and the Boston peninsula are also made in part from linked drumlin formations. Several of the Boston Harbor Islands are drumlins, including:

- Deer Island
- Thompson Island
- Spectacle Island
- Peddocks Island
- Bumpkin Islands
- Grape.Island

Grape Island, at the mouth of the Back River, is composed of two drumlins that reach a height of 70 feet and are connected by a wetland.

Peddocks Island was formed by sediments carried by water currents linked as many as five drumlins through the development of a series of connected sand spits, or tombolos (Figure 2-6).

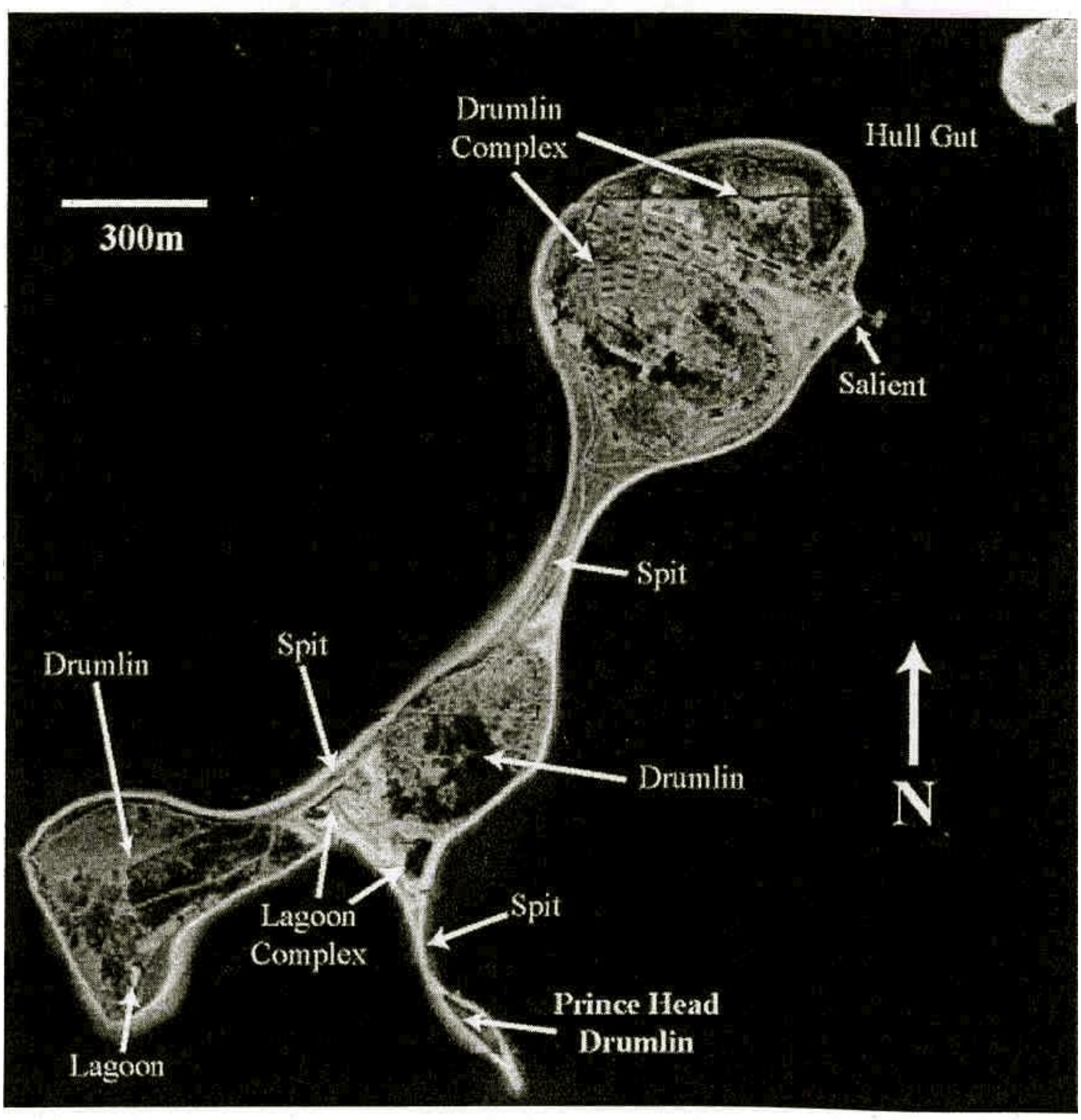


Figure 2-6. Peddocks Island in Boston Harbor is comprised of a number of connected drumlins (from Rosen and Fitzgerald, 2009).

The Nantasket Beach peninsula in Hull was likely formed in a similar manner (Figure 2-7).

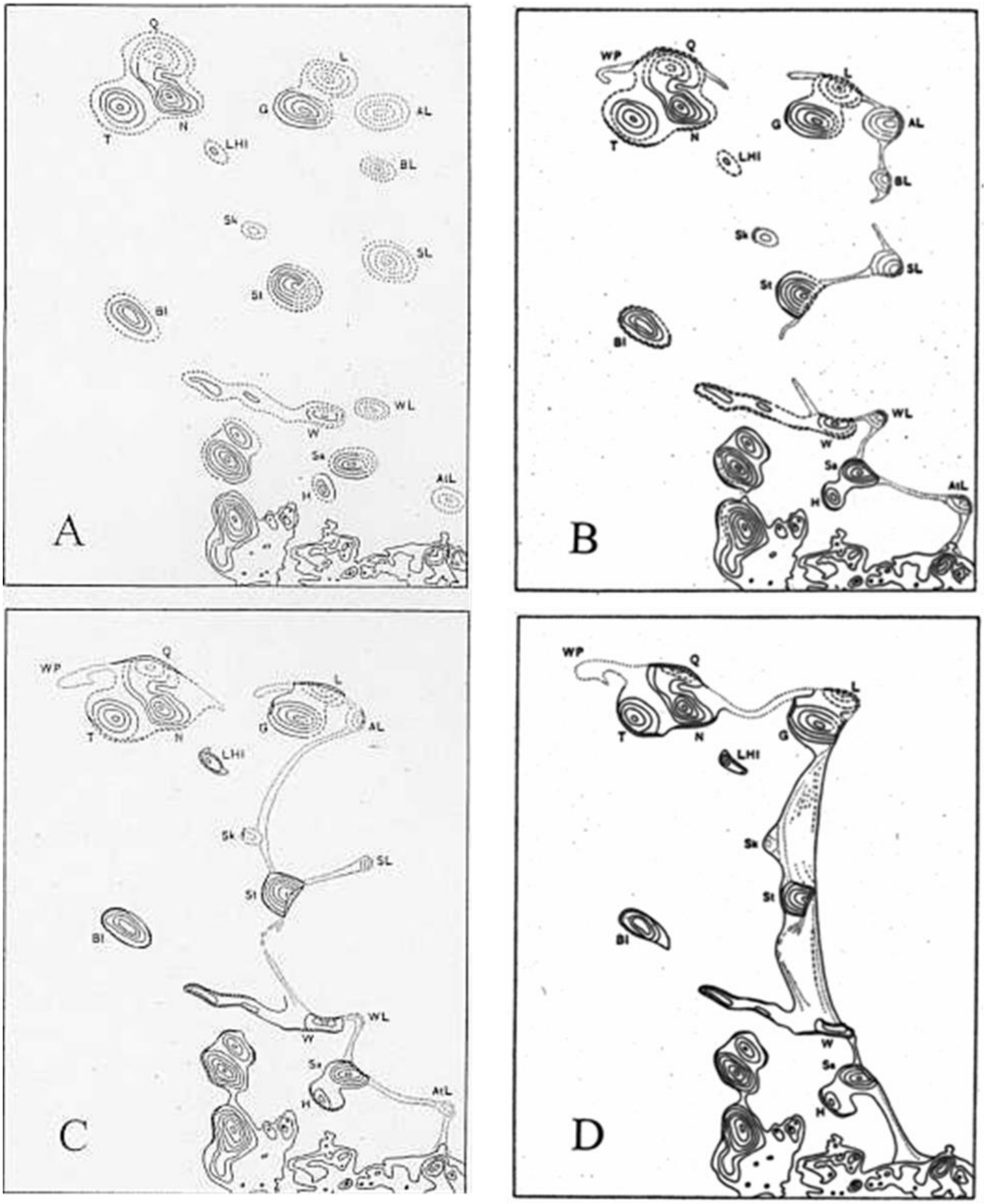


Figure 2-7. Johnson’s 1910 model of development of Nantasket Beach

In Johnsons's 1910 model of development of Nantasket Beach in Figure 2-7:

> Panel A. shows an initial drowned drumlin shoreline,
> Panel B. shows erosion of the drumlin to form sea cliffs and development of spits,
> Panel C. shows spits connecting between drumlins to form barrier beaches,
> Panel D. shows shoreline accretion resulting in a barrier beach (from Colgan and Rosen 2001).

The presence of these drumlins slows tidal currents in their immediate area and allows sand to accumulate between nearby drumlins, forming tombolos, and often capturing wedges of sand, or salients, that accumulate around the drumlins.

Along with the Boston Harbor Islands, Boston Harbor also has a number of distinct peninsulas including:

- Boston (Shawmut peninsula),
- Charlestown Neck,
- Deer Island,
- Dorchester Neck,
- Nantasket Beach,
- Hough's Neck,
- Moon Head
- Weymouth Neck

The Boston Harbor Islands, as well as the distinct peninsulas of the Boston Harbor region play an important role in the subdividing of the Boston Harbor basin into:

1. The distinct mouths of the Charles and Mystic Rivers of the inner harbor,
2. Dorchester Bay,
3. Quincy Bay,
4. Hingham Bay in the outer harbor.

2.4 Formation of River Valleys

During the post-glacial warming period and glacial retreat, glacial melt water formed streams that flowed along the ice margins to the outwash plains and cut channels through the till. In some cases, small ice margin lakes formed between the ice front and low lying upland hills surrounding the Boston basin.

Some became large bodies of water with well-defined boundaries. Historical settlement and development of the area have obscured some of the geological evidence for these glacial lakes but there is sufficient evidence available to document their existence. Many of these lakes were small lakelets but several combined to form larger lakes as the glacier retreated and more melt water accumulated in the exposed outwash plain.

Glacial Lake Bouve was formed in this manner, approximately 140 feet above sea level, and encompassing the present towns of Hingham, Weymouth, Braintree, East Quincy and the lower parts of Randolph, Holbrook and Rockland (Emerson, 1917). Its area extended from the Blue Hills in West Quincy to Prospect Hill in Hingham, about 30 miles.

In the Blue Hills region to the south of the basin, the retreating glacier blocked the flow of melt water out to the low-lying land to the east. Lake Bouve drained to the north into the Boston basin. It was a significant feature of the early post-glacial landscape and gave rise to several river watersheds including the Monatiquot River, the Mill River, Old Swamp River, and the Plymouth and Beechwood Rivers (Crosby, 1900).

Two more of the larger glacial lakes in the Boston Harbor region have been identified in parts of the present day:

1. Charles (Glacial Lake Charles), and
2. Neponset (Glacial Lake Neponset) River watersheds (Fuller, 1904; Clapp, 1904).

As the continental ice sheet continued to retreat and exposed more of the land in the watersheds, distinct drainage patterns from these lakes developed. As the lake waters continued to flow toward the eastern edge of the basin distinct drainage channels became permanent and enlarged to be the familiar rivers and streams of today.

One of the prominent features associated with Glacial Lake Bouve is the abundance of the remains of sub-glacial melt water stream channels called Eskers. Eskers are long narrow ridges of stratified glacial till (some can extend up to several kilometers and reach heights of 10's of meters) believed to be formed from the deposition of till by streams of melt water that flowed under the continental glaciers. These streams flowed toward the ice edge and into adjacent outwash plains.

The eskers remained as part of the topography after the glacier retreated from the area. Some of the Lake Bouve eskers actually suggest that for a time, these sub-glacial streams may have reversed direction of flow toward the Blue Hills, escaping through passes in the upland valleys there.

At the northern end of Lake Bouve there are a series of eskers that mark the positions of sub-glacial streams that flowed into the Boston basin. Several of these are located on the west shore of the present Weymouth Back River estuary. One of these, Great Esker (Figure 2-8), is quite prominent, consisting of two parallel ridges approximately 3 km long and rising to almost 100 feet at its highest point (Colgan and Rosen, 2001; Crosby, 1900).

The Great Esker terminates as an area of collapsed sand and gravel south of East Weymouth. It was probably deposited during the late Wisconsin near a thin, retreating ice margin. It is generally thought to be the tallest esker in North America.

Figure 2-8. Aerial view of Great Esker, Weymouth, MA (outlined in red). (from BostonGeology.com).

2.5 Post-Glacial Sea Level Rise

As the last ice age ended, the water captured in the glaciers began to return to the oceans and sea levels rose. Sea level rise in the Boston Harbor area occurred in 4 major stages:

1) glacial retreat and rapid sea level rise causing inundation of region;
2) subsequent drop in sea level, rebounding of the land mass and re-emergence of the harbor bottom,
3) more gradual rise in sea level and re-flooding of the harbor area; and
4) gradual stabilizing of sea level and present shoreline starting about 4,000-5,000 years ago (Rosen and Fitzgerald, 2009).

The historic rate of relative sea level rise (the combination of global ocean surface rise (*i.e.*, eustatic sea level rise) and changes in the land surface due to subsidence or uplift) is typically determined by radiocarbon dating of glacial deposits, intertidal peats, etc.

All of southern New England, including the area of what is today the Boston basin, is thought by many geologists to be several hundred feet higher than it was prior to the Wisconsin glaciation. Much of what is today Boston Harbor, Massachusetts Bay and the Gulf of Maine was dry land at that time. The weight of the massive glacier ground and scoured the bedrock of the Boston basin beneath it and caused significant subsidence of the land.

The post-glacial warming period which began about 14,000 years ago marked the end of the Pleistocene Epoch and hastened the retreat, thinning, breakup and final disappearance of the ice sheets. The resulting return to the oceans of the water trapped in that ice caused a relatively rapid rise in sea level which inundated the Boston basin.

During that warming period, to about 10,000 years ago, ocean levels rose 60-120 meters with levels at 7-10 meters below present about 7,000 years before present (BP) (Emery and Aubrey, 1991). It was during the initial period of rapid sea level rise that almost all of the current Boston Harbor and the lower portions of the present day river systems around the harbor first became flooded with seawater. However, the tidal range was much smaller (1-3 ft) than it is today.

During this initial rapid sea level rise, fines (clays and fine rock) named “Boston Blue Clay” for their blue-gray to olive drab color, were deposited by both near-shore waters off the coastline of the Boston basin and by stream water coming off the remnants of the glacier between 14,000 and 12,600 years ago (Rosen, *et al.*, 1993). This clay, which was as thick as 75 ft in some low-lying areas, extended into the offshore zones of Massachusetts and Cape Cod Bays as well as Boston Harbor, and extended as far inland as Watertown.

Over the next approximately 5,000 years, the elevations of sea level and the land surface changed a number of times. From about 13,000-11,000 years BP, sea level rise slowed and previously submerged land rebounded, especially to the north of Boston, as much as 20+ m, and became re-exposed with a simultaneous movement of the coastline further offshore (Kaye and Barghoorn, 1964.).

Between 11,000 and 10,000 years ago, sea level rise and land rebound kept pace with each other, creating a more stable shoreline. The sea level maintained this stable position for nearly 2,000 years before the area submerged again in response to another, more gradual rise of sea level and slowing of the rebounding of the land (Rosen and Fitzgerald, 2009).

By 9,000 years BP, sea level was about 25 m below modern mean sea level (MSL) and by 6,000 years BP sea level had risen to approximately 11 meters below MSL.

By 4,000-5,000 years BP, the rate of sea level rise had slowed significantly and the shoreline of Boston Harbor had reached approximately its present position (Figure 2-9).

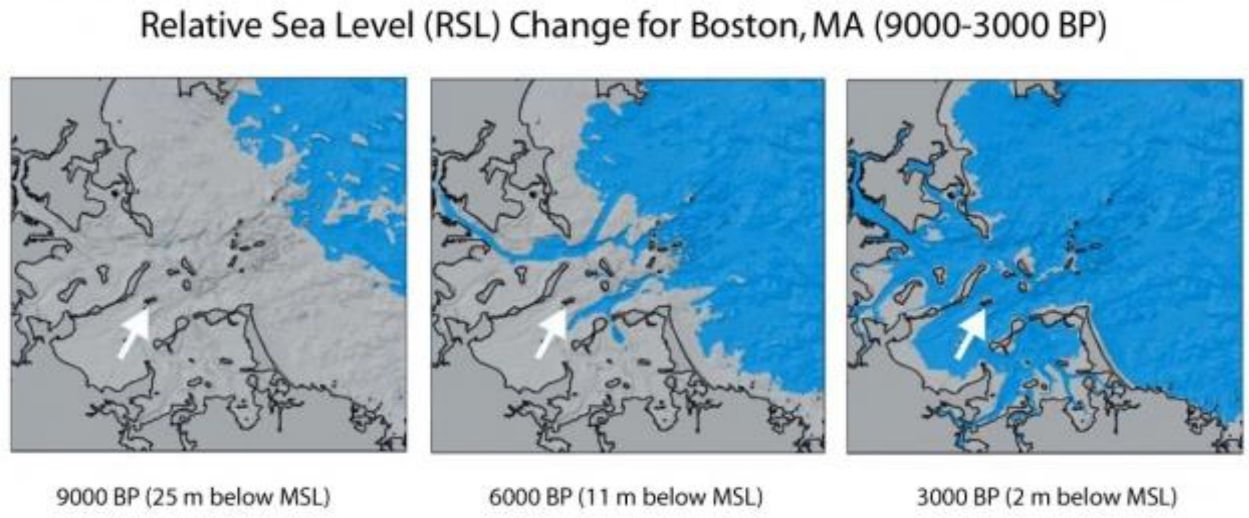


Figure 2-9. Different stages of relative sea level rise in Boston Harbor, 9,000-3,000 years BP. White arrow points at Rainsford Island as reference marker, gray areas indicate upland, and the current shoreline is shown in black outline (Institute of Maritime History; maps created from data of Peltier and Tushingham 1989).

The tidal range had also reached its present day level of about 10 feet due to rising sea levels and the particular shape and dimensions of the offshore basins:

1) Bay of Fundy,
2) Gulf of Maine,
3) Massachusetts Bay and
4) Cape Cod Bay.

These basins focus tidal currents that control both the amount and the rate of tidal flooding into Boston Harbor (Rosen, *et al.*, 1993; Rosen and Fitzgerald, 2009).

There are indications that there was a possible decrease in the average rate of rise from 0.80 ± 0.25 mm/y between 3,300 to 1,000 years BP to a rate of 0.52 ± 0.62 mm/y between 1,000 years BP and the past 150 to 500 years (Donnelly, 2006).

Radiocarbon dating of marsh peat at Romney Marsh in Revere, Massachusetts, indicates a rise in mean sea level (MSL) of close to 2.6 m in the past 3,300 years (Donnelly, 2006). As sea levels continue to rise, eventually the former salt marsh forming the base of most of Boston will once again be flooded with seawater, unless coastal controls are put in place.

2.6 Estuary Formation

Most of the studies of historic estuary formation within the Boston basin are based on data collected in areas closer to Boston. However, it is highly likely that the regional nature of these changes were also similar to those experienced in the Back River.

The first evidence of estuary formation in the inner Boston Harbor basin is found in the sediments beneath what is now the Back Bay landfill area (filled in the 19th century). This formation began about 5,600 years BP when there was a transition from upland till to intertidal salt marsh peat followed by a rapid transition to a shallow subtidal mud environment which contained abundant oyster beds.

Sediments accumulated at about 1 mm/yr while sea level rise was about 3 mm/yr. About 3,500 years BP there was another rapid transition (over a 500 year period) from the shallow muds to a more tidal/channel environment with sand and silt dominating the sediments.

The increasing tidal and saltwater influence in the inner harbor area during this period brought with it a greater diversity of benthic (bottom-dwelling) faunal communities. The most recent transition occurred about 3,000 years BP. It is identified by several layers of sand (strata) with little evidence of large faunal communities, indicative of active areas of sedimentation, likely a tidal flat with reduced rates of sea-level rise. The increase in sedimentation in the Back Bay area resulted in the colonization of greater areas of salt marsh, identified by layers of peat overlying the sand (Rosen, *et al.*, 1993).

Today both the inner and outer portions of Boston Harbor are primarily composed of fine-grained sediments, such as fine sand or mud. There are also some areas of high relief bedrock, boulders and glacial till on the sea floor in fairly close proximity to deposits of finer sand and mud.

Isolated accumulations of broken shells mixed with sand and mud are sometimes found in small cracks or low-lying areas between rock outcrops. Sediments of both the inner and outer harbors are dredged regularly to maintain the shipping channels. Notable anthropogenic features of the bottom topography include wrecks of small boats and barges, pipelines, and piles of debris (Ackerman, 2006).

The Back River estuarine basin consists mostly of glacial outwash that was cut by one of many streams carrying glacial melt water from the edge of the glacier across the outwash plain as the great ice sheets retreated about 10,000 years ago. Most of the outwash soils were composed of gravel and sand deposited on top of the bedrock, some of which can still be seen as exposed rocky outcrops, one of which is located at the present day Hewitts Cove.

After the glaciers retreated, the Back River channel stretched out beyond its present day mouth at Lower Neck and into the Hingham Bay basin, which was an exposed coastal lowland. Over the millennia, rising sea levels flooded this lowland and eventually flooded the Back River channel. When the first humans arrived in the area between 11,000 and 8,000 years ago, sea level was lower than at present by 50-100 ft or more. By about 5,000 years ago, sea level rise slowed to near present day rates and salt marshes began to flourish in the Back River basin and the greater Boston Harbor estuary.

The Back River estuary valley is part of the matrix of rivers discharging to Boston Harbor and is part of the larger and more complex Boston Harbor estuary. Estuaries are where fresh and salt waters mix, are among the most productive ecosystems in the world and are critical to the survival of marine species.

The physical nature of the Back River estuary, including salinity, temperature, dissolved oxygen and other characteristics, is discussed in more detail in Chapter 3. Estuaries are important for the numerous resources they provide; Back River resources will be described in more detail in Chapter 4. Since human populations are often concentrated in areas near estuaries, the impacts of human development have altered the estuarine watershed and resources; the changes that have occurred in the Back River system are discussed in Chapters 5 and 6. As we have become more aware of our impacts, we have developed strategies to try to restore estuaries; Chapter 7 discusses current laws, regulations, and guidance that are being used to improve the water and habitat quality of the Back River system.

The Ecology of the Weymouth Back River

CHAPTER 3: Physical Environment

3.1 Introduction

The Weymouth Back River basin is a drowned river valley estuary, also known as a coastal plain estuary. In Massachusetts and adjacent states, most estuaries that are of this type were generally formed by erosion by post glacial rivers.

The watershed encompasses approximately 18.7 sq. mi. and is part of the larger Boston Harbor region. The great majority of the Back River watershed occurs within the Towns of Weymouth (60%) and Hingham (26%) with small areas in Abington, Braintree, Holbrook, Norwell and Rockland (see Table 1-2).

The Back River basin consists mostly of glacial outwash that was cut into a channel by a glacial melt water stream as the great ice sheets retreated about 10,000 years ago. Over the millennia, rising sea levels during the post-glacial warming eventually filled the channel. By about 5,000 years ago, sea level rise slowed to near present day rates and salt marshes began to flourish. The current conditions in the Back River are maintained by watershed inputs of freshwater and the regular interactions with the tides from the greater Boston Harbor estuary.

3.2 Fresh Water Sources to the Back River: Rain, Surface Water and Groundwater

Estuaries are transitional areas where fresh waters from their watersheds meet with tidal waters from the ocean. In the Weymouth Back River estuarine system, watershed fresh waters are added by stream and river inputs, groundwater, and direct precipitation on the water surfaces.

- The two main fresh surface waters feeding into the Back River are:
    1. the Weymouth Great Pond/Mill River system and
    2. the Old Swamp River/Whitman's Pond system.

- Two smaller sources of freshwater in Hingham are:
    1. Fresh River, which drains Bear Swamp
    2. Hockley Run which drains Tucker Swamp

Tidal salt waters are introduced from the larger Boston Harbor system. These inputs are impacted by seasonal and longer term influences, large sporadic events (*e.g.*, hurricanes, nor'easter storms), and year-to-year variations in both tides and precipitation.

3.2.1 Rain

Rainfall in the Weymouth Back River watershed has been documented since 1886 at the Blue Hill Observatory and since 1961 at a NOAA Weather Station in Hingham. Average annual rainfall at Blue Hill from 1886-2015 was 48.78 inches and varied from a low of 26.96 inches in 1965 to a high of 71.0 inches in 1998. (Figure 3-1).

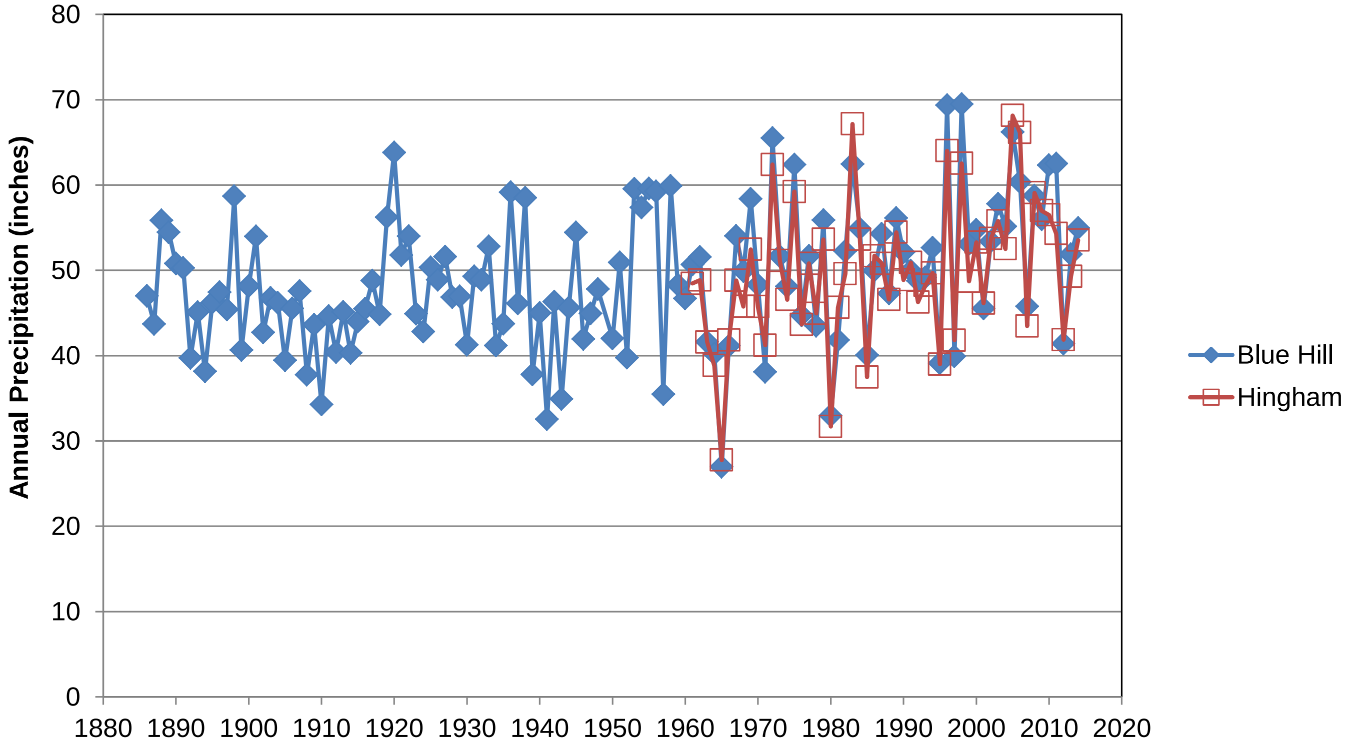


Figure 3-1. Annual rainfall in the Weymouth Back River system from 1886 through 2014.

Since the two stations are only approximately 17 km apart, annual precipitation amounts have generally been similar; average annual precipitation at Blue Hills during the existence of the Hingham station has been 51.1 inches, while the Hingham station has averaged 50.9 inches since 1961 (Figure 3-2).

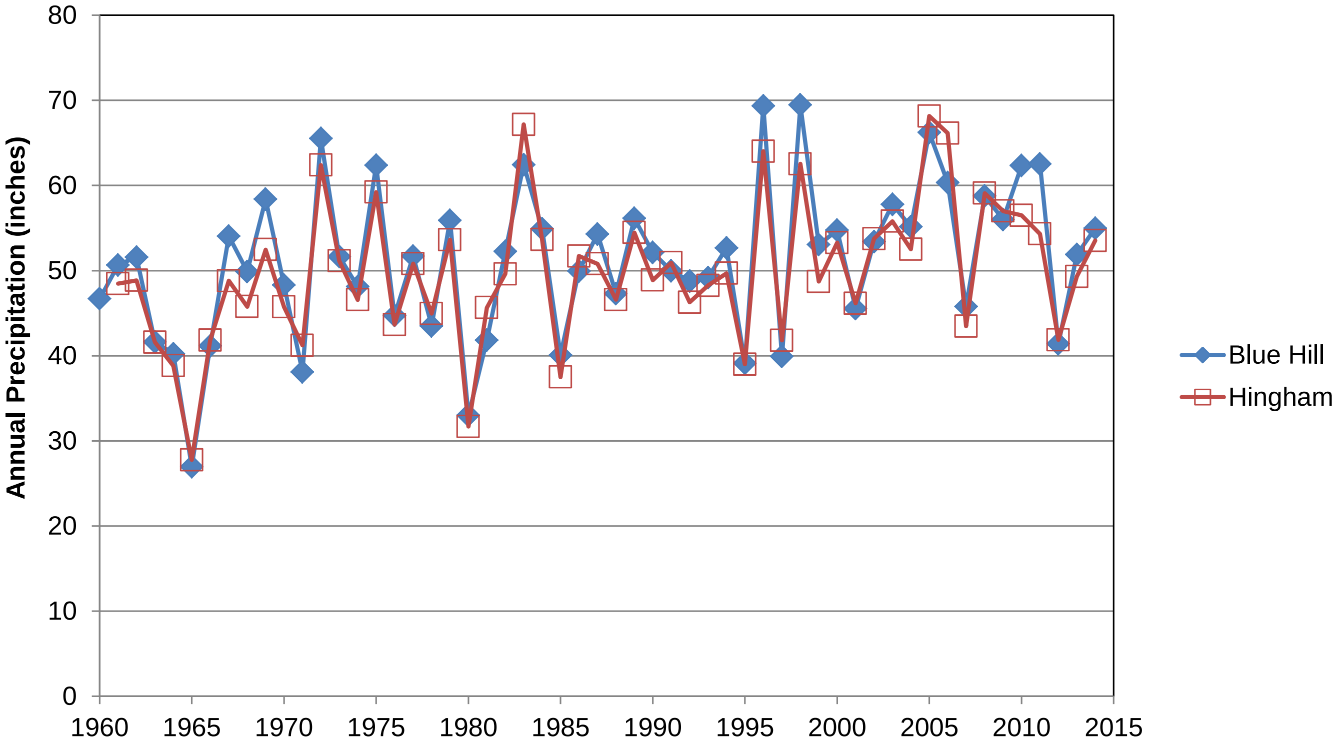


Figure 3-2. Comparison of annual rainfall at Hingham and Blue Hills from 1960 – 2014. Blue line/points indicate precipitation at Blue Hills Observatory in Milton (42°12′43″N 71°6′51″W), while red line/points indicated from NOAA weather station in Hingham (42.23°N 70.89°W). Data from NOAA, National Centers for Environmental Information (Climate Data Online: http://www.ncdc.noaa.gov/cdo-web/).

Annual rainfall has been relatively consistent over the measurement period, although there is a slight increasing trend. The trends at both stations are similar, approximately 0.2 inches increase per year. It is notable that the record at Blue Hill since 1961 (*i.e.*, when the Hingham station began recording) has a greater trend: 0.6 inches per year. It should also be noted that the year-to-year variation can be quite significant, with annual rainfall differences of up to 30 inches between years.

3.2.2 Weymouth Great Pond/Mill River

Weymouth Great Pond flows into the Mill River and is the Town of Weymouth's primary drinking water supply and is located in the southern portion of the Back River watershed in South Weymouth (Figures 3-3, 3-4).

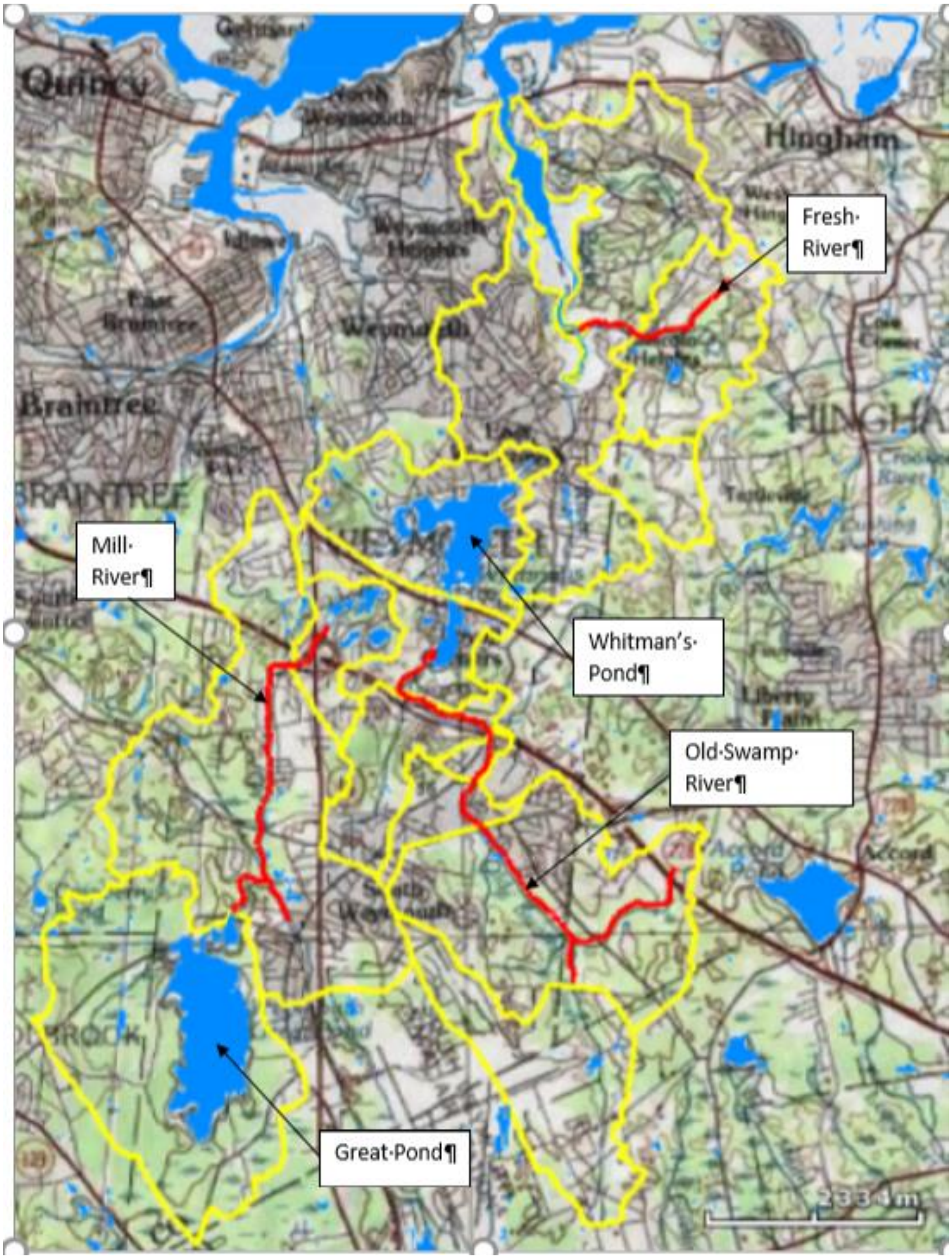


Figure 3-3. Locations of surface freshwater sources for the Weymouth Back River. Yellow outline is the Back River watershed. Blue areas are MassDEP surface waters from 1:12,000 wetlands coverage (MassGIS, 2009). Red river lines are traces from USGS topographic map, which is also the base map.

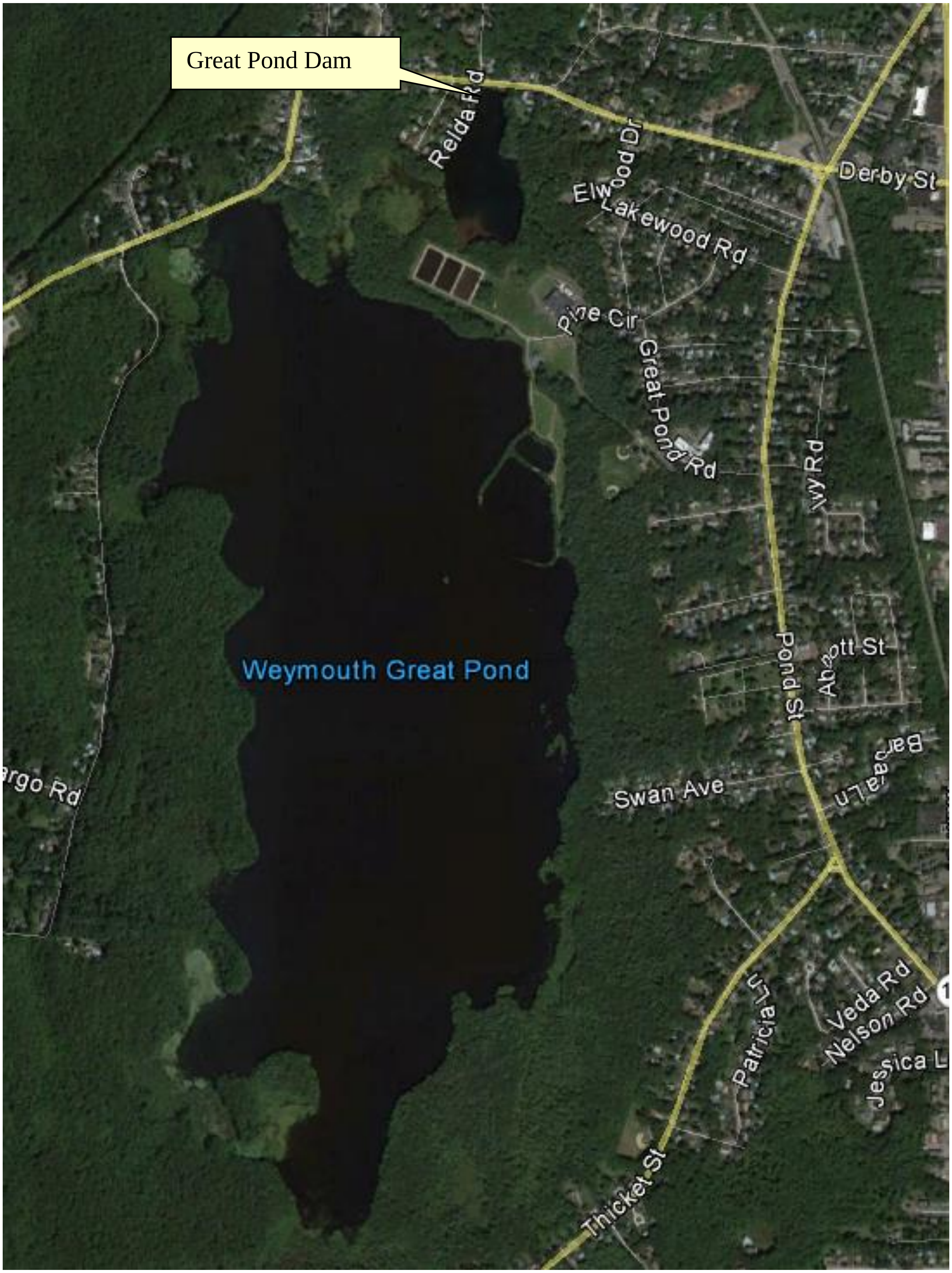


Figure 3-4. Weymouth Great Pond showing the location of the dam and discharge lagoons.

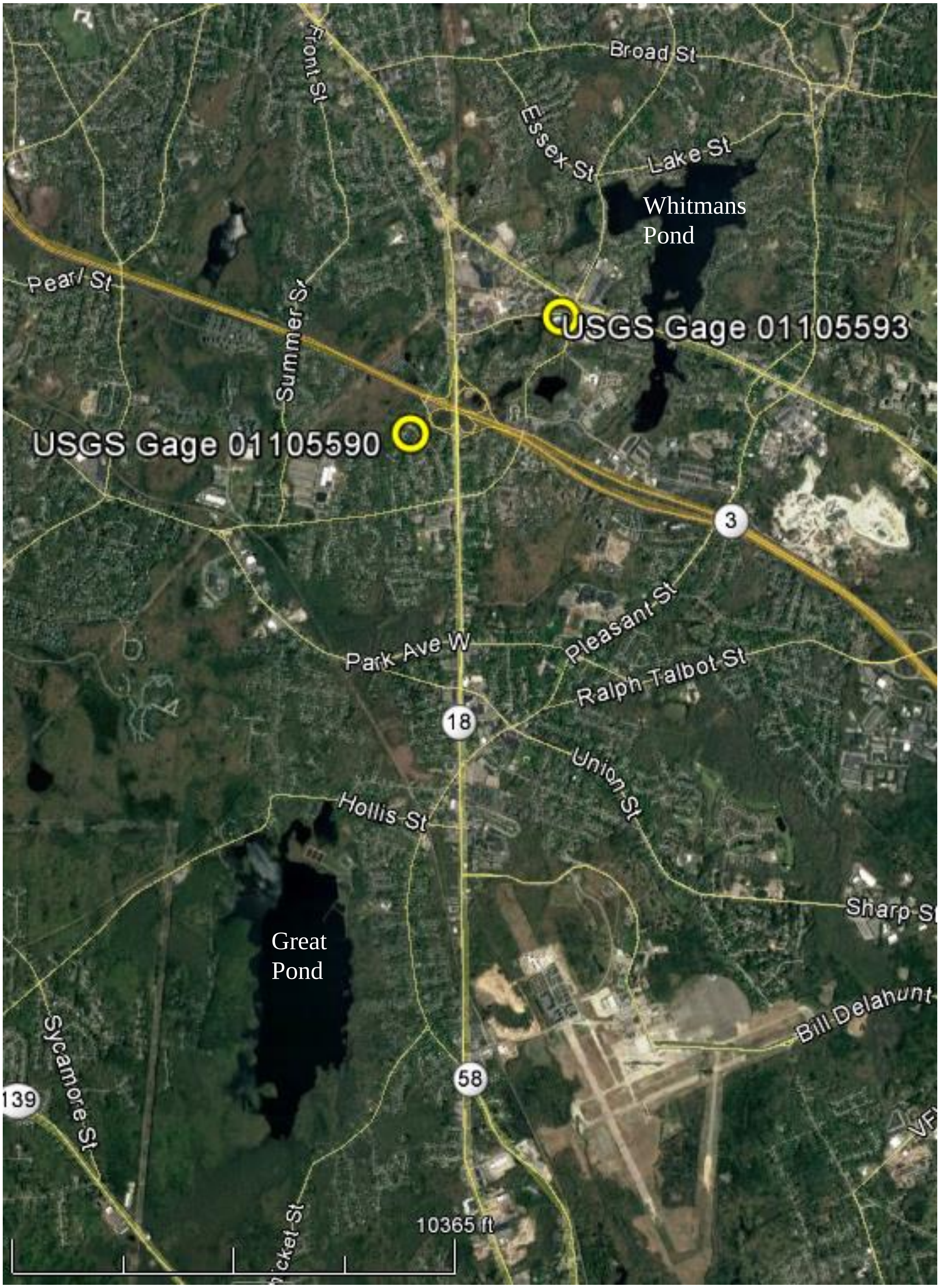


Figure 3-5. Locations of USGS stream gages on Mill River, Weymouth, MA. Great Pond is Weymouth Great Pond shown in Figure 3-4.

Weymouth Great Pond has a surface area of approximately 515 acres and a total volume of 1 billion gallons. Bathymetric data show the deepest basin to be in the northern section of the pond with a depth of 19+ ft. The central basin is 17+ ft. deep (EPG, 2007).

Weymouth Great Pond Dam is a gravity dam located at the north end of the pond at Randolph St. It was built of earthen construction in 1884 with a length of 190 feet. Water flows over the dam from Great Pond to Mill River.

The Weymouth Department of Public Works (DPW) manages these outflows to control pond water level and manage the water supply for the town. As a water supply, the amount of water in the pond is occasionally supplemented with additional sources, so the streamflow out of the pond is often heavily manipulated. As such, available measured flow rates are variable and occur only a few months of the year.

Data from 1961-1967 show flows at the dam occurring 2 to 4 months of the year ranging from 7.6 to 339.9 million gallons (MG) per month (EPG, 2008) or 0.39 to 17.53 cubic feet per second (cfs). These flows are influenced by the release of filter backwash waste water and sedimentation sludge from the Waste Water Treatment Plant into three adjacent lagoons at the north end of the pond.

The lagoons drain clean water into a cove adjacent to the dam (see Figure 3-4). Obtaining a clear understanding of water flows within the Mill River system would require measures of synchronized measurement of flows, water withdrawals, and water levels at a number of points over at least one hydrologic year.

Mill River flows from Great Pond Dam on Randolph St. north to the inlet at Whitman’s Pond near Lake Shore Drive, a distance of 3.5 miles. Limited streamflow readings in Mill River have been collected by a US Geological Survey (USGS) at two locations on the Mill River.

1. One stream station was located at Front and Windsor Streets in South Weymouth (Station No. 01105590, Figure 3-5). Stream discharge measurements were only collected during a few months during 1966 and 1967. Flows varied from 0.060 to 0.840 cfs in August and September (seven measurements), and 9.67 cfs in May (one measurement) (Table 3-1). According to the USGS, the watershed drainage area to this gage is 5.76 square miles.

2. A second stream gage was located at Middle and Winter Streets across from a shopping mall (Station No. 01105593, Figure 3-5). Stream flow data was only collected here during 1967. Flows ranged from 0 to 0.680 cfs in August and September (6 measurements) and 10.4 cfs in May (one measurement) (see Table 3-1). As this gage is slightly downstream from the other, its total watershed drainage area according to the USGS has a slightly large area (6.22 square miles) and includes the watershed to the other gage. It appears that the variable outflow over the dam is due to a mix of factors, including the rate of water withdrawal for water supply and the strong seasonal variations in rainfall and groundwater levels, both of which generally have their lowest levels during the summer. In addition, there are probably significant multi-year impacts where, for example, drought in one year may not allow water levels to sufficiently recover to average conditions by the next summer.

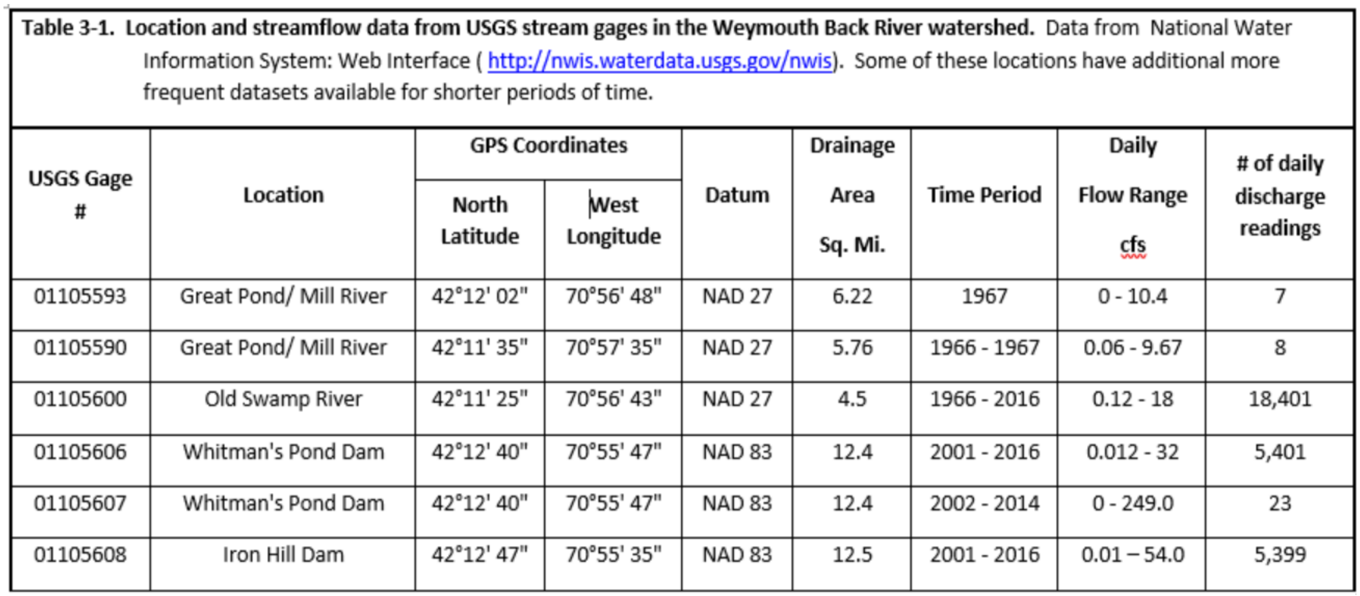


Table 3-1. Location and streamflow data from USGS stream gages in the Weymouth Back River watershed. Data from National Water Information System: Web Interface (http://nwis.waterdata.usgs.gov/nwis). Some of these locations have additional more frequent datasets available for shorter periods of time.

USGS Gage #	Location	GPS Coordinates		Datum	Drainage Area Sq. Mi.	Time Period	Daily Flow Range cfs	# of daily discharge readings
		North Latitude	West Longitude					
01105593	Great Pond/ Mill River	42°12' 02"	70°56' 48"	NAD 27	6.22	1967	0 - 10.4	7
01105590	Great Pond/ Mill River	42°11' 35"	70°57' 35"	NAD 27	5.76	1966 - 1967	0.06 - 9.67	8
01105600	Old Swamp River	42°11' 25"	70°56' 43"	NAD 27	4.5	1966 - 2016	0.12 - 18	18,401
01105606	Whitman's Pond Dam	42°12' 40"	70°55' 47"	NAD 83	12.4	2001 - 2016	0.012 - 32	5,401
01105607	Whitman's Pond Dam	42°12' 40"	70°55' 47"	NAD 83	12.4	2002 - 2014	0 - 249.0	23
01105608	Iron Hill Dam	42°12' 47"	70°55' 35"	NAD 83	12.5	2001 - 2016	0.01 – 54.0	5,399

3.2.3 Old Swamp River/Whitman's Pond

The Old Swamp River flows north from headwaters west of Pleasant Street and north of Liberty Street in Rockland. The river flows into the southern end of Whitman's Pond near Woodside Path, north of Route 3 covering a distance of 4.4 miles.

Stream discharge measurements have been collected at a USGS gaging station (No. 01105600) between the north and south bound portions of Route 3 since May 1966 (Figure 3-6). According to the USGS, the watershed to this gage is 4.5 square miles (mi^2).

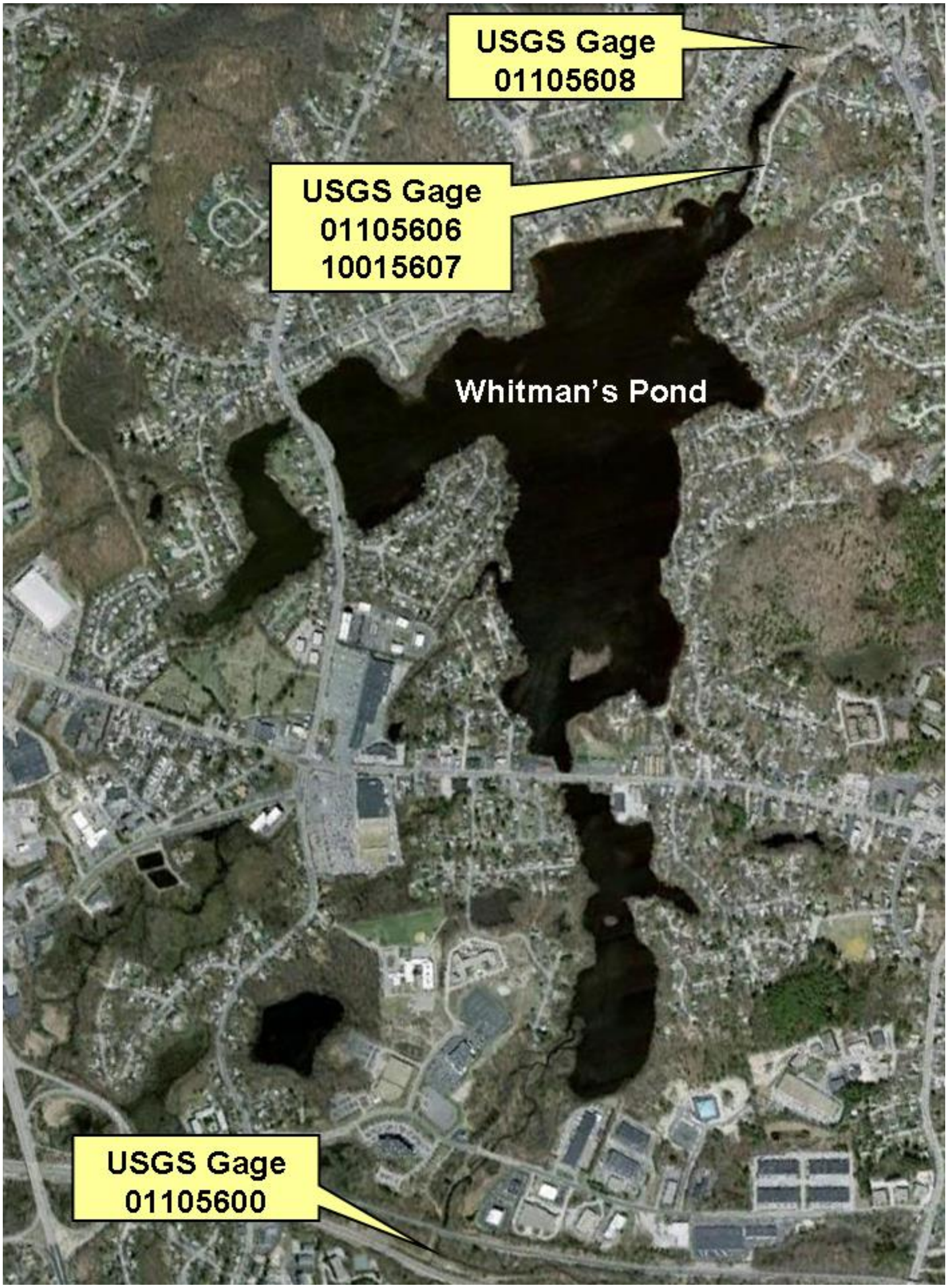
Annual average discharge data flow rates vary from 3.91 to 15.6 cfs between 1967 and 2015 with a daily range of 0.12 to 18 cfs (Figure 3-6, Table 3-1). On a per square mile basis, the average flows are approximately 1.0 to 3.5 cfs/mi^2 (average of 2 cfs/mi^2) which are at the high end of normal stream flows in the more low-lying coastal watersheds of this region (average. = 1.5 cfs/mi^2.

