GREENWICH BAY

SPECIAL AREA MANAGEMENT PLAN

Rhode Island Coastal Resources Management Council
Stedman Government Center
4808 Tower Hill Road
Wakefield, RI 02879-1900
(401) 783-3370

Greenwich Bay
Special Area Management Plan

Adopted May 10, 2005

A management program of the
Rhode Island Coastal Resources Management Council

This document was prepared for the Coastal Resources Management Council by the
Coastal Resources Center/Sea Grant, University of Rhode Island

Greenwich Bay
Special Area Management Plan

The Greenwich Bay Special Area Management Plan is an examination of watershed resources, uses, problems, and institutions as contained in an integrated coastal management plan to protect and restore the vital ecological and economic resources of Greenwich Bay. Programmatic actions contained within the SAMP are designed to ensure the preservation of the vital elements of the ecosystem, to guide future development within land and water limitations, and to resolve existing and anticipated problems.

The SAMP was developed with the municipalities of Warwick, East Greenwich and West Warwick, other state and federal agencies, and the concerned citizens of the watershed in a coordinated and collaborative fashion that address the issues affecting Greenwich Bay and its communities.

The SAMP was facilitated and managed for the CRMC by RI Sea Grant/Coastal Resources Center at the University of Rhode Island and funded through the Coastal Resources Management Council and NOAA Award # NA17OZ2351.

Coastal Resources Management Council

Stedman Government Center Suite 3
4808 Tower Hill Road
Wakefield, RI 02879

Phone: 401-783-3370
Fax: 401-783-3767
www.crmc.state.ri.us

Sea Grant Rhode Island

CRMC Coastal Resources Management Council

NOAA

Greenwich Bay Special Area Management Plan

Table of Contents

Chapter 5 - Cultural and Historical Assets

Chapter 6 - Economic Assets

Chapter 7 - Recreational Use

Chapter 8 - Natural Hazards

Chapter 9 - Regulations

Appendices

Chapter 1

Goals and Objectives

Table of Contents

Tables

Figure

Section 100
Vision

Residents cherish Greenwich Bay for its beauty and high quality of life that is tied to a thriving Bay-based economy, clean water, a strong sense of heritage, and abundant, safe, recreational opportunities.