For comparison, average stream flows in the western part of Massachusetts are 2 or more cfs/mi^2 while stream flows on Cape Cod are typically around 1.1 cfs/mi^2 due to the porous nature of the soils and higher recharge rate to the aquifer. The terrain in the Back River region includes hills rising to as much as 100 ft above sea level. The Old Swamp River drops in altitude at a rate of about 16 ft/mile from its headwaters in Rockland to the USGS gage (Zarriello and Socolow, 2003).

Whitman's Pond consists of 3 basins:

1. The main basin being the largest at 128 acres (Figure 3-7). The main basin was the original basin of the pond before it was expanded with the installation of a dam at the northern end of the pond in 1836.
2. The southern basin (South Cove) is 29.9 acres and the
3. The western basin (West Cove) is 20 acres for a total pond area of 177.9 acres (Valutkevich, *et al.*, 1983), although more recent estimates put it at 205-250 acres (*e.g.*, ESS, 2013).

Figure 3-6. Locations of USGS stream gages on the Old Swamp River and Whitman's Pond, Weymouth, MA.



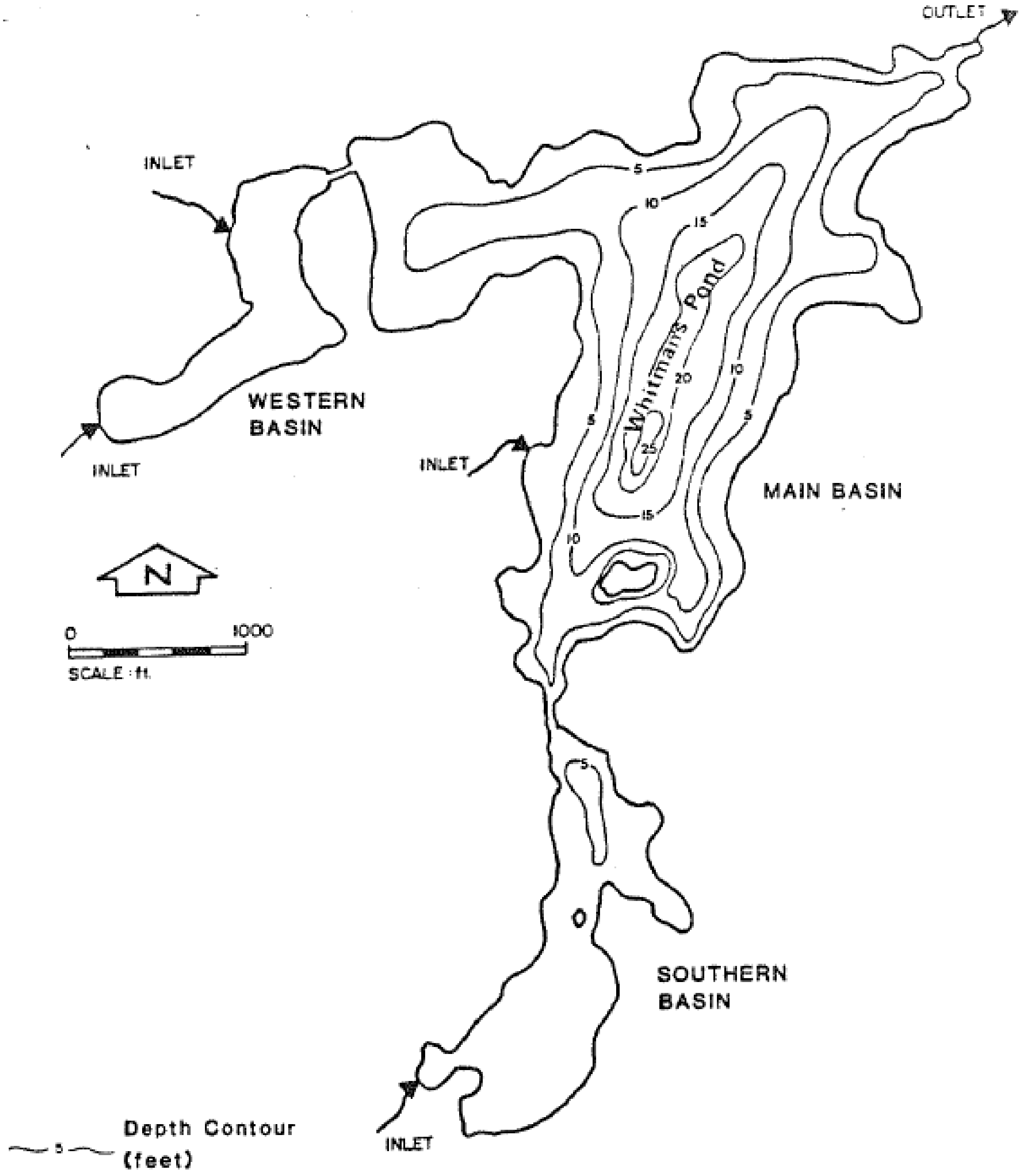


Figure 3-7. Locations of the three main basins comprising Whitman's Pond, Weymouth, MA. From Valutkevich, *et al.*, 1983.

Total volume is 1,537,422 cubic meters or approximately 405,000,000 gallons, most of which is in the main basin of the pond. West Cove is connected to the main basin during high water levels by a single box culvert, but is isolated during lower water levels and drought periods. Flow between the South Cove and Main Basin can be controlled by a sluice gate and stoplogs located at the Washington Street bridge.

Up to 50 stormwater outfalls discharge runoff to the pond (ESS, 2013). Bathymetric data indicate that the deepest point in the main basin is approximately 27 ft while the western basin is about 5 ft deep at the far end near West Lake Drive and Padula Road. South Cove reaches depths of 5-6 ft at several points along the main axis of the basin.

The Weymouth DPW manages a surface water pumping station on South Cove where water is periodically pumped and piped to Weymouth Great Pond for storage and treatment as part of the Town's water supply. Pumping varies by season with greatest volumes during the winter, but more frequent pumping during the summer (ESS, 2013). The greatest average monthly flows between 2004 and 2011 were during November and December (2.7 MGD and 2.8 MGD, respectively) (ESS,2013).

Temperature and dissolved oxygen profiles taken in the main basin of the pond in 1980-1981 (the most extensive dataset) show strong summer stratification/layering with a well-developed thermocline and oxycline from late June to early September (Figure 3-8).

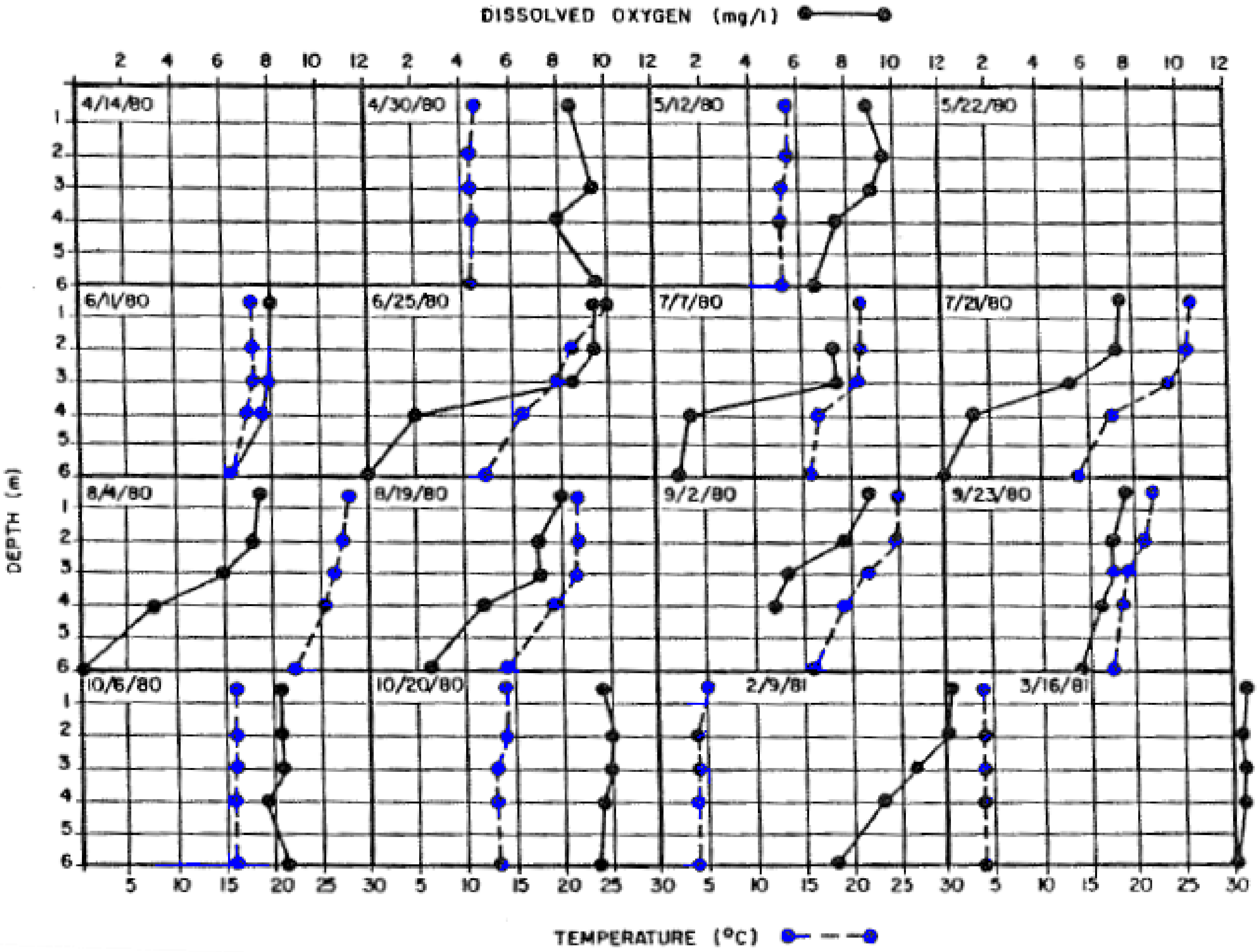


Figure 3-8. Temperature and dissolved oxygen profiles in the main basin of Whitman's Pond, April 1980 to March 1981 (modified from Figure 9 in Valutkevich, *et al.*, 1983). Note the strong temperature stratification during summer months.

Destratification (or mixing of the layers) occurred in late September with a well-mixed water column October through April. During summer stratification, recorded dissolved oxygen concentrations in the cooler, hypolimnion layer (typically deeper than 3 m) were hypoxic with concentrations regularly below the MassDEP surface water minimum of 6 mg/L (310 CMR 4).

In early February 1981 there was a distinct oxycline with concentrations dropping below 2 m, which is likely due to noted ice cover. Ice cover isolated the pond surface and prevented contact of surface waters with atmospheric oxygen to address depletion of dissolved oxygen in the water column due to sediment oxygen demand. Ice can also reduce light penetration, so any photosynthesis (which produces oxygen) would also be reduced in the water column. More recent August 2012 dissolved oxygen profile indicated anoxia in the main basin below 4.5 m and diminished concentrations at the surface (<80% atmospheric saturation) in all basins (ESS, 2013).

Surface water inputs to Whitman's Pond include:

a) the Old Swamp River inlet at South Cove,
b) from Mill River inlet into the main basin and
c) an unnamed tributary that flows into the western end of West Cove (under Greenvale Avenue) (Figure 3-9).

Surface water leaves the main basin at Whitman's Pond Dam at the north end of the main basin and waters flow from here to a second dam at Iron Hill. Here, flow is directed through one of three pathways:

1. a flood control structure which pipes water under Jackson Square where it rejoins Herring Brook below the Jackson Square fish ladder;
2. over the fish ladder at the Iron Hill Dam; and
3. some flow, depending on the volume, may be discharged over a rocky outcrop and into a stream channel that rejoins the fish ladder flow.

Weymouth Herring Wardens work with the Weymouth DPW to manage flow through these outlets to promote fish passage through five fish ladders between Back River and Whitman's Pond during the herring migration season.

Annual average discharges at the north end of Whitman's Pond at the Whitman's Pond Dam varied from 11.5 to 29.4 cfs between 2003 and 2016 (USGS Gage No. 01105606), while discharges at the base of the fish ladder at Iron Hill Dam were only 1/3 that level and varying from 3.13 to 9.75 cfs between 2003 and 2016 (USGS Gage 01105608) (Figure 3-6, Table 3-1).

Annual freshwater discharges in at all the USGS stream gauges are directly correlated to rainfall (Figure 3-10 and Figure 3-11). Months with the highest rainfall, late winter/early spring and late fall, also have the highest average discharges. Summer months are driest with smallest stream discharges. Seasonal differences in groundwater recharge (see below) and pond surface evapotranspiration, in addition to rainfall, have a significant influence on the strong seasonal pattern in stream discharge.

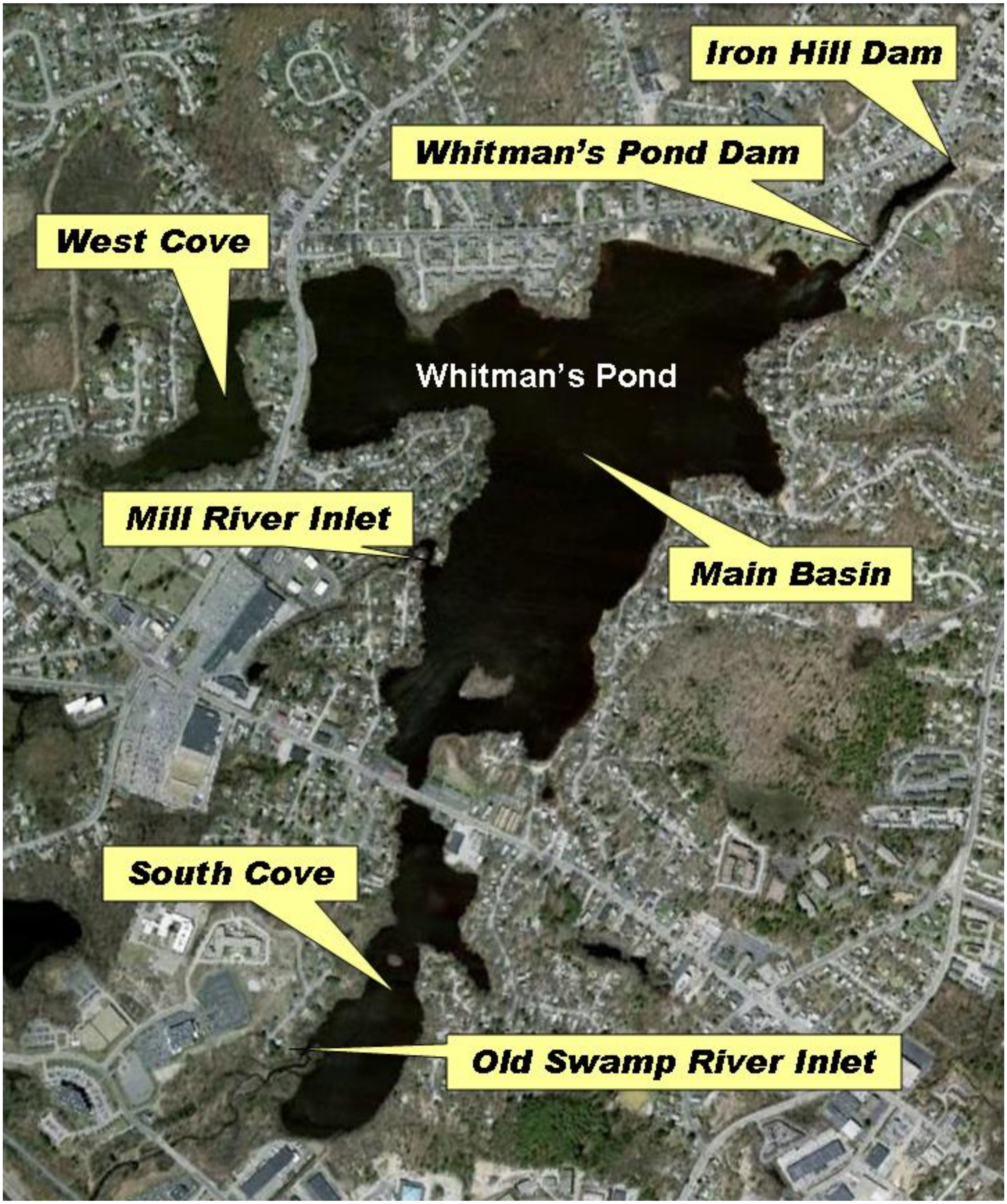


Figure 3-9. Surface water connections into and out of Whitman's Pond, Weymouth, MA.

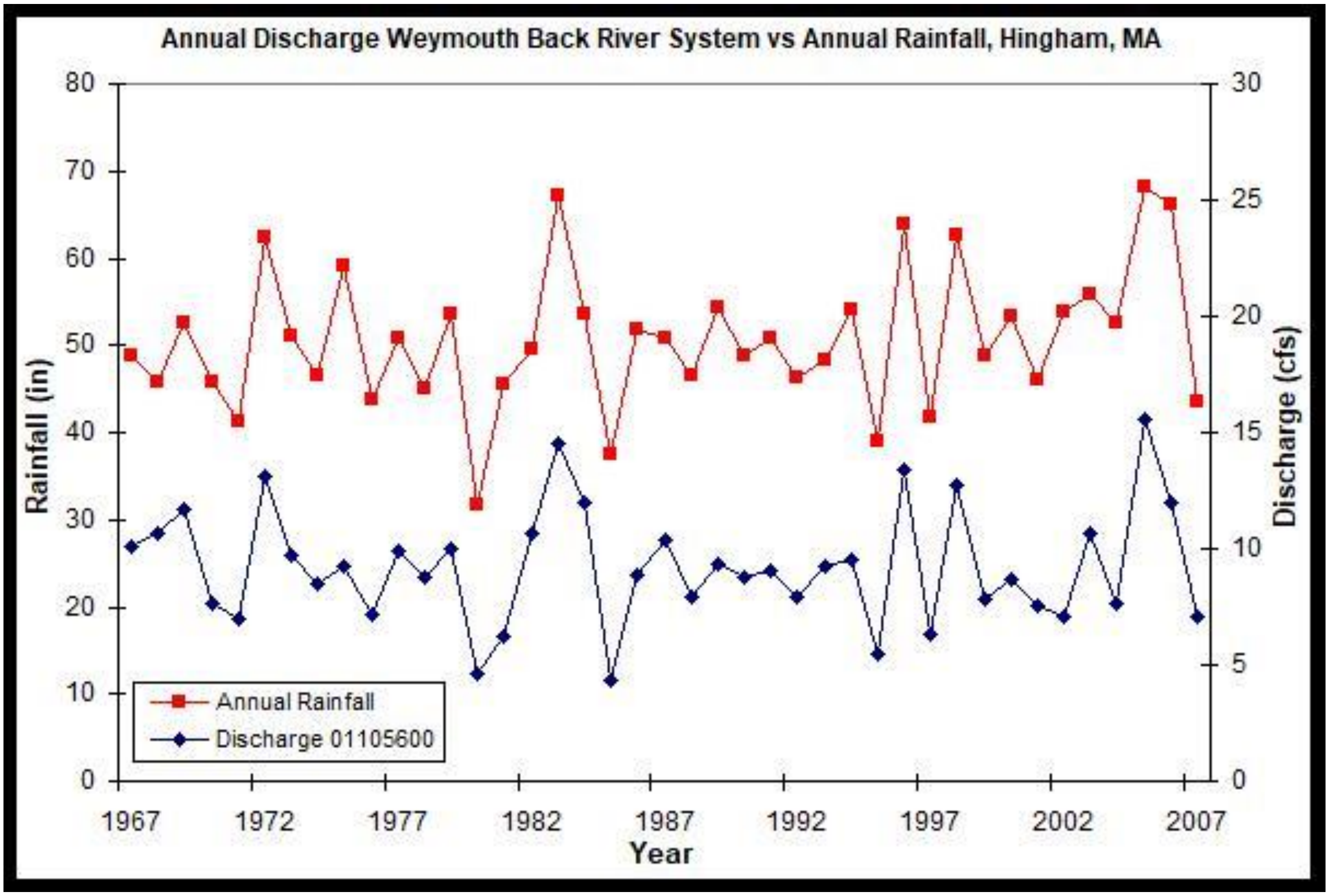


Figure 3-10. Relationship between annual rainfall in the Weymouth Back River watershed and annual water discharge rates in the Old Swamp River between 1967 and 2008. Note the strong positive relationship.

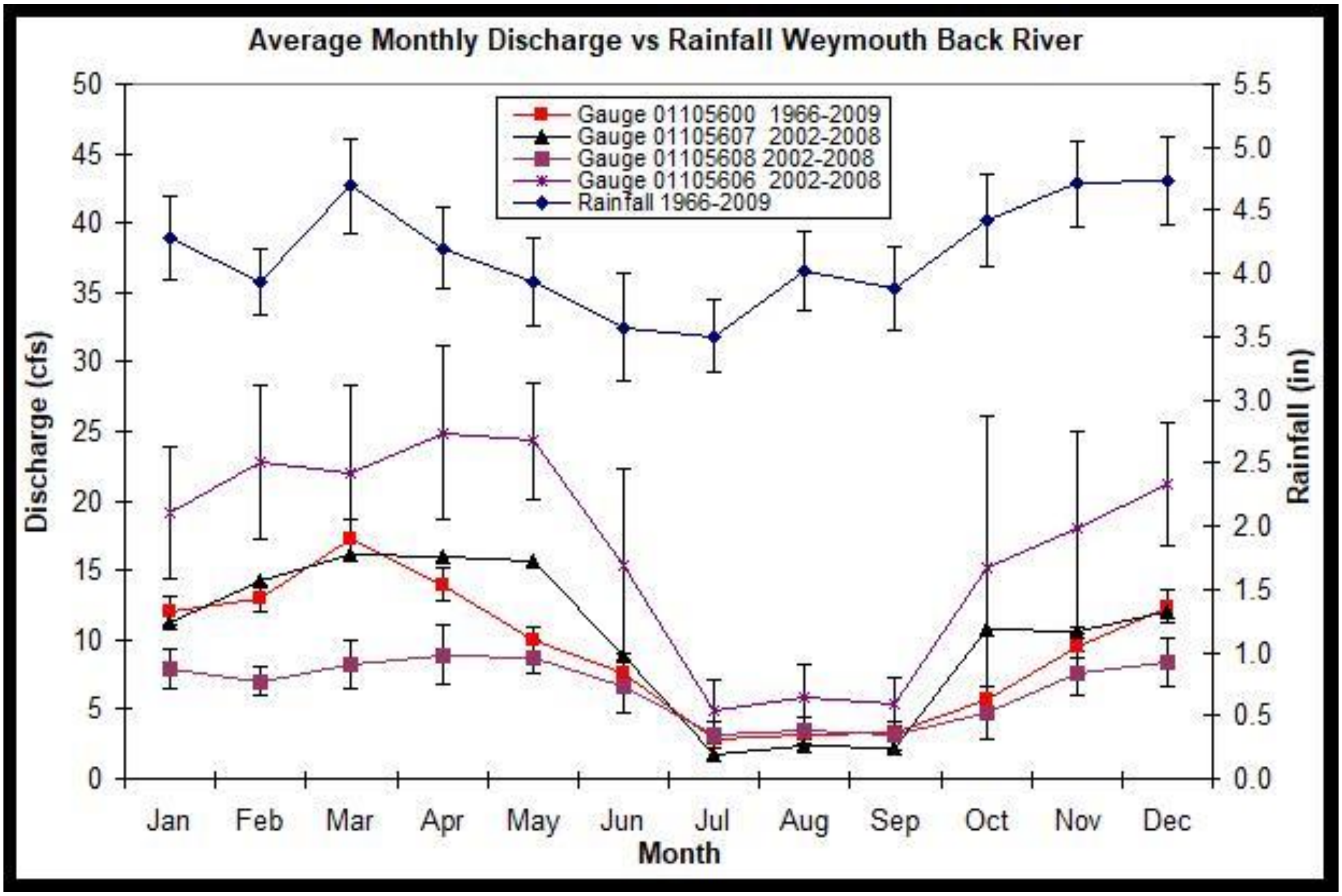


Figure 3-11. Comparison of average monthly rainfall with average monthly discharges at USGS gages on the Old Swamp River and Whitman's Pond. Values are means ±1 standard deviation. Note the delay from the decline in rainfall (March-June) to the decline in discharge at each site (May-July). All gauges tend to follow a similar pattern with lowest discharges in each stream in July-September

3.2.4 Groundwater

When the glaciers that covered the Boston Harbor region began to retreat about 10,000 years ago, they left behind large deposits of glacial till and distinct layers of sand, gravel, silt and clay, called stratified drift, on top of the underlying bedrock. Both till and stratified drift provide storage areas for groundwater (aquifers) within upland areas of watersheds.

The Back River watershed includes a groundwater aquifer that is primarily stratified sand and gravel. These aquifers can be as much as 100-150 ft deep and vary in total depth depending on the amount of recharge from precipitation, amount of water withdrawal, and vertical extent of the porous materials over the basement bedrock.

These aquifers cover about half of the area of the Neponset and Weymouth river basins. It is estimated that the aquifer holds as much as 90 billion gallons within these stratified deposits with another 15 billion gallons within till deposits. Recharge to these aquifers averages about 80 million gallons per day (Simcox, 1992; Brackley, *et al.*, 1973).

Recharge to the aquifer fluctuates over an annual cycle is shown in Figure 3-12. The water table shows characteristic increases during the spring when precipitation and recharge is greatest, followed by the gradual lowering of water levels during the drier summer and early fall. These fluctuations are larger in till than in the stratified drift, due to the greater storage capacity in stratified drift than till and the higher recharge rate.

Natural groundwater flows reach our bays and estuaries through direct discharge through seepage areas at the salt water/freshwater boundary (generally between the high tide and low tide lines) and through discharge into streams/rivers that then discharge into the bays and estuaries.

The differences between the amount of freshwater arriving in the estuary via surface waters and direct groundwater discharge are dependent on the configuration of the watershed (*e.g.*, elevations, geologic materials, recharge).

- Direct groundwater discharge rates from the watersheds in the region to Boston Harbor have been estimated at approximately 43,200 cubic meters per day (cm/d) to each of the north and south harbors (Menzie, *et al.*, 1991).
- In contrast, measurements at Wollaston Beach, only estimated groundwater discharge of 1,324 to 2,177 cm/d to Quincy Bay (equivalent to 7 to 12% of the gaged freshwater input) (Poppe and Moffett, 1993).

The chemical composition of groundwater reflects those of the aquifer soils in the region. Water is generally soft to moderately hard and slightly acidic. A significant amount of the groundwater is high in manganese and iron, exceeding suggested guidelines recommendations for public water supplies. Chloride concentrations have also increased over the years since 1960 likely due to increased use of road salt and additions from other sources such as septic effluent (Brackley, *et al.*, 1973).

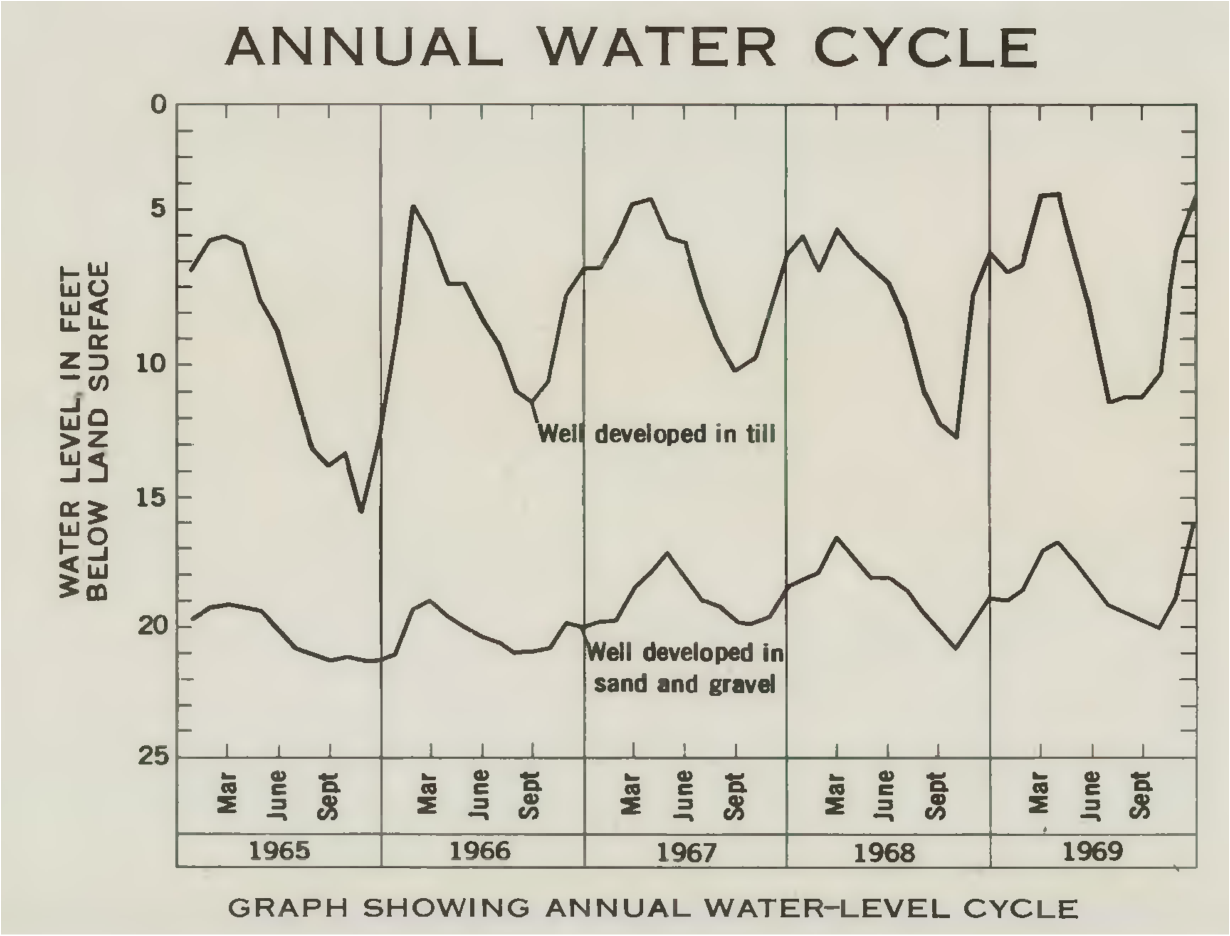


Figure 3-12. Annual water table fluctuations in the Neponset and Weymouth river basins. (modified from Brackley, *et al.*, 1973). Note that well levels were lowest when stream flow is lowest annually (as was also noted in the stream discharges noted in Figure 3-11).

The Town of Weymouth operates five public water supply wells that collect groundwater within the Back River watershed:

1. Circuit Avenue Well (01G),
2. the Main Street Well (02G),
3. the Libbey Park Well (03G),
4. Winter Street Well #1 (04G),
5. and Winter Street Well #2 (05G) (MassDEP, 2003; Town of Weymouth, 2014).

These wells have a combined safe yield of 2.64 million gallons per day and supply 18% of the town’s drinking water. These are the only municipal water supply wells within the watershed (Figure 3-13). Since these wells withdrawal water from the same watershed that supplies water to Old Swamp River and Whitman’s Pond, there is an on-going management issue about potential impacts on streamflow, particularly during dry summer periods. Water withdrawn from these wells are regularly tested for USEPA drinking contaminants and all concentrations are less than federal and state maximum contaminant levels (Town of Weymouth, 2014). All groundwater is treated at the Arthur J. Bilodeau Water Treatment Plant (AJBWTP) prior to distribution.

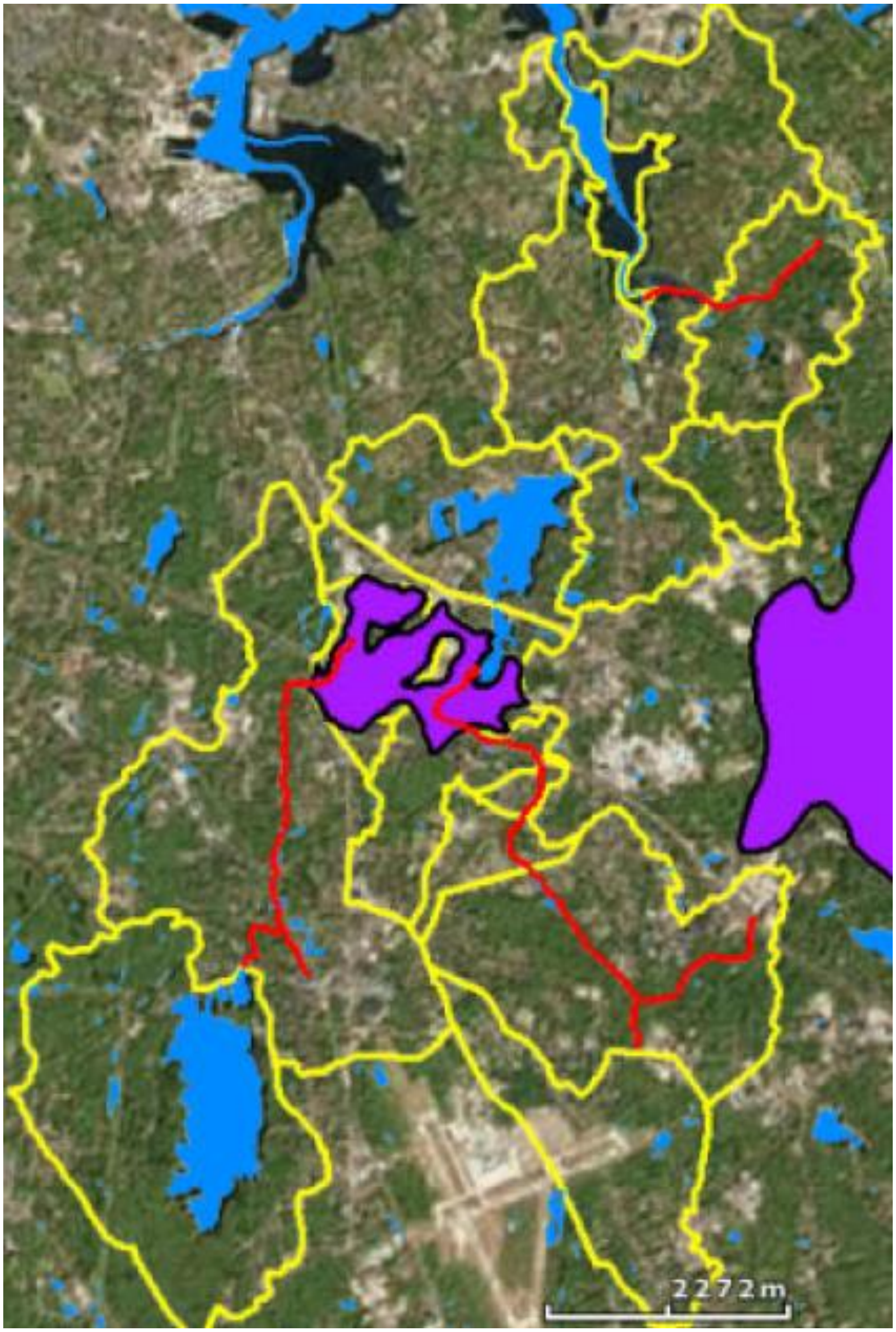


Figure 3-13. Wellhead protection areas/Zone IIs within the Weymouth Back River watershed. Areas shaded in purple indicate contributing areas to municipal drinking water supply wells (MassDEP, 2013). The Town of Weymouth operates the supply wells within the Back River watershed (outlined in yellow); the supply well contributing areas are completely within the Back River watershed.

3.3 Weymouth Back River Estuary

Most of the surface waters in the Weymouth Back River watershed are fresh, from the head waters of the Old Swamp River and from Weymouth Great Pond to the fish ladder at the base of Jackson Square. The estuarine portion of the system begins in the upper portion of the Weymouth Back River in the vicinity of the MBTA, Old Bay Colony railroad tracks.

The estuary is classified as a coastal plain or drowned river valley estuary very typical of estuaries along the U.S. Atlantic Ocean coast. It is a vertically mixed estuary which means that fresh water from Whitman's Pond and salt water from Hingham Bay mix throughout the water column from surface to bottom within the Back River waters rather than forming a fresh surface layer and a saline bottom layer.

3.3.1 Tides

Hingham Bay exchanges tidal water with the Weymouth Back River Estuary twice a day through a single tidal inlet. Boston Harbor tides are asymmetrical and can range as much as 14 feet from ebb slack to flood slack tide, but generally have an average range of 9 to10 feet (Figure 3-14).

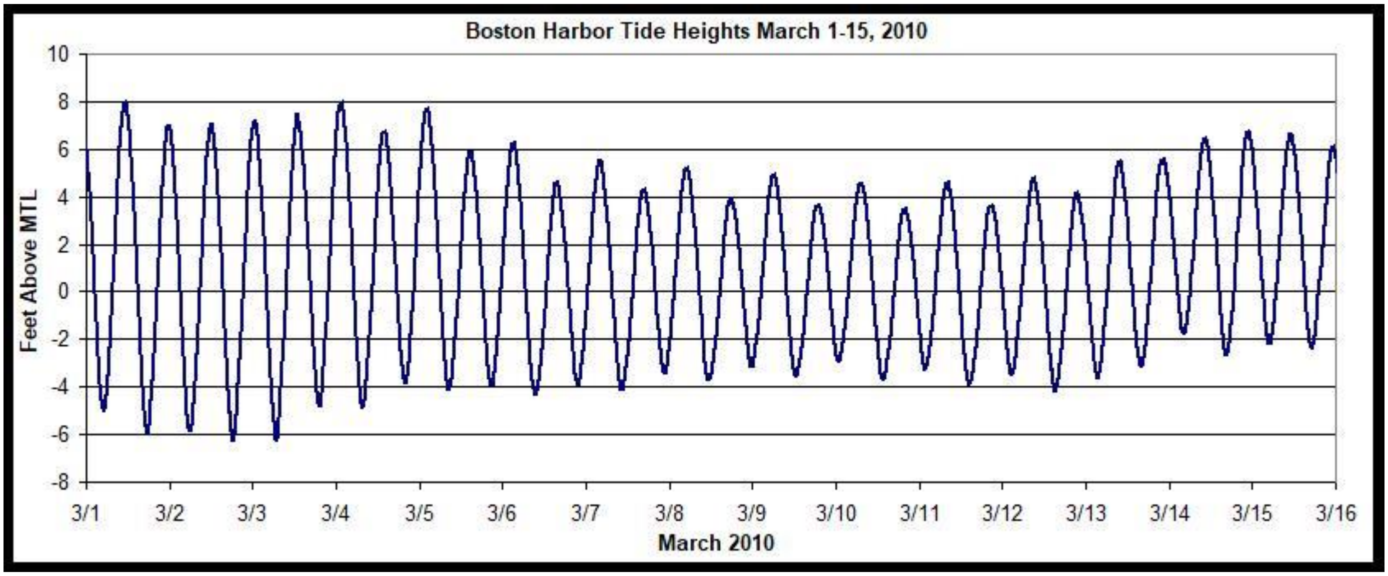


Figure 3-14. Tidal amplitudes in Boston Harbor March 1-15, 2010. Tidal heights are relative Mean Tide Level (MTL) (data from NOAA).

In the lower Back River (Route 3A Bridge), the tidal range is generally lower than in the Harbor, with an average tidal range of about 8 to 9 feet. The large tidal range creates a large intertidal zone in the Back River estuary. The estimated intertidal zone for Hingham Bay is 2,020 acres or about 24.4% of the total area (Iwanowicz, *et al.*, 1973).

As much as 50% of the Back River estuary is intertidal, most of it in the upper reaches of the river south of the Route 3A bridge (Myers, 1997; Iwanowicz, *et al.*, 1973). These areas support important estuarine resources providing habitat and food for fish and birds as part of this estuary's functioning as nursery grounds for coastal waters.

3.3.2 Wind Patterns

Wind direction and speed (1996-2010) in the Boston Harbor region show a distinct seasonal pattern. During the winter months (December-March), prevailing winds are out of the west-northwest with the highest recorded speeds in excess of 17 to 22 knots (about 20 to 25 mph). In the spring and summer (May to October), winds are predominantly from the west-southwest with maximum wind speeds at 11 to 21 knots (about 13 to 20 mph) (Figure 3-15).

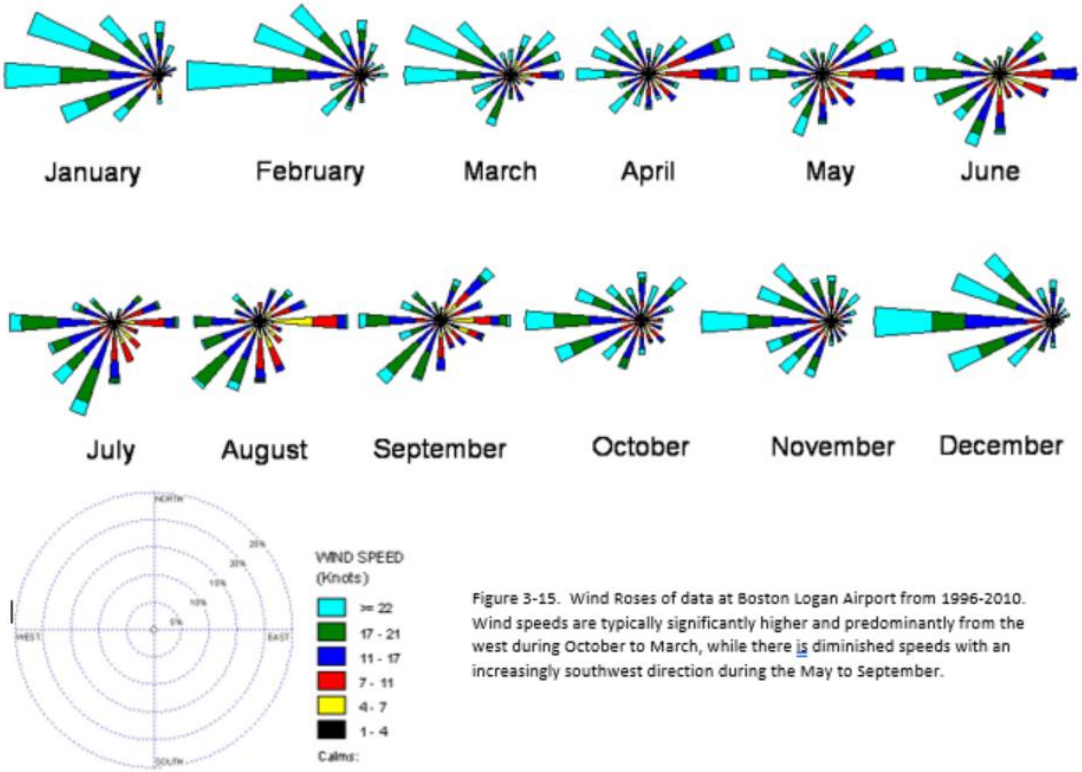


Figure 3-15. Wind Roses of data at Boston Logan Airport from 1996-2010. Wind speeds are typically significantly higher and predominantly from the west during October to March, while there is diminished speeds with an increasingly southwest direction during the May to September.

Figure 3-15. Wind Roses of data at Boston Logan Airport from 1996 through 2010.

3.3.3 Currents

Currents in Boston Harbor are largely driven by tides. Boston Harbor has two main channels which connect it with adjacent Massachusetts Bay and which produce the strongest current patterns for both flooding and ebbing tides (Figure 3-16).

1. The northern channel, President Roads, is bounded by Deer Island and by Long, Gallops and Lovell Islands.
2. The southern channel, Nantasket Roads, is bounded by Hull and Peddocks Islands and by George's Island (Figures 3-17 and 3-18).

Each of these two channels is about 15 meters or 49 feet deep, The average depth of Boston Harbor is about 4.9 meters (16 ft). Depth and width of navigation channels are regularly maintained through dredging.

Freshwater inputs from all rivers to Boston Harbor are about 20 cubic meters per second (about 700 cfs) but these flows are not strong enough to overcome the influence of tidally-driven currents.

- Flows from President Roads are toward the north harbor
- Flows through Nantasket Roads are toward the south harbor including Quincy and Hingham Bays and Weymouth Back River.

It appears that little, if any, water from the north section of the Harbor (north of Long Island), including the Charles and Mystic Rivers, flows into Quincy and Hingham Bays. These bays appear to receive waters transported through the south channel almost entirely.

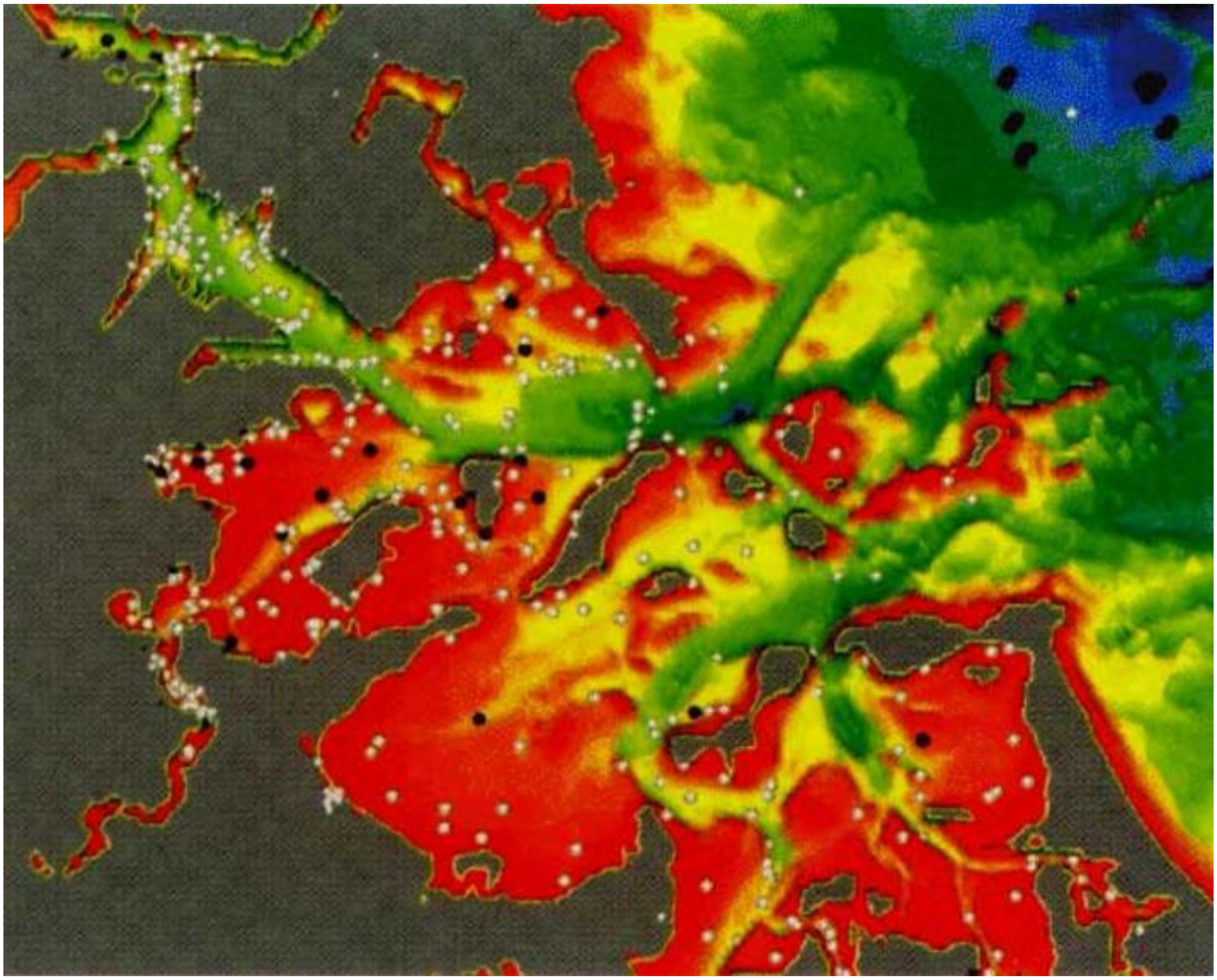


Figure 3-16. Bathymetry in Boston Harbor. Shaded relief map of NOAA bathymetry. Colors denote mean low-water depths: blue, >40 ft; green, 30-40 ft; yellow, 20-30 ft; orange, 10-20 ft; red, <10 ft. Black and white points are sample locations from the USGS-Woods Hole Contaminated-Sediments Database (map modified from http://pubs.usgs.gov/fs/boston-harbor/index.html).

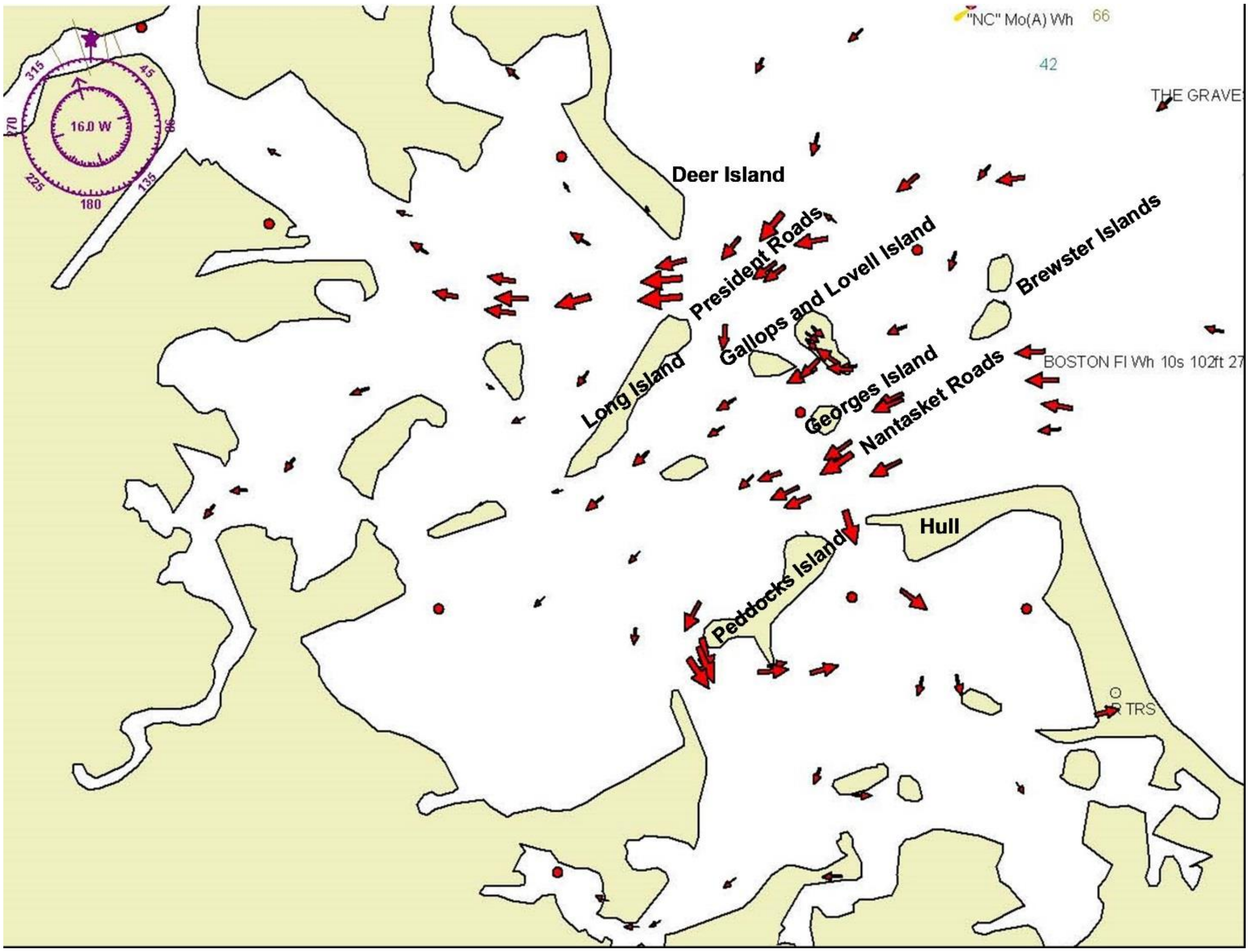


Figure 3-17. Tidal currents in Boston Harbor at mid-flood. Relative size of the vector arrow indicates current speed (from NOAA). Highest velocities are found within the inlet area, as usual in most estuaries, with relatively low velocities in the upper two-thirds of the estuary. These mid-tides support the highest velocities of the tidal cycle for this basin.