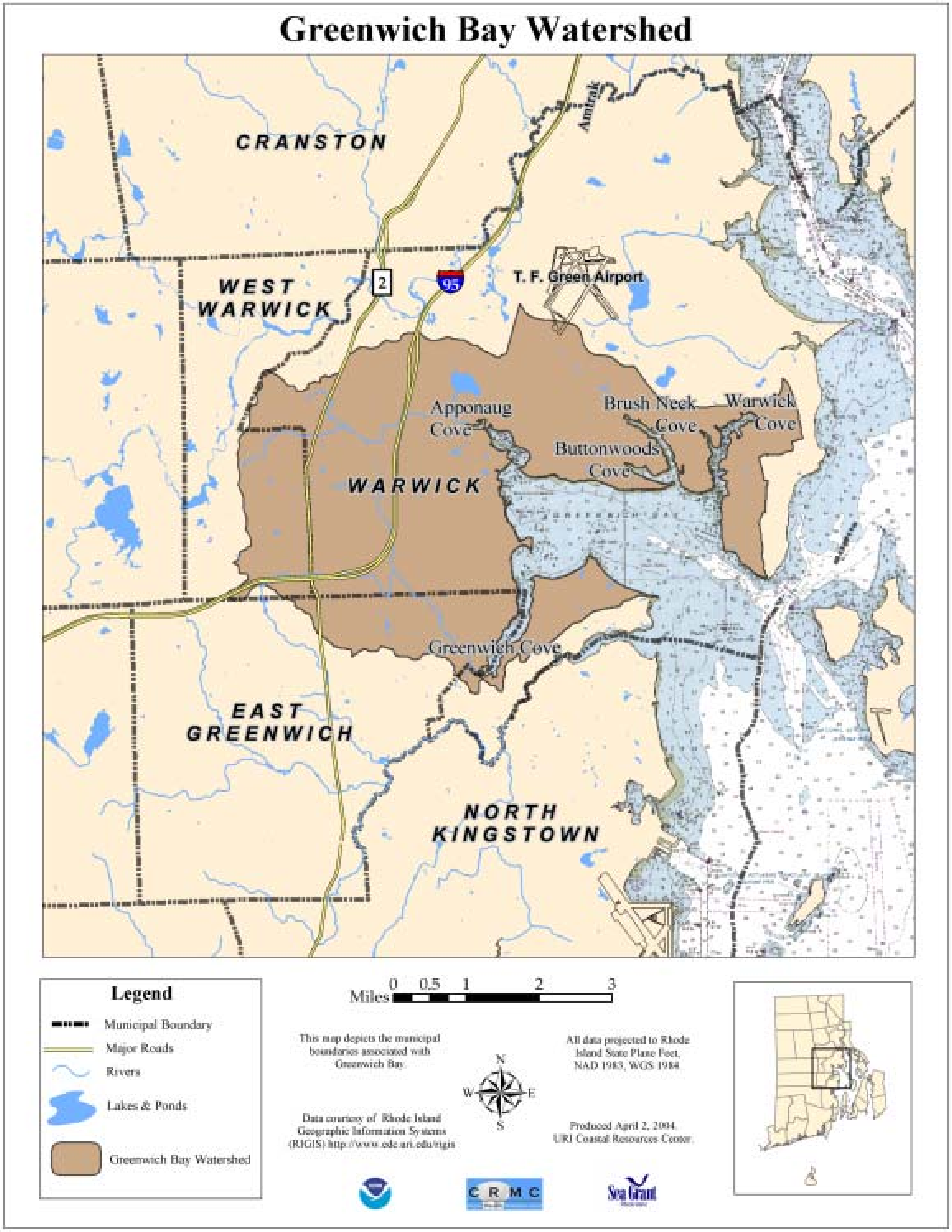
Section 110
Introduction

1. With five square miles of shallow water and five protected coves, Greenwich Bay, Rhode Island, is an estuary—a mixing basin for salt and fresh water—that has provided people with food, shelter, transportation, trade, and recreational opportunities for centuries. Today, Greenwich Bay remains a valuable commercial fishing area and recreational harbor surrounded by a 21-square-mile suburban watershed comprising three communities: Warwick, East Greenwich, and, to a smaller degree, West Warwick (Figure 1). Greenwich Bay experiences many of the problems common to growing suburban coastal communities, such as poor water quality, the loss of natural habitats, displacement of traditional commercial fisheries, privatization of the shoreline, and a lack of coordination between neighboring communities.

2. The Greenwich Bay Special Area Management Plan (SAMP) is an integrated coastal management plan to protect and restore the vital ecological and economic resources of Greenwich Bay. The R.I. Coastal Resources Management Council (CRMC) has developed this plan with the municipalities, other federal and state agencies, and the concerned citizens of the watershed to address the issues affecting Greenwich Bay and its communities in a coordinated and collaborative fashion. The seven chapters that follow provide a detailed finding of facts that describe the present status of the bay, characterize its watershed, and recommend steps to help government work with communities to restore, protect, and balance uses of Greenwich Bay for this and future generations.

3. Goals and objectives have been developed for the future of Greenwich Bay that are consistent with community visions, statewide goals for Narragansett Bay and Rhode Island, and federal policies. The five goals elaborate on the vision for Greenwich Bay. Under each goal, a series of time-bound objectives and prioritized actions have been developed. The actions summarize the regulations, recommended actions, and research needs contained in every chapter of the SAMP. In many cases, actions in one part of the plan help meet multiple goals and objectives. Together, the vision, goals, objectives, and prioritized actions provide a road map for Greenwich Bay's future.

Figure 1. Greenwich Bay watershed



Section 120
Goals

120.1 Develop leaders and stewards to coordinate and implement actions that protect the unique resources of Greenwich Bay

1. Federal and state agencies, the municipalities, university researchers, nonprofit environmental organizations, and citizen groups have achieved a certain level of cooperation, particularly through the Greenwich Bay Initiative, in addressing Greenwich Bay issues. Moving forward, increased collaboration, coordination, and public involvement will be needed to implement actions in this plan, monitor progress, and adapt the plan to incorporate new solutions and address new problems. Through collaboration and coordination, consistent decision-making by all agencies and streamlined permitting can be achieved. Some key actions to develop leaders and stewards will be the hiring of additional CRMC staff, the creation of a Greenwich Bay Implementation Team, convening an annual Greenwich Bay Public Forum, and encouraging the formation of a Greenwich Bay watershed organization (Table 1).

120.1A Objectives

1. By 2006, CRMC has funding to hire staff to coordinate and implement the SAMP.

2. By 2007, regulatory and organizational structures to coordinate and lead SAMP implementation are in place.

3. By 2008, measures to monitor progress towards SAMP goals are in place and communicated to the public and decision-makers.

4. By 2010, local capacity exists to help implement SAMP goals and objectives.

Table 1. Prioritized actions to develop leaders and stewards to coordinate and implement actions to protect the unique resources of Greenwich Bay

Priority actions	Lead agencies	SAMP section reference [1]
Create regulatory and organizational structures to coordinate and lead SAMP implementation		
1. Hire staff to coordinate and implement the SAMP	CRMC, Rhode Island General Assembly	230.2D
2. Establish a Greenwich Bay Implementation Team to guide SAMP implementation	CRMC, RIDEM, HEALTH, RIEDC, Rhode Island Rivers Council, Warwick, East Greenwich, West Warwick	230.2A, 230.2B
3. Create permanent CRMC working group or subcommittee to oversee SAMP implementation	CRMC	230.2C
4. Jointly review state and local regulations and procedures to work toward more seamless decision-making	CRMC, RIDEM, HEALTH, RIEDC, Rhode Island Rivers Council, Warwick, East Greenwich, West Warwick	230.1C
5. Provide preliminary review of activities	CRMC	230.1A, 230.1B
6. Prepare a Greenwich Bay work plan	Greenwich Bay Implementation Team	230.4, 230.2E
Implement measures to monitor progress towards SAMP goals and communicate them to the public and decision-makers		
1. Establish a Greenwich Bay Public Forum	CRMC, CAC	230.3A, 230.3B
2. Prepare regular assessments to monitor progress on achievements towards other SAMP goals and objectives	Greenwich Bay Implementation Team	230.5
3. Maintain the Greenwich Bay SAMP website	CRMC, RISG	230.3C
4. Keep legislators from the Greenwich Bay region informed and engaged	Greenwich Bay Implementation Team	230.2F
Develop local capacity to help implement SAMP goals and objectives.		
1. Encourage the formation of a watershed organization for Greenwich Bay	CRMC	470.1A.1
2. Increase citizen awareness of the Greenwich Bay watershed boundary	CRMC, RIDOT, Warwick, East Greenwich, West Warwick	470.1A.2
3. Expand the scope of the harbor management commissions to assist	Warwick, East Greenwich	230.1E

Priority actions	Lead agencies	SAMP section reference [1]
in key management tasks		
4. Support state policies incorporated in the SAMP, for example through a coastal overlay zone	Warwick, East Greenwich	230.1D

1 Reference the cited SAMP sections for specific action language.

120.2 Improve Greenwich Bay's water quality so that it is a safe place to fish and swim

1. Greenwich Bay's water quality makes it an unhealthy place to fish and swim during certain times of year, particularly following storms. In 2004, high fecal bacteria levels prompted closure of over 90 percent of Greenwich Bay proper to shellfishing, primarily after storm events, and all of Greenwich Bay's coves. From 1998-2004, high fecal bacteria levels closed Oakland Beach, Goddard Memorial State Park Beach, and Warwick City Beach to swimming an average of 15 days per beach per year during the summer. Poor water quality conditions also lead to fish kills and other nuisance conditions during the summer months. Hypoxia and anoxia regularly impact nearly 1,200 acres of Greenwich Bay—the bottom waters of Greenwich and Apponaug coves and western Greenwich Bay. High nutrient inputs, primarily nitrogen, contribute to these conditions and prevent the growth of valuable eelgrass.

2. The largest source of fecal bacteria is storm water, which carries the bacteria from septic systems, cesspools, pets, and wildlife. Boat discharges represent a much smaller potential source. Septic systems, cesspools, and the East Greenwich wastewater treatment facility are large nitrogen sources within the Greenwich Bay watershed. Narragansett Bay waters and atmospheric deposition are significant nitrogen inputs originating outside the watershed. Requiring sewer tie-ins, phasing out cesspool use, implementing storm water best management practices, establishing vegetated buffers, and continuing efforts to require advanced nitrogen treatment technology at wastewater treatment facilities are key actions to reduce fecal bacteria and nitrogen loads (Table 2). Enhanced water quality monitoring is also needed to assess progress.

120.2A Objectives

1. By 2008, 50 percent of properties with sanitary sewers available are tied in.

2. By 2008, sufficient data is collected to assess water quality improvements in Greenwich Bay.

3. By 2009, summer nitrogen loadings from Greenwich Bay and Upper Narragansett Bay wastewater treatment facilities have been reduced by 50 percent.

4. By 2010, Greenwich Bay's beaches pose no public health risks and remain open.

5. By 2012, 75 percent of properties with sanitary sewers available are tied in.

6. By 2015, 100 percent of properties with sanitary sewers available are tied in.

7. By 2015, Greenwich Bay's SA waters are clean enough to allow safe shellfish harvesting.

8. By 2015, the average frequency, duration, and extent of hypoxic or anoxic events in bottom waters of Greenwich Bay and its coves have been reduced by 50 percent.