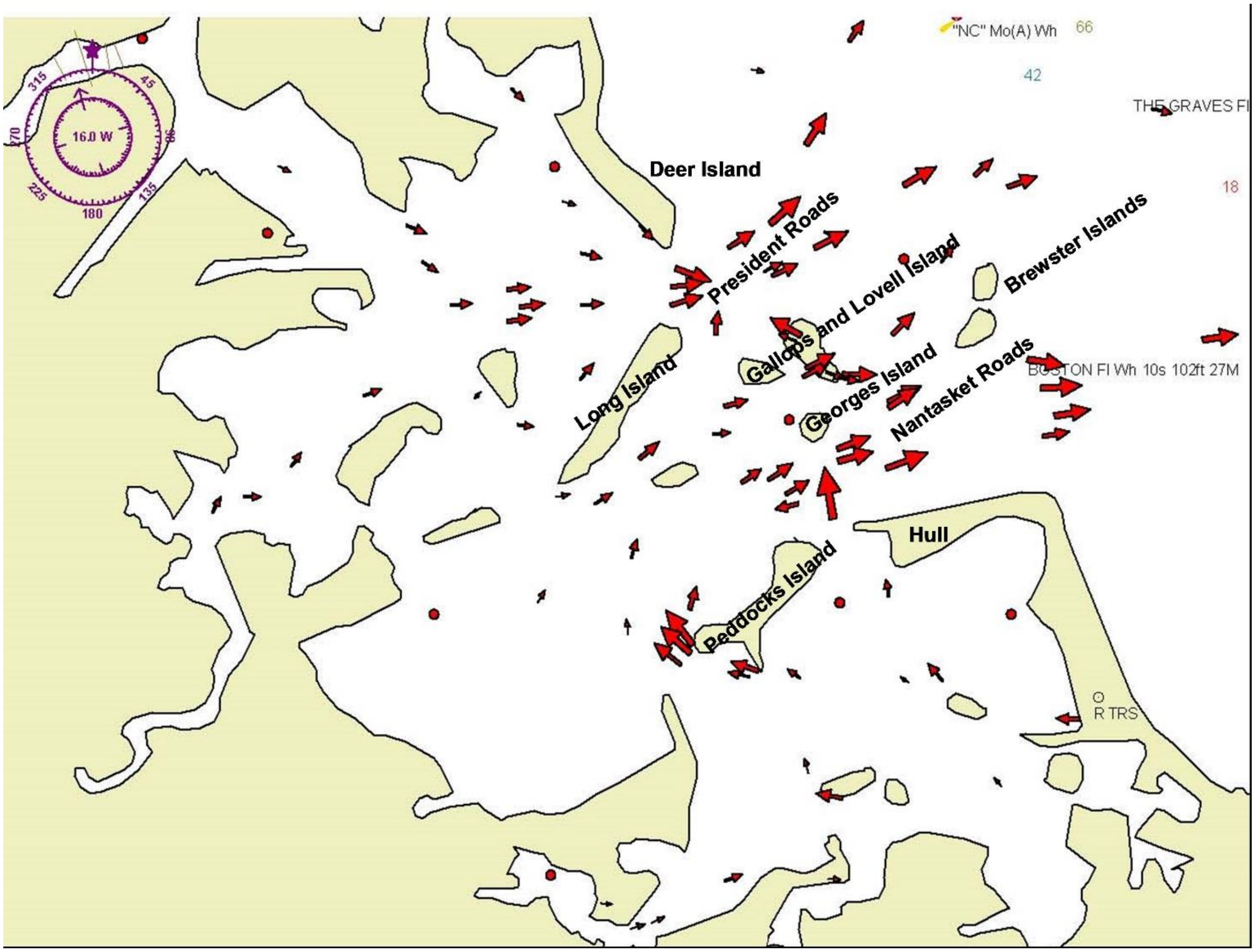


Figure 3-18. Tidal currents in Boston Harbor at mid-ebb. Relative size of the vector arrow indicates current speed (from NOAA). Highest velocities are found within the inlet area, as usual in most estuaries, with relatively low velocities in the upper two-thirds of the estuary. These mid-tides support the highest velocities of the tidal cycle for this basin.

Tidal currents are greatest at about mid-tide (middle of tidal cycle and range) with Boston Harbor currents averaging about 0.5-0.9 mph. In President Roads, currents can reach 1.6 knots or 1.8 mph. With this pattern of tidal currents, it is estimated that harbor water in the outer harbor (portions in closest proximity to Massachusetts Bay) is completely replaced with Massachusetts Bay water about every 10 days, while exchange of water in the inner harbor area, including the area around the mouths of the harbor rivers would take considerably longer.

Wind-driven currents are of secondary importance to tidally-driven currents within Boston Harbor.

- They are typically 5-10 centimeters per second, equivalent to about 0.1-0.2 mph, considerably less than tidal currents.
- Current speeds can increase significantly during storm events with strong winds (Signell and Butman, 1992). However, for the most part tidal currents dominate the Weymouth Back River estuary.

3.3.4 Temperature

Temperature and salinity measurements have been collected at a number of stations in the Back River and Hingham Bay by the Massachusetts Division of Marine Fisheries (MassDMF) and the Massachusetts Water Resources Authority (MWRA), which also collected dissolved oxygen measurements (Figure 3-19, Table 3-2).

- Average monthly water temperatures from surface readings between 1990 and 2008 show a distinct seasonal pattern at all sampling stations along the length of the estuary (Figure 3-20).
- Highest average monthly temperatures were recorded in July and August, with an overall range at all stations of 59 to 71˚F.
- The lowest average monthly values occurred in January and February, ranging from 32 to 46˚F. Temperature patterns are similar at all stations including an off shore station in Hingham Bay (MWRA Station 124, Figure 3-19).

Temperature differences between surface and near-bottom waters in the Back River estuary are generally small indicating the absence of strong stratification. Figure 3-21 shows average monthly temperatures at depths of 0.2 meters and 6 meters near the Route 3A bridge crossing (MWRA Station 86) based on readings collected between 1990 and 2008.

Surface temperatures tend to be slightly warmer than deeper temperatures with the greatest differences in the summer months. Some of the averages in Figure 3-21 are skewed by limited data; all 6 meter means are based on 1 to 3 readings while surface means are based on 10 or more readings.

Table 3-2. DMF and MWRA Sampling Station Descriptions. Stations are in order from upper to lower regions of Weymouth Back River.

STATION NO.	LOCATION DESCRIPTION	NORTH LATITUDE	WEST LONGITUDE
DMF 39	SMELT CREEK AT WHARF STREET	na	na
DMF 75	OPPOSITE ACCESS RD-HINGHAM	na	na
DMF 41	WHALE ISLAND – SOUTHEAST	na	na
DMF 74	BEAL COVE-SOUTH	na	na
DMF 37	BEAL COVE	na	na
DMF 69	POINT BETWEEN BARE & BEAL COVES	na	na
DMF 42	COVE OPPOSITE BARE COVE DOCK	na	na
DMF 36	BARE COVE - BACK RIVER	na	na
DMF 76	NARROWS	na	na
DMF 43	BACK RIVER - EASTSIDE - AT RTE 3A BRIDGE	na	na
DMF 44	MDC BARN	na	na
MWRA 86	WEYMOUTH BACK R DWNSTRM RT 3A BR	42.248333˚	70.931667˚
DMF 35	BACK RIVER, WEST SIDE STODDERS NECK	na	na
DMF 33	COVE EAST SIDE STODDERS NECK	na	na
DMF 45	PUBLIC ACCESS RAMP	na	na
DMF 34	STODDERS NECK – NORTH	na	na
DMF 46	WEBB STATE PARK	na	na
DMF 30	FOOT OF WOMPATUCK ROAD	na	na
DMF 29	BEACH LANE	na	na
MWRA 124	CROW POINT FLATS - HINGHAM BAY	42.272667˚	70.897667˚

This can lead to odd results; for example, the deep 6 m September mean should be lower than the surface mean, but the limited deep readings result in contrary results (deep mean = 69.6˚F, surface mean = 64.2˚F). The usual pattern of slightly warmer surface waters is typical of vertically well-mixed estuaries and is similar to the vertical temperature profile in Hingham Bay (MWRA Station 124).

As shown in Figure 3-22, average maximum summer temperatures are slightly lower in Hingham Bay (58.2 to 65.4˚F) than in Back River (64.6 to 69.6˚F) due to water depth. These waters also show the greatest differences between surface and bottom readings during summer months, but these are also not significant enough to prevent mixing of the water column. Overall, readings at both stations show there are no significant differences between surface and bottom temperatures.

Daily tidal flows into and out of Hingham Bay and Weymouth Back River maintain vertical mixing and similar temperatures throughout the water column. Well-mixed water columns generally do not have significant or prolonged oxygen depletion (hypoxia) because high sediment oxygen demand can be somewhat countered by replenishment from atmospheric mixing into the water column and addition of well-oxygenated water on the next incoming tide.

Well-oxygenated water provides better habitat for bottom-dwelling animals like clams and other relatively non-mobile invertebrates, and, in turn, provides a stable food supply for those organisms that feed upon them (fish, birds).

Figure 3-19. Massachusetts Division of Marine Fisheries and Massachusetts Water Resources Authority sampling stations in the Weymouth Back River estuary. Readings have been collected for temperature and salinity; MWRA also collected dissolved oxygen readings.

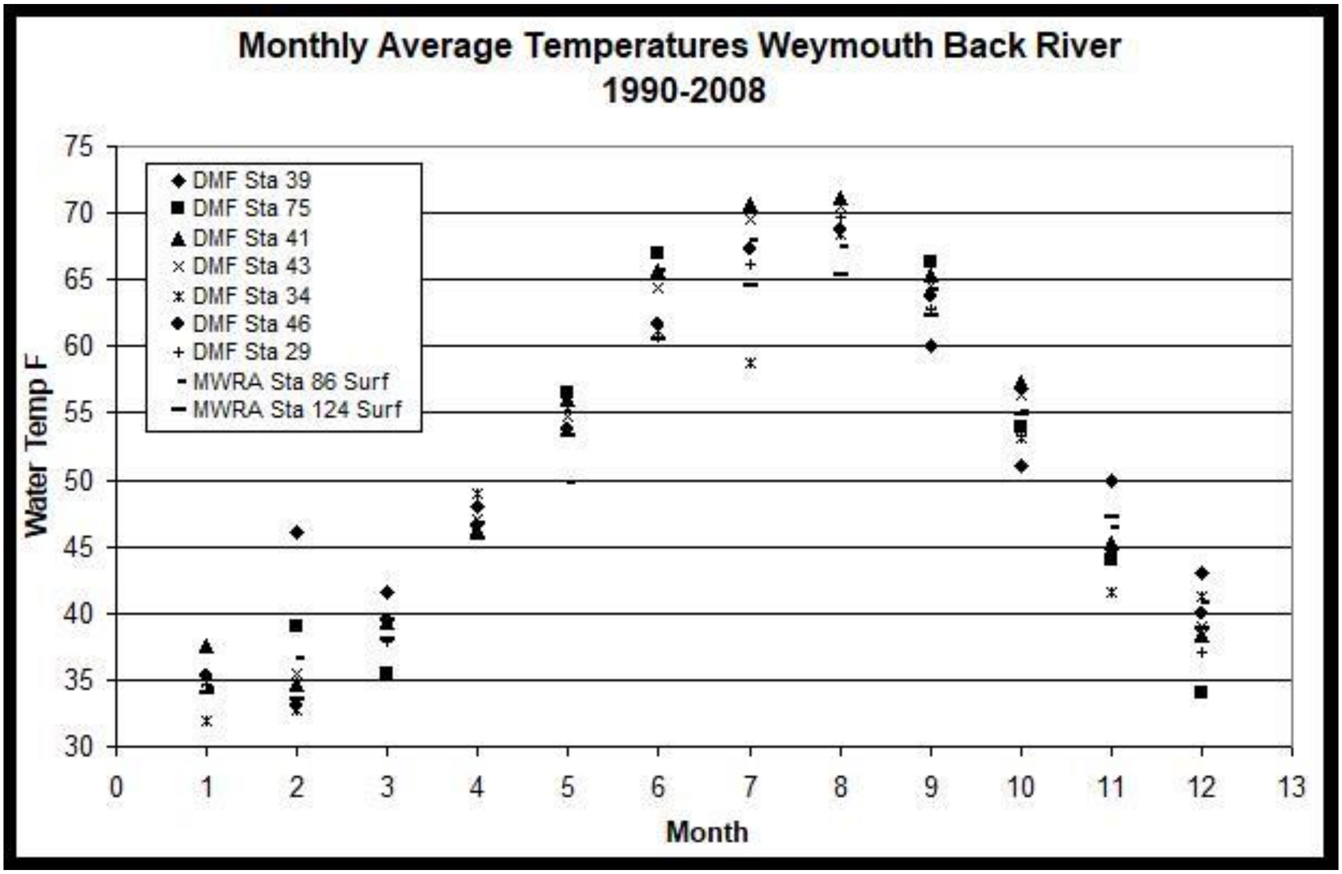


Figure 3-20. Average monthly surface temperatures 1990-2008 at selected sampling stations in the Weymouth Back River. Data are from the Massachusetts Division of Marine Fisheries and the Massachusetts Water Resources Authority. The measurements span the full tidal reach of the Weymouth Back River, yet still show little variation, indicating a high degree of horizontal mixing.

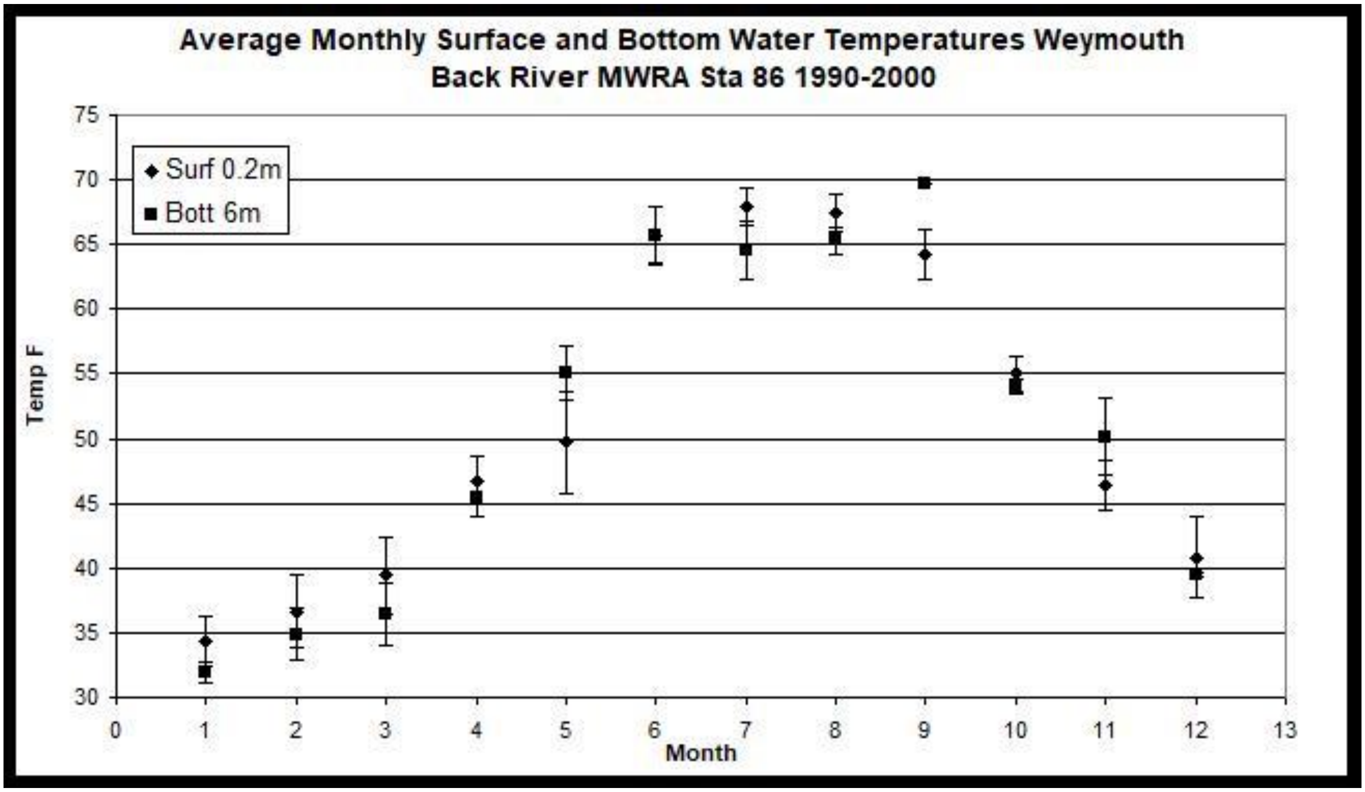


Figure 3-21. Average monthly surface (0.2 m) and bottom (6 m) temperatures at MWRA Station 86 in Weymouth Back River (just downstream of the Route 3A bridge). Averages are based on data from 1990-2008 and are shown as means ± 1 standard deviation. Surface means are based on n≥10, while bottom means are based on n=1 to 3.

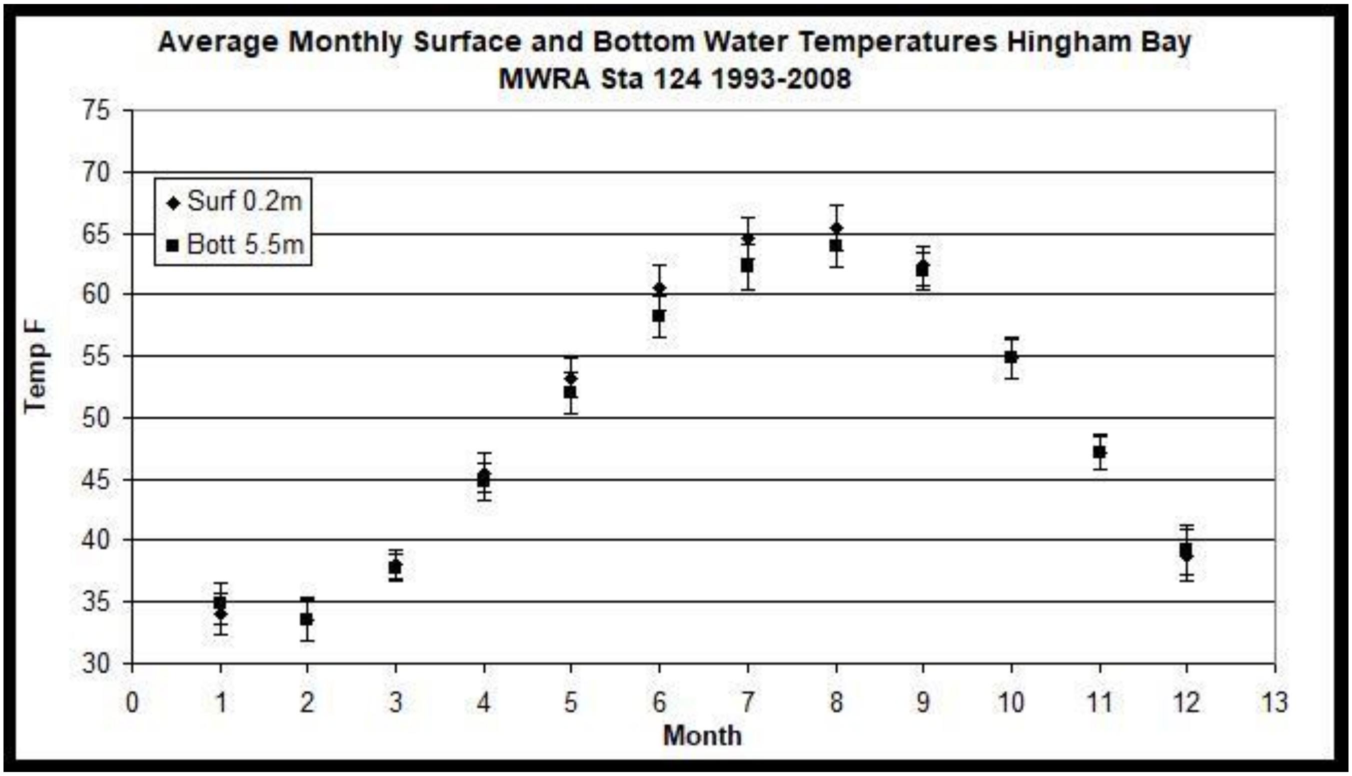


Figure 3-22. Average monthly surface (0.2 m) and bottom (6 m) temperatures at MWRA Station 124. This station is in Hingham Bay just offshore of the mouth of the Weymouth Back River. Averages are based on data from 1993-2008 and are shown as means ± 1 standard deviation.

3.3.5 Salinities

As would be expected in an estuary, salinities within the Weymouth Back River show greater spatial differences than temperature.

- Average monthly surface salinities near Hingham Bay were generally between 30 and 33 ppt (parts per thousand) then gradually decreased at each upstream station further inland (Figure 3-23).

- More inland stations show slight salinity decreases from Hingham Bay averages; for example,
    - average salinities at DMF stations 43 and 41 (just inland of the Route 3A bridge and off Whale Island, respectively) decrease into the 25 to 30 ppt range, especially during the higher river discharge periods of January to April.

    - Approximately 0.6 km further inland (DMF station 75), average monthly salinities range between 7 and 22 ppt. Another 1.2 km inland (DMF station 39) and average monthly salinities are generally <5 ppt.

Seasonal changes in salinity were also measured with a more complex pattern than temperature.

- Stations inland of DMF station 34 (off Stodder's Neck) show decreases in surface salinity with pronounced decreases in January through April (see Figure 3-23).
- At DMF station 41, average monthly salinities decline below 25 ppt in April
- and the average February salinity at DMF station 75 was 7 ppt (compared to 22 ppt in June).

These early-in-the-year salinity decreases correspond to high river discharges (see Figure 3-11). Lower summer discharges cause surface salinities at all stations except for the most inland (DMF station 39) to come into a similar range (27 to 33 ppt).

Vertical salinity differences were also more significant at the more inland stations.

- At the Hingham Bay station (MWRA station 124), surface (0.2 m) and bottom (5.5 m) salinities were generally the same and indicative of well-mixed conditions (Figure 3-24).
- At MWRA station 86, which is seaward of the Route 3A bridge and approximately 2.4 km (1.5 miles) inland, vertical salinity differences were clearly seen in the average monthly readings (Figure 3-25).

These readings show fresher water generally layered over saltier water; higher readings at the bottom (6 m) depth (generally 28 to 32 ppt) contrasted with lower readings (21 to 30 ppt) in the surface (0.2 m).

- These differences are greatest when the seasonally high river discharges were occurring in December through May (May surface average is 21 ppt, while bottom average is 29 ppt).
- During the summer months, when discharge declined, the surface and bottom salinities are closer (*e.g.*, in July surface average was 28 ppt and bottom average was 31 ppt; in October average surface and bottom salinities are essentially the same).

These salinity patterns indicate that the Back River water column is generally vertically well mixed, as also indicated with the temperature readings, except for some salinity stratification in the colder late winter and early spring. These well-mixed conditions allow regular contact with atmospheric oxygen and ensure that oxygen levels are generally sufficient for healthy benthic communities and harmful low oxygen (hypoxia) conditions are rare.

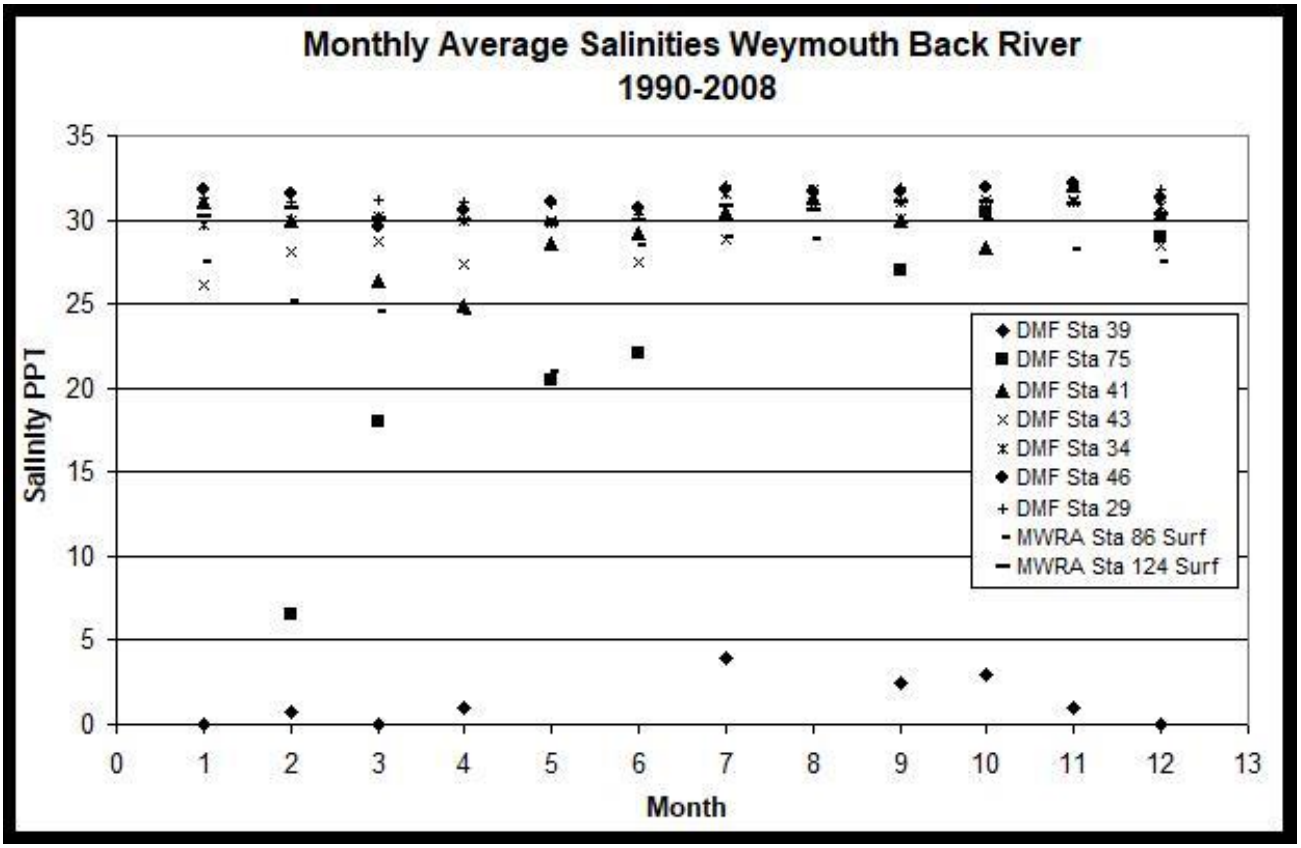


Figure 3-23. Monthly average surface salinities in the Weymouth Back River. Averages are based on data from 1990-2008 and are shown as means ± 1 standard deviation. Data are from the Massachusetts Division of Marine Fisheries and the Massachusetts Water Resources Authority. Station 86 was just seaward of the Route 3A bridge, while Station 39 was furthest inland in the main creek, just seaward of the railroad bridge.

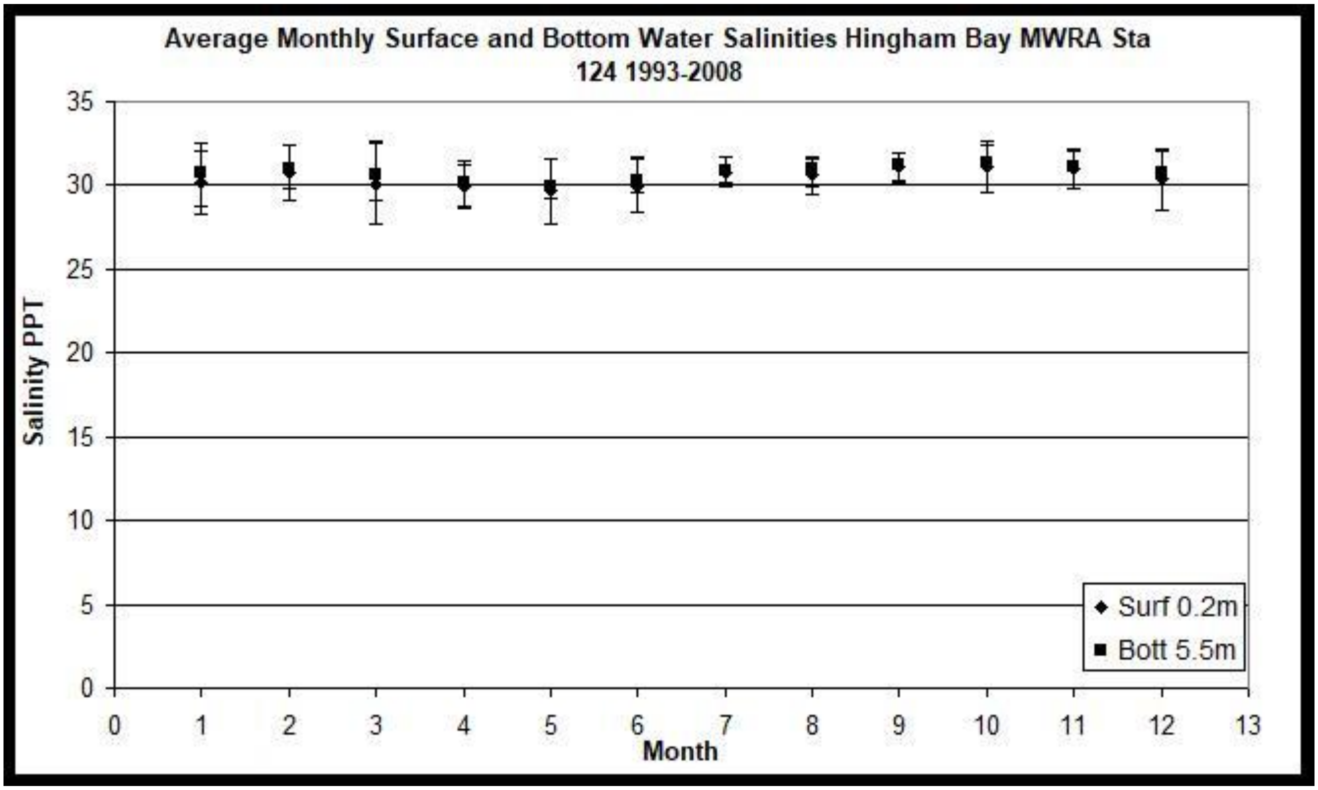


Figure 3-24. Average monthly salinities at MWRA Station 124 in Hingham Bay at 0.2 meters and 6 meters depth. Averages are based on data from 1993-2008 and are shown as means ± 1 standard deviation. The relatively constant salinities reflect the size of the offshore basin and the flushing of Boston Harbor (see Figure 3-19).

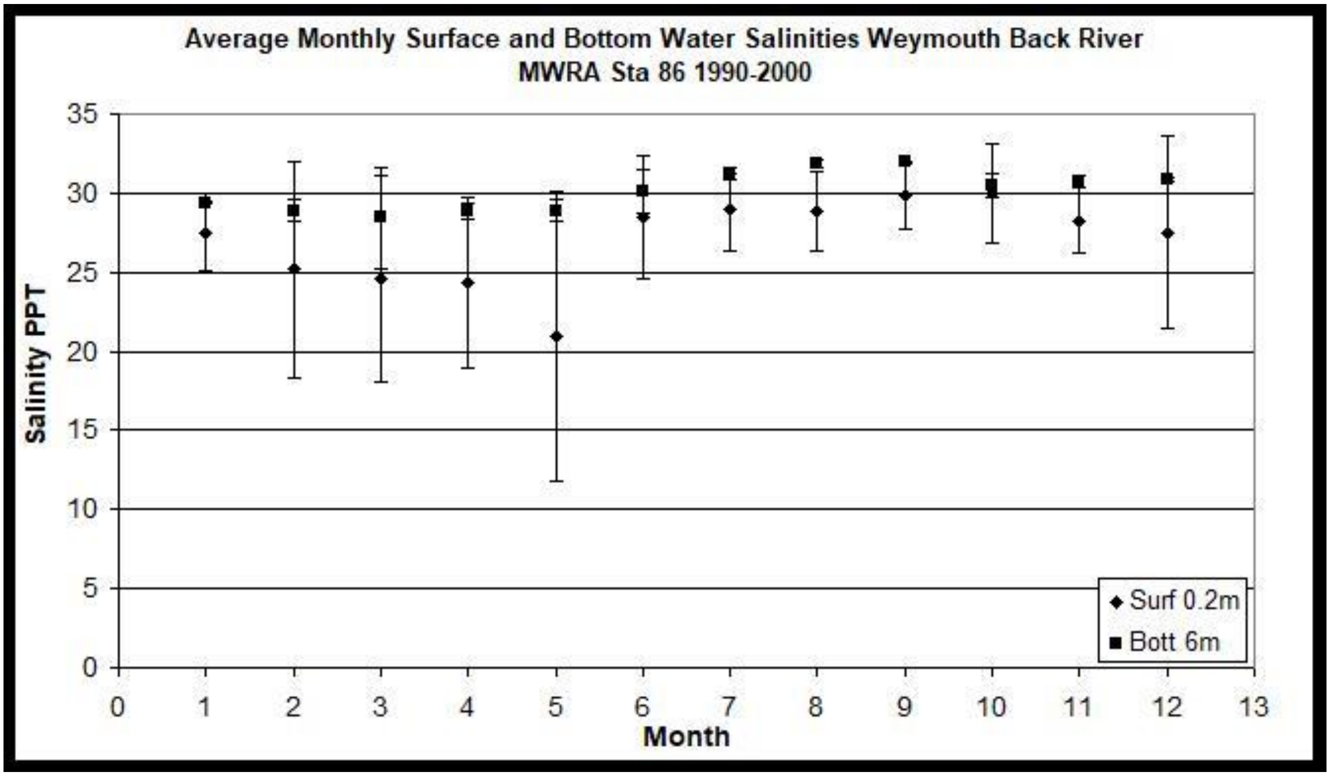


Figure 3-25. Average monthly salinities at MWRA Station 86 in lower Weymouth Back River at 0.2 meters and 6 meters depth. Averages are based on data from 1990-2000 and are shown as means ± 1 standard deviation. Salinities show seasonal impact of river discharge between December and May, similar concentrations in the summer, and fresher water generally layered above deeper saltier water.

3.3.6 Dissolved Oxygen

Dissolved oxygen is critical to aquatic life and is considered an ecosystem-structuring parameter. Low levels of dissolved oxygen can result in the wholesale restructuring of benthic communities and even their loss from a basin. Year-round dissolved oxygen concentrations in Weymouth Back River have shown little depletion and should be generally supportive of high quality benthic habitat.

Exposure of estuarine benthic animals to dissolved oxygen concentrations of 4 mg/L or less has generally been observed to be detrimental, but concentrations of less than 6 mg/L has also been shown to impact reproductive success and movement of finfish (USEPA, 2003; USEPA, 2010). Massachusetts regulations require minimum dissolved oxygen concentrations of 6 mg/L for SA waters; Weymouth Back River is classified as a SA water under Massachusetts regulations (310 CMR 4).

Average monthly dissolved oxygen concentrations in both the lower Back River estuary (MWRA Station 86) and in Hingham Bay (MWRA Station 124) show a distinct seasonal trend with lower concentrations during the summer. Levels in both surface and near-bottom waters were higher in the colder months; colder waters have greater capacity than warmer waters to "hold" dissolved oxygen. Dissolved oxygen concentrations were reduced in the summer as this capacity is reduced (Figures 3-26 and 3-27), but concentrations tend to be above 6 mg/L

Vertical water column differences in dissolved oxygen concentrations are small. Near-bottom concentrations were generally slightly less than surface levels, which would be expected due to sediment oxygen demand, but maximum differences between surface and bottom concentrations were generally 1 mg/L or less.

None of the recorded concentrations were less than 6 mg/L. Concentrations in Back River tended to drop slightly lower (6.0 to 7.5 mg/L) in the summer than in Hingham Bay (7.3 to 8.3 mg/L) likely due to the smaller volume and slightly warmer summer temperatures in the Back River (about 65 to 70˚F) compared to Hingham Bay (about 60 to 65˚F).

Maintaining high oxygen levels in the bottom waters of the Weymouth Back River is critical to its ability to maintain a high quality habitat.

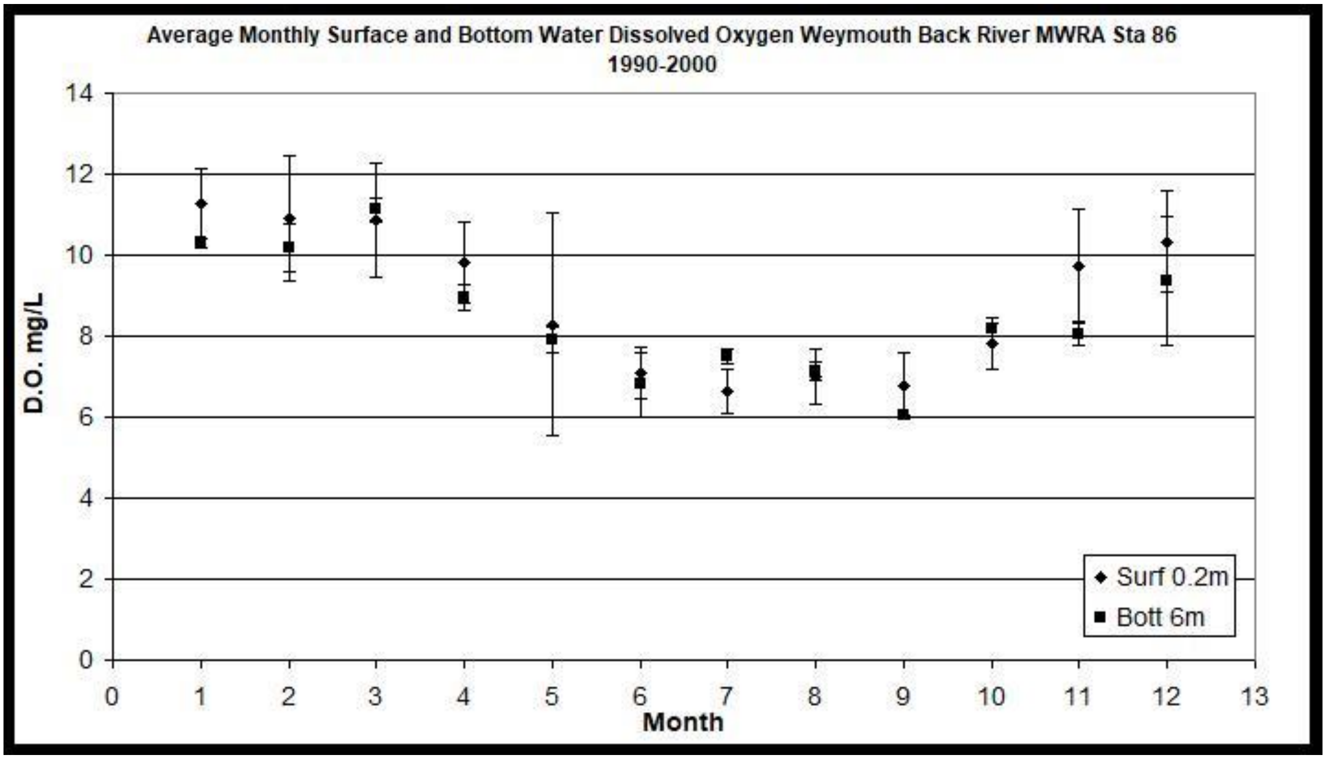


Figure 3-26. Average monthly dissolved oxygen concentrations at MWRA Station 86 in lower Weymouth Back River at 0.2 meters and 6 meters depths. Averages are based on data from 1990-2000 and are shown as means ± 1 standard deviation. Similarity in concentrations at both depths indicates a high degree of vertical mixing. Summer concentrations decrease due to loss of holding capacity for dissolved oxygen in warmer waters

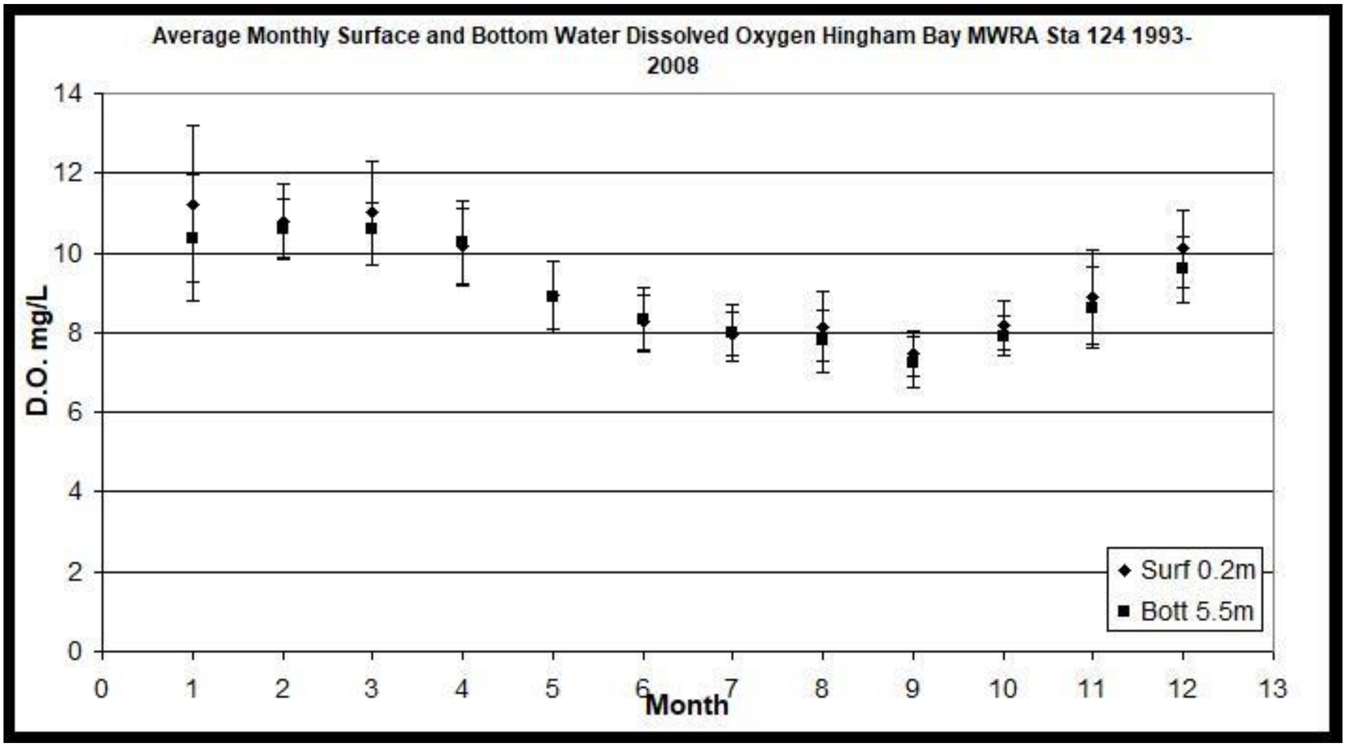


Figure 3-27. Average monthly dissolved oxygen concentrations at MWRA Station 124 in Hingham Bay at 0.2 meters and 6 meters depths. Averages are based on data from 1993-2008 and are shown as means ± 1 standard deviation. Similarity in concentrations at both depths indicates a high degree of vertical mixing. Summer concentrations decrease due to loss of holding capacity for dissolved oxygen in warmer waters.

The Ecology of the Weymouth Back River

CHAPTER 4: Natural Resources

4.1 Introduction

The natural resources of the Weymouth Back River are extensive and varied, maintaining a wide variety of habitats representative of most ecosystem types found along the mid-Atlantic Coast of the United States, including:

- Tidal wetlands,
- Tidal flats,
- Rocky Intertidal Zones,
- Hard and Soft Sediment Habitats,
- Streams, and
- Circulation-Restricted Areas.

This diversity of habitats in turn produces a diversity of plant and animal species.

The Back River watershed is located within the Northeastern Coastal Zone ecoregion (USEPA, 2003). This ecoregion extends from southern Maine to the New York City/Newark, NJ area (Figure 4-1) and includes all of eastern Massachusetts except for Cape Cod, Nantucket and Martha's Vineyard. As such, the natural resources in Weymouth Back River are more similar to southern Maine than those of southeastern Massachusetts.

With over 200 acres of open water, several salt ponds and over 100 acres each of salt marsh and tidal flat (Figure 4-2), the Weymouth Back River supports a wide variety of habitat for various finfish, shellfish, birds and other species.

Approximately 50% of the system is intertidal, most of which is located toward the head of the Back River where Herring Brook, Fresh River and Tucker's Swamp Brook empty into the salt marsh. Anadromous and catadromous fish runs exist within the system with thousands of alewives and smelt passing through the estuary to spawn in its tributary rivers and headwater ponds.

Tidal exchange through Hingham Bay supports the existence of a productive clam fishery. The expansive marshes found in this system contribute not only to providing habitat but also serve as a buffer to this resource for human activities within its watershed.

The significant presence of eskers are notable in this system (a winding ridge of stratified sand and gravel not unlike a railroad embankment), providing habitats that are somewhat unique to the area. The following chapter discusses the habitats and species of Weymouth Back River.

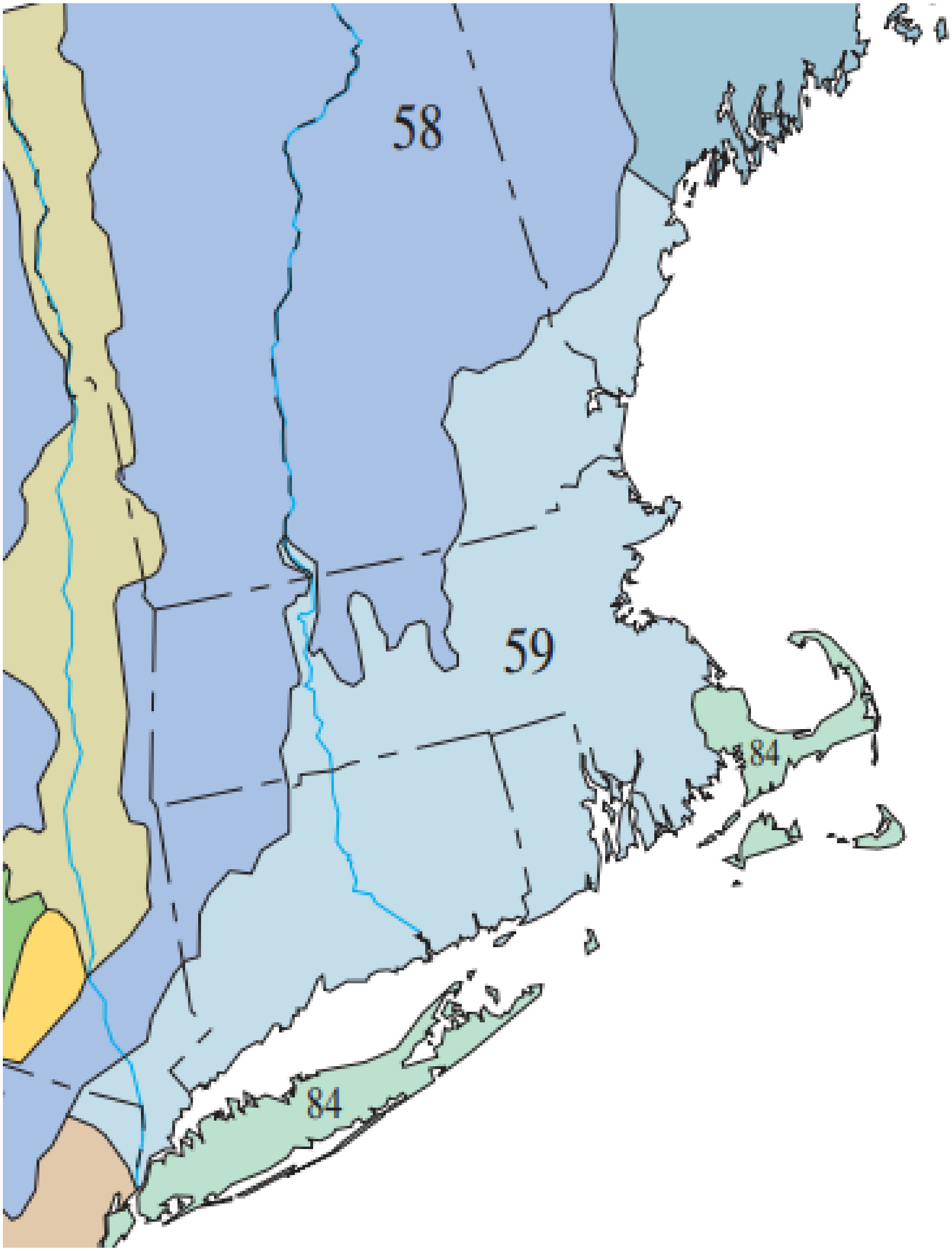


Figure 4-1. Northeastern Coastal Zone Ecoregion. The Northeastern Coastal Zone Ecoregion extends from southern Maine to New York City/Newark, New Jersey and includes all of eastern Massachusetts except for Cape Cod, Nantucket and Martha's Vineyard. (excerpt from USEPA, National Health and Environmental Effects Research Laboratory, 2003).

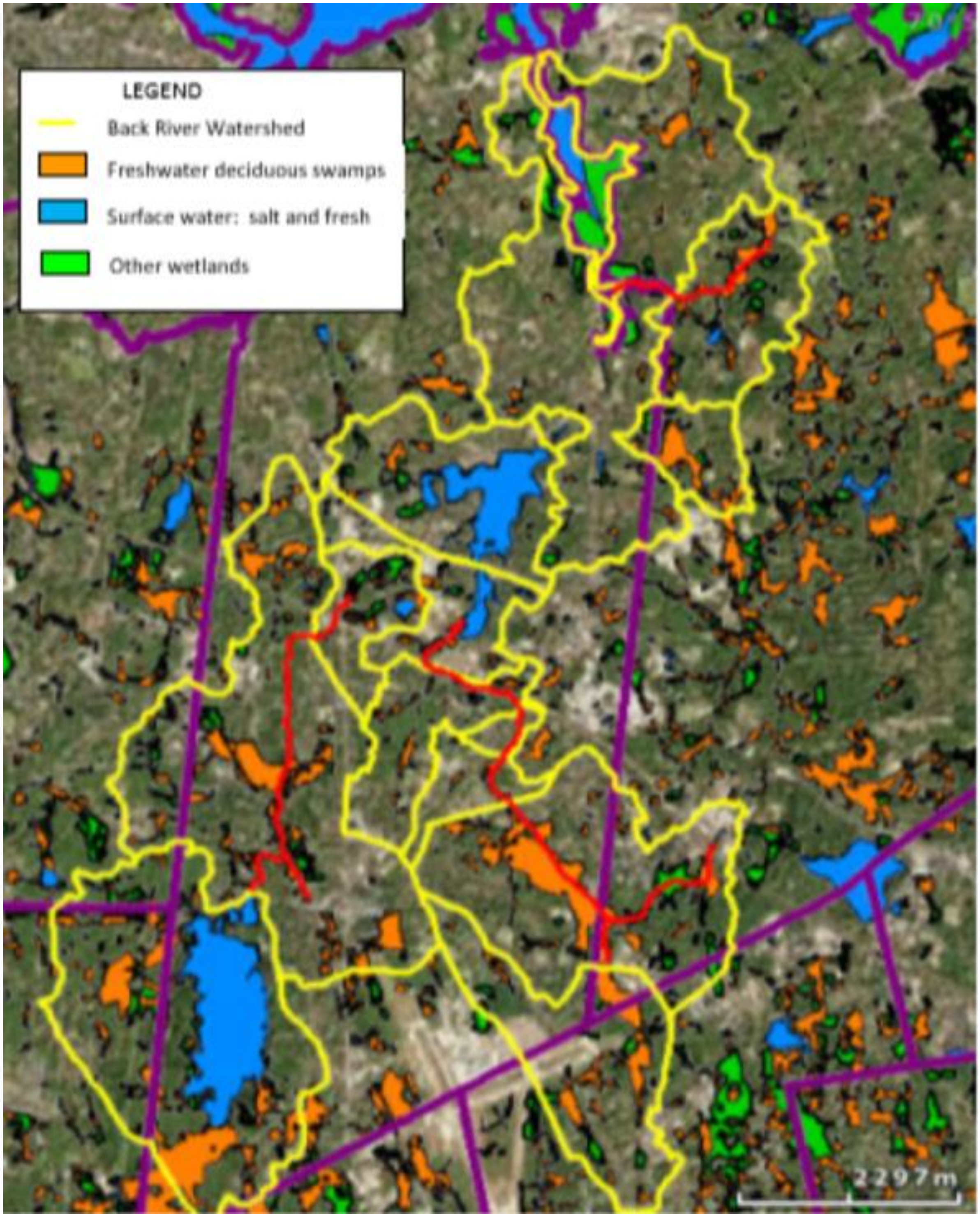


Figure 4-2. Wetlands within the Weymouth Back River watershed. Freshwater wooded deciduous swamps (shown in orange) are the predominant wetlands within the Back River watershed. Blue areas are surface waters and other wetland types are colored green. Estuarine wetlands are generally located north of Broad Street. Wetland area delineations are based on MassDEP 1:12,000 wetland coverage (available through MassGIS).

4.1 Flora

4.1.1 Salt Marshes

Salt marshes represent an important component in the ecology of the Weymouth Back River estuary and watershed. There are over 100 acres of salt marsh within the Weymouth Back River estuary (Myers, 1997). These tidal wetlands are typical of New England marshes, forming behind protective barriers or as narrow fringing marshes in low energy environments such as circulation restricted coves and embayments.