9. By 2015, eelgrass beds have been restored to Greenwich Bay.

10. By 2020, 50 percent of Greenwich Bay's coves are open to either winter season or year-round shellfish harvesting.

Table 2. Prioritized actions to improve Greenwich Bay's water quality so that it is a safe place to fish and swim

Priority actions	Lead agencies	SAMP section reference [1]
Implement actions to reduce pollution loads to Greenwich Bay, its coves, and tributaries from the land.		
1. Ensure all homes and businesses tie-in to available sanitary sewers	CRMC, WSA, Warwick, East Greenwich, RIDEM, Rhode Island General Assembly	470.3A, 470.3B.1-5
2. Phase-out cesspool use in the Greenwich Bay watershed	Rhode Island General Assembly	470.3B.6
3. Establish an inspection and maintenance program for individual sewage disposal systems (ISDS) where sewers are not available	Warwick Sewer Authority, East Greenwich, RIDEM, Rhode Island General Assembly, CRMC	470.3B.7-9, 470.3C
4. Secure funding to support clean water restoration in Greenwich Bay	Rhode Island General Assembly, RIDEM, Warwick, East Greenwich, West Warwick	470.1A.4, 470.3B.10, 470.5B.7,17, 470.6C.6
5. Enhance regular water quality monitoring in Greenwich Bay to assess trends and improvements	Rhode Island General Assembly, RI Environmental Monitoring Collaborative, EPA	470.2A.1-2,4-5
6. Implement best management practices (BMPs) to reduce storm water discharge volume and nitrogen and bacteria concentrations	RIDOT, Warwick, East Greenwich, West Warwick, Rhode Island Airport Corporation	470.5B.2-3,6,9-16,18
7. Detect and eliminate illicit discharges to storm water drains	RIDOT, Warwick, East Greenwich, West Warwick	470.5B.8
8. Continue efforts to require advanced nitrogen treatment technology at wastewater treatment facilities (WWTF)	RIDEM	470.4A.1
9. Continue efforts to implement temporary nitrogen controls at WWTF	RIDEM	470.4A.2
10. Examine the feasibility of mechanical aerators or other technologies to aerate areas in Greenwich Bay during critical summer periods	RIDEM, CRMC	470.1A.3
11. Determine potential benefit of removing high organic sediments from Greenwich Bay and its coves on dissolved oxygen levels	CRMC, RIDEM	470.1B.2
12. Consider installing and maintaining "pet waste stations" at	Warwick, East Greenwich, West Warwick	470.7B.5

Priority actions	**Lead agencies**	**SAMP section reference** [1]
popular locations for walking dogs		
13. Reduce food sources for wildlife at shoreline recreation areas	RIDEM, Warwick, East Greenwich, West Warwick	470.7B.6-7
14. Continue to groom beaches to remove wrack when beach closures occur	Warwick, RIDEM	470.1A.5
15. Require integrated pest management (IPM) on public lands	CRMC, RIDOT, Amtrak	470.8A Policy 1, 470.8B.4
16. Develop a Green Golf Course program to limit pollutants from golf courses	CRMC	470.8A Policy 2, Standard 1
Increase public awareness of water quality problems, sources, and solutions.		
1. Increase public awareness about how pets and wildlife contribute to beach and shellfish closures in the Greenwich Bay watershed	CRMC, RIDEM, HEALTH, Warwick, East Greenwich, NGOs	470.7A, 470.7B.1-4
2. Increase public awareness of problems with storm water discharges to Greenwich Bay	RIDOT, Warwick, East Greenwich, West Warwick	470.5B.19-20
3. Develop volunteer monitoring strategy	RIDEM, HEALTH, URI-CE, NGOs	470.2A.4
4. Evaluate the value of placing signs at unlicensed beaches indicating potential bacterial contamination	HEALTH, Warwick	780.2A.2
5. Create a public education and professional training program to increase awareness of BMPs for turf management	NRCS, URI-CE, SRICD	470.8B.2-3
Encourage clean boating practices.		
1. Improve pumpout availability to boats in Greenwich Bay	CRMC, RIDEM, RIMTA, Warwick, East Greenwich	470.6B Standards 1-2, 470.6C.2
2. Develop a Clean Marina Program and designate Greenwich Bay's marinas as such	CRMC, RIDEM, RIMTA	470.6C.1
3. Implement and enforce new no discharge certification and inspection program	RIDEM, Warwick, East Greenwich, RIMTA, USCG	470.6C.3-5
4. Eliminate discharges from boats with people living aboard	CRMC	470.6B Prohibition 2