The diminished velocities of tidal water as it enters these embayments results in the deposition of suspended particles, ultimately establishing sediments at an elevation within the tidal range suitable for the colonization of marsh plants. The absence of high energy waves is important to the establishment of these species, as waves prevent the formation of a stable substrate (Redfield, 1972).

In their initial formation, gradations in sediment types exist ranging from coarse sand toward the mouth of the wetland grading to fine silt toward the head. This reflects the inability of tidal waters to keep heavier materials like sand in suspension, resulting in their deposition near the mouth and subsequent deposition of finer particles nearer the headwaters.

Once substrate is available at suitable elevation and plants begin to colonize, the extensive root and rhizome systems of marsh species stabilize the sediments and the marsh becomes established; about half of the production of the dominant low marsh species, salt marsh cordgrass [*Spartina alterniflora*] is in extensive, below-ground, network of rhizomes and smaller roots (Teal and Howes, 1996).

The value of these highly productive intertidal wetlands has long been recognized as:

- habitat for waterfowl, finfish (nursery grounds for various species of fish), and shellfish,
- storm buffers for adjacent upland,
- and as potential buffers for terrestrial/watershed nutrient inputs to coastal waters.

Tidal flushing of salt marshes is also postulated as a mechanism for export of plant detritus to estuarine food webs off-shore.

These marshes support:

- an abundance of marine life, including snails, crabs, mussels, amphipods and large numbers of small fish.
- Many species of birds feed on the fish and invertebrates there as well as on the plants themselves (*e.g.*, Canada and snow geese) (Teal, 1986).
- Mammals such as voles, field mice, raccoons and skunks forage in the marsh during low tides.

Marshes are also well known for their abundance of insects such as mosquitoes and biting flies; this has led to management practices such as ditching in attempts to limit insect breeding habitats (primarily stagnant pools).

Although considered a nuisance to humans and potentially carriers of diseases such as encephalitis, these insects are in important part of the marsh ecosystem, providing substantial food sources for birds and surface feeding fish. Other insects such as plant hoppers, grasshoppers and aphids as well as many species of amphipods and spiders also represent important segments of the marsh fauna.

Coastal salt marshes in New England are generally divided into two rather distinctive zones:

1. low marsh, dominated by the salt marsh cordgrass (*Spartina alterniflora*) and
2. high marsh, dominated by the salt marsh hay (*Spartina patens*) and the spike grass (*Distichlis spicata*).

The frequency and duration of flooding primarily determine the distribution of low and high marsh zones.

- The low marsh zone is located between mean low water and mean high water,
- while the high marsh is the region lying between mean high water and spring high water.
- Both low and high marsh zones are sufficiently flooded by seawater to inhibit the growth of more freshwater marsh plants such as cattail (*Typha* species) and reeds (*Phragmites*).

Low marsh is typically flooded on every high tide and is almost exclusively colonized by *Spartina alterniflora*, occasionally with sea lavender (*Limonium nashii*) or glassworts (*Salicornia* species) present.

Spartina alterniflora exhibits two growth forms:

1. tall form (up to 1-2 meter in height) growing 1-3 meters inland from creeks and
2. short form (less than 50 cm tall) typically growing inland from the tall form is growing.

The differences in these morphologies is generally attributed to a combination of nutrient availability, sediment oxidation and plant-sediment interactions, the more productive tall form growing in better drained, more oxidized sediments (therefore increased ability to uptake nitrogen) with increased drainage of plant growth inhibitors (such as sulfides) by the greater exposure to tidal flushing (Howes *et al.*, 1986).

- These plants have adapted a system of gas filled compartments called lacunae to transport oxygen to their roots and rhizomes to support aerobic respiration and nutrient uptake in response to anoxic sediments and frequent inundation (Howes and Teal, 1994; Teal and J. Kanwisher, 1966).

- The plants have also adapted to deal with water uptake and evapotranspiration in saline sediments through the evolution of salt glands which secrete a concentrated salt solution, maintaining osmotic balance while water is being lost during evapotranspiration.

The naturally high levels of primary productivity found in salt marshes are generally attributed to the abundance of *Spartina alterniflora*.

The high marsh supports greater plant diversity than the low marsh and is dominated primarily by:

- the salt marsh hay (*Spartina patens*) and
- the spike grass (*Distichlis spicata*).

Along the upland border where the duration of tidal flooding is least, salt tolerant plants are commonly found, including black grass (*Juncus gerardi*), switch grass (*Panicum virgatum*) and chairmaker's rush (*Scirpus americanus*), salt marsh bulrush (*Scirpus robustus*), and marsh elder (*Iva frutescens*). In most of the marshes where the headwaters are fresh or brackish, stands of reeds (*Phragmites*) and cattails (*Typha latifolia*) predominate at the landward edges of the wetlands.

Although few animals live or burrow in the sediments of the high marsh zone, the historic utilization in the region of salt hay as feed and fodder for animals and its more recent use as a weed-free garden mulch has focused attention on value of these wetlands as a usable sustainable resource.

In addition to their aesthetic value, the importance of marshes as storm buffers, habitats and nursery ground for numerous species, and historically as a valuable source of salt marsh hay has long been a basis for defense in their protection. Their role as nutrient buffers for coastal waters has become evident over the years but concern now exists for the future of this valuable function because of increases in sea level rise (Kemp *et al.*, 2005).

Table 4-1 provides a listing of aquatic plant species that have been identified within the Back River system. Vascular plants listed in Table 4-1 are typical salt marsh and border species found in this ecoregion. Macroalgae inhabit both hard and soft substrates in the intertidal and subtidal habitats of the Back River estuary. They absorb nutrients from the water column and an over-abundance of populations is usually indicative of excessive watershed nutrient loading. These wetlands, both fresh and salt water are an important part of the ecology of the Back River.

Table 4-1. Aquatic Vegetation in Back River region (from Marine Resources of Hingham Bay 1973)

MACRO ALGAE – Intertidal/Subtidal
Green Algae (*Chlorophyceae*)
- Chaetomorpha sp. (spaghetti algae, green hair algae)
- Enteromorpha intestinalis (grass kelp)
- Enteromorpha linza (green string lettuce)
- Ulva lactica (sea lettuce)

Brown Algae (*Phaeophyceae*)
- Ascophyllum nodosum (knotted wrack)
- Ascophyllum Mackaii (free floating knotted wrack)
- Chorda filum (Devil’s shoelace)
- Chordaria flagelliformis (black whip weed)
- Fucus evanescens (rock weed)
- Fucus spiralis (flat wrack)
- Fucus vesiclosus (bladder wrack)
- Laminaria agardhii (kelp)

Red Algae (*Rhodophyceae*)
- Chondrus crispus (irish moss)

Polysiphonia lanosa (lobster horns)
Porphyra umbilicalis (laver, nori)
Dasya pedicellara (red laver)

VASCULAR PLANTS – Salt Marsh and border area

Artemisia stelleriana (dusty miller)
Aster semifolius (salt marsh aster)
Atriplex arenaria (seabeach orach)
Chenopodium sp. (goosefoot)
Distichlis spicata (spike grass)
Iva frutescens (marsh sider)
Juncus gerardi (marsh elder)
Limonium carolinianum (sea lavender)
Najas marina (bushy pondweed)
Rhus typhina (staghorn sumac)
Rosa rugosa (salt spray rose)
Salicornia europaea (glasswort)
Scirpus atrovirens (bulrush)
Solidago sempervirens (seaside goldenrod)
Spartina alterniflora (salt marsh cordgrass)
Spartina patens (salt marsh hay)
Suaeda maritime (sea blite)
Triglochin maritime (arrow grass)

4.1.2 Tidal Flats

There are more than 200 acres of tidal flats in the Back River estuary of which 150 are active clamming areas (Myers, 1997). Tidal flats are gently sloping, unvegetated areas extending seaward of coastal landforms to mean low water. These flats are typically exposed at low tide, revealing sediments reflective of the wave energy from sands to muds and silts.

Tidal flats are generally depositional environments, with the area and duration of exposure dependent upon tidal amplitude. They are often associated with other types of coastal environments such as embayments, salt marshes, spits and barrier beaches which provide a source of sediment for development of the flat.

Tidal currents are primarily responsible for the sediment makeup of these flats. Along shorelines exposed to higher currents and wind driven wave energies, these flats tend to be made up of coarser, sandier sediments while those flats in more protected areas such as in estuaries, wetlands, salt ponds, or behind barrier beaches generally have finer, siltier sediments.

Since the overlying water column retreats at high tide, only infaunal and epibenthic animals colonize tidal flats. However, at high tide numerous species of fish "commute" to graze on the benthos and epibenthic algae.

- The infaunal communities inhabiting the tidal flats provide a valuable resource both to the aquatic food web but also to the many species of waterfowl which feed on these organisms during low tide exposure.
- Shorebirds, feeding on invertebrates such as polychaete worms, molluscs and crustaceans, often follow the water's edge as it advances and retreats over the flats, with maximum foraging during low tide when most of the tidal flat is exposed.
- Many other species utilize the tidal flats, including crabs such as the rock crab (*Cancer irroratus*), the green crab (*Carcinus maenas*), and the blue crab (*Callinectes sapidus*) which migrate on and off the flats with the tide, feeding on submerged bivalves and annelids that live there.
- The lady or calico crab (*Ovalipes ocellatus*) will bury itself in the sandy sediments of these flats.
- Hermit crabs, *Pagurus longicarpus* and *P. pollicaris*, and snails *Ilyanassa* spp. and *Nassarius* spp. also coexist on the tidal flats; hermits utilizing the empty shells of the snails for semi-permanent homes.
- The horseshoe crab (*Limulus Polyphemus*) frequently uses the tidal flats as feeding grounds as well as spawning and, at the high water line, for deposition of its eggs.

4.1.3 Freshwater Wetlands

There are about 69 acres of freshwater wetlands within the Back River watershed not including the ponds and lakes. These marshes, swamps and bogs, are mostly associated with the ponds and streams south of the Back River estuary (NRWA, *et al.*, 2004) (see Figure 4-2).

As with salt water wetlands, species diversity is high in these habitats, and a variety of plant species are adapted to the moist conditions, including cattails and sedges which grow from the submerged sediments.

Freshwater wetlands may stay wet all year long, or the water may evaporate during the dry season (e.g., vernal pools). Freshwater wetlands are important for several reasons including flood control, wildlife habitat, and water supply, as well as for aesthetic and cultural values.

These diverse habitats support a variety of plants and animals.

- Among the plants in New England freshwater wetlands, including the Back River area, are a variety of trees such as Alder (*Alnus* spp.), Silver Maple (*Acer saccharinum*), White Cedar (*Chamaecyparis thyoides*), Ash (*Fraxinus* spp.), Tamarack (*Larix* spp.), and shrubs, rushes, sedges, pond lilies, reeds (*Phragmites*) and cattails (*Typha*).
- Among animals that inhabit these freshwater wetland habitats, many species of amphibians, reptiles, birds (waterfowl and other species), and furbearing mammals. Amphibians require water in which to lay their eggs and for the tadpoles to grow to adulthood. Insects are also an important part of freshwater wetlands, as they are in saltwater wetlands. They help to pollinate plants and provide food for birds and amphibians.

Freshwater wetlands, like estuaries, also provide very valuable natural services to people.

1. They provide fish to eat and flood protection during storms.
2. They also filter contaminants, providing cleaner drinking water and preventing contaminants from reaching the Back River estuary.

Because of these valuable services, it is important that we work to conserve our wetlands.

4.2 Fauna

4.2.1 Benthic Communities and Shellfish

Sediment characteristics primarily determine the composition and distribution of benthic communities in marine environments. Composition and grain size affects the ability of many benthic animals, notably invertebrates and bivalves, to settle and burrow. Benthic communities are also affected by the sediment organic content which provides a carbon source for both benthic deposit feeders and certain microbial communities.

For a benthic community under a vertically well-mixed water column, a high sediment organic content is beneficial in terms of diversity of species and ecological resilience. In areas where periodic stratification occurs, high sediment organic content can prompt high sediment microbial respiration rates and accompanying low oxygen conditions in bottom waters.

These hypoxic conditions can reduce larval recruitment and survival and shift benthic community structure towards lower diversity (*e.g.*, favoring less species higher in the food chain) and more opportunistic species (*e.g.*, those with short lifespan). The interaction between grain size and organic matter/oxygen is a primary driver of benthic community structures in this type of shallow coastal embayment.

In the Weymouth Back River system, the sediments generally tend to transition from rocky materials outside the mouth down to Hewitts Cove, then to gravel materials, and then to sand materials along the channel until near Beal Cove where it transitions to fine/muddy materials (Figure 4-3). Along this general transition are small inlets and coves of finer materials, although rocky sediments tend to predominate along the exterior shore areas of Webb Memorial State Park, Grape Island, and Slate Island, though the interior and more tidal protected areas tend to have gravels and sands.

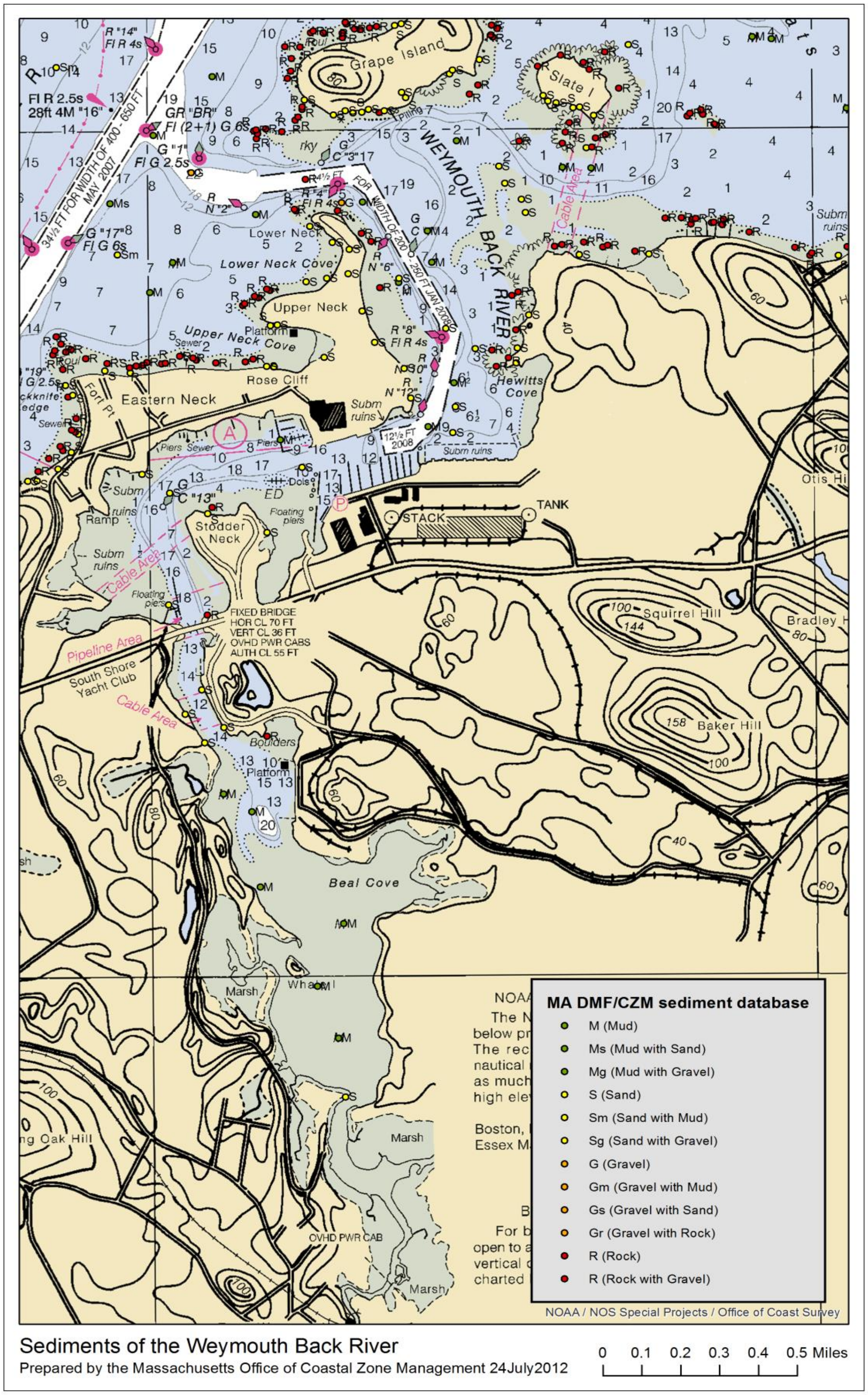


Figure 4-3. Sediments of the Weymouth Back River (Mass CZM)

Shellfish are the species that are most impacted by these benthic materials and their settings. Shellfish are important in coastal food chains as large numbers of eggs and larvae during spring and summer months provide a food source for juvenile fish and crustaceans.

Suitable habitat is important to the production of shellfish as the young of various species require specific types of substrates and/or sediment grain sizes upon which to settle or burrow. Various shellfish species have specific salinity and temperature ranges for reproduction and growth. Water circulation also plays a role by maintaining temperature and oxygen conditions along with transport of planktonic food, important since all of the harvested bivalve species are filter feeders. Their general lack of mobility makes them valuable as a commercial and recreational resource but particularly susceptible to pollution as well.

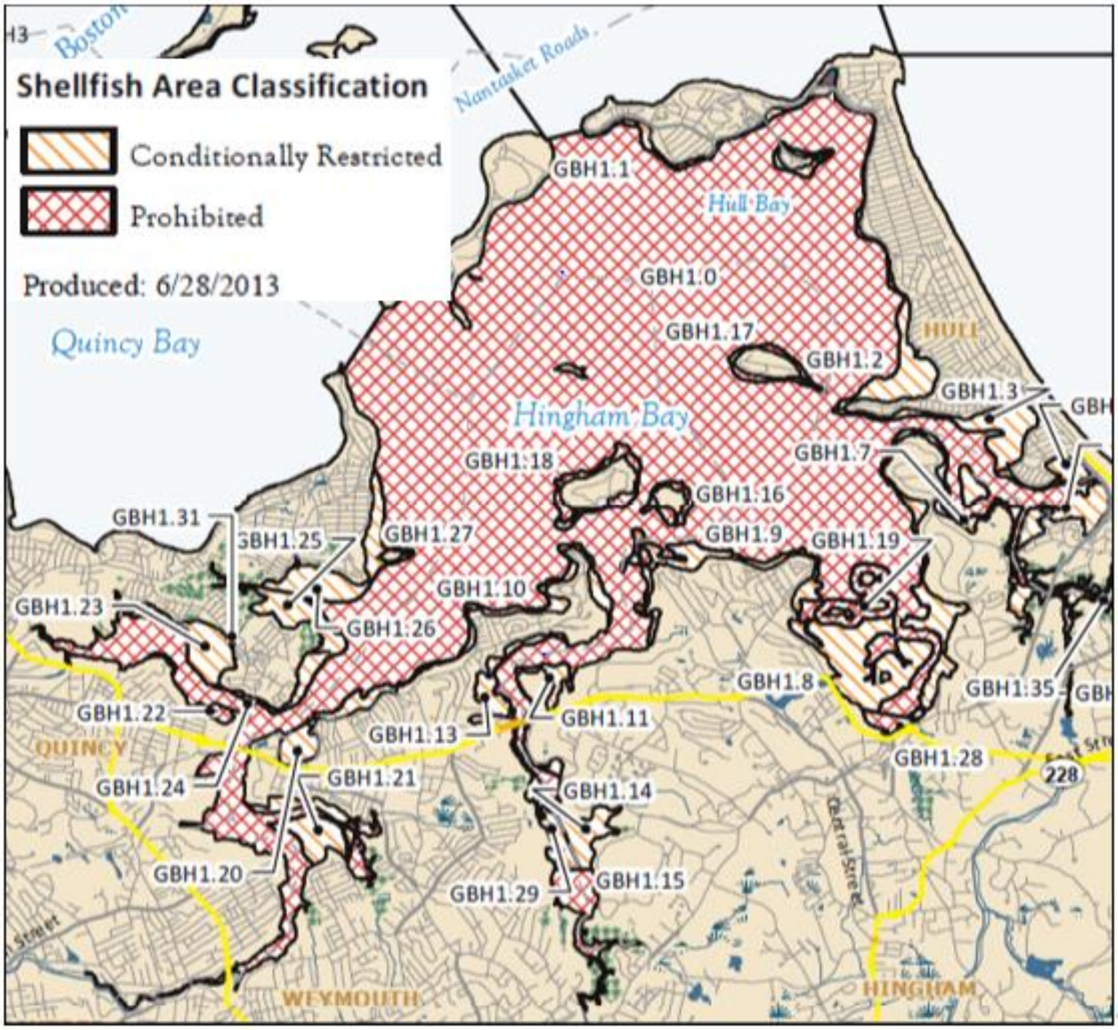


Figure 4-4. Massachusetts Division Marine Fisheries Shellfish Area Classification Map (2013). Most of the Weymouth Back River was classified as "prohibited", but there were selected areas (*e.g.*, near Beal Cove, east of Stodder Neck) where shellfishing is "conditional restricted. Modified from: http://www.massmarinefisheries.net/shellfish/dsga/GBH1.pdf (accessed 2/16/16.

Shellfish are both relatively fast growing and relatively easy to harvest, and the soft sediments of Beal Cove (see Figure 4-4) are particularly well suited for the soft shell clam *Mya arenaria*. Shellfishing is prohibited in most of the Back River system, except for this area near Beal Cove, where it is "conditionally restricted" (Figure 4-5).

Massachusetts Division of Marine Fisheries (MassDMF) has produced a shellfish habitat map that indicates a mix of soft shell clam (*Mya arenaria*) and blue mussel habitat within and around the mouth of the Back River estuary (Figure 4-4). It has been previously noted that historically mussels, oysters and lobster were prevalent in this system. However, today, numbers are lower. What caused this decline is not totally clear but it is likely changes to the system over time resulted in loss of suitable habitat and/or overfishing.

The most widespread shellfishery in the Weymouth Back River system is the soft shelled clam (*Mya arenaria*).

- Soft shelled clams are generally found in sandy or muddy sediments in protected harbors and inlets and within salt marsh creeks, burrowing in the sediment with siphons extending into the water column.
- As filter feeders, water and associated plankton are drawn in through one siphon and unused water and particles are ejected out through the other siphon.
- Their fragile shells, which generally grow 8 to 10 cm in length, are less tolerant to disturbance and are more easily broken than other species of clams such as the hard shelled quahog *Mercenaria mercenaria*.
- They have many natural predators, including raccoons, blue crabs, horseshoe crabs, and diving ducks (Newell and Hidu, 1986).
- As their shells do not close tightly, they have limited tolerance to anoxia and can suffer high mortalities due to sulfide accumulation under low oxygen conditions resulting from either natural or anthropogenic causes.
- Unless disturbed, they tend to spend their entire adult life in one place.
- In that these shellfish are more prevalent in soft, organic-rich sediments, occasional low oxygen conditions would likely be encountered, so a balance between sediment deposition, decomposition, and regular exchange of overlying waters is important for maintaining these species.
- Generally intolerant of salinities less than 5 ppt, they frequently inhabit low energy embayments where organic matter can accumulate yet with sufficient flushing and/or limited freshwater inputs to maintain high enough salinity for reproduction and growth.
- The combination of low energy/high organic matter environments and sensitivity to hypoxia can result in mass mortalities of this species, as has occurred on Cape Cod Bay under certain conditions.
- Because of the somewhat fragile nature of their shell, hydraulic dredging is being explored in some regions to decrease losses during harvest and increase yields over traditional hand tonging.
- Some recent evaluations have also suggested a threat from a type of clam leukemia that can be transferred between individuals (Metzger, *et al.*, 2015).

Blue mussel (*Mytilus edulis*) are also found in the Back River, generally closer to the mouth and often with areas overlapping with soft shell clams.

- Blue mussel adults generally prefer harder substrate than soft shell clams, often attaching to rocks, and pilings by a strong, thread-like anchor, called a byssal thread.
- Blue mussels generally prefer a 5 to 20°C temperature range, salinities above 15 ppt, are permanently attached in subtidal and intertidal beds, and typically grow up to 10 cm lengths.
- Blue mussels are filter feeders with two short siphons on the inside of the shell, which direct the flow of water in and out.
- Because of the hardness of the adult shell, predators tend to be relatively strong, including American lobster, crabs, whelks, and some fish species (*e.g.*, Tautoga) (Newell, 1989).

The American lobster (*Homarus americanus*) represents an important commercial resource in Southeastern New England, as well as supporting a small recreational fishery.

- Anecdotal information indicates lobsters were much more prevalent in the Back River historically than they are today.
- Primarily a nocturnally active invertebrate, lobsters generally hide during the daylight hours in rock or grass shelters, emerging during twilight hours to feed.
- Small lobsters frequent shallower waters near the shore, while larger individuals (occasionally up to 50 pounds) are more prevalent in deeper offshore waters.
- Relatively slow moving in its four-legged walk, lobsters have the ability to rapidly propel themselves backward for short distances by the contraction of their tail.
- The characteristic claws of the lobster perform two functions: the larger of the two, or "crusher", is designed for cracking hard objects like the shells of snails or bivalves; the smaller, sharper claw, or "cutter" is used for tearing apart prey (generally fish) or plant material.
- Lobsters are also known for their cannibalistic behavior, frequently eating other lobsters in their soft-shell (just past molting) stage and even their own young (Davis, 1989; Meinkoth, 1981).

Molts of the horseshoe crab, *Limulus polyphemus*, and frequently the crab itself can be common sights in salt marshes.

- Known as a "living fossil", horseshoe crabs have remained basically unchanged over the past 200 million years and their ancestors are estimated to have roamed shorelines roughly 350 million years ago.
- Not actually a crab at all, *Limulus* is an arthropod, related to spiders and scorpions.
- The larger females move from deeper water in early summer to lay eggs along the high tide line.
- Horseshoe crabs are particularly interesting in that they possess a blue, copper based blood with only one type of cell which can be extracted for use in various medical assays such as for infections caused by spinal meningitis and *E. coli*, as well as certain types of cancers and blood clots.

4.2.2 Fin Fish

The Weymouth Back River system maintains diadromous fish runs for:

- river herring,
- American eel,
- rainbow smelt and
- white perch.

Diadromous fish are species that spend parts of their lives in both fresh and salt water. These are further broken down into:

1. catadromous fish, which are born in marine habitats, but migrate to freshwater to grow and mature, returning to the sea to spawn, and
2. anadromous fish, where hatching and juvenile stages occur in freshwater and then migrate to mature in the ocean, returning to freshwater to reproduce.

The dominant fish species within the Back River Estuary include both residents and non-residents (migratory) species. Most prevalent in this system are:

- alewife
- American eel,
- Atlantic silverside, t
- three and four spine stickleback,
- mummichog,
- rainbow smelt,
- northern pipefish,
- striped killifish and
- winter flounder (Iwanowicz, *et al.* 1973).

Significant efforts have been undertaken in recent years to maintain and enhance smelt spawning habitat and river herring passage. The seasonal migrations have been a predictable and dependable source of fish for centuries.

The river herring population in the Back River Estuary is one of the largest north of Cape Cod (Nelson, *et al.*, 2011). The system also supported one of the largest smelt runs, however low egg populations since 1995 indicate a potential decline in the fishery likely due to sedimentation and habitat degradation (Reardon, 2010). The following is a brief natural history of the commercially and recreationally important fin-fish species found in the estuary:

<u>Winter Flounder</u> (*Pseudopleuronectes americanus*) were a mainstay of the New England groundfish industry until the mid-1930's. After this time, the populations suffered serious declines, the causes of which are as yet unclear. Winter flounder still support an important fishery utilizing coves and embayments for critical early stages of their life cycle.

The peak of the spawning season for winter flounder is generally February to March, but extends from January to May. Detailed studies in Woods Hole identified February as the peak (Breder, 1922) and February and March in the Weweantic River (Lebida, 1969). It is believed that winter flounder return to the estuaries of their origin for spawning (Perlmutter, 1939; Saila and Pratt, 1973), after which the non-buoyant egg clusters remain on the bottom until hatching occurs. The young winter flounder tend to remain within embayments during their first year, moving out into more open bay waters during summer months, and returning to spawning areas late in the fall. It is during the fall migration when the young of the species are most vulnerable to predation and fishing.

Winter flounder feed only during the day on a diet consisting primarily of benthic species of polychaetes, bivalves, gastropods and crustaceans. The winter flounder's habit of burrowing into sediments increases its potential exposure to many pollutants compared to mid-water species with the result of higher incidence of fin rot and hepatic carcinomas in areas with high concentrations of industrial organic contaminants such as New Bedford (Gardner, *et al.*, 1989). Pollution, overfishing and loss of important nursery grounds, particularly loss of wetlands, are all anthropogenic activities linked to the decline in this resource (Ursin, 1972).

Alewife (*Alosa pseudoharengus*) - The rivers and tributaries of Weymouth Back River have historically sustained significant populations of alewives. These fish were a staple in the diets of early settlers and their abundance was synonymous with the relative prosperity of coastal Massachusetts towns (Clayton *et al,*. 1978).

The abundance and regularity with which the alewives returned each year resulted in dependence on these fish in many coastal communities, especially when other fisheries declined. The value of the alewife fishery is evidenced by the substantial number of early laws and regulations in the statute books of the Commonwealth of Massachusetts protecting this resource.

However, alewives and other anadromous fish have lost spawning habitat or access to historic spawning grounds throughout Massachusetts due to obstruction of their inland migration paths or impaired water quality. The result has been sharp declines in alewife populations. By 1913, the alewife fishery in Massachusetts had declined 75% from its original levels (Field, 1913) and current levels are lower still.

In northern waters, alewives return to their spawning grounds as many as three to five times during a lifetime, whereas in southern regions they may spawn only once. Spawning migrations to freshwater ponds begin in late April to early May, depending upon water temperature. Eggs of the alewife are broadcast randomly at the spawning site, and larvae spend only their early stages in freshwater ponds, migrating out to the estuaries beginning as early as July and continuing through fall (Cooper, 1961).

Although they do not overwinter in the ponds, some spend the rest of their first year in the estuary before migrating to the sea (Clayton *et al.*, 1978). More recently, alewives have been found to spawn in the brackish waters of coastal salt ponds (up to 8 ppt), increasing their spawning habitat over that previously reported (D. Bourne, personal communication).

Alewives predominantly eat zooplankton, though they have been documented to prey on small fish (Atlantic herring, eel, etc.) and eggs and larvae of other fish while at sea (Collette and Klein-MacPhee, 2002).

Although historically caught by a variety of methods including gill nets, seines and weirs, the largest numbers of alewives are often caught in the spring by nearshore weirs or by directly intercepting the fish on their way upriver to spawn. This was accomplished by stretching nets across rivers and simply scooping the fish into barrels. More recently, precipitous declines in river herring during the 2000's resulted in a Commonwealth-wide moratorium on harvesting river herring.

Blueback Herring (*Alosa aestivalis*) - Often found with alewives (and commercially classified together with alewives as "river herring"), blueback herring are anadromous fish and have suffered similar declining populations as a result of obstructions to herring runs and the effects of pollutants on spawning stocks.

These fish enter brackish waters to spawn in spring, usually by mid-May. Being more salinity tolerant, they have a competitive reproductive advantage over alewives in that the population is not as dependent on only freshwater areas as nurseries (Chittenden, 1972; Clayton, *et al.*, 1978).

Blueback Herring feed primarily the same sources as alewife: copepods (zooplankton), pelagic shrimp, fish eggs and larvae. Both herring and alewives provide an important prey resource for many other species of fish, notably bluefish and striped bass.

Rainbow Smelt (*Osmerus mordax*) – Rainbow smelt are a schooling species of anadromous fish found primarily in nearshore waters. Migrating with seasonal changes in water temperature they travel from coastal waters to freshwater to spawn.

The spawning season begins in early March along Massachusetts Bay, influenced by increasing water temperatures (at approx. 40-42 °F), increasing day length, and the break-up of any ice cover at the spawning grounds. Sections of Fresh River support the fast flowing waters and rocky habitats preferred by these fish for spawning.

At the onset of spawning:

- adults move from more saline estuarine water into fresh or slightly brackish streams where they release eggs and milt, typically during flood tides and at night.
- Adults move back downstream into resting areas in estuaries before sunrise. Most spawning occurs in fast flowing, turbulent water in stream sections dominated by rocks, boulders and aquatic vegetation.
- Fertilized eggs sink and adhere to each other and any material on the stream bottom including aquatic vegetation.
- The larvae move downstream with freshwater currents until reaching estuarine waters.

  - Juveniles then take up residence in the deeper estuarine waters by mid-summer, with both larvae and juveniles feeding on microscopic crustaceans and other zooplankton.
  - Preferring deeper cooler waters in summer, fish return to bays and estuaries in the fall where they feed and reside during the winter months.

Adults feed primarily on small crustaceans and fish, and serve as prey for a wide variety of fish, including bluefish and striped bass, along with a number of birds and mammals.

American Eel (*Anguilla rostrata*) – The American eel is the only catadromous fish in North America, residing in freshwater and migrating to the salt waters of the Atlantic Ocean, specifically the warm waters of the Sargasso Sea between the Azores and West Indies to spawn.

- After laying 20 to 30 million eggs in these salt waters, the females die.
- Eggs take 9 to 10 weeks to hatch, and the larvae spend 9 to 12 months at drifting at sea. After this first juvenile stage (known as "glass eels" because they are transparent), they migrate into coastal estuaries where they grow and begin to develop pigment. During this stage, they reach lengths of 50-90 mm long, are called "elvers", and can be found in estuarine or fresh waters. These develop into sexually immature adults known as yellow eel, and can remain at this stage for as few as three or as many as 20+ years.
- Adult American eels can grow up to 1.5 m long and weigh up to 7 kg.

They are opportunistic scavengers and will eat any kind of small fish or crustacean. Details of their maturation process and predator/prey relationships are not well known. They vary in color depending on their habitat and are generally nocturnal. American eels are important as both an economic and ecological resource and are often caught and sold for food or bait.

Atlantic Silverside (*Menidia menidia*) – The Atlantic silverside is a common fish in North Atlantic estuaries prevalent in brackish waters. A quick swimmer, this fish schools in large numbers, often gathering in eelgrass beds to help protect individuals from predators as well as for spawning. Small (approx. 15 cm long), it eats small animals, worms, shrimp and crustaceans. Its primary predators are larger fish (striped bass, bluefish, rockfish, mackerel) and many shore birds including egrets, terns, cormorants and gulls.

Killifish (*Fundulus* species): Two species of killifish populate the Weymouth Back River Estuary, the mummichog and the striped killifish.

1. Mummichogs (Fundulus heteroclitus) are typically found in muddy marshes, channels, and grass flats along coastal areas. They travel in schools that may contain hundreds of individuals. In fact the name mummichog is derived from a Native American term which means "going in crowds."
2. The striped killifish (*Fundulus majalis*), also known as the striped mummichog, is frequently found in shallow coastal waters close to shore, rarely straying far from the shoreline. They feed in salt marshes on phytoplankton, mollusks,

crustaceans, mosquito larvae, and dead fish. Often stranded in tidal pools, they are known to "flop" across sandy barriers to reach open water.

Both species of killifish are a popular bait fish among recreational anglers. They are hardy, able to tolerate a wide range of salinities and periods of low oxygen levels. Although similar in most respects, there are a few differences between the species. The head of the striped killifish is slightly longer and thinner and the body slightly larger than the mummichog. The male striped killifish becomes brilliantly colored during the breeding season with orange sides, black back and bright yellow fins. Mummichogs also exhibit an intensification of color during the breeding season but not to this extent.

Northern Pipefish (*Syngnathus fuscus*) – Related to seahorses, the male northern pipefish has a brood pouch where the female deposits her eggs, they are fertilized by the male and carried for roughly ten days. Although they can grow up to a foot, most are considerably smaller. They feed primarily on copepods, small amphipods, fish eggs and larvae.

Northern pipefish can often be found in marshes, estuaries and harbors and particularly in eelgrass beds of nearshore shallow waters. They are tolerant of a wide range of salinities from estuarine to brackish waters.

Striped Bass (*Morone saxatilis*) – Striped bass is another anadromous fish that is primarily a nearshore and brackish water species except during migrations. Chesapeake Bay is the primary spawning ground for most of the striped bass along the East Coast and young remain in their natal estuary until about two years old.

Although primarily a summer resident, some overwintering bass have been reported in southern Massachusetts rivers. Like bluefish, they are voracious feeders, consuming both fish and invertebrates including herring, smelt, hake, squid, crabs, lobsters and polychaetes. It can be found in the Weymouth Back River Estuary (On the Water Magazine, May 13 2010) and represents one of the most important recreational fishery species in southeastern Massachusetts.

Atlantic Menhaden (*Brevoortia tyrannus*) - Although accounting for the largest portion of the United States catch, this fish is primarily used for fish meal and oils rather than direct human consumption. Menhaden populations are often variable; no commercial landings were recorded from 1963-1968 in New England (Moss and Hoff, 1989). Their speed and schooling behavior makes quantitative assessment difficult, especially since catches are generally from seines.

They spawn both at sea and in inshore waters generally between April and October with maximum abundance generally occurring in late summer when juveniles are prevalent. Juveniles and adults feed primarily on filtered phytoplankton from the upper water column.

Menhaden are considered an important prey species for most carnivorous marine fish, with a large population biomass seasonally concentrated in shallow waters.

Black Sea Bass (*Centropristis striata*) - This fish is a summer visitor, migrating inshore in spring and offshore to deeper waters in late fall. The diet of adults consists of crustaceans, fish and molluscs. Juvenile black sea bass utilize bays and estuaries as a nursery ground and, as bottom feeders, eat primarily mysids in the shallow areas. Black sea bass are born as females, transforming into males after their first spawning. As a result, females tend to predominate due to their high percentage in young age classes. In contrast, recreational catch consists primarily of males, their larger size making them sought after by sport fishermen. The selective recreational catch may impact populations by altering sex ratios and decreasing the number of males available for reproduction (Davis, 1989).

Bluefish (*Pomatomus saltatrix*) - Seasonal migrations of bluefish represent an important recreational and commercial fishery during summer months. Although spawning offshore, juveniles (known as "snapper blues") move in large numbers into the warmer inshore waters of bays and estuaries.

These fish are voracious feeders, consuming a wide variety of fish and invertebrates in the water column. Mackerel, menhaden, alewives, herring and weakfish as well as shrimp, lobster, squid, crabs, mysids and annelid worms are all part of the bluefish's diet. Because of their efficiency as a predator, bluefish were frequently blamed for decreases in other fish species within nearby Buzzard’s Bay waters (Baird, 1873; Belding, 1916). The abundance of juveniles in shallow nearshore waters also provides an important source of prey for other species.

Large fluctuations in bluefish populations occur from year to year, attributable more to environmental factors than human disturbances. The value of the recreational fishery, primarily surf-casting, party boat and individual hook and line fishing, is estimated to exceed that for the commercial fishery along the Mid-Atlantic (Saila and Pratt, 1973).

Bluefish have been a consistently important food fishery for at least the past 100 years with the juveniles exploiting prey in wetlands and embayments and the adults feeding upon the abundant larger prey species.

Many species prevalent in the Weymouth Back River Estuary are dependent on the brackish waters, found in the many tidal wetlands bordering the system, as spawning areas and, more often, as nursery habitat and feeding areas. Many of the species discussed above are predatory, exploiting fish and animal populations in wetlands during early stages of growth. Shrimp and menhaden, although the young are spawned at sea, often seek out these brackish waters as nursery grounds during their developmental stages, growing on the abundance of organic material provided in these systems.

Tidal wetlands are temporary or permanent homes to many other species of fish as well. Mummichog, killifish, silversides, and four-spined sticklebacks abound in estuarine salt marshes; other species such as alewives, Atlantic menhaden, tautog, sea bass, winter flounder and three-spined sticklebacks are only seasonal visitors, but their residence period in these marshes represents a very important stage in their life cycles. The species discussed above are not comprehensive, but are the primary species that have been identified in past studies

4.2.3 Avian Fauna

The wide diversity of habitats within the Weymouth Back River Estuary system allows in turn for a diverse population of birds (Table 4-2).

Table 4-2. Birds of the Weymouth Back River region

Snowy Egret (*Egretta thula*)
Great Egret (*Ardea albus*)
Cattle Egret (*Bubulcus ibis*)
Ring-necked Pheasant (*Phasianus colchicus*)
American Woodcock (*Scolopax minor*)
Bobwhite Quail (*Colinus virginianus*)
Belted Kingfisher (*Megaceryle alcyon*)
Osprey (*Pandion haliaetus*)
Great Horned Owl (*Bubo virginianus*)
American Kestrel (*Falco sparverius*)
Northern Harrier (*Circus cyaneus*)
Sharp Skinned Hawk (*Accipter Striatus*)
Loggerhead Shrike (*Lanius ludovicianus*)
Turkey Vulture (*Cathartes aura*)
Herring Gull (*Larus argentatus*)
Greater Black-backed Gull (*Larus marinus*)
Mallard duck (*Anas platyrhynchos*)
American Black Duck (*Anas rubripes*)
Hooded Merganser (*Lophodytes cucullatus*)
Goldeneye (*Bucephala clangula*)
Bufflehead (*Bucephala albeola*)
Canada Goose (*Branta canadensis*)
Northern Cardinal (*Cardinalis cardinalis*)
American Robin (*Turdus migratorius*)
Blue Jay (*Cyanocitta cristata*)
American Crow (*Corvus brachyrhynchos*)
Pine Siskin (*Carduelis pinus*)
Evening Grosbeak (*Coccothraustes vespertinus*)
American Redstart (*Setophaga ruticilla*)
Yellow Warbler (*Dendroica petechia*)
Great Crested Flycatcher (*Myiarchus crinitus*)
Prairie Warbler (*Dendroica discolor*)
Yellow-rumped Warbler (Dendroica coronata).
Black-throated Green Warbler (*Dendroica virens*)
Brown Trasher (*Toxostoma rufum*)
Downy Woodpecker (*Picoides pubescens*)
Yellow-shafted Flicker (*Colaptes auratus*)
Water Thrush (*Seiurus motacilla*)
Song Sparrow (*Melospiza melodia*)
American Goldfinch (*Spinus tristis*)
Field Sparrow (*Spizella pusilla*)
House Wren (*Troglodytes aedon*)
Cedar Waxwing (*Bombycilla cedrorum*)
Slate-colored Junco (*Hyemalis cismontanus*)
Tufted Titmouse (*Baeolophus bicolor*)
Black-capped Chicadee (*Parus atricapillus*)
Phoebe (*Sayornis phoebe*)
Cliff Swallow (*Petrochelidon pyrrhonota*)
Chimney Swift (*Chaetura pelagica*)
Baltimore Oriole (*Icterus galbula*)
Catbird (*Dumetella carolinensis*)
Scarlet Tanager (*Piranga olivacea*)
Mourning Dove (*Zenaidura macroura*)
Rufous-Sided Towhee (*Pipilo erythrophthalmus*)
Common Grackle (*Quiscalus quiscula*)
European Starling (*European Starling*)
American Bittern (*American Bittern*)
Glossy Ibis (*Plegadis falcinellus*)
Great Blue Heron (*Ardea herodias*)
Black-crowned Night Heron (*Nycticorax nycticorax*)
Double-crested Cormorant (*Phalacrocorax auritus*)
European Cormorant (*Phalacrocorax carbo*)
Common Loon (*Gavia immer*)
Common Tern (*Sterna hirundo*)
Red Tail Hawk (*Buteo jamaicensis*)

From Inventory of Natural Resources and Land Use in the Weymouth Back River ACEC 1997.

The system provides breeding or feeding habitat to some 150 different species (Myers, 1997) Marine and estuarine birds harvest the aquatic resources of open waters, intertidal marshes and mudflats along with various terrestrial species which opportunistically feed within intertidal areas.

4.2.4 Mammals, Amphibians and Reptiles

The Back River and the Back River watershed provide habitat for a wide variety of mammals, reptiles and Amphibians. They utilize the many resources in the watershed for food, nesting, and breeding. Table 4-3 below is list of known mammals, reptiles and amphibians in the Weymouth Back River region.

Table 4-3. Mammals, Reptiles and Amphibians of the Weymouth Back River region (from Inventory of Natural Resources and Land Use in the Weymouth Back River ACEC 1997)

Mammals
Red Squirrel
Grey Squirrel
Northern Flying Squirrel
Raccoon
Woodchuck
Red Fox
Muskrat
Opossum
Eastern Cottontail
Eastern Chipmunk
Short-tailed Shrew
White-footed Mouse
Little Brown Myotis
Big Brown Bat
Meadow Vole
Striped Skunk
Short tail Weasel

Reptiles and Amphibians
Northern Spring Peeper
Green Frog
Bullfrog
Wood Frog
Northern Leopard Frog
American Toad
Eastern Garter Snake
Black Rat Snake
Northern Water Snake
Spotted Salamander
Red Backed Salamander
Eastern Box Turtle
Wood Turtle
Ambystoma opacum Marbled Salamander

Several species are State listed species of concern and are protected (Table 4-4).

Table 4-4. State Listed Species of Concern in the Weymouth Back River Region 2010 (Natural Heritage & Endangered Species Program (NHESP), Massachusetts Division of Fish and Game)

Category	**Species**	**Common Name**	**Status**
Amphibian	*Ambystoma laterale*	Blue-spotted Salamander	Special Concern
Amphibian	*Ambystoma opacum*	Marbled Salamander	Threatened
Reptile	*Terrapene carolina*	Eastern Box Turtle	Special Concern
Reptile	*Glyptemys insculpta*	Wood Turtle	Special Concern
Bird	*Bartramia longicauda*	Upland Sandpiper	Endangered
Bird	*Podilymbus podiceps*	Pied-billed Grebe	Endangered

Bird	*Sterna hirundo*	Common Tern	Special Concern
Bird	*Tyto alba*	Barn Owl	Special Concern
Bird	*Ammodramus savannarum*	Grasshopper Sparrow	Threatened
Bird	*Circus cyaneus*	Northern Harrier	Threatened
Bird	*Asio flammeus*	Short-Eared Owl	Endangered
Butterfly/Moth	*Callophrys hesseli*	Hessel's Hairstreak	Special Concern
Butterfly/Moth	*Spartiniphaga inops*	Spartina Borer Moth	Special Concern
Dragonfly/Damselfly	*Anax longipes*	Comet Darner	Special Concern
Dragonfly/Damselfly	*Enallagma laterale*	New England Bluet	Special Concern
Dragonfly/Damselfly	*Somatochlora linearis*	Mocha Emerald	Special Concern
Fish	*Notropis bifrenatus*	Bridle Shiner	Special Concern
Mussel	*Ligumia nasuta*	Eastern Pondmussel	Special Concern
Vascular Plant	*Asclepias purpurascens*	Purple Milkweed	Endangered
Vascular Plant	*Bidens hyperborea*	Estuary Beggar-ticks	Endangered
Vascular Plant	*Eriocaulon parkeri*	Parker's Pipewort	Endangered
Vascular Plant	*Houstonia longifolia*	Long-leaved Bluet	Endangered
Vascular Plant	*Lycopus rubellus*	Gypsywort	Endangered
Vascular Plant	*Senna hebecarpa*	Wild Senna	Endangered
Vascular Plant	*Ranunculus micranthus*	Tiny-flowered Buttercup	Endangered
Vascular Plant	*Triosteum perfoliatum*	Broad Tinker's-weed	Endangered
Vascular Plant	*Conioselinum chinense*	Hemlock Parsley	Special Concern
Vascular Plant	*Panicum philadelphicum ssp. philadelphicum*	Philadelphia Panic-grass	Special Concern
Vascular Plant	*Ranunculus pensylvanicus*	Bristly Buttercup	Special Concern
Vascular Plant	*Sabatia kennedyana*	Plymouth Gentian	Special Concern
Vascular Plant	*Aristida tuberculosa*	Seabeach Needlegrass	Threatened
Vascular Plant	*Platanthera flava var. herbiola*	Pale Green Orchis	Threatened
Vascular Plant	*Rumex verticillatus*	Swamp Dock	Threatened
Vascular Plant	*Asclepias verticillata*	Linear-leaved Milkweed	Threatened
Vascular Plant	*Ophioglossum pusillum*	Adder's-tongue Fern	Threatened
Vascular Plant	*Rumex pallidus*	Seabeach Dock	Threatened

4.3 Unique and Threatened Habitats

4.3.1 Anadromous Fish Runs

As mentioned above, anadromous fish runs are an important component of the fisheries of the Weymouth Back River Estuary. Streams linking marine and fresh water bodies provide runs for several species of fish that grow to maturity in the ocean and migrate to freshwater to spawn.

Living primarily in salt water, anadromous fish such as alewives (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), white perch (*Morone americana*), and rainbow smelt (*Osmerus mordax*) migrate up tidal streams to brackish and freshwater systems where after spawning, the fry hatch and eventually return to the sea.

Except for rainbow smelt which migrate from February through April, migration of the other species begins in April (when the water temperatures of inland rivers and streams begin to warm up relative to colder waters offshore) and generally continues into June.

Anadromous fish typically return to the place where they were hatched, although it is not entirely clear how they identify any particular stream except perhaps for the unique water chemistry which may be associated with one area versus another. Anadromous fish runs within the Weymouth Back River Estuary include the Herring Run Brook and Fresh River.

- Herring Brook has an annual herring run with six fish ladders along the journey from the Weymouth Back River to Whitman's Pond.
- Fresh River has runs of both eel and smelt. Five smelt breeding areas have been identified, two in Hingham, and three in Weymouth (Henderson Planning Group, 1988).

4.3.2 Vernal Pools

Vernal pools are seasonal bodies of freshwater that provide an important predator-free breeding habitat for animals such as amphibians and invertebrates. They generally appear in the spring with the onset of snow melt and the rainy season, and then disappear during the drier summer months.

There are numerous vernal pools throughout the Weymouth Back River watershed (see Figure 4-5). Vernal pools are wetlands protected under the Massachusetts Wetlands Protection Act and regulations (310 CMR 10), and local wetland regulations, but because of their temporary nature may be difficult to identify.

Given their importance as a breeding habitat for many threatened and endangered species, the Natural Heritage & Endangered Species Program (NHESP) administers a program to "certify" vernal pools to ensure they are properly identified and protected. Certification is based on an evaluation of the species present in a prospective vernal pool. Certified vernal pools in the Back River watershed are mostly located in three clusters: 1) near Weymouth Great Pond, 2) in the upper reaches of Old Swamp River, and 3) near Fresh River (see Figure 4-5). Potential vernal pools, where species have not been confirmed by NHESP, are located throughout the watershed.

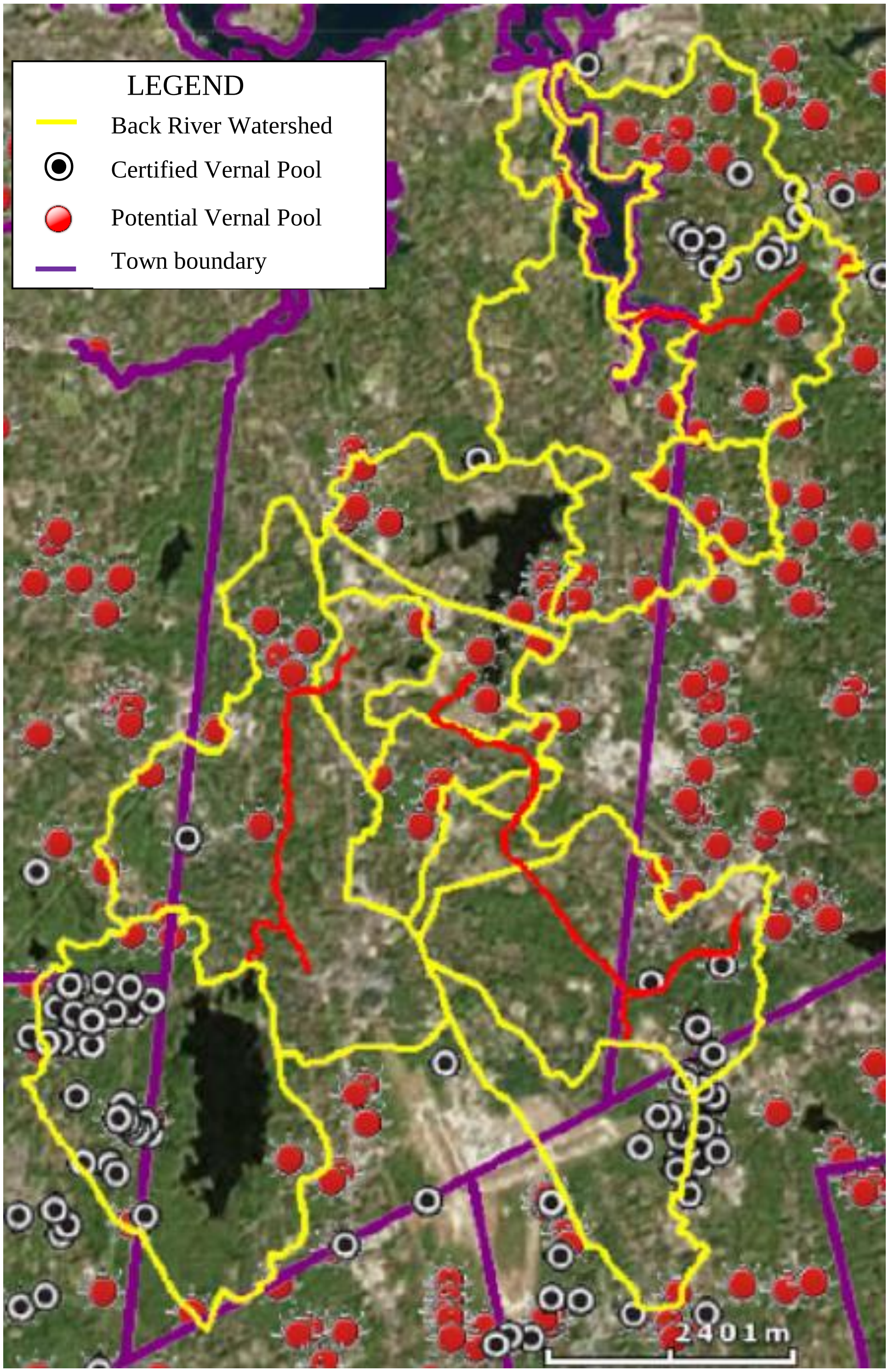


Figure 4-5. Vernal Pools of the Weymouth Back River area. Certified vernal pools are clustered in three areas: 1) near Weymouth Great Pond, 2) in the upper reaches of Old Swamp River, and 3) near Fresh River (shown with the black and white circle). Potential vernal pools are located throughout the watershed (shown with the red dot). Both certified and potential vernal pool datasets are from Natural Heritage & Endangered Species Program via MassGIS (updated 5/15 and 7/13, respectively).