Priority actions	Lead agencies	SAMP section reference [1]
5. Increase public awareness of boater BMPs and no discharge requirements	CRMC, RIDEM, RIMTA	470.6C.7-9
6. Advertise compliance with a clean marina program to attract clients and educate the community of marinas' role in marine resources stewardship	Marinas	680.1C.2
Identify remaining pollution discharges and sources to Greenwich Bay, its coves, and tributaries.		
1. Identify BMPs that reduce storm water discharge volume and nitrogen and bacteria concentrations in the remaining discharges	CRMC, RIDEM	470.5B.1
2. Identify and prioritize storm water discharges needing BMPs	RIDOT, Warwick, East Greenwich, West Warwick	470.5B.4-5
3. Identify and rank sources of bacterial contamination to Greenwich Bay in specific areas	RIDEM, CRMC, HEALTH, RIDOT, Warwick, East Greenwich	470.1B.1, 470.2A.3, 470.6D
Increase acreage of coastal and riparian buffers in the Greenwich Bay watershed.		
See Table 3 for priority action summary		
Facilitate public and private dredging needs while protecting and enhancing natural resources.		
See Table 4 for priority action summary		
Limit economic and environmental impacts from natural hazards.		
See Table 5 for priority action summary		

1 Reference the cited SAMP sections for specific action language.

120.3 Maintain high quality fish and wildlife habitat in the Greenwich Bay watershed

1. Continued development in the Greenwich Bay watershed and on the bay threaten the remaining natural habitats that support fish and wildlife. Greenwich Bay is one of the most abundant areas for quahogs in Rhode Island. Dredging can eliminate and expansion of in-water structures can diminish access to valuable commercial quahog resources. Over 5,100 acres of undeveloped forests, wetlands, and other open areas, such as Mary's and Baker's creeks, remain in the Greenwich Bay watershed, providing many valuable services, such as fish and wildlife habitat, flooding protection, and water purification. Onshore development could replace these remaining areas with pavement and man-made habitats attractive to nuisance species. In addition, many wetlands and rivers have been disturbed and degraded by past activities and surrounding development. Some key actions to protect and restore the most important areas are establishing quahog resources preserves, eliminating disincentives for preserving and restoring coastal vegetated buffers, removing structures preventing anadromous fish movement on rivers, and directly acquiring land and development rights for priority lands (Table 3).

120.3A Objectives

1. By 2010, there are 50 acres of quahog resource preserves on Greenwich Bay.
2. By 2010, the number of variances granted to CRMC coastal buffer zone regulations have been reduced by 50 percent in the Greenwich Bay watershed.
3. By 2015, 100 acres of naturally vegetated coastal and riparian buffers have been restored in the Greenwich Bay watershed.
4. By 2015, 120 acres of fish and wildlife habitat have been restored in the Greenwich Bay watershed.
5. By 2020, 700 acres of priority lands in the Greenwich Bay watershed have been preserved, including fish and wildlife habitat, through direct acquisition or conservation easements.

Table 3. Prioritized actions to maintain high quality fish and wildlife habitat in the Greenwich Bay watershed

Priority actions	Lead agencies	SAMP section reference [1]
Increase the acreage of coastal and riparian buffers in the Greenwich Bay watershed.		
1. Increase compliance with coastal buffer zone policies without needing to request or grant variances	CRMC, Warwick, East Greenwich, Rhode Island Mortgage Bankers Association	390.7B Policy 4, Prohibitions 1-2, Standards 2, Variances 1, 390.7C.6-8
2. Update and develop standards for coastal buffer zone management in suburban areas	CRMC	390.7B Policy 1
2. Promote the voluntary establishment of vegetated buffers	CRMC, Warwick, East Greenwich, West Warwick, NGOs	390.7B Policy 2, 390.7C.1-3, 390.8A.6
3. Preserve remaining riparian buffers on Greenwich Bay's tributaries	RIDEM, CRMC, Rhode Island General Assembly, Warwick, East Greenwich	390.7C.4-5
4. Increase enforcement of vegetated buffer policies	Warwick, East Greenwich, CRMC, NGOs	390.7C.10
5. Increase awareness of the benefits of coastal and riparian vegetated buffers	CRMC, RIDEM, NRCS	390.7C.9
6. Establish coastal and riparian buffers on public lands	RIDEM, Warwick, East Greenwich, West Warwick	470.8B.1
Restore and preserve fish and wildlife habitat in the Greenwich Bay watershed.		
1. Preserve remaining freshwater wetlands in the Greenwich Bay watershed	RIDEM, CRMC, Rhode Island General Assembly, Rhode Island Airport Corporation	390.5B.1-5
2. Identify additional critical lands in the Greenwich Bay watershed and prioritize specific parcels for acquisition	Greenwich Bay Implementation Team, NRCS, URI	390.8A.3
3. Acquire land and conservation easements in the Greenwich Bay watershed to preserve wildlife habitat and protect water quality	Warwick, East Greenwich, Rhode Island General Assembly, CRMC, RIDEM, HEALTH, WSA	390.7B Policy 3, 390.8, 780.4A
4. Restore tidal and freshwater wetlands in the Greenwich Bay watershed	CRMC, RIDEM, Warwick, East Greenwich, NRCS, EPA, USACE, NGOs	390.5A, 390.5B.6-9, 390.5C
5. Restore anadromous fish runs	RIDEM, CRMC, Warwick, East Greenwich	390.2B.4