4.3.3 Threatened and Endangered Species

Habitats change due to alterations in the either the physical surroundings or the flow of nutrients or energy within an ecosystem. Human alterations can rapidly alter habitats or accelerate natural changes that typically occur over thousands of years.

NHESP has identified a number of species of special concern, threatened or endangered within the Weymouth Back River region (see Table 4-4). NHESP has also documented the habitat ranges for these species (*i.e.*, Priority Habitats), as well as likely habitats based on species behavior (*i.e.*, Estimated Habitats) (Figure 4-6).

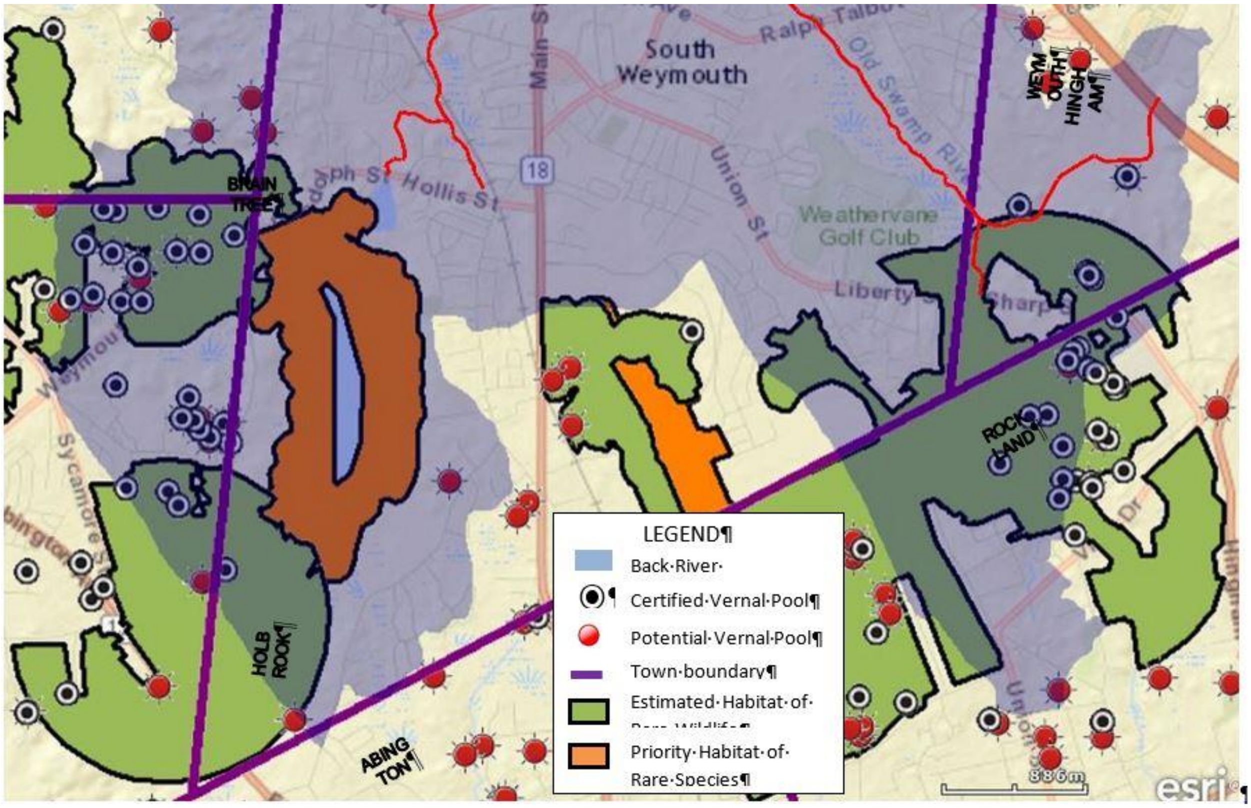


Figure 4-6. NHESP Habitats in Weymouth Back River watershed. Natural Heritage & Endangered Species Program (NHESP) priority habitats (shown in orange) are based on documented observations of rare species, while estimated habitats use known rare species behaviors, such as breeding ranges and favored habitat types to extend the documented observations to adjacent areas that share these characteristics (shown in green). Rare and estimated habitats in this area generally overlap, so all estimated areas are also priority areas. These NHESP habitats are only located in the upper reaches of the Back River watershed. Both estimated and priority habitat spatial datasets are from Natural Heritage & Endangered Species Program via MassGIS (updated 7/13 and 3/09, respectively

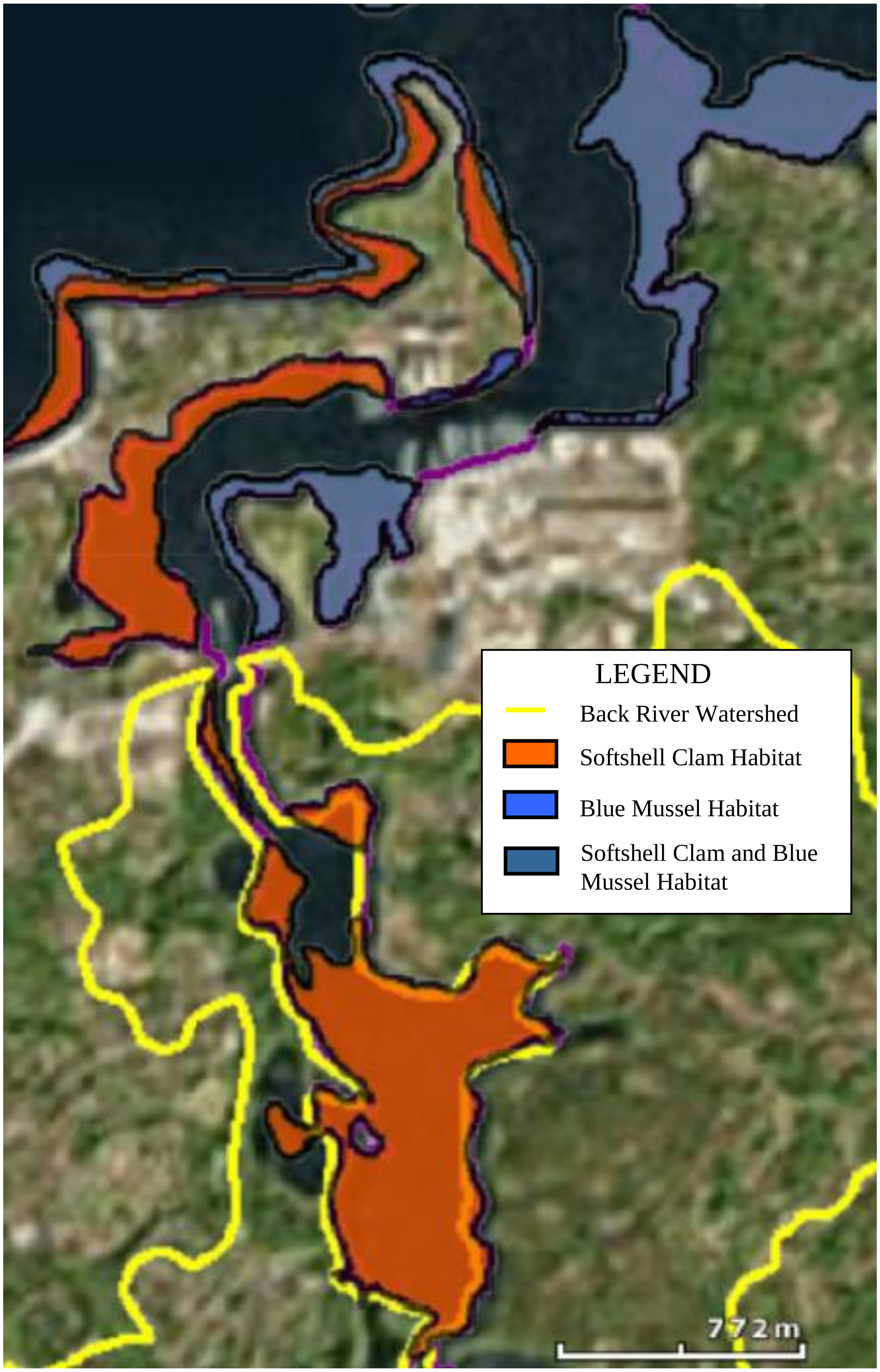


Figure 4-7. Massachusetts Division Marine Fisheries Shellfish Suitability Areas. Areas suitable for indicated species of shellfish (soft shell clam and blue mussel) are based on DMF and local Shellfish Constables expertise, input from commercial fishermen, and information contained in maps and studies of shellfish in Massachusetts. Areas based on DMF GIS coverage available from MassGIS (accessed 2/18/16; last updated 5/11). These layers should be used as guidance; habitat alterations can cause fluctuations in the location of preferred habitats.

Species relying on particular habitats may lose their role in the overall function of an ecosystem and this can ripple through the rest of the ecosystem, changing many other associated habitats and species interactions including:

1. altering or eliminating predatory and prey relationships
2. shifting the balance between aquatic plant communities from phytoplankton to rooted plants,
3. increasing organic loading to sediments.

Identifying species changes is a primary way of identifying impacts on overall ecosystems. Most states and the federal government have regulatory programs that identify threatened or endangered species. Massachusetts has such a program administered through the Natural Heritage & Endangered Species Program (NHESP).

The Ecology of the Weymouth Back River

CHAPTER 5: Land Use, Economy and Fisheries

5.1 Introduction

Water quality and ecosystem function in any surface water system (*e.g.*, estuary, river, pond) are a function of the physical characteristics of the system (*e.g.*, depth, area) and the watershed that is attached to the system.

Watersheds add water to the surface water and carried with that water are nutrients and other contaminants that reflect the characteristics of the watershed. Adding additional complexities to the relationship between surface water and its watershed is how the watershed land use changes over time; contaminants can be added, and then retained by the system sediments, even though the land use source has been replaced by a different land use.

Contaminants can be from a variety of sources and some can be crucial for healthy ecosystem function at some level and then exceed that level and fundamentally harm the ecosystem. Nutrients such as nitrogen and phosphorus are necessary to feed the phytoplankton and other aquatic plants that are the base of surface water food chains, but too much can result in excessive organic material in the sediments, high oxygen demand, and loss of fish and shellfish habitat. Other contaminants, such as oils and other hydrocarbons, can impact the survival of specific species such that whole portions of the ecosystem will be diminished.

Watershed pollutants enter aquatic ecosystems at both:

- easily identifiable point sources such as outfall pipes and sewer overflows,
- and at more diffuse non-point sources such as septic system flows, stormwater runoff, and excessive agricultural and landscape fertilizers.

Non-point sources are especially difficult to identify and quantify, yet they often have significant and longer-lasting impacts on aquatic ecosystems, equal to or greater than the more easily identifiable point sources.

The variety of pollutants from a watershed is usually correlated with the variety of land use types with the watershed. Therefore, it is useful to look at the variety of land uses of the communities within a particular watershed as well as general economic characteristics of these communities to better understand the general environmental impacts and, particularly the sources and patterns of pollution there.

5.2 Land Use History

5.2.1 Town Foundings

Historical evaluations of early New England life largely rely on materials written by European explorers of the area, but it is clear that Native Americans greeted those explorers. Algonquans tribes of the area tended to live semi-nomadic lives relying on slash-and-burn agriculture (corn, beans, squash) that kept villages in an area for a few years before moving to another. Hunting followed plentiful populations, but also significantly utilized fishing, shellfishing, and large sea mammals, such as seals and whales.

The Boston Harbor-Weymouth Back River area was first explored by European explorers beginning in the late 1400's, but some archeological evidence also suggests that Vikings made voyages to the area (at least to Newfoundland) much earlier.

John Cabot, an Italian (also known as Giovanni Caboto) sailing under commission for Henry VII of England, was the first of the recorded voyages to New England region during 1497 and 1498. His initial intent was to find a Northwest Passage around North America to the Pacific Ocean for commerce, but instead came back with reports of a huge potential cod fishery, probably near the Grand Banks. His later exploration took him along the New England coast possibly as far south as the Chesapeake Bay.

Giovanni da Verrazzano, an Italian explorer sailing with support from King Francis I of France in 1524, also set sail to discover a Northwest Passage, as well to claim lands in North America for France. Verrazzano first landed in North America in Cape Fear in what is now North Carolina and sailed north along the coast to the Hudson River, Narragansett Bay, Cape Cod, Maine and finally Newfoundland. The first surviving maps of the New England coast stemmed from these voyages (Figure 5-1).

Bartholomew Gosnold, an English explorer, sailed to Maine in 1602, then turned south, famously sailing into Provincetown Harbor in 1602, naming Martha's Vineyard after his daughter, and establishing a small settlement on Cuttyhunk Island, which is now part of the Town of Gosnold (all of the Elizabeth Island off the southwest Cape Cod). Gosnold is also credited with naming Cape Cod, based on catches of cod so plentiful that the excess had to be thrown overboard (Clemensen, 1979). He provided a more refined map of the region north of Rhode Island and the chronicles of abundant resources and peaceful encounters with natives prompted more exploratory voyages (*e.g.,* Brereton, 1602).

These voyages included trips:

- seeking the Northwest Passage (*e.g.,* 11 voyages of Samuel de Champlain),
- chronicling resources for future commercial endeavors, and
- national claims of the lands.

One of the more notable voyages was the 1605 trip of George Weymouth, who sailed for the recently formed East Indian Company, explored the Maine Coast and Cape Cod, and kidnapped some Patuxet natives, including Tisquantum (Squanto), whose insights and understanding of English would later be crucial for the survival of the Plymouth Pilgrim colony during their first winter in 1620.

Figure 5-1. New England section of 1527 map by Visconte Maggiolo. Maggiolo supposedly developed this map based on Giovanni da Verrazzano's voyage in 1524. Shown near the top is "Lavoradore" (Labrador). Original map has Labrador at the bottom, so some of the text is upside down. Modified from digital image of map from Ambrosian Library in Milan. Map is in the public domain and available through Wikipedia (https://en.wikipedia.org/wiki/File:1527-TeraFlorida.jpg).

This rapid sequence of explorers from multiple countries increased interest in the New World and accelerated the move toward deeper explorations and colonization, particularly of New England and Massachusetts.

Among the most noted early European explorations of the Boston Harbor region are those of Captain John Smith. Smith is probably most famous for his part in the establishment of the Jamestown settlement in Virginia and how Pocahontas, a chief's daughter, saved his life, but he also named the area of Massachusetts, New Hampshire, and Maine, "New England" based on voyages to the region in 1614. His map based on those voyages is among the most widely distributed and the use of English place names are retained in many areas to present (Figure 5-2).

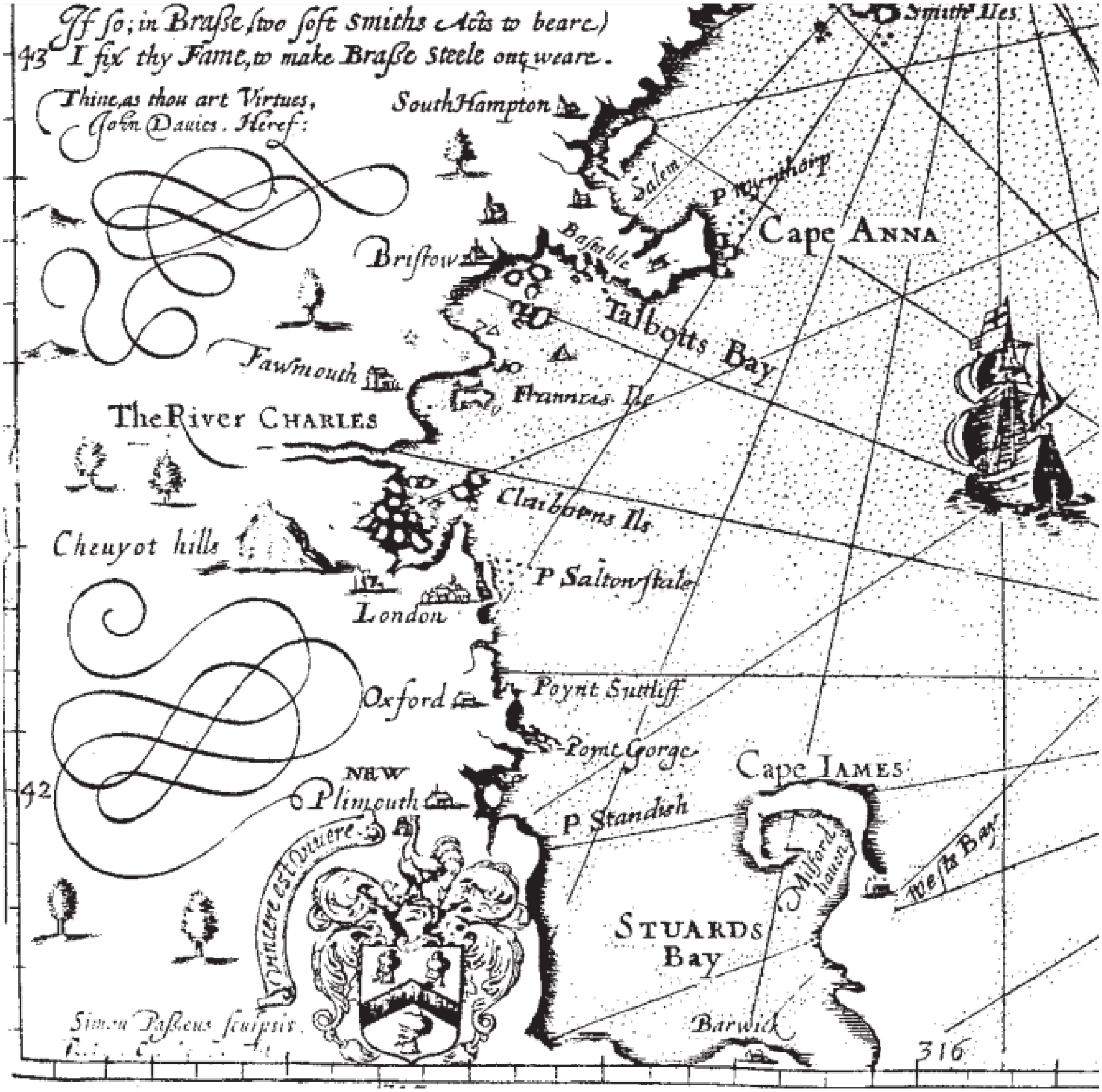


Figure 5-2. Massachusetts section of 1616 map by John Smith. This map is based on Smith's voyages to the area in 1614 and was published to accompany the publishing of his book: *A description of New England, or, Observations and discoveries in the north of America in the year of Our Lord 1614, with the success of six ships that went the next year, 1615.* This map includes the first naming of the area as "New England" and the addition of English place names, some of which endure today. Modified from digital image of map from University of Nebraska Lincoln, Digital Commons.

His description of the voyages was accompanied by a call to exploit the areas resources for fishing, farming, ship building and fur trading and he argued forcefully for the English settlement and colonization of the area. Included in his 1616 map was a fictitious town labeled "New Plimouth"; his map was carried by the Pilgrims on the Mayflower in 1620 when they landed and adopted the name for their own colony (Blanding, 2014).

The Back River area was first colonized in April, 1622 by Thomas Weston, a London merchant with the intent to establish a profitable plantation. The colony, often called the Wessagusset or Weston colony, included between fifty and sixty men with no colonial experience and inadequate provisions (Adams and Nash, 1905).The colony fort was placed on the east side of Kings Cove off the Fore River (Figure 5-3).

Figure 5-3. Current aerial photograph of area of initial 1622 Wessagusset colony and subsequent 1623 Weymouth colony. The initial Wessagusset colony established their settlement north of Kings Cove, while the Weymouth colony was established nearby, but somewhat further inland.

The lack of provisions led colonists to begin stealing from both the Plymouth colony to the south and the local natives, working for the natives building canoes, and, eventually, a proposed joint attack on the natives with the Plymouth colony. This proposal was rejected, but a warning from a local sachem about a planned native attack against both colonies eventually led to Plymouth sending soldiers under Miles Standish to help defend the Wessagusset colony.

After Standish and his soldiers killed several of the native leaders, the colony disbanded in the spring of 1623 with survivors either joining the Plymouth colony or returning to England. The events surrounding this colony damaged relations between the natives and the colonists for years.

While the Wessagusset colony was failing, the Plymouth Council for New England granted Robert Gorges, son of the colonial governor of Maine, a patent for a new settlement within an area of 10 miles of coast and 30 miles inland including the entrance to Boston Harbor (Nash, 1885) and commissioned him as Governor-General with authority over both his new colony and Plymouth (Adams and Nash, 1905).

Gorges intended to establish a permanent colony supported by the Church of England and arrived with families in August 1623. His settlement was further inland from the first colony, generally located between Great Hill and Mill Cove in current Weymouth. (Town of Weymouth, 2014).

The colony was, however, quickly abandoned by Gorges in the spring of 1624 due to financial difficulties. Several families remained, however, and were supported by Plymouth until Wessagusset became part of the Massachusetts Bay Colony in 1630. At that time, approximately 300 people were living in and around the colony settlement (Town of Weymouth website) with a variety of Protestant sects, including Puritans from Boston, Pilgrims from Plymouth, Quakers, Baptists, and Episcopalians from the Church of England. Religious disagreements often led to people moving among various communities/settlements.

In 1635, Reverend Joseph Hull arrived from Weymouth, England with 21 families (roughly 100 people) and the colony was officially established as a "plantation" (roughly equivalent to incorporating as a town) and the plantation was named "Weymouth" (Nash, 1885). By 1639, when Hull left the area for Cape Cod, there were about 150 families (900 people) in the town.

During this time, ferries had been built connecting Weymouth with neighbors and bridges were being built to better facilitate inland travel (Nash, 1885). Mills had also been built along streams for various activities, though some evidence exists that tidal movements were also used to power early mills (Forman, 1970).

Most of the population lived in North Weymouth, though plantations extended from the shore to King Oak Hill and Whitman's Pond. Most houses were built of logs with "coarse grass found at the head of beaches above the salt water" (Nash, 1885). In 1642, the land title to the town was purchased from the natives. In 1652, two thousand areas running from Hingham to Braintree were established as town commons.

Between 1635 and 1636, commissioners were appointed to establish boundaries between Weymouth and the Plymouth Colony and Bare Cove, which would eventually become Hingham (Nash, 1885). Hingham was first settled in 1633. Most of the settlers were from East Anglia and were escaping religious persecution with their Puritan leaders: Rev. Peter Hobart, who arrived in 1635, and Rev. Robert Peck, who emigrated with additional settlers in 1638.

In 1635 the Town was incorporated as Hingham, named after the town in East Anglia where many of the settlers had originated, although the land was not purchased from the natives until 1665. By 1640 there were about 200 inhabitants. In 1770, part of Hingham known as the Second Parish split from the town and incorporated as the Town of Cohasset, from an Algonquin word, "conahasset" meaning "long rocky place".

The Town of Braintree was first settled in 1625 when Thomas Morton and a Captain Wollaston from Plymouth colonized the area around what is now the Merrymount section of Quincy near Black's Creek. Braintree was incorporated in 1640 and included at the time the present City of Quincy, the Town of Randolph and parts of the Town of Milton. Portions of the Town of Braintree separated in 1793 to form the Town of Randolph. In 1872, East Randolph separated from the Town of Randolph and incorporated as the Town of Holbrook.

Abington was originally part of the Town of Bridgewater and incorporated as a town by order of the General Court of Massachusetts Bay in 1712. The Town of Rockland was split off from Abington in 1874. Norwell was first settled in 1634 as a part of the town of Scituate. It was incorporated in 1849 as South Scituate and changed its name to Norwell in 1888.

5.2.2 Economic and Demographic History

Economic activity in the Back River watershed has gone through a series of transitions that mirror national historic trends. Early economic activity focused on utilization of natural resources. This was followed by a transition to more industrial activities, and then to the more service-oriented economy we have today.

The early economy of the Back River watershed focused on farming, hunting and fishing, mostly within the town boundaries. Crops, including corn, wheat, rye, and oats, and dairy products like butter and cheese were produced, consumed within the town, and traded with nearby colonies, towns and natives.

- Corn, often called "Indian corn', was the primary grain grown in the initial settlements.
- Rye began to supplement corn in the mid-1700's to make firmer bread (Hamilton, 1951).

Initial efforts to fully capitalize on the natural resources were thought to be somewhat thwarted by the inability to get boats larger than canoes into the interior portions of the Weir River and Back River, to transport pelts, timber, and other goods to the colony settlement as compared to the opportunities afforded by the larger size of the Charles River (Weymouth Historical Society, 1923).

5.2.2.1 Natural Resources

Fishing provided a significant portion of the early food supply for Weymouth and other towns in the area. The earliest mention of a herring run in Town of Weymouth records is 1648, suggesting that herring were an important food source from the beginning of the colony (Nash, 1885).

As early as 1637, two years after Weymouth and Hingham were incorporated, towns recognized the potential economic importance of this fishery and the first leases for fishing rights were granted by Hingham on the Weir River (then called Lyford's River).

In 1724, Weymouth town records showed that the mills had likely restricted herring spawning enough for the town to establish an alewife committee to charge mill owners to allow "convenient passage for fish into Whitman's Pond" (Nash, 1885). Fishing rights in the Back River were sold or leased and fish caught were purchased by the town and resold to raise money for the school system.

- By the late-1800s, the Back River had only a limited alewife fishery; in 1912, only 50 barrels of alewives were harvested.
- The state-wide alewife fishery value peaked in 1888 with 6,291,931 pounds caught for a value of $83,530 ($2.0 million in 2015 dollars).
- By 1908, the state-wide fishery had dropped to 4,062,000 pounds caught for a value of $45,000 ($1.1 million in 2015 dollars)[2].

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[2] All dollar amounts in this chapter are contemporary; 2015 estimates based on US Bureau of Labor Statistics Consumer Price Index and pre-Consumer Price Index inflation estimates by Robert Sahr, Oregon State University

Unlike the local natives, who relied heavily on them as a food source, soft shell clams (*Mya arenaria*) were not a large part of the diet of the early settlers and were used mostly as a supplement when other foods were scarce. Their popularity as a bait source grew during the early 19th century and the Boston Harbor region was one of the more productive areas (*i.e.*, the north shore from Gloucester to Newburyport was the largest and most productive region of coastal Massachusetts for soft shell clams).

By the latter half of the century, soft shell clams had also become important as a commercial food source due to the creation of inland markets.

- In 1888, over 240,000 bushels of clams had been taken from all areas of the Massachusetts coast for a value of nearly $128,000 ($3.1 million in 2015 dollars).
- By 1905, the value of the fishery had increased so that the 217,500 bushels harvested were worth almost twice the value of the 1888 catch at $209,545 ($5.4 million in 2015 dollars).

Clam harvests also declined in the Back River as the alewife fishery declined. The Boston Harbor region was among those areas remaining with potential for productive clam harvesting, but pollution from sewage had closed these areas, stopping all harvest for human consumption.

It was not until 1930 when a depuration (or purification) plant[3] was built in Newburyport that commercial clamming resumed, but only by Master Diggers. A Master Digger is licensed by the Massachusetts Department of Environmental Protection to harvest and transport contaminated shellfish for depuration. In 1970, Weymouth and Hingham produced over 1,000 bushels of soft shell clams from the Hingham Bay area flats which were transported to Newburyport for depuration.

Historic records first make note of a mackerel fishery in Hingham in 1752. The fishery grew to reach its peak in 1831. Several supporting industries grew around the fishery for ship's hardware, chandlery, and cordage.

- After 1831 the fishery began to decline, although the catch value continued to increase until 1855.
- In 1831 there were 61 vessels in the region that harvested over 50,000 barrels of fish for sale, either fresh or salted.
- By 1865 there were only 10 vessels with a combined catch of slightly over 8,000 barrels.
- By 1875, the mackerel fishery had disappeared.

5.2.2.2 Industrial Activities

By the time of the American Revolution, lumber, milling and shipbuilding had expanded and shoemaking continued to be a major part of the industry and commerce in the Back River region.

The population of the area by then had increased to about 3,500 as industries grew and recruited workers. Other industrial activity in the area has included:

- fertilizer production,
- ice harvesting,

(http://liberalarts.oregonstate.edu/spp/polisci/research/inflation-conversion-factors-convert-dollars-1774-estimated-2024-dollars-recent-year).

[3] A shellfish depuration facility for shellfish contaminated with sewage bacteria is designed to hold shellfish in clean water for a sufficient period to allow the bacteria to be purged or die to bring levels in the shellfish into the acceptable range. Depuration can also be done in clean natural waters by transferring the shellfish, often for extended periods.

- iron works,
- textiles,
- and some mining.

Mills were constructed to provide grain grinding (grist mills), creating timber (saw mills), and power for various industrial activities. In 1640, a grist mill and saw mill were built at the outlet of Whitman's Pond by William Waltham. At tidal grist mill was also built on Mill Cove in 1669.

Products were produced primarily for local use.

- Salt was produced by evaporation on a large scale starting in 1635 and bog iron was found in 1645 (MHC, 1979).
- Bog iron is typically formed by anaerobic bacteria concentrating dissolved iron into pellets and can be found around ponds, lakes and streams.
- Some local shipbuilding also occurred during these early years on the Fore River.

In 1693, Gideon Tirrell establishes Weymouth's first wool mill near Washington and Middle Streets along the Mill River near the current site of the Stop & Shop/Walmart plaza. In 1697, Weymouth's first tannery was established. There was some tanning and leather goods production for export to Boston, including a growing shoe industry.

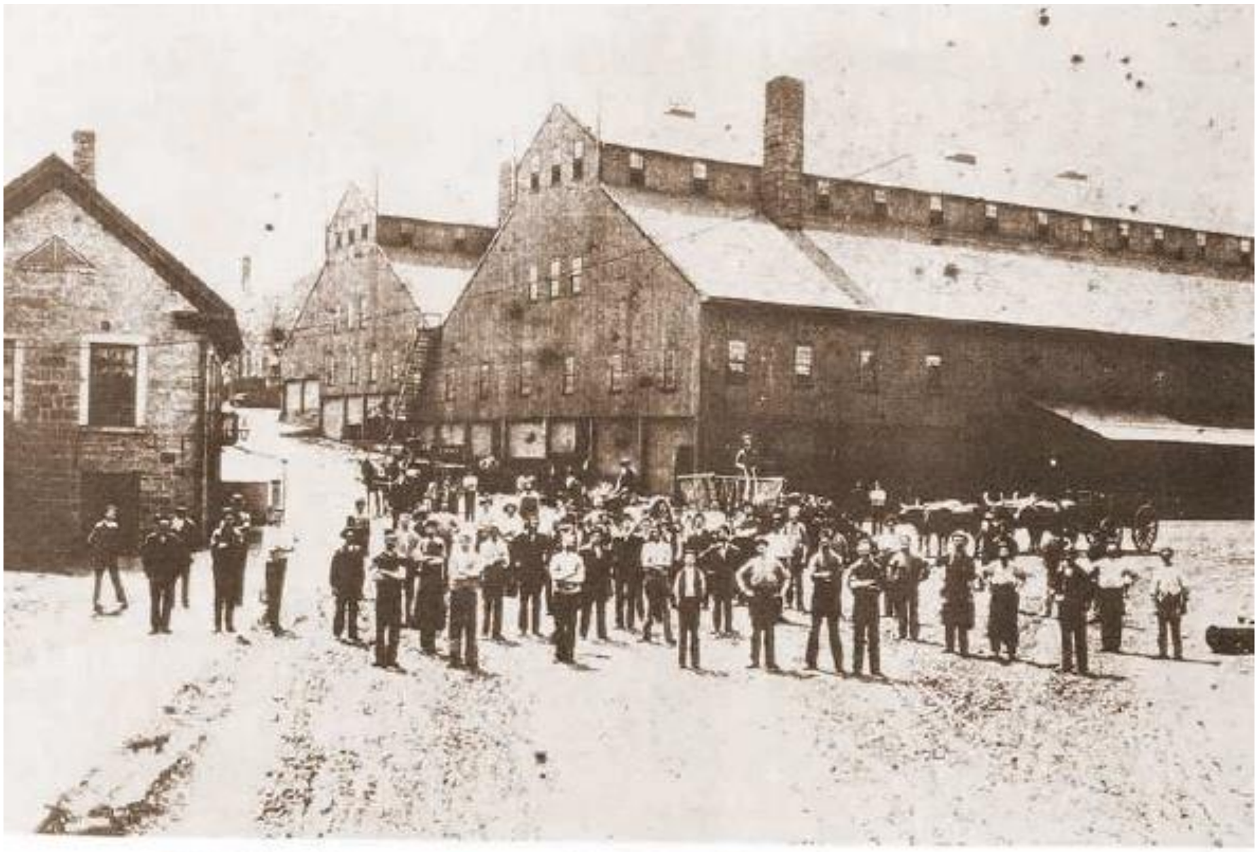
Lumbering was common in the watershed and more lumber and grist mills were built along the Mill River. Bog iron extraction was increased. There was also some quarrying of slate in the area for roofing.

Throughout the 18th century, lumber, milling and shipbuilding expanded on both the Fore and Back Rivers. Shoemaking began to specialize with individual shops creating portions of the shoes rather than the whole thing under one roof.

During the 19th century, industrial work began to become more prominent and shifted from iron and lumber production in the early years to a more diverse mix in the late portion of the century.

In 1808, the first shoemaking factory in Weymouth was constructed by James Tirrell and in 1815 a machine for mass-producing shoe pegs was invented.

In 1846 the Weymouth Iron Works was established in East Weymouth near Whitman's Pond to make nails, hammers, edge tools, ploughs, guns, scales, balances and tacks for the expanding shoe industry (Figure 5-4).



Weymouth Iron Works Photo Courtesy G. Stinson Lord

Figure 5-4. Weymouth Iron Works, near Jackson Square in the 19th century (Town of Weymouth, 350th Anniversary Committee, 1972). The mill extended from the bottom of Iron Hill Street to an area near Commercial Street.

Weymouth Iron Works bought up land in the Whitman's Pond – Back River area, and built several dams (Figure 5-5), flooded adjacent wetlands and acquired the alewife fishing rights from the town. The dams blocked passage to spawning grounds in Great Pond.

Figure 5-5. Upper Falls of Weymouth Iron Works. The house at the top center of the picture encloses a water wheel for capturing energy from the flow of water out of Whitman's Pond. Modified from digital image from Weymouth Public Libraries Historical Photograph Collection (Digital Commonwealth, Massachusetts Collections Online, accessed March 11, 2016).

The Iron Works burned in 1869, but were rebuilt and continued to operate until the 1880s.

With access to railroad transport, Weymouth Landing became a major shipment point for lumber. At around the same time and perhaps because of greater rail access, shipbuilding saw an accompanying decline in the first half of the century (shipbuilding in the area would continue into the 20th century).

Between 1861 and 1887, more than 2,500 ships were unloaded at Weymouth Landing (Town of Weymouth, 1972). Wharves also existed at Weymouth Iron Works and the Bradley Fertilizer Plant. Exporting of shoes increased and the shoe industry expanded and began supplying shops in Louisiana and California. A mechanical shoe stitching machine introduced in the late 1850's increased production further and more shoe factories were built (Figure 5-6).

In 1860, the Bradley Fertilizer Plant (later to become Agrico) began operations on Weymouth Neck for the production of fish farm nitrates for fertilizer and fireworks. The plant continued to expand through the late 19th century.

Figure 5-6. Stetson Shoe Company, sole selection room, Weymouth, MA (circa 1874). Modified from digital image from Weymouth Public Libraries Historical Photograph Collection (Digital Commonwealth, Massachusetts Collections Online, accessed March 11, 2016).

Ice cutting grew to prominence during the 1880’s on both Great and Whitman’s Ponds. The South Boston Ice Co. exported ice to four major southern cities while Cushing Brothers cut and stored ice for local use.

In 1890, granite began to be quarried near the Weymouth/Hingham line and reached its peak in the 1920s, when it was employing 200-300 men.

The 20th century brought more changes to the economy of the Back River region. Military contracting, including shipbuilding, expanded, while natural resource uses declined. The United States Navy expanded significantly in the Back River region.

- In 1906, the Navy established a naval ammunition magazine for the North Atlantic Fleet along the Back River in the Bare Cove area of Hingham. The depot was a major supplier of munitions during WWI and was also used as a training camp for Navy personnel.
- From 1941 to 1965, the Navy expanded the facility into what is now Wompatuck State Park, focusing on mine production, munitions storage, and research and production of rocket engines.
- By 1945, over 2,400 civilians and military personnel worked there.
- The base was decommissioned in 1961.

In 1941, the Navy along with Bethlehem Steel, which owned and operated the Fore River Shipyard, purchased 96.5 acres of shoreline and adjacent upland along the Back River across from the Agrico Plant on Weymouth Neck to expand the shipbuilding capacity of the main plant. It built over 200 Destroyer Escorts for the war effort in three and a half years and employed as many as 30,000 people before finally closing in 1986.

Also in 1941, the South Weymouth Naval Air Station was built on approximately 1,442 acres in South Weymouth and parts of Abington and Rockland. Its purpose was to serve as a lighter-than-air facility to patrol the North Atlantic coast for German submarines. After the war, the base continued its mission in anti-submarine warfare. The base remained active until its closure in 1997.

5.2.2.3 Population

The first federal census was in 1790, so estimates of Weymouth populations prior to then tend to be based on church estimates of the number of families or number of dwellings. Just prior to the arrival of recorded European colonies during the early 1600's, early histories indicate that the Native American population in New England was significantly reduced by some form of epidemic.

- Following the initial colony attempts, the population of Europeans in the Weymouth area was estimated to be around 300 in 1630 (South Shore Historical Society).
- By 1643, the population is estimated at 900.
- At the time of the first census, the population was 1,469.
- As of the 2010 census, the population of the Town of Weymouth was 53,743 (Figure 5-7).

Population in Weymouth grew rapidly during a number of periods.

- During the period between 1840 and 1870 (*i.e.*, the height of the initial industrialization in the town), population grew by 28 to 44% between each of the 10-year US Censuses.
- After this period, populations grew 3 to 17% every ten years before growing by 39% between 1920 and 1930.
- Following World War II, the population grew 37% between 1940 and 1950 and 47% between 1950 and 1960.
- After reaching a peak of 55,601 in the 1980 US Census, population has remained relatively stable in each of the subsequent censuses with decreases of 0.1 to 2.8% during each ten-year period.

The 2014 US Census population count for Weymouth was 55,643.

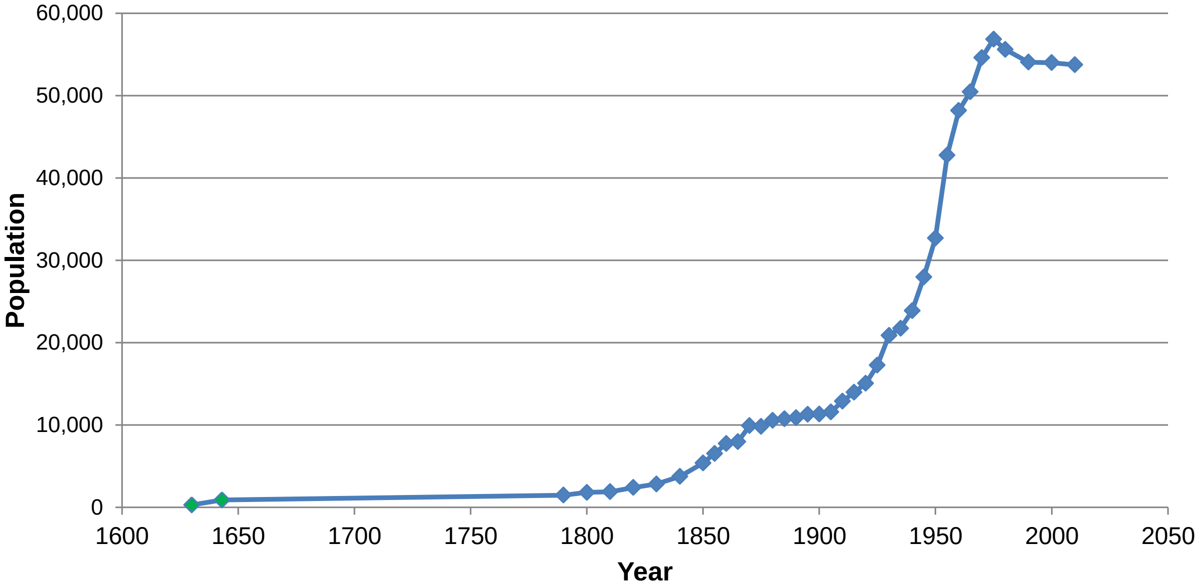


Figure 5-7. Town of Weymouth Population 1630-2010. The first federal census was in 1790. Prior to that, population estimates in the Weymouth area (indicated by the green dots) were based on church estimates of the number of families or number of dwellings; Native American population estimates generally are based on larger areas and cannot be definitively assigned to the Weymouth area. At the time of the first census, the population was 1,469. The graph shows both US Census estimates which occurred every ten years and Massachusetts estimates which occurred at the midpoint between US Censuses. As of the 2010 US Census, the population count for the Town of Weymouth was 53,743.

5.3 Present Day Land Use

Based on town assessor classifications from 2011 to 2013, land use in the Back River watershed was predominantly residential with an accompanying mix of commercial and industrial land uses. Among conventional land use groupings:

- single family residences occupied the largest portion of the watershed (29%)
- with another 10% of the watershed area occupied by other residential properties (Figure 5-8).
- Commercial land uses were 5% of the watershed area and
- industrial land uses were 4%.

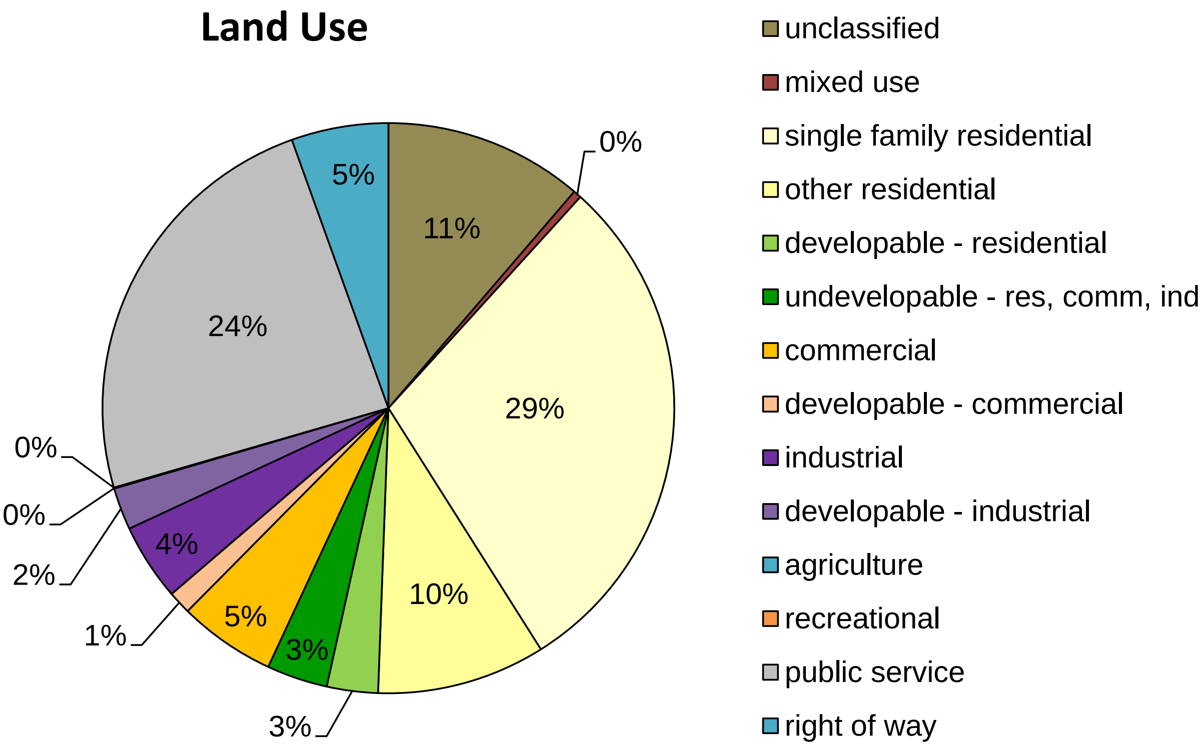


Figure 5-8. Land Use Areas within the Back River Watershed. Categories are based on town assessors' classifications available through MassGIS (mostly 2011 to 2013) and general categories in MassDOR (2014). Residential development occupied the largest amount of watershed area (39%), divided above into two categories: single family residences and other residential development. Public service land is the next largest category, which are mostly town-owned lands. Town assessors classified 6% of the watershed area as developable lands (combined residential, commercial, and industrial).

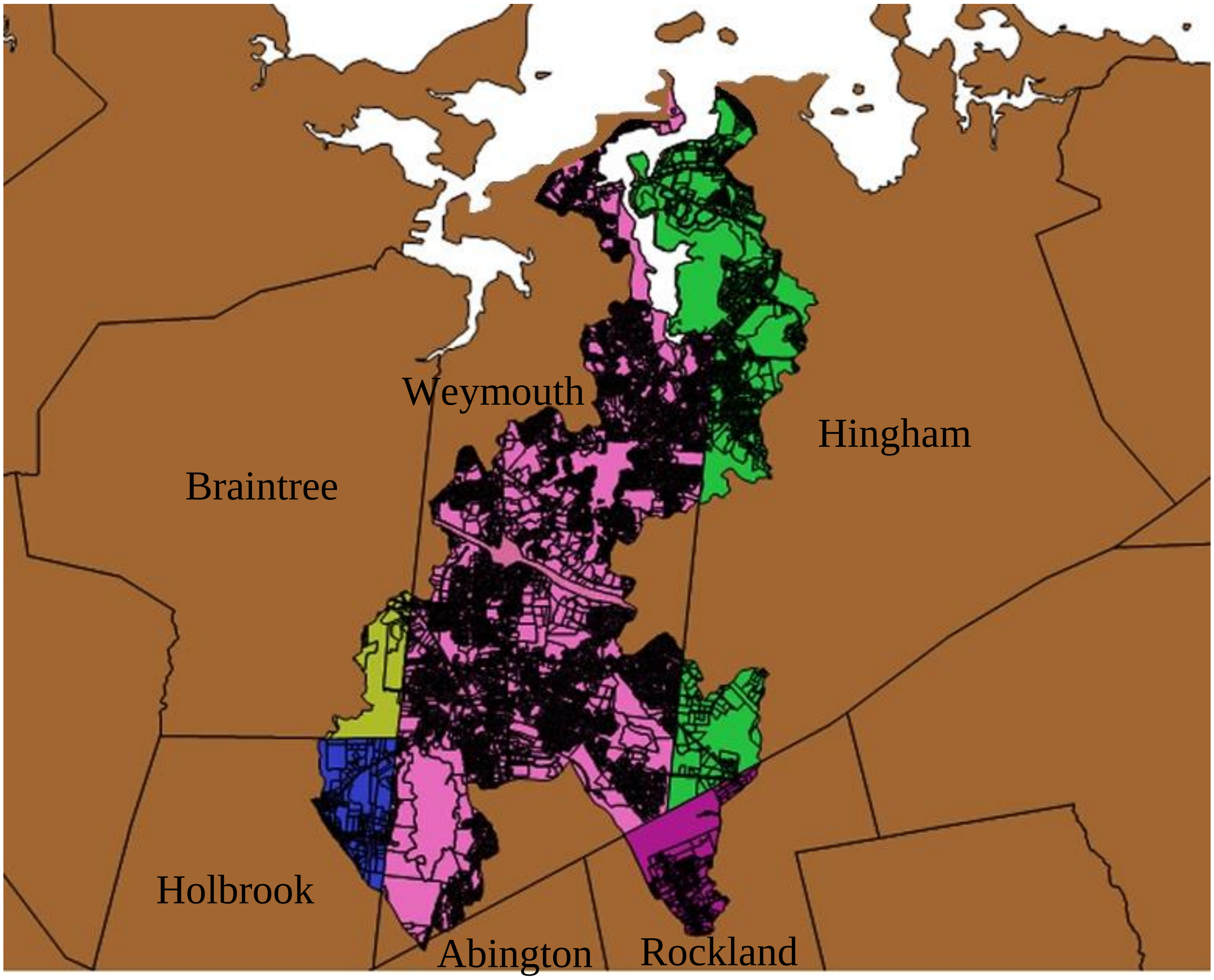


Figure 5-9. Portions of each town within the Back River Watershed. The majority of the Back River watershed is located within the Town of Weymouth with the watershed running from north to south through the middle of the town. The watershed also includes portions of the following towns: Hingham, Rockland, Abington, Holbrook, and Braintree. Figure includes assessors' parcels from each of the towns (generally from 2011 to 2013) and town boundaries; parcels and boundaries are available from MassGIS.

Developable residential, commercial, and industrial lands were 3%, 1%, and 2% of the watershed area, respectively. Public service lands, such as town-owned open space, schools, and town offices, were 24% of the watershed area.

Single family residences within the watershed were relatively modest. The average single family residential lot was 15,284 square feet with an average building area of 1,602 square feet. The average year built of these residences was 1942 (or 74 years old). Based on town assessors' records, the average assessed value of these residences was $331,968 and, collectively, they represent 55% of the total assessed value within the Back River watershed. Review of 2010 US Census information shows that for the three primary towns within the watershed (*i.e.*, Weymouth, Hingham, and Holbrook), the majority of housing units were occupied by homeowners.

Review of land use within the past 45 years shows that forest land within the towns in the watershed has largely been converted to residential land uses.

- In 1971, state land use classifications showed that the Town of Weymouth had 3,811 acres of forest land (MacConnell land use category 3; MassGIS, 2002).
- Between 1971 and 1985, the forest areas decreased by 347 acres and the area of two residential categories increased by roughly the same amount: the multi-family residential category increased by 138 acres and the area of medium high-density residential category increased by 122 acres.
- Between 1985 and 1999, almost all the forest area decrease was converted to single-family housing (loss of 381 acres from the forest category and gain of 330 acres in the medium high-density residential category).

Lands in the Urban Open Space category also decreased. Similar changes were seen in the other towns in the Back River watershed, although Hingham had a greater conversion to the low density residential category. Similar state-wide land use reviews using these categories have not been completed since 1999.

5.4 Demographics of Towns within the Back River Watershed

A brief geographical description and land use discussion of the towns within the Back River watershed follows. Information was gathered from town websites, local historical commissions, the US Census Bureau, and the Massachusetts Historical Commission.

5.4.1 Abington

Abington is a small suburban community approximately 19 miles south of Boston with a 2010 US Census population of 15,985 people. Abington has a total area of 10.2 square miles or 6,509 acres and celebrated its 300th anniversary in June 2012. Only a small portion of the town (4 acres) is within the Back River watershed (Figure 5-9). The portion of Abington in the Back River watershed consists primarily of older single family residences (average year built of 1952) and town conservation land (about 1 acre).

Historically, the town was a major manufacturer of shoes from the mid-19th to the mid-20th century with supporting industries such as tanning and tack manufacturing. There was an active timber industry that supplied ship building activity in the North River (Scituate, Hanover) as well as other shipyards in Hingham, Weymouth and other coastal communities. Industrial activity was centered in South Abington (now Whitman), while north Abington, including the small area within the Back River watershed, was used mostly as residential land.

Today Abington is primarily a residential community with several small and medium size businesses. At the time of the 2010 US Census, 37.5 % of the employed population worked in management, business, science and arts occupations and 30.4% worked in sales or office occupations. The largest portion of the employed population (27.8%) worked in educational services, health care, and/or social assistance. Median household income was $81,500.

5.4.2 Braintree

The Town of Braintree is a coastal suburban residential community 12 miles south of Boston with a 2010 US Census population of 35,744. It is located on the western side of the Back River watershed (see Figure 5-9). The Town has shoreline on the Fore River along its northern border. The town has a total area of 14.5 square miles or 9,293 acres. Approximately 373 acres of the town's area is within the Back River watershed, located in the southeastern portion of the town adjacent to Holbrook and Weymouth. This area includes some large parcels classified by the town assessor as developable for commercial and industrial development. The largest parcel in this portion of the town is the Devon Wood Condominium development (>220 acres).

The lumber industry, which supported area ship building operations, and the Braintree Iron Forge, from 1646 to 1653, were early industries in this town, which then included what is now Quincy and Randolph. Other iron works, a copper plant and granite quarrying were added in the early 19th century but were short-lived. The shoe manufacturing industry grew in the 19th century but failed to expand beyond small shops.

At the time of the 2010 US Census, Braintree's population was employed in a diverse set of fields. The largest portion of the employed population (23.3%) worked in educational services, health care, and/or social assistance with 11 to 12% working in: a) Professional, scientific, and management, and administrative and waste management services, b) Finance and insurance, and real estate and rental and leasing, and c) Retail trade. Median household income was $87,500.