Priority actions	Lead agencies	SAMP section reference [1]
6. Evaluate changing water use classifications to protect adjacent beach habitat	CRMC	390.6C.2
7. Develop adopt-a-wetland, adopt-a-shoreline, and adopt-a-stream programs	Warwick, East Greenwich, NGOs, CRMC	390.1
8. Increase awareness and enforcement of existing recreational vehicle restrictions	Warwick	390.6C.1
Protect native species for their economic and intrinsic value		
1. Establish quahog resource preserves to protect shellfish beds from development and serve as brood stock	CRMC, RIDEM	390.2A Policy 1, Prohibition 1, 390.2B.1-2
2. Limit loss of and disturbance along beach areas to protect horseshoe crab spawning	CRMC, RIDEM	390.6B, 390.6D
3. Determine impacts of low dissolved oxygen on shellfish recruitment	RIDEM	390.2C
4. Increase public awareness of loose dogs disturbing nesting birds	Warwick	390.3B
Limit the impact of nuisance species		
1. Consider developing management plan to control Canada geese and mute swans	RIDEM, FWS	470.7B.8
Limit economic and environmental impacts from natural hazards		
See Table 5 for priority action summary.		

1 Reference the cited SAMP sections for specific action language.

120.4 Improve recreational opportunities on Greenwich Bay and its shoreline

1. Proper facilities and quality access to the shoreline are necessary for boating, fishing, swimming, and other activities on Greenwich Bay. In 2003, Greenwich Bay's 33 marinas, 268 acres of mooring areas, and 67 residential docks accommodated approximately 4,000 boats, making it one of the most popular recreational harbors in Rhode Island. In 2003, there were 27 CRMC–designated public rights-of-way to the shoreline, but 67 percent were not clearly identified by a sign, at least 30 percent were not adequately maintained, and 45 percent did not have parking available. The part-time enforcement authorities on Greenwich Bay are challenged by growing safety concerns from the large and growing boating population and the bay's shallow waters and narrow channels. Marking and maintaining existing shoreline access, acquiring land to improve access parking and amenities, employing a full-time harbormaster, facilitating private facility dredging, and dredging a new, safer channel to Warwick Cove are some key actions to improve recreational opportunities in light of expected demand (Table 4).

120.4A Objectives

1. By 2007, all CRMC–designated public rights-of-way are marked clearly with a sign.
2. By 2010, all CRMC–designated public rights-of-way are maintained.
3. By 2010, local groups have adopted 25 percent of CRMC–designated public rights-of-way to Greenwich Bay and its coves.
4. By 2010, 75 percent of CRMC–designated public rights-of-way have at least 1-2 parking spaces available within walking distance of the right-of-way.
5. By 2010, the number of accidents and incidents involving boats on Greenwich Bay has been reduced by 50 percent.
6. By 2010, measures are in place that facilitate dredging in Greenwich Bay and allow for the beneficial reuse of material in Greenwich Bay whenever possible.
7. By 2015, there are 50 percent more CRMC–designated public rights-of-way to Greenwich Bay and its coves.
8. By 2015, there is a new, safer channel at the entrance of Warwick Cove.
9. By 2015, a program exists to maintain sand on Oakland Beach.

Table 4. Prioritized actions to improve recreational opportunities on Greenwich Bay and its sho reline

Priority actions	Lead agencies	SAMP section reference [1]
Increase quality recreational access to Greenwich Bay.		
1. Prevent encroachment and loss of existing public access	CRMC, Warwick, East Greenwich, RI General Assembly	780.5B Policy 1-2, Prohibition 1, Standards 1-2, 780.5C.1-4
2. Ensure maintenance of public rights-of way	Warwick, East Greenwich, CRMC, RISAA, NGOs	780.5B Policy 3, 780.5C.5
3. Increase public access sites along Greenwich Bay	CRMC, Warwick, East Greenwich	780.5B Policy 4-6, 780.5C.6
4. Increase funding to maintain and enhance public access	RI General Assembly, Warwick, East Greenwich, RIDEM	780.5C.7-10
5. Increase awareness of public access sites along Greenwich Bay	CRMC, Warwick, East Greenwich, RIMTA	780.5B Policy 7-8, 780.5C.11-13
6. Acquire land and conservation easements in the Greenwich Bay watershed to improve public access	Warwick, East Greenwich, RI General Assembly, CRMC, RIDEM, WSA	390.7B Policy 3, 390.8, 780.4A, 780.5C.14
7. Improve parking at public rights-of ways	Warwick, East Greenwich	780.5C.14
8. Enhance access and recreational opportunities at Chepiwanoxet Park	Warwick	780.5C.15
9. Revisit and revise as appropriate mooring standards for mushroom anchors to allow for a wider range of options	Warwick, East Greenwich	780.1A.6
Ensure boater and swimmer safety on Greenwich Bay.		
1. Employ a full-time harbormaster to administer a more intensive harbor patrol program	Warwick	780.1A.1
2. Enter into a formal agreement authorizing reciprocal enforcement authority by the harbormasters and law enforcement personnel in Greenwich Cove	Warwick, East Greenwich	780.1A.2