5.4.3 Hingham

The Town of Hingham is primarily a residential suburb of the greater Boston area with a 2010 US Census population of 22,175. It is located on the western side of the Back River watershed (see Figure 5-9). The town covers an area of 25 square miles or 16,026 acres. The Town has shoreline on the Back River, Weir River, and Hingham Bay along its northern border. Approximately 2,723 acres of the town's area (17% of the town) is within the Back River watershed, located in two sections, a larger northern section mostly bordering on the estuarine portion of the watershed and a smaller southern section near the Town of Rockland. Most of the parcels (74%) within the Back River watershed are single family residences, while the largest parcel is the town-owned Bare Cove Park (>360 acres).

The early economy of Hingham focused on lumber and grist mills and fishing. The mackerel industry grew in the 19th century along with several supporting industries including copper and brass foundries. The shoe and textile industries grew during the 19th century as well. Industrial activity reached its peak between 1855 and 1875. After this period, industries began to decline and Hingham became increasingly residential. In the 20th century two major military installations were established in the town: the Naval Ammunition Depot in 1906 and the Hingham Shipyard in 1941 (with Bethlehem Steel). The Merriman Division of Quamco was established in 1966 with foundry and metal working operations. Company activities included chromium plating; pressing and sintering of granulated iron, copper, and graphite; heat treating; rust protection; induction hardening; machining; and degreasing.

At the time of the 2010 US Census, Hingham's population was employed in a diverse set of fields. The largest portion of the employed population (23%) worked in educational services, health care, and/or social assistance with 18% working in professional, scientific, and management, and administrative and waste management services, 16.5% working in finance and insurance, and real estate and rental and leasing, and 12% working in retail trade. Median household income was $98,890.

5.4.4 Holbrook

The Town of Holbrook is an inland residential community located approximately 16 miles south of Boston with a 2010 US Census population of 10,791. Originally part of Randolph and Braintree, it is located on the southwestern side of the Back River watershed (see Figure 5-9). The town has a total area of 7.4 square miles or 4,736 acres. Approximately 529 acres of the town is within the Back River watershed in an area adjacent to Weymouth and Braintree. According to the town assessor, most of the parcels (61%) with the portion of town within the Back River watershed are single family residences with the largest parcels (30 to 45 acres) generally owned by the town or Norfolk County.

After incorporation as a town in 1872, the primary economic development in town (and the region) was the shoe industry which lasted until the end of the century. As shoe manufacturing moved out of the region, Holbrook became mostly residential with the economic expansion of Boston, Braintree and Brockton.

At the time of the 2010 US Census, Holbrook's population was employed in a diverse set of fields. The largest portion of the employed population (21%) worked in educational services, health care, and/or social assistance with 13% working in construction industries, 13% working in retail trade, and 12% working in finance and insurance, and real estate and rental and leasing. Median household income was $62,623.

5.4.5 Rockland

The Town of Rockland is an industrial community about 20 miles south of Boston with a 2010 US Census population of 17,489. Rockland is located at the southeastern extent of the Back River watershed (see Figure 5-9). The town has a total area of 10.1 square miles or 6,464 acres. Approximately 576 acres of the town is within the Back River watershed in an area adjacent to Weymouth and Hingham. According to the town assessor, most of the parcels (68%) with the portion of town within the Back River watershed are single-family residences and the largest parcel within the town's portion of the watershed (~220 acres) is a portion of the former South Weymouth Naval Air Station.

The timber industry grew in Rockland (then part of Abington) in the 18th century, supplying materials to North River shipyards. In the late 18th and 19thcentury, Rockland became a center for shoe production and incorporated as a town in 1874. The 20th century brought further commercial expansion until the Great Depression in the 1930s when the shoe industry collapsed.

At the time of the 2010 US Census, the largest portion of Rockland's employed population (24%) worked in educational services, health care, and/or social assistance with 15% working in retail trade. Between 8% and 9% worked in the following employment categories: a) construction, b) manufacturing, c) professional, scientific, and management, and administrative and waste management services, and d) arts, entertainment, and recreation, and accommodation and food services. Median household income was $64,512.

5.4.6 Weymouth

The Town of Weymouth is primarily a residential community approximately 12 miles south of Boston with a 2010 US Census population of 53,743. The majority of the Back River watershed (65%) extends through the middle of Weymouth, including the western shoreline of the estuary and the tributary river/streams. The Town has shoreline on the Back River, Fore River, and Hingham Bay along its northern border. The town has a total area of 21.6 square miles or 13,824 acres, of which 7,919 acres are within the Back River watershed. According to the town assessor, most of the parcels (79%) with the portion of town within the Back River watershed are single-family residences and the largest parcels (>100 acres) within the town's portion of the watershed are owned by the Town of Weymouth.

Historically, the town is one of the earliest settlements in the Boston Harbor region (1622). Early economic activity was primarily lumber and grist mills, shipbuilding and shipping, fishing, and tanning, which gradually transitioned to industrial activities associated with shoe production. Industrial plants included the Weymouth Iron Works and Bradley Fertilizer Plant. During World War II, the South Weymouth Naval Air Station was built to monitor enemy shipping in the North Atlantic using dirigible aircraft. After the war, the station transitioned to aviation training before closing in 1997.

At the time of the 2010 US Census, the largest portion of Weymouth's employed population (26%) worked in educational services, health care, and/or social assistance with 12% working inretail trade, 11% working in professional, scientific, and management, and administrative and waste management services, and 10% working in finance and insurance, and real estate and rental and leasing. Median household income was $65,849.

The Ecology of the Weymouth Back River

CHAPTER 6: Changes in the Back River System

6.1 Introduction

After the first European settlers arrived in Back River region in the early 1600's, the landscape began to undergo changes as upland and waterways were modified to provide drinking water and food for a growing population and accommodate commercial and industrial activities. These changes mirrored those of the greater Boston Harbor region, which became a major center of commerce and trade.

The Back River and tributary streams were dammed for commercial and industrial use. Culverts were installed to allow roads and railways to cross over streams and wetlands. As the land uses changed from forests and meadows, the waterways that were always natural conduits for runoff now also included domestic and industrial waste.

As the intensity of these land uses increased, water quality began to deteriorate and sediments in the waterways became depositories for industrial chemicals, excessive nutrients, and higher sediment loads. These changes altered the natural movement of water and associated nutrients, sediments, and other contaminants, as well as altering associated habitats.

Today, the habitats and water quality in the Back River and its tributaries are a reflection of both the current and historic development within the watershed. Excessive nutrient loading has been the major cause of the deterioration in water quality in areas of the Back River system, especially Whitman's Pond.

Wetland systems naturally hold nutrients, but as these loads exceed the capacity of the system, the habitats are altered. Excessive nutrients feed microscopic and rooted aquatic plants (phytoplankton and macrophytes, respectively) and their growth alters light availability and habitats for other species.

As the plant community changes, habitat niches for fish and insects are altered, sometimes to the point of eliminating species within an area where it historically thrived. Excessive nutrient loads can cause sediment buildup to the point where oxygen demand from sediment bacteria consume more oxygen than can be replenished by the atmosphere or incoming tidal water and shellfish, plants, and aquatic invertebrates habitats are then ruined.

Since these species form the base of most ecosystems, the availability of food and habitat for the species that depend on them (*e.g.*, birds, fish, aquatic mammals and reptiles) are also altered and sometimes eliminated.

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Other watershed changes have led to increased bacterial inputs and industrial contaminants. These contaminants, combined with nutrient impacts, raise issues about recreational use of water and adequate and safe drinking water supplies.

- Bacterial inputs from failing septic systems, sewer leaks, and storm water discharges can contaminate habitats like shellfish beds and make beaches unsafe for swimming.

- Industrial activity in the watershed has resulted in significant contamination of sediments in Whitman's Pond and the Back River, as well as certain parcels within the watershed. Industrial contaminants within the watershed have included: PCBs (polychlorinated biphenyls), metals (*e.g.*, arsenic, lead, and mercury), and pesticides and other PAHs (polycyclic aromatic hydrocarbons).

This chapter discusses the changes in the Back River system that have occurred within available written history and how they have impacted the ecology and water quality. Chapter 7 discusses the available management tools, including laws and regulations and further changes that could lead to habitat and water quality restoration.

6.2 Drinking Water

Depending on how drinking water is distributed and then returned within a watershed, it can alter water balance for ponds and wells and also change stream flows.

Drinking water for buildings within the watershed originally came from private or village wells, streams, or ponds until the early 1800s. Private wells were usually located on the same lot as the building, often within a basement to ensure private access. Because withdrawal and use were mostly on the same parcel, water within the overall Back River watershed generally stayed within the same areas it had been historically. Since that same lot was also usually the location where an outhouse or privy was located, there was potential for contamination of the well. Use of streams and ponds for mills created potential conflicts between commerce and drinking water.

In the early 1800s, these potential conflicts and contamination concerns began to lead toward the creation of multi-lot drinking water supplies and eventually municipal public water.

- In 1825, the Weymouth Aqueduct Corporation (WAC) was formed after Micah Raymond encountered salt water in his well on Commercial Street (MAPC, 1984). This private corporation piped water from a spring to six properties and operated until 1855.
- In 1854, John Snow released his famous study of a London cholera outbreak linked to a public drinking water pump, which altered many conceptions about siting of public water sources within cities (Paneth, *et al.,* 1998).

Over the next 30 years, the WAC added more customers and other supply springs before closing down in 1855. The WAC appears to be the only community system that existed in Weymouth prior to the funding and creation of the Weymouth Water Works during the 1880's.

The Weymouth Water Works was the start of the municipal drinking water system that is in place today. In 1885, the Weymouth Water Commission (WWC) was established to administer the system, which included Great Pond as the primary source, 34 miles of distribution pipe, 475 service connections, and a two million gallon standpipe (MAPC, 1984).

The system was expanded and refined as issues arose through the subsequent decades.

- In the early 1900's, concerns about water quality in Great Pond led to rules prohibiting boating, fishing or ice cutting on the pond without a permit from the WWC. WWC granted these permits until 1911 when the WWC voted to prohibit these activities.

- In 1927, the town approved funding for the taking of land around the pond to provide additional source water protections.

- In 1933, the town approved funding for a 4 million gallons per day (MGD) sand filter to treat drinking water prior to distribution. The filtration plant was completed in 1936.

- In 1941, a hot summer lowered water levels enough that a number of private wells went dry and prompted discussions about seeking additional water supply sources.

- In 1944, the WWC constructed a supply well off Circuit Avenue.

- Post-war population growth led to expansion of the system, including:
    - more standpipes,
    - a Main Street well in 1951,
    - a Whitman's Pond well in 1959,
    - and a Winter Street well and expansion of the filtration plant in 1963 (MAPC, 1984).

- In 1956, the town created the Department of Public Works to administer the drinking water system.

- In 1975, a treatment facility on Winter Street was constructed for iron and manganese removal from the groundwater wells in the Mill River area.

- By 1983, the public water supply system had approximately 14,000 connections.

- In 2010, the Great Pond treatment plant was replaced.

- By 2014, there were 16,096 public water supply connections (Town of Weymouth, 2014).

Inadequate water supply due to low water levels and lack of precipitation has often led to pumping from other surface waters in the Back River system to provide supplemental drinking water. In 1949-50, 1957, 1964-1965, and 1979-1981 drought conditions led to actions to increase supply and decrease demand, including pumping from Whitman's Pond and/or Old Swamp River, temporary connections to Quincy's water supply system, restrictions on new building permits, and voluntary bans on outdoor water use. In 1964, water levels in Great Pond had fallen so low that it was estimated that the pond was within one day of running dry (MAPC, 1984). Other issues affecting adequate water supply have included a two-year closure of the Main Street well by contamination from leaking gasoline tank in the early 1970's.

The South Cove of Whitman's Pond, which is fed by the Old Swamp River, became an active water supply source in 1966, when a pump station was installed at South Cove, adjacent to Washington Street and the culvert that connects the South Cove to the main body of Whitman's Pond. Because the South Cove is a spawning ground for river herring, pumping from South Cove during herring spawning, juvenile development and outmigration periods is coordinated with the Weymouth Herring Wardens and the Division of Marine Fisheries (DMF). The goal of this coordination is to ensure that water supply needs are met while also ensuring that herring have access to their spawning grounds, that juveniles are not entrained in the pumps, that outmigration of adults and juveniles is not blocked, and that there is sufficient outflow from Whitman's Pond to provide safe passage for juveniles down the fish ladders and into the Back River system.

Except in cases of a declared water supply emergency, the water supply pumps at South Cove are only allowed to operate when the sluice gate that separates South Cove from the main body of Whitman's Pond is in a closed position. During dry summer and fall periods, the DPW sometimes lowers the sluice gate to collect water in South Cove. This practice blocks the natural flow of water and aquatic organisms (including juvenile herring) and, if conducted for extended periods of time, can impair water quality and pose a danger to aquatic life. The town is currently operating with a draft protocol that assists in balancing water supply and fishery needs, but additional work is needed to finalize and formalize the protocol.

Between 1979 and 1982, average water use in the town was 4.15 million gallons per day (MGD). Between 1998 and 2002, the average use had increased to 4.44 MGD. By 2014, the average water supplied from the town sources was 4.66 MGD with an average of 4.27 MGD being treated at the two treatment plants (3.51 MGD coming from the Great Pond treatment plant) (Town of Weymouth, 2014). The current state regulatory withdrawal limit for the whole town is 5.0 MGD with an estimated safe yield of 6.27 MGD.

Public water supply withdrawals have an impact on water levels in rivers and ponds, particularly during the summer months when natural flows decrease but water demands increase. The Mill River, which originates at the outflow of Great Pond and is one of the major inputs to Whitman's Pond, often runs dry in the summer. Weymouth's drinking water wells are all located within the Mill River watershed with the exception of the Libbey Parkway well which is located within the Old Swamp River watershed. Both the Mill River and the Old Swamp River flow into Whitman's Pond which is tributary to the Back River. The water supply withdrawal permit for Winter Street Well #1 limits pumping during summer months in order to minimize impacts on the Mill River.

Under Weymouth's Water Management Act permit, mandatory water-use restrictions are tied to water levels in Great Pond. Until the drought of 2016 triggered a partial outdoor water ban due to extremely low water levels in Great Pond, the town had not imposed a mandatory water restriction for over a decade.

The Town of Weymouth water supply watershed is 12.87 square miles and extends into the towns of Abington, Braintree, Hingham, Holbrook, and Rockland (Figure 6-1). Within this area are 396 acres of wellhead protection areas (*i.e.*, MassDEP Zone II areas). As of 2003, potential high risk land uses within the water supply watershed, include 42 underground fuel tanks, one Superfund site, 9 gasoline stations, railroad tracks and yards, fuel oil distributors, industrial parks, and 4 large quantity hazardous waste generators (MassDEP, 2003). There are also numerous medium and low risk potential contamination sites.

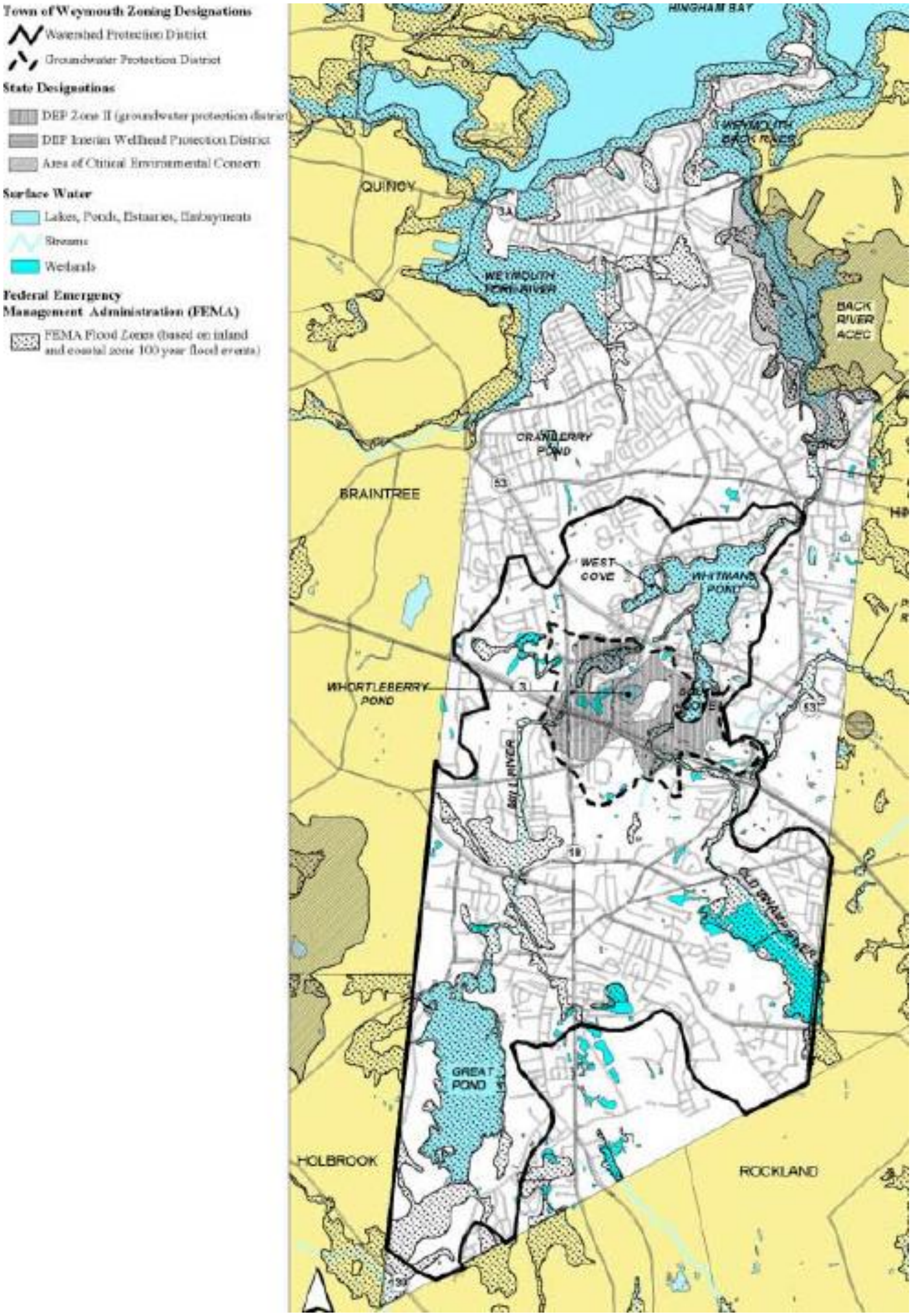

Figure 6-1. Town of Weymouth Watershed Protection District. From Map I-11 in 2001 Town of Weymouth Master Plan (Cecil Group, 2001).

6.3 Wastewater and Sewers

As mentioned above, disposal of human waste prior to the 19th century generally occurred on the same lot where drinking water was pumped. Americans also generally followed European traditions of individuals being responsible for their own wastes. Most wastes were disposed of in cesspools, manure pits or privy vaults (*i.e.,* pits) that were filled and emptied with pails; ditches were often dug along roads to allow wastewater to flow to surface waters or wetlands when it rained (Melosi, 2008).

Because of these practices, epidemics of yellow fever and cholera regularly occurred in high density urban areas. This link between wastes and disease generally was not formalized until the mid-19th century. Boston was among the first cities to form a health department in 1797, but its activities were generally associated with removing nuisances associated with garbage or industrial wastes thrown into streets. In 1823, city officials assumed authority over street gutters and specifically prohibited their use for the disposal of fecal matter in 1833. It is likely the communities in the Back River watershed followed the same patterns of dealing with human waste. Statewide standards for cesspools and septic systems (Title 5) were not adopted in Massachusetts until 1978. The Town of Weymouth began building a sewer system in 1947 and the majority of the town was sewered by 1980 (Town of Weymouth website).

A sewer system necessarily removes human wastes from the site of their origin, but it also removes the water that is used to transport those wastes. This tradeoff means that while the nutrients and bacteria are moved and treated, the water that used to recharge the downgradient stream, estuary, or pond is now removed from the watershed. In Weymouth, sewering completely removes pumped water from the Back River watershed.

The current town sewer system includes over 320 miles of sewer lines, which are connected to the Massachusetts Water Resources Authority (MWRA) system at 11 different locations in the town. The wastewater travels through Nut Island and then to the Deer Island Treatment Plant where it is treated and then discharged through diffusers located 9.5 miles out into Massachusetts Bay. The Town of Weymouth Water and Sewer Division estimates that approximately 97% of the town is connected to the sewer system. As of 2015, 468 homes are not connected to the municipal sewer system.

Given the era of the initial Weymouth sewer system design, the town has had issues with a large volume of infiltration/inflow (I/I) into the sewer system from stormwater and groundwater. This additional volume is a concern because it uses up capacity in the system during wet weather events.

When the capacity of the system is exceeded, sewage treatment is inadequate and sewage-contaminated overflow is discharged into low-lying wetlands and waterways, and can back up into homes and businesses. The Weymouth DPW began working on this issue in 1985 and removed most of the major sources by 1994; but between 2000 and 2008 there were 133 overflow events over 295 days. These overflow events occurred at Whitman's Pond, Mill River, Back River, Fore River and Old Swamp River.

Beginning in 2003, the town began a series of sewer system repairs and upgrades under the town's Capital Improvement Program to reduce the overflows. These system changes greatly reduced the overflow events; between 2006 and 2014 there have been nine known overflow events lasting 18 days.

6.4 Impervious Surfaces

Roads and buildings are typically less porous than the lands they are built over. As such, they generate greater stormwater runoff, greater contaminant loads, and provide more efficient transport of the runoff and contaminants to surface waters or groundwater.

Concentrated runoff in targeted areas can alter stream flow or salinities necessary for sustaining habitats and contain nutrients, hydrocarbons, and metals.

About 2,600 acres or 22.5% of the Back River watershed area is made up of impervious surfaces (*e.g.*, roads, parking lots, driveways, roofs, sidewalks).

Aquatic ecosystems are susceptible to degradation of water quality when as little as 10% of a watershed is comprised of impervious surfaces (Brabec, *et al.*, 2002).

MassDOT GIS coverages indicate that approximately 600 acres of the impervious surfaces are road surfaces.

Typically, stormwater from roadways in the Back River watershed is collected in catch basins and piped to outfalls that discharge at low points into wetlands and waterways. A 2004 study documented that 46 stormwater outfall pipes discharged into Whitman's Pond (Figure 6-2).

Four of these sites had flow during dry weather conditions and were sampled, revealing nitrogen, phosphorus, total suspended solids, fecal coliform, and enterococcus.

Review of the other Whitman's Pond reports (*i.e.*, DWPC, 1983; Metcalf & Eddy, 1983; ESS, 2014) do not include wet weather runoff measurements, so the amount of contaminants is largely unquantified.

6.5 Hydrologic Restrictions/Changes

Addition of dams and culverts for road or railroad crossings can alter natural stream flows, wetland functions and contaminant and nutrient loads.

These kinds of impacts can have ripple effects, including altering upstream habitats and species niches, as well as those in downstream estuaries and rivers. Given the long history of development within the Back River watershed, there have been numerous changes in the system that have altered the watershed hydrology.

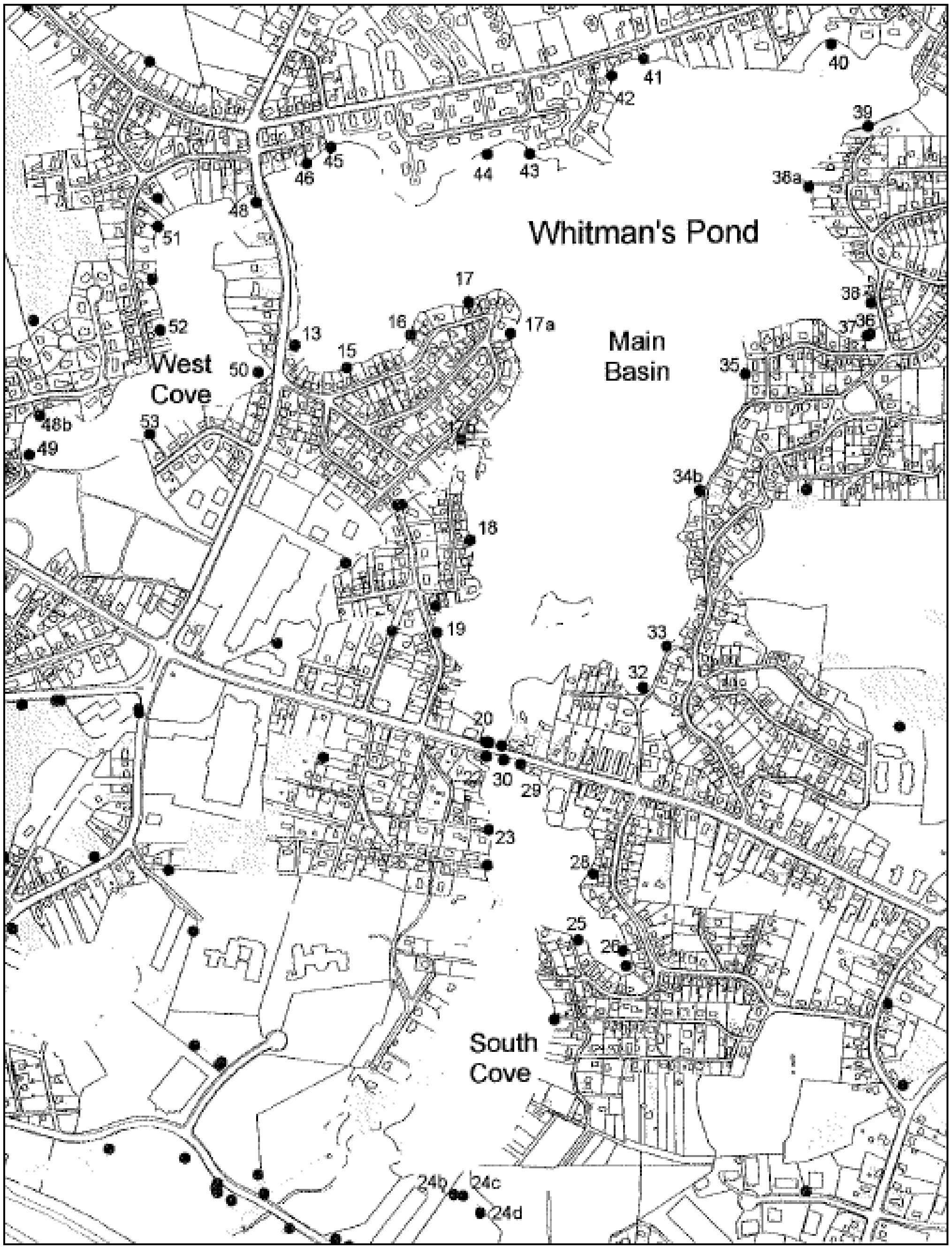

Figure 6-2. Whitman's Pond Stormwater Outfall Pipes. 46 outfall pipes were identified and four had flow during dry weather conditions. Samples collected from the four with flow had concentrations of a number of contaminants, including nitrogen, phosphorus, total suspended solids, fecal coliform, and enterococcus. From Figure 11 in BETA (2004).

6.5.1 Dams

Great Pond was historically a major spawning ground for herring, but there have been a number of competing uses within the Back River watershed that have altered the path herring would take from the estuary to Great Pond. According to MassDEP databases, there are currently three dams along the herring path to Great Pond: Iron Hill, Whitman's Pond, and Great Pond. There also appear to be a number of historic small dams along the Mill River that are now road crossings; the number of dams should not be surprising given the number of mills that used to operate along the river (Nash, 1885). The Iron Hill and Whitman's Pond dams are equipped with fish ladders that allow herring passage to Whitman's Pond, but there is no fish ladder providing passage over the dam at Great Pond. The most downstream impediment is the old mill behind what is now the Shaw's Plaza (on Middle Street).

The Iron Hill dam was the first built in the watershed and was constructed by Weymouth Iron Works at the north end of Whitman's Pond in 1836. This dam raised the level of the pond 4 feet and resulted in an increase the size of the pond by flooding surrounding wetlands mostly in the West Cove and South Cove areas. This change would have had the impact of increasing the water retention time in Whitman's Pond, while also likely decreasing the flow of downstream nutrients and sediments. By 1919, the effect of the dams and pollution from the Iron Works had reduced the numbers of migrating fish (Donahoe, 1979).

River herring traveling from the main body of Whitman's Pond to South Cove and up into the Old Swamp River also face obstructions. As described above in Section 6.2, migration into and out of South Cove is periodically blocked by the sluice gate at Washington Street. Upstream herring migration in the Old Swamp River can be impeded if the sluice gate at the dam located upstream of Libbey Industrial Parkway is in a closed position. The dam was installed in the 1990s to divert water to a sediment nutrient uptake pond (SNUP). The dam and SNUP were constructed for the purpose of improving Old Swamp River water quality before discharge into Whitman's Pond. However, the SNUP has not been maintained and it is not clear what, if any, ecological improvements the system is providing at this time.

6.5.2 Culverts

Culverts under roads, parking lots, or other development can impede stream or tidal flow and often restrict fish passage. In the Mill River system, passage from the Back River to Whitman's Pond includes six culvert systems that total 590 feet in length. There are two culverts under the MBTA Rail Road tracks that are 6 ft in diameter and about 100 ft long. Tides control the ability of the fish to pass through this culvert; low tides can go below culvert inverts preventing passage. The culvert under Broad Street, upstream of the first ladder in Jackson Square, is about 120 ft long. Another culvert is located under Commercial Street, about 40 ft in length just above the second fish ladder at upper Jackson Square. Beyond Jackson Square, a 190 ft culvert runs parallel to Water Street. In periods of high flow, adult herring can have difficulty negotiating the high velocities in the concrete pipe section of this culvert. Two more culverts run: 1) under Pleasant Street south of the Police Station (60 ft) and 2) under Iron Hill Street (120 ft). The structural integrity of these culverts is another issue affecting the long-term health and sustainability of the herring run. Investigations have identified potentially serious structural concerns with several culvert sections.

6.5.3 Fish Ladders

Fish ladders are a restorative management technique to allow spawning fish to swim around obstructions caused by dams and travel further upstream to spawn. According to a 2005 MassDMF Survey, there are seven passable obstructions/fish ladders between the Back River estuary and Whitman's Pond (Brady, *et al.*, 2005). The seven passable obstructions are:

1) Broad Street Dam,
2) Middle Pool Dam,
3) Jackson Square Dam,
4) Elevation change under Jackson Square,
5) Pleasant Street Dam,

6) Iron Hill Dam, and
7) Whitman's Pond Dam.

Table 6-1. MassDMF Weymouth Back River Obstructions and Fishways. Total stream length – 4.8 miles with River herring, smelt, white perch present. Table inputs selected from Brady, *et al.*, 2005.

	Obstruction	**River mile**	**Type**	**Material**	**Spillway Width**	**Spillway Height**	**Pool Area**
					ft	**ft**	**ac**
1	Broad St Dam	4.2	Dam	Concrete	-	-	0
2	Middle Pool Dam at Youth Center	4.2	Dam	Concrete	4	1.4	0.1
3	Jackson Sq Dam	4.3	Dam	Concrete	28	4.3	0.1
4	under Jackson Weymouth Sq	4.4	Elevation change	Concrete	12.5		
5	Pleasant St Dam	4.5	Dam	Concrete	8.2	5.7	0
6	Iron Hill Dam	4.6	Dam	Stone/concrete w/wooden boards	6.8	18.1	1.6
7	Whitman's Pond Dam	4.8	Dam	Concrete	53.5	15.0	175.0
8	Washington St Control Structure	5.7	Dam control structure	Concrete and metal	10.5	9	29.3
	Fishway		**Type**	**Material**	**width**	**Length**	**# of baffles**
					ft	**ft**	
1	fishway		Notched weir-pool	Concrete	4.8	130	14
2	fishway		Notched weir-pool	Concrete	7.9-10.6	21	3
3	fishway		Notched weir-pool	Concrete with wooden baffles	4	35	6
4	fishway		Stream baffles	wooden baffles	12.5	146	3
5	fishway		Notched weir-pool	Concrete	3	89.2	13
6	fishway		denil	Concrete with wooden baffles	3	288.5	86
7	fishway		denil	Concrete with wooden baffles	3	85.8	26

Table 6-1a. MassDMF Weymouth Back River Obstructions and Fishways. Total stream length – 4.8 miles with River herring, smelt, white perch present. Table inputs selected from Brady, *et al.*, 2005.

	Obstruction	River mile	Type	Material	Location	
					Lat	Long
1	Broad St Dam	4.2	Dam	Concrete	42º 12’ 56.555”	70º 55’ 22.461”
2	Middle Pool Dam at Youth Center	4.2	Dam	Concrete	42º 12’ 53.965”	70º 55’ 25.225”
3	Jackson Sq Dam	4.3	Dam	Concrete	42º 12’ 53.875”	70º 55’ 25.393”
4	under Jackson Weymouth Sq	4.4	Elevation change	Concrete	42° 12’ 52.332”	70° 55’ 25.928”
5	Pleasant St Dam	4.5	Dam	Concrete	42° 12’ 46.371”	70° 55’ 32.578”
6	Iron Hill Dam	4.6	Dam	Stone/concrete w/wooden boards	42° 12’ 47.280”	70° 55’ 39.306”
7	Whitman's Pond Dam	4.8	Dam	Concrete	42º 12’ 40.195”	70º 55’ 46.031”
8	Washington St Control Structure	5.7	Dam control structure	Concrete and metal	42º 11’ 59.050”	70º 56’ 19.158”
	Fishway		**Type**	**Material**	**Notch width**	**Pool length**
					ft	**ft**
1	fishway		Notched weir-pool	Concrete	3	7
2	fishway		Notched weir-pool	Concrete	4	9.9
3	fishway		Notched weir-pool	Concrete with wooden baffles	2	6-7
4	fishway		Stream baffles	wooden baffles	-	44-80
5	fishway		Notched weir-pool	Concrete	1.5	7
6	fishway		denil	Concrete with wooden baffles	-	-
7	fishway		denil	Concrete with wooden baffles	-	-

Mass DMF rates all of these as "passable" and they have a variety of design features depending on the elevation change (Table 6-1). Prior to the fish ladder system, it was necessary to carry alewives over the dam at Whitman's Pond for spawning purposes.

Beyond the second fish ladder at Jackson Square is a pool, referred to as the "Middle Pool", where spawning fish rest prior to continuing toward Whitman's Pond. As a relatively quiescent section, the pool also fills with sediments and has been dredged by the town three times in the last 15 years.[4] Fish cannot travel to Weymouth Great Pond due to a dam at Middle Street.

6.5.4 Wetland Losses

Wetlands are productive ecosystems within larger watersheds that trap and utilize sediments and nutrients and provide diverse habitat niches for a variety of plants and animals. Wetland types can range from those located along river, streams, ponds, and estuaries to isolated wetlands that are intermittently connected to groundwater via fluctuations or those that derive all of their water from precipitation on their surface. Loss of wetlands reduces nutrient and sediment filtering capacity within a watershed, as well as altering how streamflows react to storm events or how much erosion occurs along shorelines.

In the Boston Harbor region there has been a significant loss of estuarine marsh and interior wetland habitats due to a variety of reasons. Much of the loss occurred before the end of the 19th century but poor record-keeping and the lack of effective mapping of wetlands areas make documentation difficult. By 1893, there were over 5,000 acres of marsh habitat in the Boston Harbor region. By 1952, that number had been reduced to less than 3,000 acres. A comparison of wetlands within the Neponset River estuary in 1893 to those in 1952 showed that most of the losses there were due to conversion to upland for commercial development and transportation infrastructure.

In the Back River, there was a net loss of 780 acres between 1952 and 1971 due mostly to development draining and filling wetlands.

- The Julia Field ash landfill in Weymouth is an example of a filled wetland converted to upland.
- The construction of the Hingham Shipyard in 1941 caused wetland losses to make its shoreline infrastructure possible with its slipways for ship and boat launches.
- Other historical marinas, boatyards, and docks, as well as commercial/industrial sites, likely have contributed to historical wetland loss in the Back River watershed.

Comparison of 1971 to 1995 showed an additional 197 acres had been lost primarily to the creation of open water but also to some development and other draining and filling.

6.6 Water Quality Contaminants

Contamination of water resources can be due to excessive loads of naturally occurring factors (*e.g.*, nitrogen, phosphorus, sediments), secondary impacts (*e.g.*, low dissolved oxygen due to excessive nutrient loads), and/or addition of contaminants from specific land uses (*e.g.*, discharge of oil and gas residuals from industrial land uses, bacteria from wastewater sources). Addressing contamination requires understanding the source, the mechanism of transfer to the water, how it impacts the water/habitats, and potential mitigation strategies. This section discusses some of the contaminants within the Back River watershed.

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[4] It was last dredged in February 2016.

Massachusetts maintains regulatory standards for all of its surface waters (314 CMR 4). These regulations include descriptive and numeric water quality standards for various classes of waters based largely on how waters are used and the ecosystems they support. There are separate standards for salt and freshwater systems and classes for each (fresh: Class A, B, C; salt: Class SA, SB, and SC). The descriptive standards for each class of waters also include an accompanying set of numeric standards for the following four factors: dissolved oxygen, pH, temperature, and bacteria. A further distinction is made between warm and cold water fisheries in freshwater ponds.

Given that the estuarine portion of the Back River is within a state-designated Area of Critical Environmental Concern (ACEC), the SA standards would apply to all portions of the estuary. All other fresh waters within the ACEC would likely be classified as Class A waters. As drinking water supply sources, Weymouth Great Pond and Whitman's Pond and their tributaries are classified as Class A surface waters, while all other freshwater ponds outside of the ACEC are Class B waters. MassDEP surface water classifications are included in the Massachusetts surface water regulations (314 CMR 4.06).

MassDEP is also required under the federal Clean Water Act to identify all waters that are failing to attain the surface water quality standards. These waters are classified as "impaired" and MassDEP is required to identify the contaminant that is causing the impairment. Each of these impaired waters is required to have a Total Maximum Daily Load (TMDL) established for each contaminant causing the impairment. The TMDL is a target limit or concentration that, if attained, will remove the impairment. MassDEP is required to submit to EPA every two years a list of all waters in the Commonwealth, including those that are impaired (MassDEP, 2015a).

6.6.1 Bacterial Contamination

Bacteria contamination is generally due to wastewater sources (*e.g.*, sewer overflows or failing septic systems), but can also be from other sources, including stormwater systems with connections to mammal wastes and/or large animal populations, such as pets, farm animals or large natural populations (*e.g.*, geese). Bacterial contamination can cause illness in human and is sometimes found in drinking waters, swimming areas, or food sources.

As noted in Figure 4-7, shellfish harvesting in all of Hingham Bay and most of the Back River estuary is prohibited largely due high levels of bacteria in the water. Selected areas can be harvested by commercial diggers as long as the shellfish are allowed to sufficiently depurate (*i.e.*, live in clean water to allow purging of contaminants). MassDEP has also classified the following areas as impaired due to fecal coliform in the most recent Massachusetts Integrated List: Hingham Bay, the Back River/Mill River to Whitman's Pond, the stream from Elias Pond to Whitman's Pond, and the Old Swamp River from Rockland to Whitman's Pond (MassDEP, 2015a). There are no public beaches within the Back River watershed, but periodic private beach closings (*e.g.*, Wompatuck Beach in Hingham) have occurred because of bacterial contamination.

Bacterial testing and regulations are generally based on organisms associated with fecal contamination: fecal coliform, enterococci, and *E. coli*.[5] MassDEP, under the rules of Clean Water Act primacy, has

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[5] Tests for these bacteria are generally used to assess exposure of water to fecal matter, although these tests may not be indicative of harmful bacteria. Fecal coliform bacteria are generally found in the intestines of warm-blooded animals and testing results were not as specific as desired. EPA guidance now recommends testing for 1) E. coli, a diverse group of many bacteria, most

the ability to issue limits/standards that are different, but not less than federal limits, and has numerical bacterial limits implemented through surface water regulations that differentiate between drinking water and recreational sources (314 CMR 4). Shellfish bacterial limits in SA waters are based on fecal coliform with a geometric mean limit of 14 organisms per 100 ml and no more than 10% of the samples exceed 28 organisms per 100 ml (314 CMR 4.05(4)4.a.). Bathing beaches and natural water SA limits are no single enterococci sample during the bathing season shall exceed 104 colonies per 100 ml and the geometric mean of the five most recent samples shall not exceed a geometric mean of 35 enterococci colonies per 100 ml (314 CMR 4.05(4)4.b.). Massachusetts currently does not have *E. coli* limits for salt waters.

MassDMF and MWRA collected bacterial samples at 18 stations within the Back River estuary (Table 6-2) for a number of years (1990-2008).

Results show that summer conditions during rain storms (wet events) produce the most exceedances of the bacterial limits in the Back River. “Wet” and “dry”events were both sampled during two seasons: winter (November-April; Figure 6-3) and summer (May-October; Figure 6-4). A sampling event qualified as a wet event if there were at least 0.25 inches of rain in the three days prior to the sampling.

Table 6-2. Weymouth Back River Department of Marine Fisheries (DMF) and Massachusetts Water Resources Authority (MWRA) bacteria sampling stations.

Station Number	Sampled By	Location
29	DMF	Beach Lane, Hingham
33	DMF	Stodders Neck East, Hingham
34	DMF	Stodders Neck North, Hingham
35	DMF	Stodders Neck West, Hingham
37	DMF	Beal Cove North, Hingham
39	DMF	Wharf Street, Weymouth
41	DMF	Whale Island, Weymouth
42	DMF	Cove Dock, Weymouth
43	DMF	Route 3A Bridge
44	DMF	MDC Barn, Weymouth
45	DMF	Public Boat Ramp, Weymouth
46	DMF	Webb State Park, Weymouth
69	DMF	Beal Coves, Hingham
74	DMF	Beal Cove South, Hingham
75	DMF	Fresh River, Hingham
76	DMF	Narrows, Hingham
86	MWRA	Back River, North of Route 3A Bridge
124	MWRA	Hingham Bay South of Bumkin Island

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strains of which are harmless, but some will make humans sick, and 2) enterococcus, similarly a diverse bacterial genus, generally associated with growth in human intestines.

Figure 6-3. Summer Fecal Coliform Exceedances in Weymouth Back River (1992-2008). Exceedances of Massachusetts water quality standards for Fecal Coliform bacteria during summer (May-October) wet (W) and dry (D) sampling events (Massachusetts Dept. of Marine Fisheries). Red indicates exceedance of both water quality standards; yellow one standard; green neither standard.

Figure 6-4. Winter Fecal Coliform Exceedances in Weymouth Back River (1992-2008). Exceedances of Massachusetts water quality standards for Fecal Coliform bacteria during winter (November-April) sampling events (Massachusetts Dept. of Marine Fisheries). Red

indicates exceedance of both water quality standards; yellow one standard; green neither standard.

Fecal coliform contamination in the Back River is severe, especially in summer. In the summer, geometric means of data collected from wet sampling events are consistently higher than those of dry events (Table 6-3).

Summer Station	Years	Wet Geometric Mean	%>28	N	Summer Dry Station	Dry Geometric Mean	%>28	N
29	1992-2008	10	17.6%	17	29	10	17.2%	64
30	1992-2008	8	15.8%	19	30	9	9.2%	65
33	1992-1999	35	40.0%	5	33	6	9.1%	11
34	1992-1999	9	25.0%	12	34	6	2.8%	36
35	1992-2008	11	16.7%	18	35	13	20.3%	64
36	1992-2008	42	53.8%	26	36	24	35.5%	76
37	1992-2008	31	40.0%	25	37	16	25.3%	75
39	1992-1999	1326	100.0%	8	39	944	100.0%	6
41	1992-2008	32	66.7%	9	41	21	34.2%	38
42	1992-2008	25	37.5%	24	42	16	27.4%	73
43	1992-2008	34	40.0%	30	43	16	19.8%	81
44	1992-2008	24	41.7%	24	44	13	25.0%	76
86*	1990-1999	15	26.7%	45	7	7	6.5%	77
45	1992-2008	22	30.8%	26	45	19	34.6%	78
46	1992-2008	9	8.0%	25	46	11	16.7%	78
69	1992-2008	40	42.3%	26	69	17	28.8%	73
74	1995-2008	35	50.0%	22	74	14	19.1%	68
75	1995-1996	140	83.3%	6	75	56	75.0%	4
76	1995-2008	15	15.8%	19	76	13	14.9%	67
124*	1993-2008	6	14.30%	140	124	4	4.10%	269

Table 6-3. Summer (May-October) fecal coliform bacteria concentrations in Weymouth Back River. Geometric means (organisms/100 ml) from MassDMF and MWRA (*) sampling stations during wet and dry sampling events, 1990-2008.

Massachusetts bacterial limits for fecal coliform were exceeded at all but one of the stations during summer wet events and 15 of the 20 stations during summer dry events. In contrast, during the winter, wet events exceeded limits at 9 of the stations and dry events had exceedances at 7 of the stations (Table 6-4).

Winter Station	Years	Wet Geometric Mean	%>28	N	Winter Dry Station	Dry Geometric Mean	%>28	N
29	1992-2008	8	9.5%	21	29	7	8.5%	59
30	1992-2008	9	4.8%	21	30	7	10.0%	60
33	1992-1999	7	16.7%	6	33	11	18.2%	11
34	1992-1999	5	8.3%	12	34	6	10.0%	32
35	1992-2008	8	8.7%	23	35	7	8.5%	59
36	1992-2008	10	7.7%	13	36	8	3.1%	65
37	1992-2008	10	7.7%	13	37	10	9.4%	64
39	1992-1999	207	83.3%	6	39	435	100.0%	10
41	1992-2008	11	0.0%	6	41	14	11.1%	27
42	1992-2008	14	13.3%	15	42	7	4.8%	62
43	1992-2008	16	26.1%	23	43	9	8.9%	79
44	1992-2008	9	15.8%	19	44	10	6.7%	75
86*	1991-2000	12	29.4%	17	86	5	4.4%	45
45	1992-2008	9	10.0%	20	45	10	10.4%	77
46	1992-2008	8	5.3%	19	46	10	7.6%	79
69	1992-2008	12	23.1%	13	69	11	11.9%	67
74	1995-2008	11	8.3%	12	74	8	1.8%	57
75	1995-1996	21	0.0%	1	75	16	40.0%	5
76	1995-2008	13	15.4%	13	76	8	3.1%	64
124*	1993-2008	8	16.90%	65	124	8	16.40%	122

Table 6-4. Winter (November-April) fecal coliform bacteria concentrations in Weymouth Back River. Geometric means (organisms/100 ml) from MassDMF and MWRA (*) sampling stations during wet and dry sampling events, 1990-2008.

Fecal coliform counts in all settings were the highest at Station 39 at Wharf Creek, which is adjacent to the former Weymouth Wharf Street Landfill. This landfill was active from 1949 to 1977, is unlined, and was closed and capped in 2007 (MassDEP, 2015b). Landfills can be major sources of bacteria, nutrients, and other contaminants depending on what was buried. Many landfills in Massachusetts included septage lagoons, which generally have high and persistent contaminant loads.

Enterococci and *E. coli* were only tested by MWRA and only at two stations: #86 (north of the Route 3A bridge) and #124 (off-shore in Hingham Bay) (see Figure 6-3). The geometric means of enterococci samples collected in both summer and winter and in wet and dry weather did not exceed the State water quality standards (Table 6-5). However, several individual samples did exceed the 104 colonies/100ml standard; approximately 10% of the samples at station #86, near the South Shore Yacht Club, exceeded the standard during both wet and dry sampling during the summer. Approximately 3% of station #124 samples exceeded the enterococci standard during wet winter events, but did not have any exceedances during wet summer events (n=4). None of the dry summer or winter samples exceeded the enterococci standard. A small number of *E. coli* samples (<3%) from the two MWRA stations exceeded the enterococci and fecal coliform standards (Table 6-6).

Table 6-5. Summer (May-October) and Winter (November-April) Enterococcus bacteria concentrations in Weymouth Back River and Hingham Bay. Geometric means (colonies/100 ml) from MWRA sampling stations during wet and dry sampling events, 1992-2008.

Enterococcus Station ID	Years	Wet Geometric Mean	%>104	N	Dry Geometric Mean	%>104	N
Summer							
086	1990-2000	9	8.9%	45	4	0%	78
124	1993-2008	4	0%	189	3	0%	353
Winter							
086	1990-2000	15	11.8%	17	4	0%	44
124	1993-2008	5	3.4%	89	3	0%	187

Table 6-6. Summer (May-October) and Winter (November-April) *E. coli* bacteria concentrations in Weymouth Back River and Hingham Bay. Geometric means (organisms/100 ml) from MWRA sampling stations during wet and dry sampling events, 1992-2008.

E. coli Station ID	Years	Wet Geometric Mean	%>28	N	Dry Geometric Mean	%>28	N
Summer							
086	1990-2000	ND	ND	0	ND	ND	0
124	1993-2008	4	2.0%	50	3	2.4%	83
Winter							
086	1990-2000	ND	ND	0	ND	ND	0
124	1993-2008	3	0%	24	3	1.5%	65

A closer examination of Figure 6-4 shows that bacterial exceedances diminish as sites move closer to the mouth of the Back River. In the summer, the greatest frequency of exceedances of the water quality standards occurs in the upper part of the estuary. Bacteria survival tends to be worse in higher salinity, higher oxygen, lower temperature, lower sunlight, and higher pH environments (Neger, 2002). Based on the collected data, the higher salinity/greater tidal flushing seems to lower bacterial exceedances in the Back River.

6.6.2 Excessive Nutrients

Nutrients, such as nitrogen and phosphorus, are necessary for sustaining healthy aquatic ecosystems; these are the building blocks for the growth of phytoplankton and other plants, which form the base of the food chain and capture most of the energy for these types of ecosystems. However, as watershed land is changed from forests to housing, shops, factories and roads, the potential grows to add more nutrients and change the balance between the species living in the ecosystem. Chronic nutrient loading from upland sources to rivers, lakes and estuaries is one of the most serious problems facing communities throughout the world today. Nutrient enrichment of these systems sets off a cascade of ecosystem changes, including increased phytoplankton, changes in submerged aquatic vegetation (SAVs) populations, "nuisance" blooms of blue green algae (*i.e.*, cyanobacteria), sediment accretion, and low oxygen events. Alterations in the plant community often impair important habitats for benthic invertebrate communities and fish (spawning/nesting grounds), which in turn alter food resources of birds. At the highest levels of nutrient loading, rapid anoxic events (depletion of oxygen) can cause fish kills and persistent anoxia can make sediments diversity deserts, where only bacteria thrive.

Sources of excessive nutrients can include septic systems, wastewater treatment facilities, leaking sewer pipes, fertilized lawns and other turf, agriculture, and landfills. Estuaries, streams, and lakes and ponds can all be impacted by excessive nutrients, although the various individual characteristics of each system will determine the level of sensitivity and which nutrients have the greatest impact. Source reduction is typically the most effective way of managing nutrients, but other techniques such as increased tidal flushing or enhanced natural attenuation may be possible depending on the system.

Since the Massachusetts surface water standards do not have numeric standards for excessive nutrients, the primary factors for determining whether water quality meets these standards are contained in the descriptive (and more flexible) portions of the regulations (314 CMR 4). Since high amounts of excessive nutrient loads also eventually trigger dissolved oxygen impacts, these numeric standards may also impact compliance with the regulations. Only one system within the Back River watershed, the Mill River, is currently identified by MassDEP for being impaired by nutrients. (see Table 6-7). The most recent MassDEP Integrated List (2015a) also mentions a portion of the Back River estuary as being impaired for low dissolved oxygen, which is indirectly related to nutrients.

Table 6-7. Impaired Water Bodies in Back River Watershed. These are listings from the MassDEP Category 5 Waters "Waters Requiring a TMDL" portion of the 2014 Final Integrated List. An integrated list is required to be submitted and approved every two years under the Clean Water Act and the 2014 List is the latest USEPA-approved list.

Name	Segment ID	Description	Size	Units	Impairment Cause
Hingham Bay	MA70-07	The area defined between Peddocks Island and Windmill Point; from Windmill Point southeast to Bumkin Island; from Bumkin Island southeast to Sunset Point; from Sunset Point across the mouth of the Weir River to Worlds End; from Worlds End across the mouth of Hingham Harbor to Crow Point; from Beach Lane, Hingham across the mouth of the Weymouth Back River to Lower Neck; and from Lower Neck midway across the mouth of the Weymouth Fore River	4.8	square miles	Fecal Coliform
					PCB in Fish Tissue
					other

Mill River	MA74-04	Headwaters, west of Route 18 and south of Randolph Street, Weymouth to Pond, Weymouth (portions culverted underground).	3.4	miles	Fecal Coliform
					Nutrient/Eutrophication Biological Indicators
Old Swamp River	MA74-03	Headwaters just west of Pleasant Street and north of Liberty Street, Rockland to inlet Whitman's Pond, Weymouth.	5.2	miles	Fecal Coliform
Weymouth Back River	MA74-05	Outlet Elias Pond, Weymouth to the base of the fish ladder north of Commercial Street, Weymouth.	0.4	miles	Fecal Coliform
					Nutrient/Eutrophication Biological Indicators
Weymouth Back River	MA74-13	From the base of the fish ladder north of Commercial Street, Weymouth to mouth between Lower Neck, Weymouth (to the west) and Wompatuck Road, Hingham.	0.86	square miles	Fecal Coliform
					Other
					PCB in Fish Tissue
Whitman's Pond	MA74025	Weymouth	147	acres	(Non-Native Aquatic Plants*)
					DDT
Notes: * TMDL not required (Non-pollutant)					

Within the Back River watershed, there are a number of resources with nutrient-related monitoring data that should be considered impaired:

Mill River
The Mill River upstream of Whitman's Pond (MassDEP Segment ID: MA74-04) is listed in the most recent MassDEP Integrated List (2015a) as requiring a TMDL for nutrients and pathogens. Dissolved oxygen levels were between 6.7 and 11.8 mg/L but no pre-dawn samples were taken (DO minimum for Class A waters is 6 mg/L).[6] Ammonia levels ranged between below detection to 0.122 mg/L. Total Phosphorus ranged between 0.005 and 0.047 mg/L with an EPA Ecoregion threshold of 0.035 mg/L. It is not clear from available data why Mill River is listed as being impaired by nutrients.

Whitman's Pond
As an occasional public water supply, Whitman's Pond is classified by MassDEP as a Class A water (MassDEP Segment ID: MA74025). Whitman's Pond is listed on the 2014 Integrated List

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[6] Photosynthesis provides dissolved oxygen to the water column, so pre-dawn measurements will provide a "cleaner" assessment of dissolved oxygen concentrations without plants adding additional DO.

of Waters as being impaired by DDT, but is not listed for nutrients. However, the 1983 MassDEQE water quality results showed regular bottom hypoxia and nutrient concentrations above recommended EPA ecoregion limits and limited sampling since then have generally confirmed these impairments. Dissolved oxygen profiles throughout the MassDEQE assessment showed deep summer concentrations regularly below the MassDEP regulatory minimum of 5 mg/L and occasionally anoxic concentrations (<1 mg/L) (Figure 6-5). Persistent hypoxia and anoxia in deep waters are usually indicative of excessive nutrients in ponds and lakes. Total Phosphorus levels have ranged from 0.01 to 1.10 mg/L, while the ecoregion limit is 0.008 mg/L (EPA, 2001). Secchi clarity readings collected during the MassDEQE assessment had an average of 1.8 m or 28% of the water column, which is poor for a shallow pond (*e.g.*, Eichner, *et al.*, 2003). Secchi depth is an indicator of the amount of suspended particulate matter in a water column, which generally is predominantly phytoplankton.

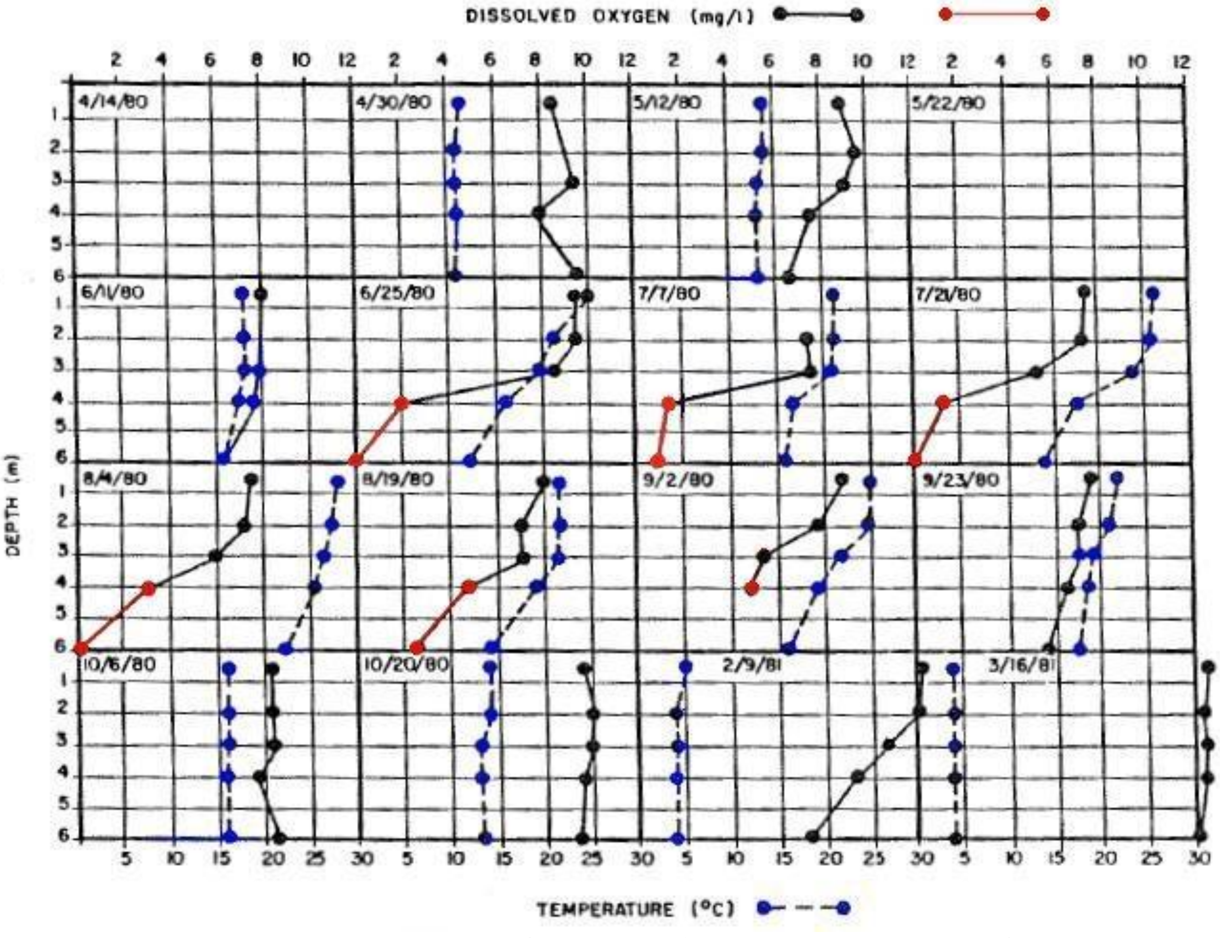

Figure 6-5. Whitman's Pond Dissolved Oxygen Profiles at deepest location (1980-1981). DO profiles collected at Station 1 are indicated by black dots connected by solid black lines except for concentrations that are less than the MassDEP regulatory minimum of 5 mg/L, which are indicated by red dots with solid red lines. Temperature profiles are indicated by blue dots with dashed lines. Modified from Figure 9 in MassDEQE (1983).

Weymouth Back River (fresh)

The freshwater segment of Back River that runs from the outlet at Elias Pond to the base of the fish ladder north of Commercial Street (MassDEP Segment ID: 74-05) is classified in the surface water regulations as Class B warm water fishery and is impaired for fecal coliform and low dissolved oxygen in the most recent MassDEP Integrated List (2015). Typically low dissolved oxygen is indicative of excessive nutrients, but the number of nutrient measurements in the freshwater portion of the river are small (n<10; *e.g.*, Socolow, *et al.*, 1999) with concentrations both above and below the USEPA ecoregion threshold (EPA, 2000). The section of river from the outlet of Whitman's Pond to the confluence with the stream coming from Elias Pond is not classified as a segment in the MassDEP listings.

Weymouth Back River (salt)

According to MassDEP's latest integrated list, the Back River estuary portion (MassDEP Segment ID: 74-13) has listings for other impairments (*e.g.*, PCBs and fecal coliform), but no listing for nutrient-related impairments (MassDEP, 2015a). Hingham Bay has similar impairment listings.

6.6.3 Toxic Pollutants

Toxic pollutants are usually the by-products of industrial activity within a watershed and will run the range from metals such as lead, arsenic and mercury, to organic compounds such as pesticides, PCBs fuels, oils, and other carbon compounds. The pollutant mix will usually reflect the mix of industrial operations, though some compounds can be concentrated in particular areas by accidental spills, on-site waste disposal and fires that occurred on the property.

The history of the Boston Harbor region is one of industrial development from the early 1800s to the present. As mentioned in previous chapters, the Back River watershed has included a variety of industries and municipal uses with the potential to contaminate groundwater and surface waters, including bog iron mining and processing, shoe factories, fertilizer manufacturing, military installations, paint factories, and landfills. All of these generally produced various toxics as by-product of their activities and standard practices for their handling and disposal at the time of their use have often created legacy contamination in the watershed that is being addressed in current cleanup activities.

Toxic chemicals can move to surface waters through groundwater transport, erosional or runoff transport or wind transport. Transport via water occurs when dissolved compounds are delivered to surface waters, intertidal and subtidal environments. Transport via air is usually through wind erosion of contaminated soils and particle deposition in surface waters with settling to sediments. Many toxic pollutants are fairly insoluble in water and, therefore, tend to settle and accumulate in the sediments of rivers, lakes and estuaries where bottom dwelling and feeding animals will ingest them directly. If these animals are, in turn, consumed by others in significant enough quantities and the pollutants are not degraded, the animals at the top of the food chain, including humans, can be subjected to high doses of the original pollutants. Partial, natural degradation of original compounds may also create "daughter" compounds with similar characteristics. This movement through the food chain is called bioaccumulation and this process can create health hazards for people and alter ecosystem food webs by harming species that may be sensitive to the contaminants.

The Massachusetts Department of Environmental Protection (MADEP) has listed dozens of sites within the Back River watershed which have been investigated for toxic pollutants. Most have been remediated. Some have been remediated with limitations placed on the uses of the sites and some are still in the process of being investigated or remediated. Many are small commercial sites such as several gas stations, auto junk yards or private residences. Several are larger, more complex sites such as:

- the Weymouth Neck Landfill/fertilizer plant,
- South Weymouth Naval Air Station, the Hingham Shipyard,
- the Merriman Division of Quamco Inc. and
- the Naval Ammunition Depot.
-

Notable areas of known toxic pollutant contamination are briefly discussed below:

Weymouth Neck

Weymouth Neck has hosted a number of land uses that have legacy industrial contaminants. The south of the Neck is historically the site of the Bradley/AGRICO Fertilizer plant (1861-1966, Figure 6-6). In 1966, the fertilizer company, The American Agricultural Chemical Company (TAACC), merged with Continental Oil Company, and the plant was shut down. Continental Oil Company eventually became ConocoPhillips Company.

In 2003, as part of a federal Superfund assessment, ConocoPhillips accepted responsibility for the cleanup of the site and implemented a comprehensive remediation program under the direction of URS Corporation. Much of the impacted material was removed to an undeveloped consolidation area on Weymouth Neck where it was capped with clean soil and landscaped. This method permanently isolated the impacted soils from exposure to human contact and the environment.

Figure 6-6. Bradley/Agrico Fertilizer Plant, Weymouth Neck. Fertilizer plant is shown in the center of the picture; view is looking south along Weymouth Neck. The docks of the Hingham Shipyard can be seen on the opposite shore (left side of picture). The current Webb Memorial Park would be located just off the right side of the picture. Source: Weymouth Historical Society.

The former TAACC site is approximately 19 acres and is just south of Webb Memorial State Park on the north side of the mouth of the Back River estuary. The site includes a 6-acre developed portion (on which lie East Bay Condominiums and Essex Leasehold Condominiums) and a 13-acre undeveloped portion which included sand and gravel piles, areas of red-colored soil and scraps of leather on the ground surface. The remains of a concrete pad in the southwestern corner of the property marked the location of the former main production building of the fertilizer factory, most of which is now overgrown with shrubs. The remains of the wharf used to ship and receive raw materials and finished goods from the fertilizer factory is also located to the south of the concrete pad, and extends eastward toward the mouth of the Back River. It should also be noted that the Webb Memorial State Park site was a former Nike anti-aircraft missile installation that was built in 1956 and was operational until 1974. During its active period, the site contained a large underground storage facility for up to 30 missiles.

Soil testing at former TAACC site on Weymouth Neck has found that it was contaminated with a variety of organic and inorganic compounds due to years of activity associated with the plant processes, including: oil, gas, acid, and naphtha storage tanks, a fluorine plant, grease house, auto repair facility, electric shop, engine shop, machine shop, paint shop, bone steaming plant, lump plaster facility, acid house, oil house and storage of coal and fertilizer (URS, 2010). Two major fires at the site in 1913 and 1946 also likely released unknown quantities of contaminants. Site assessment activities to quantify the locations and concentrations of specific contaminants at the site began in the early 1980s. Soil and groundwater on site, and intertidal sediments and shellfish adjacent to the site were analyzed for both organic and inorganic contaminants.

Organic contaminants were found mostly in the top 6 inches of soil after testing soils down to depths of up to 20 ft. Polycyclic Aromatic Hydrocarbons (PAHs) were the most prevalent, including: benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, dibenz(a,h)anthracene and indeno[1,2,3-cd]pyrene; all of these are formed by incomplete burning of organic matter and had concentrations exceeding EPA and MassDEP concentrations limits. Concentrations ranged from approximately 0.5 to 10 ppm. Pesticides and PCBs were also detected but were probably not associated with fertilizer manufacturing processes.

Several metals were also consistently detected in the soil testing including lead, arsenic, zinc, iron, copper, chromium and cadmium; lead, arsenic and beryllium exceeded EPA and MassDEP concentrations limits. Arsenic, along with lead, was detected throughout the site in some of the highest concentrations of any of the soil contaminants on the site. Arsenic levels were detected as high as 2,600 to 3,320 ppm[7] in some areas (Figure 6-7), while lead was found in concentrations as high as 6,000 to 11,000 ppm[8] throughout the site (Figure 6-8). Most of the arsenic and lead were found in the top layers of soil but high concentrations were also detected as deep as 15 to 20 ft. This finding is likely due to industrial processes that used lead-lined chambers to combust pyrite rocks (iron sulfide) to obtain sulfuric acid for making fertilizer.

In addition to lead, other by-products of this process were arsenic and iron oxide, the highly contaminated "red soils" seen throughout the site. Piles of leather scraps, mixed in with ground animal bones, fish scraps and other organic wastes used to make fertilizer, were also scattered around the site. They contained up to 100 ppm of arsenic, up to 5,670 ppm of chromium, 616 ppm copper and 922 ppm lead. Corresponding MassDEP background soil concentrations are 20 ppm arsenic, 30 ppm chromium, 40 ppm copper, and 100 ppm lead (MassDEP, 2014).

Data analysis showed that intertidal sediment concentrations of arsenic and lead ranged from 1.5 to 30.3 ppm and 3.5 to 129 ppm, respectively. Shellfish tissue concentrations ranged from 1.1 to 1.6 ppb arsenic and 0.92 to 1.5 ppb lead. None of the levels in shellfish tissues taken from the Weymouth Neck area were significantly greater than those found in shellfish at other sites around Boston Harbor.

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[7] MassDEP background concentration is 20 ppm (MassDEP, 2014).

[8] MassDEP background concentration is 100 ppm (MassDEP, 2014).

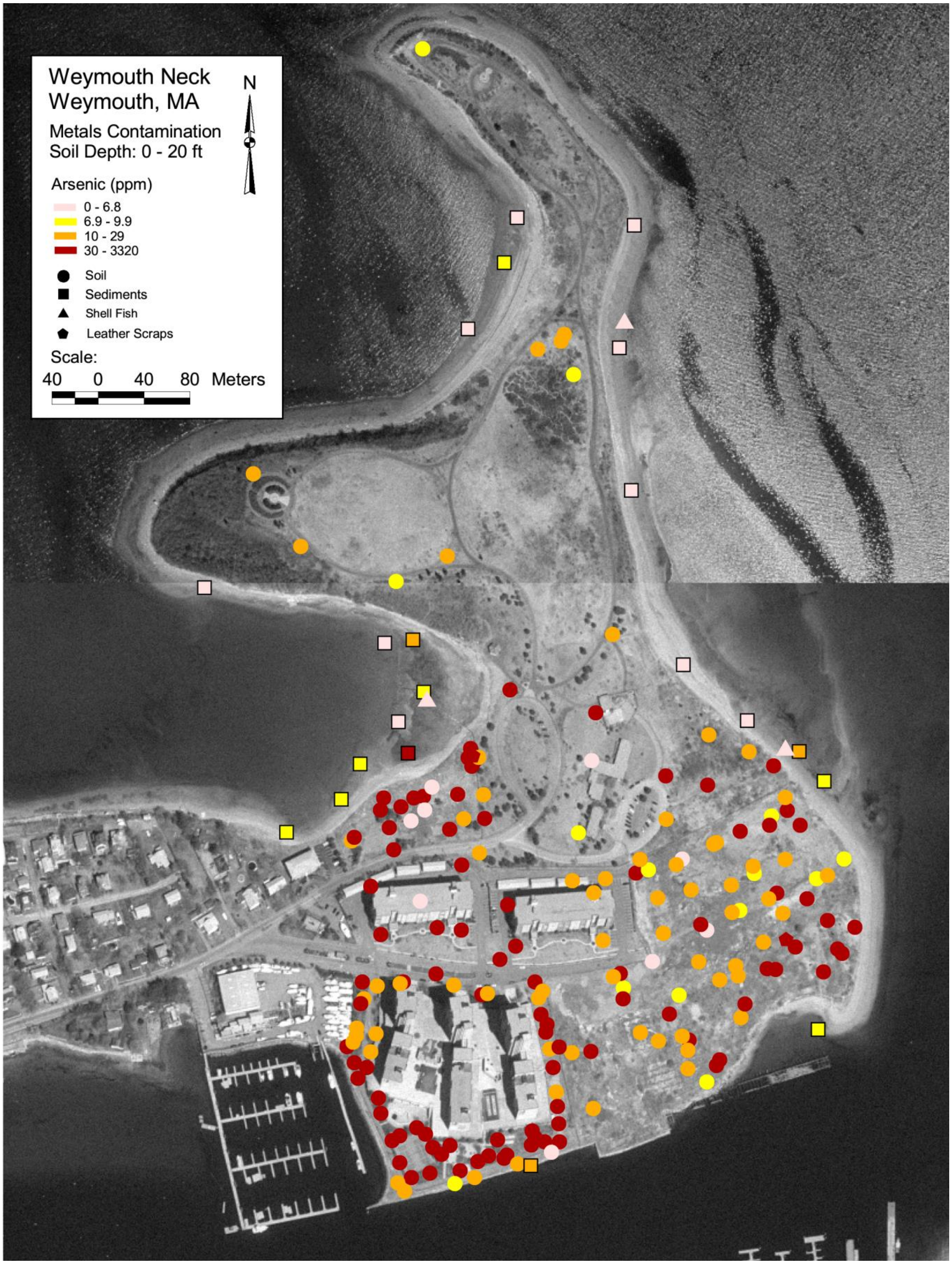

Figure 6-7. Arsenic contamination: Weymouth Neck. Locations of sampling sites where arsenic was found in soils, sediments, shellfish and piles of leather scraps. Orange locations exceeded ecological risk level, while red locations exceeded human health risk standards. Data from Mass DEP, GZA and EPA site investigations, 1988-2000.

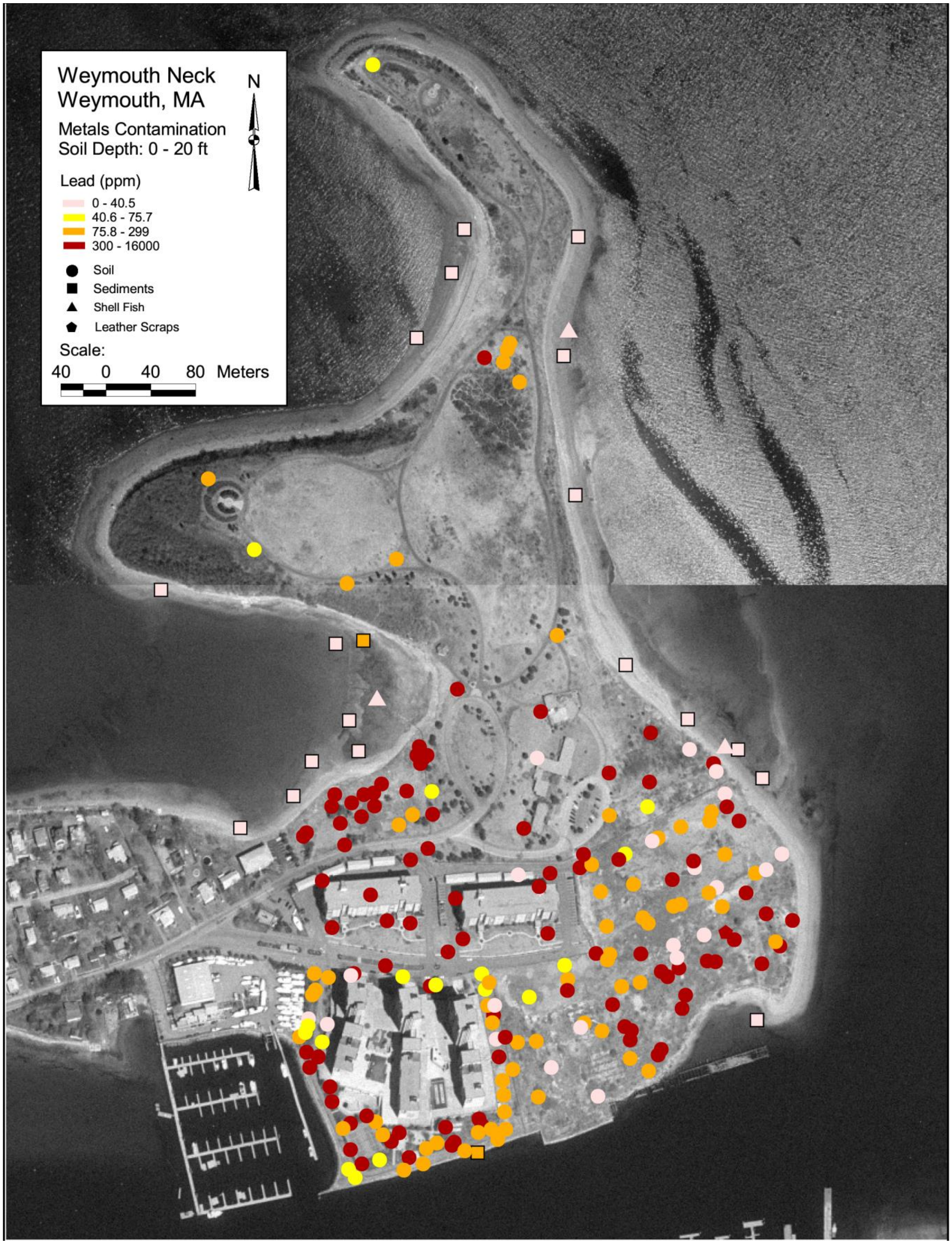

Figure 6-8. Lead contamination: Weymouth Neck. Locations of sampling sites where lead was found in soils, sediments, shellfish and piles of leather scraps. Orange locations exceeded ecological risk level, while red locations exceeded human health risk standards. Data from Mass DEP, GZA and EPA site investigations, 1988-2000.

South Weymouth Naval Air Station

The former South Weymouth Naval Air Station (NAS) is approximately 1,442 acres in size and located in the towns of Weymouth, Abington, and Rockland. A portion of the site is within the Back River watershed. The Navy used the NAS it as a base for dirigible aircraft that patrolled the North Atlantic during World War II (Figure 6-9). The Station was closed at the end of the war and then reopened in 1953 for aviation training. The facility closed permanently in 1997.

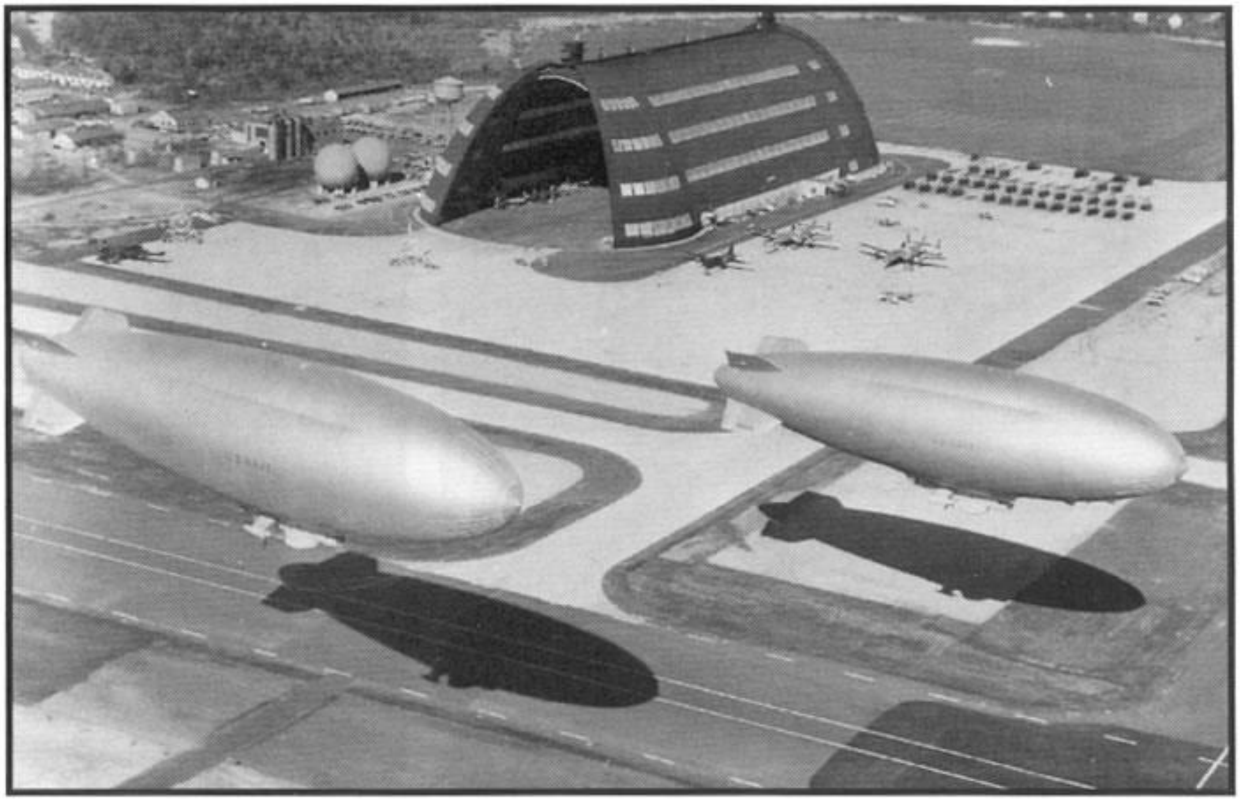

Figure 6-9. South Weymouth Naval Air Station 1940s. The South Weymouth Naval Air Station is approximately 1,442 acres in size and partially located within the southern portion of the Back River watershed and the towns of Weymouth, Abington, and Rockland. It was established by the Navy as a base for dirigible aircraft that patrolled the North Atlantic during World War II. The Station was closed at the end of the war and then reopened in 1953 for aviation training. The facility closed permanently in 1997. Source: Weymouth Historical Society.

In 1994, the NAS was added to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, *i.e.*, Superfund) list as a hazardous waste site. Since that time, the Navy and it contractors have identified more than 150 potential hazardous waste sites within the NAS boundaries and investigated and developed cleanup strategies for those sites with excessive contamination. According to US EPA, the Navy has spent more than $67 million on the investigation and cleanup and has transferred more than 1,280 acres for redevelopment to a variety of private entities and government organizations.[9]

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[9] USEPA Superfund Site Status Database: https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0101826

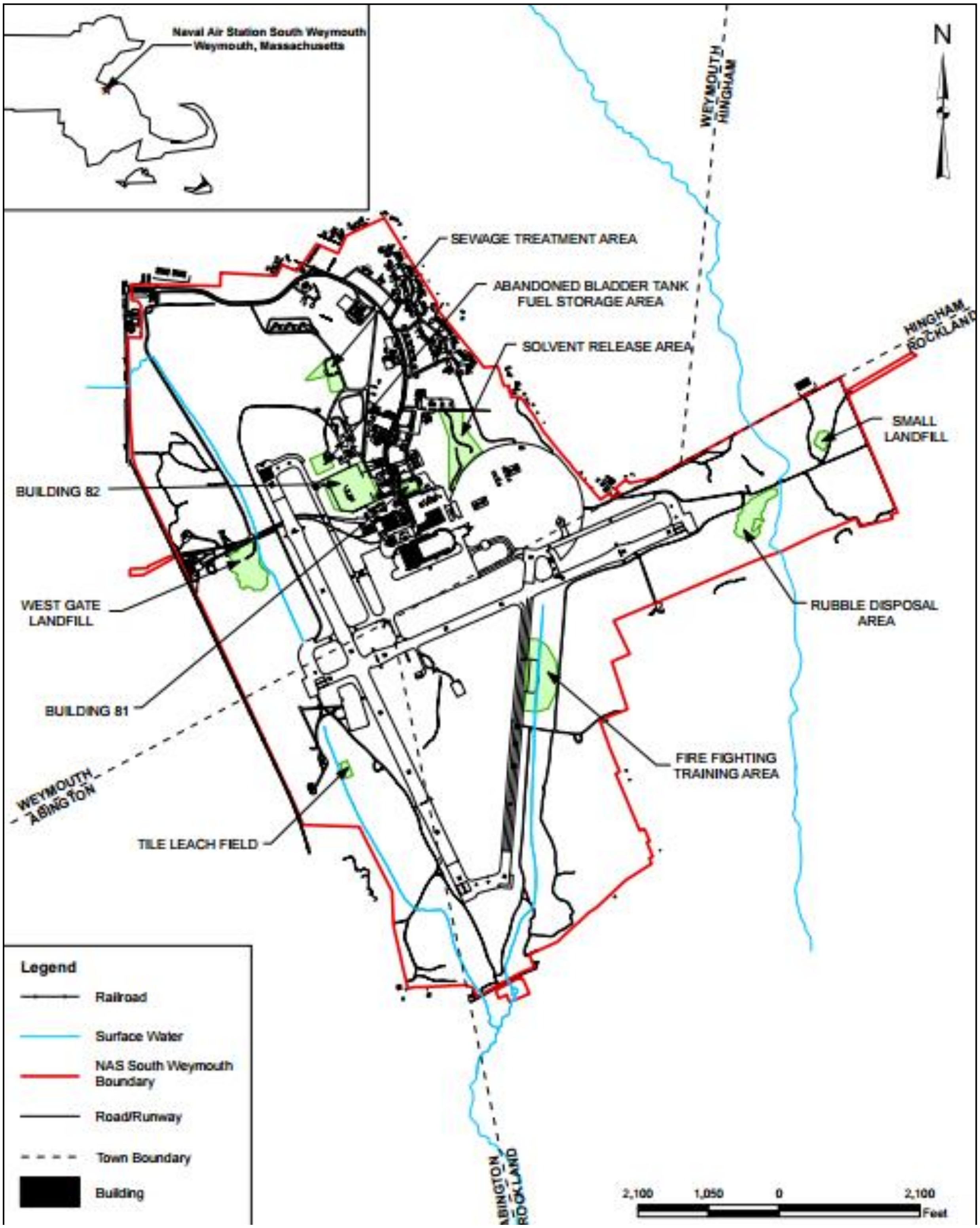

Figure 6-10. South Weymouth Naval Air Station Layout. Indicates location of Rubble Disposal Area, Small Landfill, (both on right side of figure) and West Gate Landfill (left side of figure). Source: Tetra Tech, 2012.

Notable hazardous waste sites within the NAS site are shown in Figure 6-10 and include:

> *West Gate Landfill*: 5.25 acre site operated from 1969 to 1972 as the main solid waste disposal area for the NAS. Material testing within the landfill exhibited concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, and metals in excess of background conditions. The remedy for this area included a soil cover and long-term monitoring as well as land use restrictions (Tetra Tech, 2007).
>
> *Building 81*: Former site of the Marine Air Reserve Training Building and the former vehicle maintenance garage. In 1991, an underground storage tank, associated piping and a small quantity of soil were removed. After 1998 groundwater sampling detected contaminants and the Navy failed to clean residual contamination using chemical oxidation in 2000 to 2001, the site was transferred to the Superfund program for additional study and cleanup.
>
> *Building 82*: Former site of a U.S. Marine Corps for aircraft maintenance hangar with contamination identified in floor drain system and nearby drainage ditch. The long-term remedy for the area includes groundwater treatment, land use restrictions and monitoring.
>
> *Fire Fighting Training Area*: Training operations began at this area in the mid-1950s with waste oil and other fuels burned for firefighting training purposes. Soil and groundwater evaluations generally found limited contamination and a No Further Action determination was agreed to under CERCLA in 2008 (Tetra Tech, 2012).
>
> *Industrial Operations Area*: 12 sites in this area were either immediately addressed and/or closed out; four were identified for further assessment. A removal action addressed surface soil contamination in the center part of the area.
>
> *Rubble disposal areas (RDA) and the small landfill (SL):* 3.8 acre and 0.8 acre sites, respectively, operated from 1972 until the mid-1980s that are adjacent to the Old Swamp River, which flows into Whitman's Pond. Soil samples from RDA contained volatile organic compounds (VOCs), PCBs and heavy metals. Groundwater samples were contaminated with heavy metals. RDA soils were excavated, the area was capped, restrictions were placed on use of the land and groundwater, and a long-term monitoring plan was instituted (EPA Final Remedial Investigation, January 2001). At the SL, thallium and zinc were present in groundwater but not at levels that would pose a risk (EPA Final Remedial Investigation, January 2001).

Naval Ammunition Depot

The current location of Bare Cove Park on the Hingham side of the Back River was the primary location of a United States Naval Ammunitions Depot (USNAD) from approximately 1914 through the 1950s. The land was used primarily for agricultural purposes until the Navy acquired 905 acres of land between 1906 and 1913 (208 acres in Weymouth and 697 acres in Hingham) to replace an older magazine in Chelsea, MA (ACOE, 1993). The USNAD assembled gun ammunition, mines, torpedoes, and pyrotechnics, and tracked and stocked ammunition and components for the First Naval District.

Facilities on the site expanded through activities associated with World War I and World War II. By 1937, there were 130 buildings on the site connected by eleven (11) miles of track. In 1941, approximately 3,800 acres in Hingham/Cohasset/Scituate/Norwell were acquired for the Hingham Naval Ammunition Depot Annex. By the end of World War II in 1945, the Depot facilities were the main ammunition supplier for Naval Forces of the U.S. Atlantic Fleet. At its peak in June, 1945, the Depot facilities employed 2,091 civilians along with 721 naval officers and sailors and 375 Marine guards.

After the war, the USNAD was placed into a "maintenance" status and civilian employment dropped to 50 personnel. It was reactivated to full operation in 1950 at the start of the Korean Conflict. Its mission was to maintain ammunition and explosives in stores, furnish reserve capacity, and to produce and overhaul/rework rockets. Activity decreased at the USNAD at the end of the Korean Conflict and the majority of the Annex land was transferred to the Commonwealth of Massachusetts in 1967. In 1971, the USNAD was declared "surplus" and the following year, the USNAD was officially transferred to the Town of Hingham. The town developed a number of uses for the site including the creation of Bare Cove Park.

As part of testing munitions on the site, munitions and other chemicals were regularly burned on the property. The original 1993 ACOE site assessment also indicated burial of some shells near the river and concerns about unexploded ordinance. The burning and detonation of munitions by the Navy and the Army was restricted primarily to an area in the southeastern portion of the property. Materials burned or detonated include, but are not limited to: incendiary bombs, unserviceable pyrotechnic ammunition, chemical ammunition, irritant hand grenades, tracers, aircraft flares, detonators, black powder igniters, and cordite. Soil testing within the former USNAD has found arsenic, PAHs, EPHs, PCBs, and asbestos above regulatory limits. Efforts to remove these contaminants have included excavation and removal of materials. The Army Corps of Engineers maintains responsibility for any contamination that may be discovered on site.

The Army Corps of Engineers conducted a remedial investigation in 2018 to identify and remove potential ordnance and explosive waste pollutants from the USNAD. A report documenting the investigation is expected to be published in early 2019.

Julia Field

Julia Field is located off Julia Road near Great Esker Park. Historic USGS Quadrangles published between 1893 and 1947 show the site as wetland/open water, but subsequent quads show the site as filled. The Town of Weymouth used the site for the disposal of solid waste and ash from a municipal trash incinerator. Once the site reached capacity, the site was covered with soil and converted to a park and playing field. In 2006, during preliminary investigations for redevelopment of the park, soil borings indicated the presence of lead, cadmium, and PAHs, the latter two above regulatory limits. Further site investigations showed that the ash material was resting on wetland peats in many areas, but that downgradient contaminant concentrations were not above ecological limits (Environmental Partners, 2007). The recommended mitigation plan included removal of 2,013 tons of contaminated material, covering the remaining material with a geotextile cap, and covering the cap with 1,342 cubic yards of clean fill. An additional recommended step was to institute a deed addendum that limits digging on the site to no more than three feet below ground surface.

Merriman/Quamco/PCC Specialty Products site

The Merriman site is located at 100 Industrial Park Road in Hingham within the Old Swamp River subwatershed. The 15.88-acre was developed in 1966 as a brass foundry and metal working business producing brass, bronze and stainless steel parts (Tighe and Bond, 1996). Operations on the site included industrial wastewater lagoons and three large underground storage tanks (3,000 to 15,000 gallon capacities). In 1987, a site investigation found contaminated groundwater and soils attributable to the site. Initial investigations found hazardous chemicals both on-site and migration to off-site locations (*e.g.*, in tributary to Old Swamp River). Detected chemicals above regulatory limits were primarily VOCs (mostly 1,1,1-TCA and 1,1-dichloroethene) and metals. Soils were removed from the site in 1987 and a groundwater treatment system was installed. The site was under review both by EPA under Superfund and MassDEP under the Massachusetts Contingency Plan (MCP). Monitoring on the site shows that while VOC concentrations have decreased, they continue to persist above regulatory limits (GZA, 2016).

Hingham Shipyard

The Hingham Shipyard was built by the US Government soon after the outbreak of World War II on 96.5 acres of shoreline and adjacent upland along the Back River near its mouth at Weymouth Neck (Figure 6-11). It operated throughout the War and turned out over 200 ships. During the 1950s, various portions of the shipyard were leased to civilian operations. Following the 1958 sale of the property, ownership passed through a series of marina operators, commercial/industrial uses, and warehousing. In 1997, the property was converted into a Condominium/Retail complex.

Review of historical activities on the site during its shipyard years showed the use of a wide variety of oil and hazardous materials at a number of buildings within the shipyard. Materials included chlorinated hydrocarbons, fuel oil, gasoline, and inorganic compounds related to electroplating (Hidell-Eyster, 1996). Soil and groundwater investigations between 1989 and 1995 found concentrations of many contaminants above regulatory limits, including chromium, lead, copper, zinc, cyanide, VOCs, total petroleum hydrocarbons (TPHs), polycyclic aromatic hydrocarbons (PAHs), PCBs, oils, and grease. The complex mix of contamination across a number of sites within the former shipyard parcel has led to a complex mix of remedial strategies. Most of the sites have been remediated/mitigated either through excavation and replacement with clean fill or activity use limitations.

Figure 6-11. Hingham Shipyard, Weymouth Back River 1940s. View is looking toward the east with the mouth of the Back River toward the top of the figure. Source: Hingham Historical Society.

Whitman's Pond

In Whitman's Pond, sediment analyses were completed in 1981, 2001, and 2012. The earlier samples had metals concentrations that were generally determined to be consistent with urban environments (BETA, 2004), but more extensive sampling in 2012 (ESS, 2014) found concentrations of cadmium, chromium, lead, and nickel above the most stringent MCP thresholds in various portions of the pond and its tributaries, including the Mill River, South Cove, and West Cove. Other detected compounds included PCBs, arsenic, zinc, and acetone. Whitman's Pond also has a fish consumption advisory issued by the Massachusetts Department of Public Health for DDT in American Eel: "The general public should not consume any American Eel from this water body" (MassDPH, 2013).

Back River Shellfish

The shell fishing industry in the Back River has been severely impacted by contamination from bacteria and toxic pollutants, specifically pesticides. Soft shell clams (*Mya arenaria*) analyzed in 1972 for a suite of pesticides including DDT, malathion and dieldrin, were found to contain levels as high as 1.6 ppm (DDT) which can be toxic to shellfish, causing growth impairment and significant mortality (Iwanowicz, *et al.*, 1973).

6.7 Invasive Species

Non-native plants and animals have been colonizing aquatic and terrestrial habitats in New England for many years. The Boston Harbor region is vulnerable to these invasions because of its deep water port facilities which bring people, materials and goods to the area from all over the world. Transport is also facilitated by commercial shipping (ballast water and fouling on hulls of ships), the import of bait, importing shellfish seed stocks, aquaculture, bio-medical research, aquarium supplies, food sources and ornamental uses.

Invasives usually get a foothold in local habitats because of competitive advantages over native species. These competitive advantages can include: a) lack of natural predators or competitors that exist in their "home" settings, b) physiological advantages allowing more efficient or a wider range of use of nutrients, water, or energy, and/or c) more rapid or larger brood reproduction. Since the mix of species within a given ecosystem is collectively balanced among predator and prey relationships and transfer of energy and nutrients that have developed over thousands of years, an invasive species can alter that balance and produce ripples throughout an ecosystem. The history of biological invasions is well-documented but the problem persists.

A number of Massachusetts agencies and non-governmental organizations (NGOs), as well as federal agencies are working on efforts to reduce the incidence of invasions and slow the spread of those that have gained a foothold in this region. The USGS currently has a list of 25 invasive aquatic species within Norfolk County (Table 6-8).

Table 6-8. USGS List of Invasive Aquatic Species within Norfolk County. Norfolk County includes the Weymouth portion of the Back River Watershed). Native species are those native to the United States, but outside of their usual range, while Exotic species are those that are not native to the United States. Source: US Geological Survey, NAS - Nonindigenous Aquatic Species Database (http://nas.er.usgs.gov/queries/StateSearch.aspx; accessed May 3, 2016)

Group	Family	Scientific Name	Common Name	Native/ Exotic	Fresh/ Marine/ Brackish
Amphibians-Frogs	*Hylidae*	*Hyla cinerea*	Green Treefrog	Native	Freshwater
Coelenterates-Hydrozoans	*Olindiidae*	*Craspedacusta sowerbyi*	freshwater jellyfish	Exotic	Freshwater
Crustaceans-Crayfish	*Astacidae*	*Pacifastacus sp.*	crayfish	Native	Freshwater
Fishes	*Centrarchidae*	*Lepomis macrochirus*	Bluegill	Native	Freshwater
Fishes	*Centrarchidae*	*Micropterus dolomieu*	Smallmouth Bass	Native	Freshwater
Fishes	*Centrarchidae*	*Micropterus salmoides*	Largemouth Bass	Native	Freshwater

Fishes	*Centrarchidae*	*Pomoxis nigromaculatus*	Black Crappie	Native	Freshwater
Fishes	*Clariidae*	*Clarias batrachus*	Walking Catfish	Exotic	Freshwater
Fishes	*Cyprinidae*	*Carassius auratus*	Goldfish	Exotic	Freshwater
Fishes	*Cyprinidae*	*Cyprinus carpio*	Common Carp	Exotic	Freshwater
Fishes	*Esocidae*	*Esox niger*	Chain Pickerel	Native	Freshwater
Fishes	*Ictaluridae*	*Ictalurus punctatus*	Channel Catfish	Native	Freshwater
Fishes	*Poeciliidae*	*Gambusia holbrooki*	Eastern Mosquitofish	Native	Freshwater
Fishes	*Salmonidae*	*Salmo salar*	Atlantic Salmon	Native	Freshwater-Marine
Mollusks-Gastropods	*Viviparidae*	*Cipangopaludina chinensis malleata*	Chinese mysterysnail	Exotic	Freshwater
Mollusks-Gastropods	*Viviparidae*	*Viviparus viviparus*	snail	Exotic	Freshwater
Plants	*Haloragaceae*	*Myriophyllum spicatum*	Eurasian watermilfoil	Exotic	Freshwater-Brackish
Plants	*Hydrocharitaceae*	*Egeria densa*	Brazilian waterweed	Exotic	Freshwater
Plants	*Lythraceae*	*Trapa natans*	water chestnut	Exotic	Freshwater
Plants	*Potamogetonaceae*	*Potamogeton crispus*	curly-leaf pondweed	Exotic	Freshwater
Reptiles-Snakes	*Viperidae*	*Agkistrodon piscivorus*	Cottonmouth	Native	Freshwater
Reptiles-Turtles	*Emydidae*	*Cuora flavomarginata*	Yellow-margined Box Turtle	Exotic	Freshwater
Reptiles-Turtles	*Emydidae*	*Graptemys geographica*	Northern Map Turtle	Native	Freshwater
Reptiles-Turtles	*Emydidae*	*Trachemys scripta elegans*	Red-eared Slider	Native	Freshwater
Reptiles-Turtles	*Trionychidae*	*Pelodiscus sinensis*	Chinese softshell	Exotic	Freshwater

A 2012 survey of Whitman's Pond found three exotic invasive aquatic plants: fanwort (*Cabomba caroliniana)*, variable-leaf milfoil (*Myriophyllum heterophyllum) and* curly-leaf pondweed (*Potamogeton crispus)* (ESS, 2013). Fanwort has been a nuisance for over three decades and nearly 86 acres of the 200 acre pond was characterized by dense plant cover. Impaired water quality has created conditions in the pond that favor the growth of these invasives over native pond plants. ESS (2013) also noted two emergent invasives around the edges of the pond: common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*),.

6.8 Global Warming

Between 1970 and 2000, temperatures in the Northeast have increased nearly 0.5°F per decade with winter temperatures increasing even faster (1.3°F per decade) (Frumhoff, *et al.*, 2007). These changes are a reflection of a warming planet, which also impacts a number of constituent factors, including sea level rise, storm frequency and intensity, and ecosystem changes. This section provides a brief overview of some of these issues.

6.8.1 Sea Level Rise

The sea levels in Boston Harbor have been constantly changing since the continental glaciers that covered this region retreated north 10,000 years ago. Much of Boston Harbor was a low-lying coastal plain which has gradually been inundated by sea level rise over the millennia. Most of the historic sea level rise here occurred from 10,000 to 3,000 years ago. It was during this time that the Back River valley was inundated by water from Massachusetts Bay and Boston Harbor to form the present estuary with its characteristic morphology. Since that time, sea levels have kept close to their present levels.

Over this period, two factors have had the biggest influence on the impact of sea level rise in the coastal zone: land subsidence and changes in the oceanic sea levels. When the glaciers covered North America, the weight of the glaciers caused the land underneath to sink. When the glaciers retreated, the land formerly underneath them gradually rebounded. At the same time, all of the water retained in the glaciers was gradually released to the oceans causing sea levels to rise. The present rate of sea level rise is increasing due to climate change.

Predictions of future sea level rise are based on a number of factors, including thermal expansion of water as it warms, whether land stores more water, and how the global glaciers and ice sheets (*e.g.*, Antarctica and Greenland) react to the warming climate (IPCC, 2013). The latest international modeling predicts a likely range global sea level increase of 0.26 to 0.55 m between 2081 and 2100 compared to the 20 year mean between 1986 and 2005, but notes that regional impacts will not be uniform.[10] NOAA measurements of sea level in Boston Harbor between 1920 and 2015 showed an increasing trend of 2.79 mm/yr (±0.16) (Figure 6-12). If this trend continues, the rise is roughly in line with the predicted global increase; Boston would see a relative sea level increase of 0.24 m by 2100. IPCC (2013) analysis, however, notes that it is "very likely" that the rate of global mean sea level rise during the 21st century will exceed the rate observed between 1971 and 2010 largely due to increases in ocean warmth and loss of glaciers and ice sheets, so variability should be expected in how the rises occur.

As sea level rises, it covers upland and causes erosional retreat of upland faces. The United States Geological Survey (USGS) has developed models to assess vulnerability of the US Atlantic Coast to the impacts of sea level rise (Lentz, *et al.*, 2015). These models incorporate factors for a series of ranges for a) sea level rise, b) vertical land movement, c) elevation, d) land cover, e) response of the land to sea level rise, and f) whether the response will be static or dynamic. This is an update on previous USGS work that completed a preliminary assessment of vulnerability that concluded that areas of highest vulnerability are typically high-energy coastlines where the coastal slope is low (Thieler and Hammar-Klose, 1999). The coastline of northern New England, including the Boston Harbor region, generally showed a relatively low vulnerability to future sea-level rise due to the steep coastal slopes and rocky shoreline characteristic of the region, as well as the large tidal range (Figure 6-13).

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[10] IPCC, 2013. Chapter 13, Section 13.5. Projections of Global Mean Sea Level Rise. pp. 1179-1191.

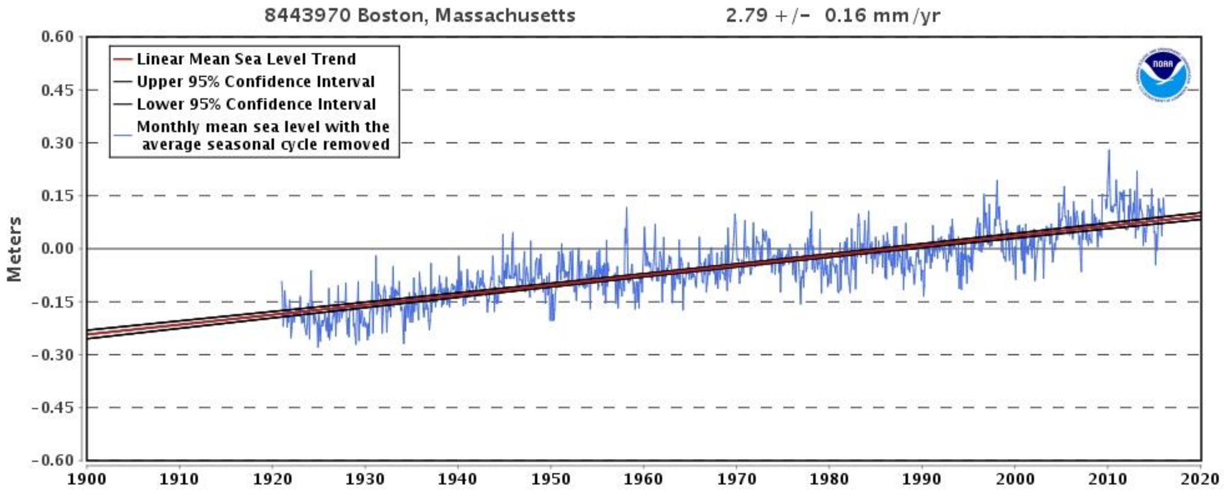

Figure 6-12. Mean Sea Level Trend – Boston (1921 to 2015). The mean sea level trend is 2.79 millimeters/year with a 95% confidence interval of +/- 0.16 mm/yr based on monthly mean sea level data from 1921 to 2015. If this trend continued, sea level at this site would increase by 0.24 m by 2100. The plotted values are relative to the most recent Mean Sea Level datum established by NOAA's Center for Operational Oceanographic Products and Services.Source:NOAA, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8443970 (accessed 5/4/16).

Sea level rise also impacts salt marshes. New England salt marshes are generally accreting sediment as fast as the land is subsiding so these marshes are being maintained. Accretion in these marshes is largely due to the yearly growth and decomposition of roots and rhizomes which add to the organic matter or peat in the sediments. Inorganic accumulation of sediment is relatively small by comparison. If this balance between accretion in the marsh sediments and sea level rise is significantly altered (*i.e.*, if sea level rise accelerates faster than marsh accretion can keep up), some marsh areas will be converted to open water. Salt marshes exist in predominantly loose unconsolidated sediments and require low energy areas to successfully exist and keep up with sea level rise. If sea level rise encroaches into these habitats, marshes can move further inland, but these movements can be limited and constrained by roads, culverts and other infrastructure.

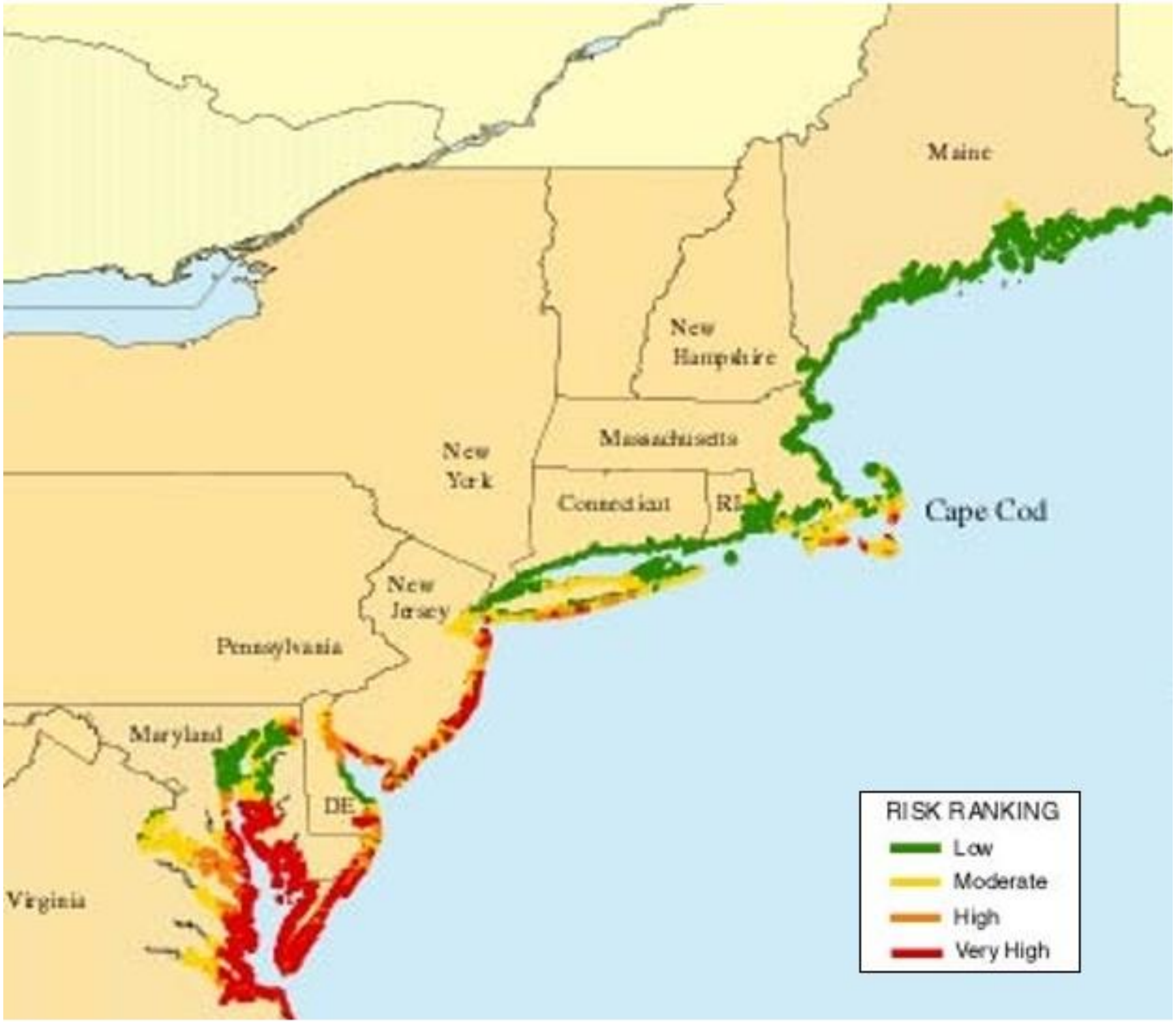

Figure 6-13. Coastal Vulnerability to Sea Level Rise. Excerpt from USGS assessment based on: a) geomorphology, b) shoreline erosion and accretion rates, c) coastal slope, d) rate of relative sea-level rise, e) mean tidal range, and f) mean wave height (Thieler and Hammar-Klose, 1999). This assessment was completed as an initial assessment; more recent modeling incorporates dynamic response of the landscape and ranges for many of the listed factors.