Priority actions	Lead agencies	SAMP section reference [1]
3. Increase mooring fees to support harbor management	Warwick	780.1A.3
4. Update authorization to regulate activities in tidal waters	Warwick	780.1A.4
5. Increase personal watercraft user awareness of state and local safety laws	Warwick, East Greenwich	780.1A.5
6. Consider designating known swimming areas off limits to personal watercraft use	Warwick	780.2A.1
Facilitate public and private dredging needs while protecting and enhancing natural resources.		
1. Develop a sediment management plan for Greenwich Bay	CRMC, RIDEM, Warwick, East Greenwich, RIMTA, State Geologist, URI, USACE	780.6B.1
2. Acquire funding to dredge an alternative channel to Warwick Cove and use dredge material to nourish Oakland Beach	CRMC, Warwick	780.6B.2
3. Coordinate private dredging projects	Marinas, CRMC	780.6B.3
4. Review and revise, if needed, minimum physical and chemical parameters for beach nourishment	RIDEM, CRMC, HEALTH	780.6B.4
5. Explore expanding dredging windows	CRMC, RIDEM	780.6B.5

1 Reference the cited SAMP sections for specific action language.

120.5 Enhance water-dependent economic development on Greenwich Bay and its shoreline to maintain the areas unique sense of place

1. Greenwich Bay's historic and economic heritage is being lost. Expanding residential development and non-water-dependent business, and other economic and environmental forces threaten to displace Greenwich Bay's traditional commercial fisheries. Jobs have been lost in recent years with, at most, 550 people employed in fisheries—many part-time—in 2001. Shoreline development could disturb unidentified Native American artifacts, and other cultural, historical, and archaeological resources. Greenwich Bay's water-dependent businesses are vulnerable to the economic impacts from the next large hurricane or other natural hazard. It has been over 50 years since the last large hurricane hit Greenwich Bay. Grandfathering existing quahog facilities on Greenwich Cove, reviewing shoreline development permit applications for potential impacts on cultural, historical, and archaeological resources, ensuring that in-water structures are built to limit damage from storms, and facilitating the clean-up of storm debris (particularly the clean-up of marina debris by marina owners) are some key actions to maintain Greenwich Bay's sense of place.

120.5A Objectives

1. By 2010, programs to limit economic and environmental impacts from natural hazards are in place.

2. By 2010, mechanisms are in place to protect Greenwich Bay's cultural, historical, and archaeological resources.

3. By 2011, full-time employment in water-dependent industries and the tourism industry in the Greenwich Bay watershed has increased by 25 percent.

Table 5. Prioritized actions to enhance water-dependent economic development on Greenwich Bay and its shoreline to maintain the areas unique sense of place

Priority actions	Lead agencies	SAMP section reference [1]
Cultivate water-dependent businesses and tourism along Greenwich Bay.		
1. Ensure affordable dock space for the shellfishing industry	CRMC, RIEDC, East Greenwich, Warwick	680.1, 680.2A.1
2. Expand aquaculture opportunities in Greenwich Bay	RIMTA, Rhode Island Shellfishermen's Association	680.2A.3-5, 680.2.3
3. Improve the marketing of Rhode Island shellfish	Rhode Island Shellfishermen's Association, RIEDC	680.2A.2
4. Ensure opportunity to transplant shellfish resources prior to dredging	CRMC, RIDEM, Rhode Island Shellfishermen's Association	390.2A Standards 1-2, 390.2B.3-4
5. Consider developing a comprehensive tourism strategy	Warwick, East Greenwich, RIEDC	680.2B.1-4
6. Consider requesting growth center designations for Warwick and East Greenwich	Warwick, East Greenwich	680.2D.3
7. Conduct research to demonstrate the link between a clean environment and improved economic performance	-	680.3.1
8. Conduct a study to quantify the economic importance and environmental impacts associated with recreational boating and marinas in Greenwich Bay	RIEPC	680.3.2
9. Prepare a marine resources development plan	CRMC	680.2D.1-2
10. Research potential dredging projects at the entrance to Brush Neck and Buttonwoods Coves and Warwick Cove	USACE, CRMC	780.6C.1-2
11. Explore expanding support and staffing of high school programs for technical training in boat building and repair and marina management	Warwick, East Greenwich, RIMTA	680.2C.1
12. Advertise compliance with the clean marina program to attract clients and educate the community of marinas' role in marine resources stewardship	Marinas	680.2C.2