Dieback and loss of wetland systems can occur relatively quickly; re-establishment in new areas can take much longer.

6.8.2 Storms

The Northeast US is a region with diverse weather, but recent changes in the size and frequency of storms has the potential to alter ecosystems. The Northeast has experienced the largest increase in extreme precipitation of any region in the US; the Northeast saw more than a 70% increase in the amount of precipitation falling in large events (the highest 1% of all events) between 1958 and 2010 (Horton, *et al*., 2014). Since the 19th century, there has been an increase in the annual number of storms in the New England region, at least 160 storms of winds greater than 30 mph between 1870 and 1975. On average the region gets about one major storm every 1-2 years with smaller ones occurring more often. Northeast precipitation models project that the region will see an increase in the number of days with precipitation totals greater than 1 inch over the next 50 years (NOAA, 2013).

Larger storms can have important effects on coastal structures, protected salt marshes, and stream dynamics. Overwash of dune sand onto salt marshes caused by high winds and storm surges can change the structure of dunes and cause die out of affected marsh grasses if the elevation rise prevents all but the highest tides from flooding the marsh plain. A “Nor’easter” pushing water into Boston Harbor can cause exceptional tidal increases. High winds can uproot trees and salt spray can desiccate plants resulting in death, compromised survival or population loss (*i.e.*, loss of leaves and/or flowers/fruit). Heavy rains can increase stream flows and create scour of stream banks that typically are dry and mobilize sediments and other contaminants. These high freshwater flows can alter increase sediment and contaminant loads to downstream estuaries and temporarily alter density stratification, which, in turn, can prompt oxygen depletion.

In 2010, major spring storms caused a major disruption to the Weymouth Herring Run when the gate at the end of the Jackson Square flood control tunnel opened due to heavy flows and thousands of fish entered the dead-end tunnel and perished..

6.8.3 Other Ecosystem Functions

Average annual temperatures in the Northeast coastal regions are generally between 50°F to 60°F with common summer heat waves (≥3 days above 90°F), but very rare three-day runs above 100°F. Of the twenty winters between 1992 and 2011, 15 have had above-average temperatures (NOAA, 2013). Review of unregulated river flow between 1900 and 2000 has found that, in the past 30 years, the average date of peak snowmelt has occurred 1 to 2 weeks earlier than the historic average (Hodgkins, *et al.*, 2003). Northeast climate models project that the freeze-free season will increase by 19 days by 2050 (NOAA, 2013).

Increases in temperature, river flow, and growing season will favor certain species and disadvantage others, while also causing a cascade of events throughout ecosystems. For example, higher temperature water has a lower capacity for dissolved oxygen, so low oxygen concentrations in ponds or estuaries can be exacerbated or have more frequent occurrences of hypoxic or anoxic events. More frequent anoxic events will mobilize more nutrients from pond or estuary sediments allowing higher growth rates for phytoplankton. Higher phytoplankton growth rates can shade out rooted aquatic plants and mobilize more nutrients as they senesce. When these sorts of relationships are detailed down to specific species in particular portions of selected estuaries or ponds, the cascades of altered relationships become profoundly complex.

The Ecology of the Weymouth Back River

CHAPTER 7: Management

7.1 Introduction

Management of individual environmental systems is a balance between the characteristics of the system and the application of regulations and laws that often are developed for more generalized settings or smaller segments within the system (*e.g.*, wetlands, drinking water supplies, etc.). Within the mix of regulations and laws are often plans that provide guidance about management of the system or portions of the system, but do not have the legal standing of a regulation. Regulations are usually implemented and enforced through agency staff or local appointed volunteer board members and decisions about what constitutes compliance can change as laws are amended and regulations are reworked. These decisions can be similarly altered by development of new information about portions of the system (*e.g.*, water quality data showing a source of widespread contamination) or development of management plans that a community then uses to guide implementation of regulations. How these generalities apply varies by how political boundaries are drawn (*e.g*., does a system watershed cross state or town boundaries). Management of the Weymouth Back River watershed will necessarily involve the Commonwealth of Massachusetts and a number of agencies, the US Government and a number of its agencies, and portions of the watershed governed by six towns: Weymouth, Hingham, Abington, Braintree, Rockland, and Holbrook.

This chapter generally discusses the strategies and regulatory requirements that play a role in management of the Back River system. This focus will discuss the roles of various agencies or boards that are collectively responsible for management and the regulations and laws that guide their decisions. Since specific implementation is often based on precedents in previous decisions and details of regulations that often require agency staff interpretation, discussion in this chapter will focus on the overarching goals of the guiding laws, regulations, and management plans.

7.2 Federal Management

The United Stated Environmental Protection Agency is the primary agency created by the US Congress to be responsible for the implementation of the federal environmental management laws, such as:

> Clean Water Act: basic structure for regulating discharges of pollutants into the waters of the United States and establishing surface water quality standards. Key programs/permits: Total Maximum Daily Loads (TMDLs), National Pollutant Discharge Elimination System (NPDES), Clean Water State Revolving Funds.
>
> Safe Drinking Water Act: established to protect the quality of US drinking water; focuses on all waters (surface or groundwater) actually or potentially designed for drinking use. Key regulatory provisions: development of Maximum Contaminant Levels (MCLs), regular monitoring and reporting.

Clean Air Act: requires EPA to establish national air quality standards for specific pollutants; original list had six pollutants (*e.g.*, lead, carbon monoxide), but this has been expanded by a number of amendments as scientific studies have provided better understanding of concerns (*e.g.*, ozone depletion due to aerosol propellants, understanding of certain gases roles in enhancing global warming). Key regulatory provisions: development of National Ambient Air Quality Standards (NAAQS), requirements for State Implementation Plans (SIPs).

Federal Insecticide, Fungicide and Rodenticide Act: regulation of pesticide distribution, sale, and use. All pesticides distributed or sold in the United States must be registered (licensed) by EPA and it must be demonstrated, among other things, that using the pesticide according to specifications "will not generally cause unreasonable adverse effects on the environment." Key regulatory provisions: labeling requirements governing use and storage, laboratory analytical methods.

National Environmental Policy Act: requires all branches of government give proper consideration to the environment prior to undertaking any major federal action or federally funded project that significantly affects the environment. Key regulatory provision: Environmental Impact Statements (EIS).

Resource Conservation and Recovery Act: governs the disposal of solid and hazardous waste, including underground storage tanks. Key regulatory provisions: classification/regulation of hazardous waste generators, requirements for hazardous waste transporters, regulation of "cradle to grave" hazardous waste tracking/disposal.

Comprehensive Environmental Response, Compensation, and Liability Act (Superfund): federal ability to clean up uncontrolled or abandoned hazardous-waste sites as well as accidents, spills, and other emergency releases of pollutants and power to seek out responsible parties and assure cooperation in cleanups. Key regulatory provisions: National Priorities List, application to former military sites.

Among the key federal provisions that have shaped environmental management within the Back River watershed are: Clean Water Act, Safe Drinking Water Act, and the Superfund Act. Application of each of these is discussed in more detail below.

7.2.1. Clean Water Act

The primary overarching federal surface water quality management law is the Clean Water Act (33 U.S.C. §1251 *et seq*.), which was adopted in 1972, but had its original basis in laws passed in 1948.[11] The Clean Water Act (CWA) includes provisions for regulating acceptable amounts of contaminants in surface waters [*e.g.*, Total Maximum Daily Loads (TMDLs)] and acceptable amounts of contaminants discharged into surface waters [*e.g.*, National Pollutant Discharge Elimination System (NPDES)]. The TMDL provisions of the CWA were included in the original Act, but EPA focused initial implementation on the NPDES individual permit program to regulate

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[11] Federal Water Pollution Control Act of 1948.

point sources of pollutant discharge (generally out of pipes) and development of Best Available Technology treatment for various industrial processes (Houck, 2011).
A TMDL is required for any public surface water (typically defined by a state) that fails to attain state surface water standards[12]; a TMDL identifies the standard that is not attained and establishes an appropriate contaminant limit for the water body to bring it back into attainment. During the 1990's, environmental advocacy groups began suing EPA to try to accelerate the development of TMDLs. At one point, lawsuits regarding the pace of TMDL development existed in 35 states. Eventually EPA was either placed under consent decree or agreed to establish TMDLs in 27 states if the states failed to act (USEPA, 2009). Massachusetts has developed TMDLs at a pace that has avoided a consent decree. A recent Congressional review of national TMDL implementation suggested that while numerous TMDLs have been developed (>50,000 at the time), restoration of US waters is not being achieved because of difficulties addressing non-point source pollution (*i.e.*, pollution from "non-pipe" sources, such as septic systems, agricultural fields, and stormwater runoff) and inadequate management guidance within approved TMDLs (USGAO, 2013).

One of the TMDL-related provisions in the CWA is that states are required to submit a status list of all public surface waters (*i.e.*, whether the surface waters attain state standards) and whether any of the surface waters are "impaired" (*i.e.*, whether the surface waters fail to attain standards). If a water body is assessed as impaired, the state is required to list the cause of impairment and whether a TMDL has been developed to establish a target for restoration of the body. An update of the status list is required every two years; Massachusetts submitted its latest list in June 2014 and it was approved by EPA in December 2015 (MassDEP, 2015). See Table 6-7 for most recent list of impaired Back River watershed segments according to MassDEP.

The NPDES provisions of the CWA focus on regulation of point source discharges[13] into waters of the United States. Application of the NPDES program originally focused only on site-specific sources, such as wastewater treatment and industrial facilities, but more recently has evolved to provide general permits for similar types of discharges. Each point source is required to have an NPDES permit that specifies acceptable pollutant concentrations. Most NPDES permit programs are implemented by the states, but Massachusetts is one of four states where USEPA has direct responsibility for NPDES compliance.[14] CWA/NPDES compliance was the basis for the Boston Harbor cleanup and construction of the outfall pipe from the Massachusetts Water Resources Authority (MWRA) wastewater treatment facility at Deer Island. MWRA treats wastewater collected within most of the Back River watershed, including the municipal sewer systems for Weymouth, Braintree, and Hingham. As of the writing of this section, there are no individual facility NPDES permits in the Back River watershed.

General NPDES permits apply to a number of uses within the Back River watershed, including municipal stormwater discharge and runoff from construction sites. The Phase II municipal separate storm sewer systems (MS4s) NPDES permitting applies to any municipal stormwater systems within US Census blocks or tracts with a population of at least 50,000. All of the towns

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[12] Massachusetts surface water standards are included in 314 CMR 4. Massachusetts standards include both numeric limits and descriptive goals for various categories based on their use (*e.g.*, for drinking water or recreational use) or their characteristics (*e.g.*, salt vs. fresh water).

[13] Typically, out of a pipe.

[14] The other three states are: Idaho, New Mexico and New Hampshire.

within the Back River watershed are regulated under the MS4 program, which includes requirements for a survey of stormwater system components and development of stormwater management program. There is also a general NPDES permit that applies to any construction activities on one or more acres. The NPDES Construction General Permit requires the approval of a Stormwater Pollution Prevention Plan (SWPPP) that should include erosion and sediment control best management practices. Massachusetts NPDES permits, individual, general, and stormwater are listed on a USEPA website: https://www3.epa.gov/region1/npdes/mass.html.

7.2.2. Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) tasked the USEPA with the responsibility to oversee all public drinking water supplies and sources in the United States and set water quality standards to ensure that all public drinking water is safe. The SDWA (42 U.S.C. §300) was originally passed by Congress in 1974 and has been amended in 1986 and again in 1996. USEPA has largely maintained the development of water quality standards, but has generally passed the implementation of the source water and supplier protection provisions of the SDWA to the states through regulations (called "primacy"[15]) that ensure the SDWA provisions are adequately addressed by individual states. Massachusetts has primacy for the SDWA and implements its provisions through the MassDEP.

Under the SDWA, there are three types of public water supply systems: a) community water systems (*i.e.*, provide water to the same people year-round; typically municipal supplies), b) non-transient non-community water systems (*i.e.*, provide water to same people at least 6 months, but not all year; typically schools, churches, etc. that have their own water system), c) transient non-community water systems (*i.e.*, provide water to people who do not remain for a long period). The MassDEP listing of public water supplies[16] shows that the Weymouth Department of Public Works, which operates the town's municipal water supply system, is the only public water supplier located within the Back River watershed.

Water quality standards developed by USEPA include both mandatory levels (*i.e.*, Maximum Contaminant Levels or MCLs) and non-enforceable health goals (*i.e.*, Maximum Contaminant Level Goals or MCLGs) for each listed contaminant. USEPA currently has MCLs for over 90 contaminants, which are divided among six categories: a) Microorganisms, b) Disinfectants, c) Disinfection Byproducts, d) Inorganic Chemicals, e) Organic Chemicals and f) Radionuclides.[17] Under the primacy provisions, Massachusetts can have the same standards or more stringent standards and Massachusetts has adopted a few Massachusetts MCLs (MMCLs) for selected additional contaminants.[18] If an MCL is exceeded, the supplier is required to remove the source from production, provide an alternative source, and work to reduce the concentration. Community water suppliers are also required under a SDWA rule to prepare an annual Consumer Confidence

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[15] Requirements for state SDWA primacy are in: 40CFR142, Subpart B.

[16] MassGIS Data - Public Water Supplies: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/pws.html

[17] Table of Regulated Drinking Water Contaminants: https://www.epa.gov/ground-water-and-drinking-water/table-regulated-drinking-water-contaminants

[18] 2016 Standards & Guidelines for Contaminants in Massachusetts Drinking Water: http://www.mass.gov/eea/agencies/massdep/water/drinking/standards/standards-and-guidelines-for-drinking-water-contaminants.html

Report (CCR) that lists all the contaminant detections and their concentrations. The Town of Weymouth produces an Annual Water Quality Report that functions as a CCR and these reports from 2011 to 2015 are available on the town's website.[19] All contaminant detections were below MCLs and MCLGs.

7.2.3. Superfund Act

The Superfund Act, officially known as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), was signed into law in 1980.[20] CERCLA directed USEPA to respond to hazardous substances releases or threatened releases and created a tax on chemical and petroleum industries to fund clean ups of abandoned/uncontrolled hazardous waste sites. CERCLA included provisions for listing of long-term contaminated sites [*i.e.*, the National Priorities List (NPL)] and established guidelines/procedures for responding to hazardous substances releases or threatened releases (*i.e.*, the National Contingency Plan). CERCLA was adjusted by the 1986 Superfund Amendments and Reauthorization Act (SARA). SARA amended certain portions of CERCLA, including a) increasing state involvement in Superfund cleanups, b) enhanced public participation, c) increased focus on human health, and d) increasing the size of the trust fund for cleanup of hazardous waste sites to $8.5 billion. There are currently 32 NPL listed sites in Massachusetts with South Weymouth Naval Air Station as the only listed site within the Back River watershed.[21]

7.3. Commonwealth of Massachusetts Management

Massachusetts environmental management is largely coordinated through the Executive Office of Energy and Environmental Affairs (EEA), which is directed by a governor-appointed Secretary. The Secretary of EEA oversees six agencies: the Department of Environmental Protection, the Department of Agricultural Resources, the Department of Conservation and Recreation, the Department of Energy Resources, the Department of Public Utilities, and the Department of Fish and Game. Each of these departments is responsible under law for implementation of various regulatory programs and many are divided into a number of divisions that specialize in particular aspects of management and/or regulation. Discussed below are a number of key departments or divisions that either have or could have a significant role in management of the Back River.

7.3.1. Department of Environmental Protection

MassDEP is responsible for the implementation of over 19 laws.[22] Many of these laws and their associated regulations have the potential to impact environmental management of the Back River ecosystem, including:

a. permitting of land uses, such as docks and seawalls, along shorelines, rivers, and Great Ponds (*e.g.*, Chapter 91 permits; regulations in 310 CMR 9),

b. regulation of drinking water quality and quantity (*e.g.*, quality is largely regulated in 310 CMR 22, while water quantity management is regulated in 310 CMR 36),

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[19] http://www.weymouth.ma.us/water-sewer/pages/water-system

[20] P.L. 96-510 (http://uscode.house.gov/statviewer.htm?volume=94&page=2767; accessed 8/10/16).

[21] Chapter 6 provides more description of South Weymouth Naval Air Station (see Section 6.6.3 Toxic Pollutants).

[22] List of MassDEP laws and associated regulations are at: http://www.mass.gov/eea/agencies/massdep/service/regulations/ (accessed 8/12/16).

c. regulation of hazardous waste sites (*e.g.*, Chapter 21E (the Massachusetts Superfund Law); regulations in 310 CMR 40),

d. regulation of water quality in surface waters (*e.g.*, Massachusetts Clean Waters Act (MGL c. 21 §§ 26-53; regulations in 314 CMR 4),

e. regulation of wetlands (e.g., Wetlands Protection Act and Rivers Protection Act, MGL c. 131 § 40 and MGL c. 258, respectively), and

f. regulation and funding of water pollution abatement projects (*e.g.*, the State Revolving Fund (e.g., MGL c. 29C and MGL c. 78; regulations in 310 CMR 44 and 310 CMR 45).

Collectively these laws and their implementing regulations, as well as required coordination with other state and federal agencies mean Massachusetts DEP has the potential to play a significant role in any management decisions for the Back River.

For example, the Town of Weymouth maintains a water supply system that, withdrew an average of 4.55 million gallons per day from groundwater wells and surface water sources in 2015. This water was treated at the Great Pond and Bilodeau treatment plants before being distributed to 16,125 service connections (Town of Weymouth, 2015). Given that most of the used water is removed via the municipal sewer system and treated at the MWRA Deer Island facility, water balance needs to be sustained to ensure that adequate flows are maintained in the Old Swamp River, Mill River, and Back River and adequate water levels are maintained in Great Pond and Whitman’s Pond. This water balance is reviewed and approved by MassDEP under the Water Management Act regulations (310 CMR 36).

Other provisions of MassDEP drinking water regulations that impact the Back River communities include:

- regular water quality reporting to ensure that any detected contaminants remain below MassDEP water quality limits;
- certification of the water quality labs where water quality samples are sent (310 CMR 42);
- procedures for delineation of contributing areas to water supply wells; and
- requirements for suppliers to provide citizens/consumers with an annual water quality report (301 CMR 22).

MassDEP also certifies that the drinking water supply is operated by properly trained managers that are regularly trained in updated operations (236 CMR 2) and ensures that any immediate contaminant threats within the contributing areas are rapidly and completely addressed (310 CMR 40).

Application of MassDEP regulations are also notable in the planned redevelopment of the former Weymouth Naval Air Station, now known as Union Point. This project will require connection to an alternative water supply. In September, 2016, Weymouth Mayor Hedlund and the Union Point master developer, LStar, signed a five-year agreement (ratified by the Southfield Redevelopment Authority) that will provide up to 600,000 gallons per day of water to Union Point while the developers secure a permanent connection to the MWRA water system. The permanent connection will require approval of MassDEP and the Massachusetts Water Resources Commission under the Inter-basin Transfer Act (MGL, c. 21, sec 8B-8D; regulations in 313 CMR 4.00).

7.3.2. Department of Fish and Game

The MassDFG includes the Division of Fisheries and Wildlife (MassDFW), the Division of Marine Fisheries (MassDMF), and the Division of Ecological Restoration (MassDER). With the estuarine and river sections of the Back River ecosystem, MassDMF regulates[23] the recreational and commercial capture of finfish (*e.g.*, eel, bluefish, halibut), including the minimum size of individual fish, the fishing season for individual species, and the number of fish that can be caught. MassDMF also develops management strategies for river herring and shellfish, including how shellfish will be grown and processed. MassDFW regulates hunting, fishing, and trapping, including when migratory game birds (*e.g.*, ducks, geese) can be hunted, minimum sizes and seasons for specific lake and pond fish, and review of proposed Massachusetts Nature Preserves. This latter responsibility also interacts with MassDFW regulatory responsibilities for management of the Massachusetts Endangered Species Act (MESA).[24] MESA defines endangered and priority species and their habitats and the rules for proposed projects within or near these areas; MESA is implemented through the Natural Heritage and Endangered Species Program.[25]

MassDMF completes periodic monitoring of marine resources in order to provide feedback on management strategies. Brady, *et al*. (2005) reviewed anadromous fish passages in Back River. Nelson, *et al.*, (2011) reviewed river herring stocks in Massachusetts, including extensive discussion of the Back River. Evans, *et al.*, (2015) reviewed marine fisheries species in Massachusetts estuaries and proposed time of year restrictions for coastal alterations to protect the various species. MassDMF has implemented species restoration projects, as well, including the 2006 Shellfish Stock Enhancement Project that included Back River (Estrella, 2009). MassDMF has also completed routine bacterial monitoring in the Back River estuaries to help inform the shellfish management program.

MassDMF also provides local technical assistance related to implementation of their regulations. Given the long history of local management of coastal resources in Massachusetts,[26] MassDMF usually works with local herring and shellfish wardens to ensure enforcement of state fisheries and shellfish regulations. This close working relationship also creates opportunities to ensure that local management initiatives, such as rehabilitation of fish ladders and weirs, meet resource system-wide management objectives.

7.3.3. Department of Conservation and Recreation

MassDCR includes the Division of State Parks and Recreation, which is responsible for the management of Massachusetts State Parks. The Back River watershed has three state parks: Stodder's Neck, Abigail Adams Park, and Webb Memorial (Figure 7-1). These properties are managed and owned by MassDCR. MassDCR is also responsible for EEA's Area of Critical Environmental Concern (ACEC) reviews and any future resource management plans.[27] The Back River watershed includes the Weymouth Back River ACEC (Figure 7-2), which was designated

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[23] 322 CMR

[24] MGL c 131A; 321 CMR 10.

[25] Figure 4-6 shows the upper portion of the Back River watershed and MESA/NHESP regulated areas.

[26] Lind, H. 2009. History of Molluscan Fishery Regulations and the Shellfish Officer Service in Massachusetts. *Marine Fisheries Review*. 71(3); 50-60.

[27] ACEC resource management plans are the responsibility of towns within the ACEC; MassDCR has guidance available on the how a management plan should be prepared. The Back River ACEC does not have a management plan.

in 1982, includes approximately 950 acres and most of Weymouth’s Great Esker Park and Hingham’s Bare Cove and Brewer-More Parks. An ACEC designation requires closer scrutiny of all government and private projects within its boundaries to “preserve, restore, or enhance the resources of the ACEC”[28] and to minimize adverse impacts. EEA is also required to “acquire useful scientific data on the ACEC.”[29]

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[28] 301 CMR 12.12(1)(b)

[29] 301 CMR 12.12(1)(a)

Figure 7-1. Parks in the Weymouth Back River watershed owned and managed by the Massachusetts Department of Conservation and Recreation, Division of State Parks and Recreation. Parks are: Stodder's Neck, Abigail Adams Park, and Webb Memorial. Delineations are based on MassGIS Protected and Recreational Open Space Coverage (http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/osp.html; accessed 8/11/16).

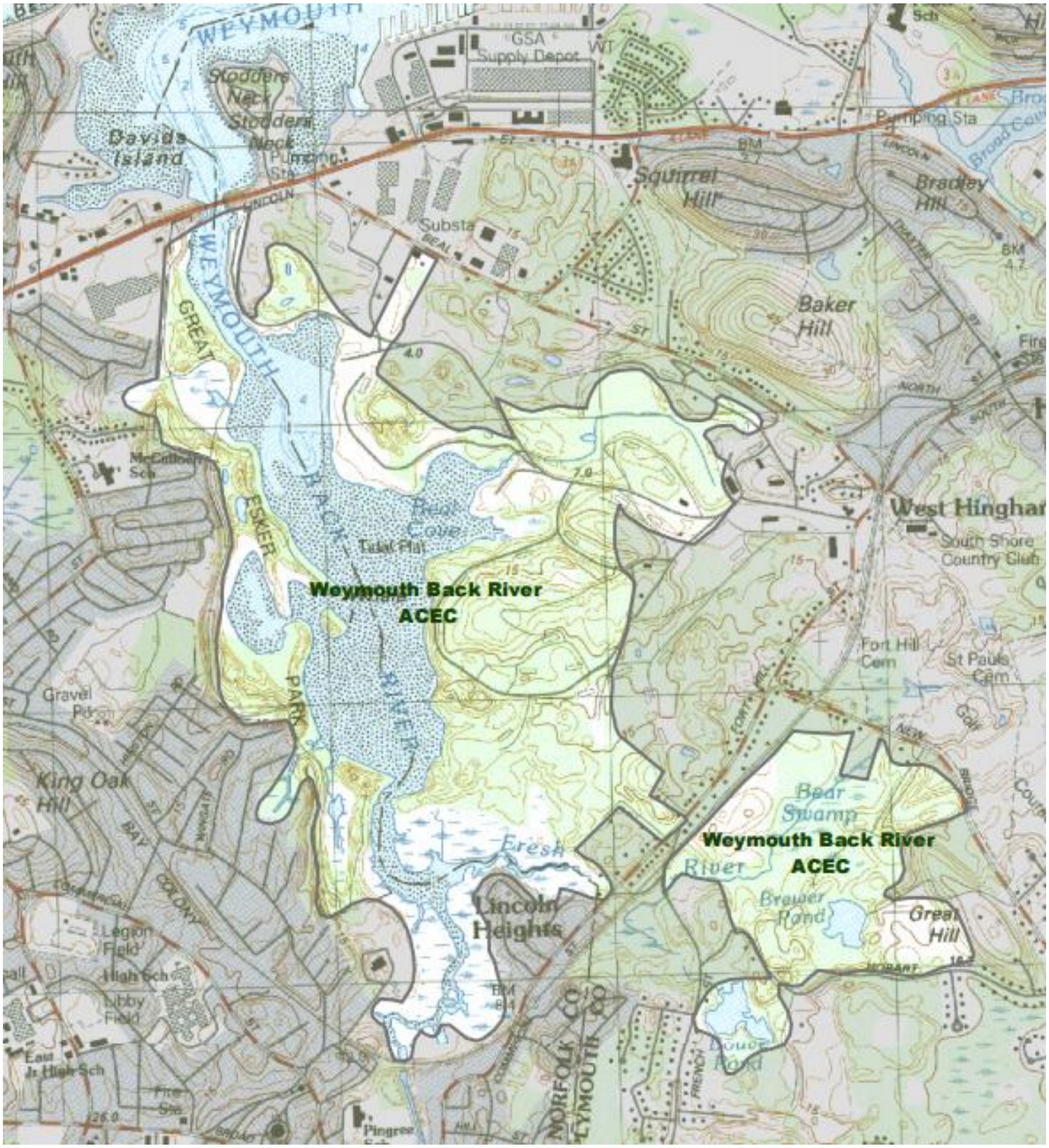

Figure 7-2. Weymouth Back River Area of Critical Environmental Concern. The Back River ACEC was designated in 1982, includes approximately 950 acres, and is shared by the Towns of Weymouth and Hingham. The ACEC includes portions of Great Esker Park in Weymouth and Hingham's Bare Cove and Brewer-More Parks. Figure is excerpted from: http://www.mass.gov/eea/docs/dcr/stewardship/acec/acecs/maps/weymouth-back-river-acec-map-tile-28a.pdf (accessed 8/11/16).

7.3.4. Office of Coastal Zone Management

MassCZM was created in 1983 as an office within Executive Office of EEA with the responsibility of implementing the federally-approved Massachusetts coastal zone plan. MassCZM is responsible for reviewing projects that may come under state review for consistency with the coastal zone plan, including regional plans, harbor plans, and project permits.[30] MassCZM is also responsible for the state's Coastal Facilities Improvement and Harbor Planning Grants programs[31] and coordination of the Ocean Management Plan, which has performance standards for a number of coastal activities, including renewable energy projects, underwater cables and pipelines, and sand and gravel extraction.

MassCZM also manages the Coastal Pollutant Remediation (CPR) Grant Program and the Coastal Resiliency Grant Program, both of which have benefitted the Back River system. The Town of Weymouth received a CPR grant to design stormwater retrofit projects to improve the quality of stormwater runoff to the Herring Run. As of this writing Weymouth is in the second year of Coastal Resiliency Grant funding to open up a tidal restriction in Great Esker Park (at Puritan Road). In FY2014, MassCZM awarded the Town of Hingham a Coastal Communities Resilience Grant f for a Climate Change Vulnerability, Risk Assessment and Adaptation Study that reviewed the potential management strategies for impacts of sea level rise, including management of natural and infrastructure systems.[32]

7.3.5. Massachusetts Environmental Policy Act

The MEPA office is housed within the Executive Office of EEA with the responsibility of coordinating and implementing MEPA reviews. MEPA reviews are generally triggered by projects exceeding specified thresholds (*e.g.*, altering 10 acres of wetlands).[33] The thresholds are tiered so exceeding lower thresholds (*e.g.,* altering 25 acres of land) will require filing of an Environmental Notification Form (ENF), while exceeding higher thresholds (*e.g.,* altering 50 acres) will require filing of an Environmental Impact Report (EIR). A MEPA review allows coordinated review of a project across all of the state agencies and public participation through public hearings and comment periods. An ENF allows the Secretary of EEA to review the project to meet the overarching standard of the MEPA regulations: "all feasible means to avoid Damage to the Environment or, to the extent Damage to the Environment cannot be avoided, to minimize and mitigate Damage to the Environment to the maximum extent practicable."[34] An ENF typically includes a brief description of the project and is often accompanied by supplementary information to help clarify the details of what is proposed. If an EIR is required, the review of ENF information will help the Secretary describe what types of further information are required (*e.g.*, a "MEPA scope"). The MEPA process in many ways parallels the federal National Environmental Policy Act review process.[35]

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[30] 301 CMR 20

[31] 301 CMR 22

[32] Kleinfelder. 2015. Climate Change Vulnerability, Risk Assessment and Adaptation Study. Completed for the Town of Hingham. Available at: http://www.hingham-ma.com/DocumentCenter/Home/View/1082

[33] 301 CMR 11

[34] 301 CMR 11.01(1)(a)

[35] 40 CFR 1508

MEPA produces a report, The Environmental Monitor, every two weeks that lists the status of MEPA reviews, including ENFs, EIRs, and Notices of Project Change.[36] MEPA reviews within the Back River watershed have included:

- Columbian Square Redevelopment Project: Weymouth
- Naval Air Station Redevelopment Project: Abington, Rockland, and Weymouth
- Avalon Hingham Shipyard: Hingham
- Weymouth Herring Passage and Smelt Habitat Restoration Project: Weymouth
- Hingham Shipyard Marina Dredging: Hingham
- Great Esker Park Salt Marsh Restoration: Weymouth

7.4 Municipal Management

Local regulations and decisions usually have more frequent impact on the management of the Back River ecosystem than federal laws and regulations. Many of local regulations are implemented in part through town boards and involve both staff and appointed/elected citizens (*e.g.*, Conservation Commissions and Massachusetts Department of Environmental Protection enforce the Massachusetts Wetlands Protection Act). This section briefly discusses these state and local laws and regulations, the responsible agencies and/or citizen boards, and how they impact management of the Back River estuary. These descriptions are not meant to be definitive, but merely to provide a better context for their role in management.

7.4.1. Conservation Commissions

The Massachusetts Wetlands Protection Act became law in 1972 and is detailed in M.G.L. c. 131, § 40 and the accompanying implementing regulations in 310 CMR 10. A major modification occurred in 1996, when the Rivers Protection Act was incorporated into the Wetlands Protection Act procedures. Details are included in the Act and the regulations, but wetlands are generally defined as any land covered by water (*e.g.*, ponds, estuaries, rivers), any land periodically covered by water (*e.g.*, tidal flats, salt marshes, interior freshwater wetlands, intermittent streams), and the banks leading to these features. Certain minor activities are categorically excluded from review (*e.g.*, unpaved pedestrian walkways less than 30 inches wide[37]), but most other land use activities proposed within or within 100 ft of these features, or within 200 feet of a perennial river, must be reviewed by the Conservation Commission in the town where the activity is proposed.

The regulations detail the review, public hearing, and appeal process, including timing, variances, and coordination required for projects also reviewed under other laws and regulations, such as the Massachusetts Environmental Policy Act (MEPA) and the Massachusetts Contingency Plan (MCP). Wetland areas can be defined on a site-specific basis using criteria defined in the act and regulations. As might be expected for a law adopted in 1972, the regulations have been modified a number of times and MassDEP has a number of policies and guidance documents that clarify application of the Act.[38]

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[36] http://web1.env.state.ma.us/EEA/emepa/#

[37] 310 CMR 10.02(b)2.a.

[38] MassDEP guidance and policies are listed at: http://www.mass.gov/eea/agencies/massdep/water/watersheds/wetlands-protection.html ; accessed 8/11/16).

Most municipal Conservation Commissions have adopted local bylaws or ordinances that are more stringent than the requirements in the Wetlands Protection Act. These local modifications are typically part of town ordinances/code and can be modified by Town Meeting or Town/City Council. Typical Conservation Commission meetings will include public hearings on projects required to be reviewed (*e.g.*, land development, reuse, stormwater system changes), discussion of the details of these projects (*e.g.*, definition of wetland areas based on plants/soils, natural drainage issues), and votes by the Commission to specify their assessment of the project and how the details and conditions will ensure that the goals of the Act and local bylaws are upheld. Most towns, including Hingham and Weymouth, have professional staff (*i.e.*, a conservation agent) to assist and provide guidance to the Commission.

If anyone has a concern about whether activities should be reviewed by the Commission, they may file a Request for Determination with the Commission for an official assessment of whether the Act applies. A Conservation Commission decision on an application (Notice of Intent) for a non-exempt project is called an Order of Conditions and this decision will generally include requirements (*e.g.*, setbacks from wetlands) that the project applicant will need to follow in order to be in compliance with the Wetlands Protection Act and the local bylaw or ordinance, if applicable. All Commission decisions issued under the state law may be appealed to MassDEP. Decisions issued under a local bylaw or ordinance may be appealed to Superior Court.

Since the Back River water sheet, the surrounding wetlands, the contributing streams and ponds in the watershed (see Figures 4-2 and 4-3) are all defined as wetlands under the Wetlands Protection Act, the municipal Conservation Commissions play an important role in the protection and management of the Back River ecosystem. Recent examples of projects reviewed by municipal conservation commissions in the Back River watershed include:

- Whitman's Pond vegetation management,
- Lovell Field athletic field,
- Great Esker Trail expansion,
- cleanup of Weymouth Neck, and
- Hingham's large developments near Bare Cove Park

Conservation Commissions may also work with other town departments to develop management plans for specific areas. An example in the Back River watershed is the Back River Trail Plan (2005), which was jointly prepared by the Weymouth Conservation Commission and Department of Planning and Community Development. This plan presented a strategy to link Abigail Adams State Park with the Iron Hill Fish Ladder site with details of stream crossings, bike access, and interpretive landmarks.

7.4.2. Planning Boards/Zoning Board of Appeals

Planning Boards were first established in Massachusetts in 1913 (M.G.L. c. 41, § 70) and the law for current responsibilities was approved in 1936 (M.G.L. c. 41, § 81A). A Planning Board is charged with developing guidance for future development within their municipality, including development of a master plan that addresses land uses, housing, economic development, open space and recreation, natural and cultural resources, services and facilities, and transportation. Master plan development typically involves coordination with all other municipal boards, review and adjustment of existing zoning areas and regulations and subdivision regulations. Many of the municipalities within the Back River watershed, including both Weymouth and Hingham, have adopted Master Plans. Since Planning Boards work to prepare a municipal master plan and prepares details on uses of watershed lands, the guidance and regulations developed by the Planning Boards within the respective municipalities have the chance to significantly determine the management of the Back River resources.

Planning boards typically have zoning regulations implemented through a municipal zoning bylaw or ordinance. The local zoning bylaw that creates zoning districts for different uses, such as residential, commercial, or industrial land uses. The bylaw typically includes details about zones within the town where these land uses are preferred and specific details associated with the development of properties within these zones, such as lot size, building size and height, and road setbacks. The zoning regulations may also include special overlay districts with specific goals (*e.g.*, historic preservation, water supply protection) that include additional details required of development within these districts, such as limits on the quantities of hazardous materials within water supply protection areas. Planning Boards often also have subdivision regulations that detail acceptable design standards (e.g., road lengths, utility access) for multi-lot residential developments. Modifications to these Planning Board regulations may occur at Town Meeting or Town Council hearings, depending on the form of municipal government.

Typical Planning Board meetings will include public hearings on proposed development projects with discussion of how the project conforms to local regulations and where variances might be requested. Planning boards typically have professional staff (*e.g.*, town planner) to assist and provide guidance to the Board and zoning requirements are typically enforced through a town Building Inspector. Each municipality may also have a Zoning Board of Appeals. This board functions as an in-town forum to appeal Planning Board or Building Inspector decisions. The ZBA may reverse, affirm, or modify decisions.

Planning Boards may also function to focus community efforts on issue-specific plans. For example, the Weymouth Planning Board was the main sponsor of the town's Open Space and Recreation Plan, which also involved the Recreation Commission, Conservation Commission, Community Preservation Committee, and Waterfront Committee.[39]

7.4.3. Boards of Health

Creation of governmental boards to protect public health has been a long-term concern of Massachusetts citizens; the first Board of Health in Massachusetts was established in 1799 in Boston.[40] Municipal boards of health typically have regulations that address disease prevention and control and food safety, but they also have often have authority over factors that impact environmental quality, such as solid waste, air pollution, toxic materials, and septage and septic systems. A board of health (BOH) may adopt regulations provided the board follows proper public notification of the regulation under consideration; BOH regulations do not need to be approved by Town Meeting or Town Council vote.

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[39] Town of Weymouth Open Space and Recreation Plan. 2014.

[40] http://www.mahb.org/boards-of-health/

In areas without sewers, BOHs are responsible for the implementation of the state Title 5 septic system regulations.[41] These systems are a primary source of a number of water contaminants, including nutrients (nitrogen and phosphorus) and pharmaceuticals. But their presence does help to maintain water balances and streamflows since sewers transfer water from watersheds. Some BOHs in septic system-dominated communities with impaired estuarine water quality have implemented requirements for innovative septic that remove nitrogen. BOHs may also implement local regulations for private drinking water wells. The combination of well and septic system regulations can have an impact on land use and development patterns. BOHs within the Back River watershed have adopted regulations for septic systems supplementary to the state Title 5 regulations (*e.g.*, Hingham), hazardous materials management (*e.g.*, Weymouth) and private well regulations (*e.g.*, Weymouth).

7.5. Potential Future Management Issues

Most of the current management structure was developed to address well defined issues identified at the time (*e.g.*, shellfish bacterial contamination) or anticipated issues that were identified as likely near-future management concerns (e.g., excessive watershed nutrient loading). Effective management and monitoring feedback to address the identified issues incorporated within the current regulatory structure remains a challenge, but as new research and advances in technology are developed, there are some additional management issues that are being slowly incorporated into the environmental management structure. Refinement of responses will require additional time, but as of the writing of this report, initial management responses are being developed. These issues are briefly discussed below.

7.5.1. Sea Level Rise

As discussed in Chapter 3, sea levels in the Boston area have been rising for over 10,000 years after the last ice age began to release water stored in the continental ice sheets. Since 1921, the US National Oceanic and Atmospheric Administration (NOAA) has maintained a tidal recorder at Fort Point Channel in Boston Harbor.[42] Over this period of record, water levels have increased approximately 10 inches or 2.79 mm/year with approximately half due to land subsidence and half due to a rise in absolute sea level (see Figure 6-12). If this rate of increase continues, water levels will be approximately 6 inches higher in 50 years (MassCZM, 2013). Higher water levels mean greater chance for coastal damage and flooding during storm surges associated with nor'easters and hurricanes, as well as the impacts on barrier islands and low-lying inland areas near estuaries.

A larger concern is that the increases in global temperatures will a) increase the temperature of the oceans, causing thermal expansion of the waters and b) cause ice on land surfaces, like Greenland and Antarctica to melt and further increase the volume of the oceans. Since 1976, the average of global land and ocean temperatures has been warmer than the long-term average between 1880 and 2015 (Figure 7-3). The highest projections show that water levels will be approximately 34 inches higher in 50 years (MassCZM, 2013). Obviously, there is a large source of uncertainty between the measured sea levels and the projected modeled future sea levels. The difficulty in

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[41] 310 CMR 15

[42] NOAA station website: http://tidesandcurrents.noaa.gov/stationhome.html?id=8443970 (accessed 8/15/16).

developing management strategies is defining what are appropriate responses/strategies that incorporate these uncertainties.

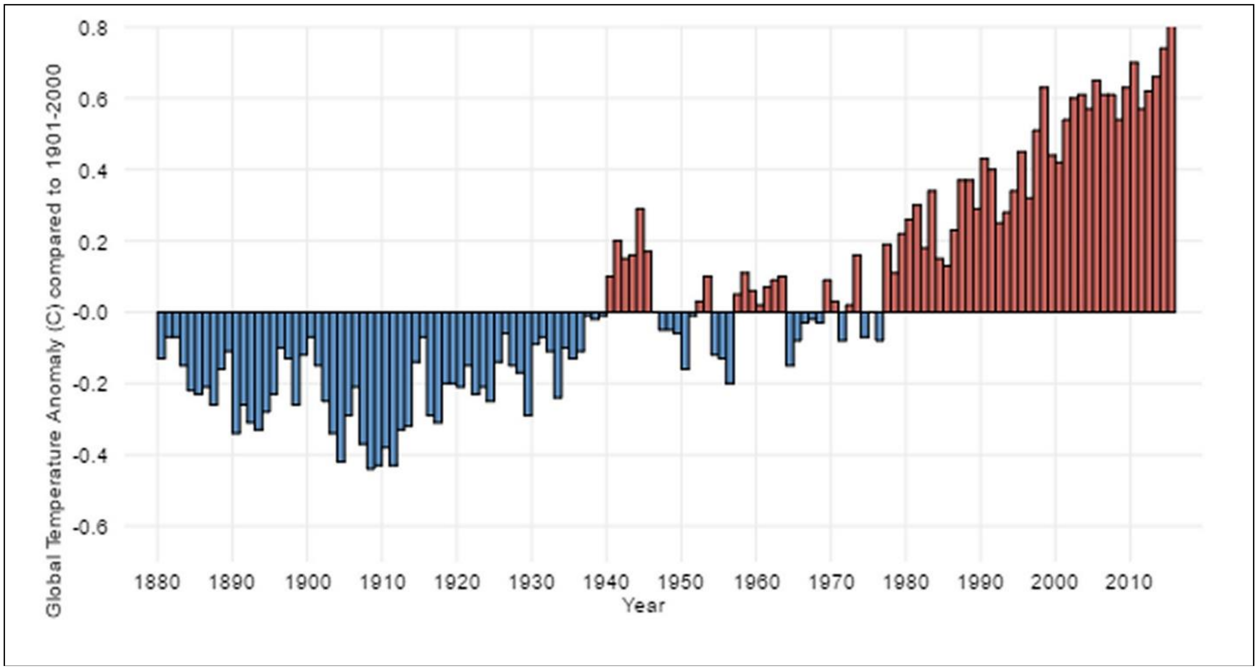

Figure 7-3. Average global land and ocean surface temperature compared to 1901-2000 average. Every year since 1976 has been warmer than the long-term average. Modified from: https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (accessed 8/15/16).

NOAA and many of the US cities have begun developing strategies. NOAA has created Sea Level Rise Viewer visualization tool that looks at elevations and potential impacts of sea level rise along the US coast.[43] Boston, for example, has begun to survey buildings and infrastructure for potential impacts, stressed flood proofing strategies for new buildings, redevelopment of existing buildings, and existing buildings in planning and regulatory discussions, and begun to complete detailed identification of all low-lying areas.[44] Massachusetts has recommended a similar strategy of creating vulnerability assessments (MassEOEAA, 2013). Hingham completed a coastal vulnerability project in 2015 that review potential impacts to coastal infrastructure and natural systems.[45]

In 2016, Governor Baker issued Executive Order 569,"Establishing an Integrated Climate Change Strategy for the Commonwealth." This Executive Order requires state government to provide assistance to cities and towns to complete climate change vulnerability assessment and resiliency planning. Weymouth was awarded a grant under the new program in 2017.

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[43] NOAA Sea Level Rise Viewer: https://coast.noaa.gov/slr/ (accessed 8/15/16).

[44] http://www.cityofboston.gov/climate/adaptation/

[45] Kleinfelder. 2015. Climate Change Vulnerability, Risk Assessment and Adaptation Study.

7.5.2. Pharmaceuticals and other organic contaminants in water

As laboratory techniques have become more refined, limits of detection have decreased and research has begun to identify pharmaceuticals and other organic contaminants in surface waters and drinking water supplies. In 2002, the US Geological Survey completed the first nationwide survey of 95 pharmaceuticals, hormones, and other organic wastewater contaminants (OWCs) and found 80% of the 139 sampled streams had detectable concentrations. These OWC included steroids, insect repellants, caffeine, antimicrobial disinfectants, codeine, ibuprofen, and acetaminophen (Kolpin, *et al.*, 2002). Further monitoring has found that these and other contaminants are pervasive, but are generally at concentrations below those associated with human health concerns. However, potential impacts on aquatic species, including phytoplankton, zooplankton, bacteria, and fish are generally not well defined and are the subject of widespread research. Developing management strategies for such pervasive distribution is a challenge and most of the initial discussions of strategies have largely relied on minimizing human contact (*e.g.*, restricting wastewater discharge in water supply areas), but development of further research may lead to additional strategies to protect other species (*e.g.*, Blair, 2016).

7.5.3. Invasive Species

Ecosystems in the Back River have evolved over thousands of years often with species mixes changing due to natural changes (*e.g.*, increases or decreases in temperature) and/or addition of new species transported by wind or water. However, the increase in the range of human travels over the past 500 years has facilitated transplanting of species outside of their usual range (usually with the transporting of seeds). Newly introduced species enter an area without the competitors and predators that provided balance in their home ecosystem; without these controls, these invasive species have the opportunity to significantly alter their new ecosystems.

There are a number of significant invasive species throughout the United States, including zebra mussels, kudzu, lionfish, and Burmese pythons. Most of these are notable for their high growth rates, rapid reproduction, and utilization of a wide range of food types.

In Massachusetts, most of the invasive species are somewhat less obvious, but just as prolific. Examples in Massachusetts include:

- Green crab (*Carcinus maenas*), native to Europe;
- Brown trout (*Salmo trutta*), native to Europe; and
- Eurasian watermilfoil (*Myriophyllum spicatum*).[46]

These species displace and outcompete native species based on a variety of factors. As an example, the natural habitat range of Oriental bittersweet (*Celastrus orbiculatus*) is eastern Asia, but it is now found throughout the eastern United States and Canada. It was introduced to the United States in the mid-1800's as an ornamental plant. Unlike its cousin, the American bittersweet (*Celastrus scandens*), it is unappealing to common North American herbivores, such as deer, produces more berries than the American bittersweet, and is more energy efficient with its growth. More berries produce more opportunities to be spread by birds and its ability to grow in low light in established canopies allows it to form dense, smothering stands that climb and overtop saplings and mature

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[46] USGS Nonindigenous Aquatic Species (NAS) tracking system: http://nas.er.usgs.gov/queries/StateSearch.aspx (accessed 8/16/16).

trees and inhibit other plant growth. Removed from its natural habitat, Oriental bittersweet has no natural predators or competitors and grows largely unchecked without human intervention (*e.g.*, pesticides).

Control of invasive species is an on-going challenge. Misplaced species are a potential threat to economic and quality of life factors, including agricultural resources (including logging) and water quality. Invasive aquatic plants, in particular, can alter nutrient dynamics, alter predator/prey relationships (*e.g.*, providing more hiding areas for smaller species), and impact recreational waters through excessive growth.

Individual towns have instituted regular boat ramp monitoring of boats and trailers to try to avoid the spread of invasive aquatic plants. MassDCR conducted a five year monitoring program and found approximately 8% of boats/trailers had fragments of non-native plants.[47] Massachusetts also has regulations for seed sales to try to limit extraneous species (330 CMR 6) and generally has targeted species of concern individually through existing Department of Food and Agriculture (MassDFA) authority. Massachusetts General Law (M.G.L. c. 128, § 24) allows the MassDFA to inspect any property where "noxious weeds, trees, shrubs or other plants are present." Massachusetts largely relies on citizens to report non-native species and tracks reports on national databases.[48]

In the Back River watershed, a number of aquatic invasive plants have been identified in Whitman's Pond. Invasives, such as fanwort (*Cabomba caroliniana*), variable-leaf milfoil (*Myriophyllum heterophyllum*) and curly-leaf pondweed (*Potamogeton crispus*) have been identified in Whitman's Pond and efforts to control fanwort, in particular, have been occurring for over three decades (ESS, 2013).

Recommended strategies for control of these and other aquatic plants in the pond have included: drawdown, harvesting, and herbicides. These types of efforts are consistent with other invasive controls where efforts generally have to turn to management of the growth rather than complete removal once the population has become established. This finding also reinforces the importance of preventing these species from being introduced in the first place.

7.6 Back River Management Future

As listed in this Chapter, management of the Back River extends across municipal, state, and federal responsibilities and depends on public advocacy and consensus. The wide extent of these responsibilities will require on-going coordination, as well as a firm understanding of ecosystem functions, monitoring of changes, and use of this information to create consistent goals. These efforts will also require commitment on the part of all parties to adequately consider downstream and community impacts of all decisions.

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[47] MassDCR Boat Ramp Monitor Program: http://www.mass.gov/eea/agencies/dcr/water-res-protection/lakes-and-ponds/boat-ramp-monitor-program-generic.html (accessed 8/16/16)

[48] *e.g.*, Early Detection & Distribution Mapping System, maintained at The University of Georgia - Center for Invasive Species and Ecosystem Health; https://www.eddmaps.org/ (accessed 8/15/16).

Commitment to attain effective management often requires access to sufficient funding to complete activities such as collecting data, developing plans, or designing infrastructure. Typical non-local funding sources are pass-through grant funding provided by federal agencies (*e.g.*, USEPA) and administered by a state agency (*e.g.*, MassDEP). An example of this type of funding is Clean Water Act section 319 and 604b grant funds, which are typically distributed by MassDEP through a public proposal and review process. Funding of this type is distributed in a number of ways by state agencies. Some communities or groups of communities have also been successful in joint funding projects through federal agencies with match requirements (e.g., US Geological Survey) or projects developed with private consulting firms or academic institutions. Local municipal funding is typically developed through public discussions and approval of budget items at Town Meetings/Town Council.

Development of management projects typically are best achieved when all stakeholders in the associated resource area are part of the project. Integration of various stakeholders, including watershed organizations, community groups, and private businesses, allows their concerns to be addressed in the development of the management objectives and plans for their implementation. This public integration generally ensures that all concerns are incorporated into the management project.

Management Activities: Potential Town Government Partners

Elected and appointed officials form the core of town government decision-making. Management requires active coordination to ensure that all facets are addressed. The names of these partners may vary depending on the form or organization of town government:

- Mayor/Town Council/Board of Selectmen
- Department of Public Works
- Conservation Commission
- Health Department/Board
- Planning Department/Board
- Recreation Department

Management Activities: Potential State and Federal Government Partners

State and federal partners are able to assist in addressing any permits that may be required for management activities, may be able to secure funding for development of management plans, collection of necessary data/information, and infrastructure designs and construction, and/or may be able to provide technical assistance. Management requires active coordination to ensure that all facets of state government concerns are addressed. Applicable partners may vary depending on the details of propose management activities:

- State Representatives and Senators
- Federal Representatives and Senators
- Division of Marine Fisheries
- Department of Environmental Protection
- Coastal Zone Management
- Massachusetts Bays Program
- Executive Office of Energy and Environmental Affairs
- Department of Conservation and Recreation
- Department of Fish and Game

- Massachusetts Environmental Policy Act office
- Massachusetts Environmental Trust
- Massachusetts Department of Transportation
- United States Environmental Protection Agency
- United States Geological Survey
- National Oceanic and Atmospheric Administration
- United States Army Corps of Engineers
- Natural Resources Conservation Service

Management Activities: Potential Non-Government Partners

Non-government partners, such as local watershed groups, are usually effective advocates for management activities. In the Back River watershed there are a number of non-government organizations that could assist in ensuring that management activities succeed, including the following:

- Back River Watershed Association
- Friends of Great Esker Park
- Friends of Bare Cove Park
- Whitman’s Pond Association
- East Weymouth Neighborhood Association
- Fore River Watershed Association

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