Priority actions	Lead agencies	SAMP section reference [1]
Limit economic and environmental impacts from natural hazards.		
1. Ensure that in-water structures and structures in flood zones meet design and building standards that limit damage during storms	CRMC, RIEMA, USACE, Warwick, East Greenwich, Marinas	860.1A.2, 860.1C.3-4, 860.2A.1, 860.2B.1, 860.2C.1, 860.2D.1
2. Facilitate cleanup of debris following storms	CRMC, RIDEM, RIRRC, Warwick, East Greenwich, RIMTA, Rhode Island General Assembly	860.1A.3, 860.2A.2-4, 860.2B.2-3, 860.2C.2-3, 860.2D.2
3. Adopt multi-hazard mitigation strategies to access federal assistance	Warwick, East Greenwich	860.2C.4
4. Educate boat and dock owners on methods to reduce damage and speed up recovery after storms	RIMTA	860.2D.3
5. Develop an early hazard warning system for marinas	CRMC, RIEMA	860.2B.4
5. Remove boats from high hazard areas prior to storms	RIMTA, Warwick, East Greenwich	860.2B.5
6. Increase public awareness of high erosion areas	CRMC	860.2D.4
7. Identify shoreline locations where stabilization is not appropriate	CRMC	860.2A.5
8. Preserve land in the Greenwich Bay watershed to mitigate natural hazards	Warwick, East Greenwich, Rhode Island General Assembly, CRMC, RIDEM, WSA	390.7B Policy 3, 390.8, 860.1A.4, 860.2A.6, 860.2C.6
9. Implement tree maintenance program	Warwick, East Greenwich, CRMC	860.2C.7, 860.2D.5
10. Inventory structures within high risk flood zones at rate risk level	Warwick, East Greenwich	860.2C.8
11. Create a communication strategy to prevent tourism losses after hazard events	Warwick, East Greenwich, RIEDC	860.2C.9
12. Consider initiating a business alliance to implement disaster planning toolkit for small businesses	Chamber of Commerce	860.2A.7
13. Increase public awareness of hazard evacuation routes	Warwick, East Greenwich	860.2C.5, 860.2D.6
14. Conduct a study on the potential impacts of the predicted sea	-	860.3.2

Priority actions	**Lead agencies**	**SAMP section reference [1]**
level rise on the Greenwich Bay Watershed		
Protect Greenwich Bay's cultural, historical, and archaeological resources.		
1. Allow the RIHPHC to review all major permit activities and use their guidance for decision-making and permit stipulations	CRMC, RIHPHC	530.1B.1-3, 530.2.5
2. Investigate the potential of signing a memorandum of agreement with the Narragansett Indian Tribe to facilitate negotiations between the tribe and the state regarding archeological resources	CRMC, RIHPHC	530.2.3
3. Incorporate sites identified by RIHPHC into coastal and riparian buffer areas	CRMC	530.1B.4
4. Identify cultural, historical, and archaeological resources	Warwick, East Greenwich, RIHPHC, CRMC	530.1A.3, 530.2.2, 530.3, 680.2B.5-6
5. Educate the public about the value of cultural, historic, and archaeological resources of the Greenwich Bay watershed	Warwick, East Greenwich, RIHPHC, NGOs	530.1A.2, 530.2.4
6. Acquire land and conservation easements in the Greenwich Bay watershed to preserve historic areas	Warwick, East Greenwich, RI General Assembly, CRMC, RIHPHC	390.7B Policy 3, 390.8, 530.2.1
7. Ensure that cultural, historical, and archaeological resources are not compromised by runoff or storm water infrastructure	CRMC, RIDEM, Warwick, East Greenwich	530.1B.5
Facilitate public and private dredging needs while protecting and enhancing natural resources.		
See Table 4 for priority action summary		
Increase the acreage of coastal and riparian buffers in the Greenwich Bay watershed.		
See Table 3 for priority action summary		

1 Reference the cited SAMP sections for specific action language.

Section 130
Glossary of institutional acronyms

CAC	Greenwich Bay Citizens Advisory Committee
CRMC	R.I. Coastal Resources Management Council
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FWS	U.S. Fish and Wildlife Service
GBIT	Greenwich Bay Implementation Team
HEALTH	Rhode Island Department of Health
HMGP	Hazard Mitigation Grant Program
NBEP	Narragansett Bay Estuary Program
NFIP	National Flood Insurance Program
NGO	Non-Government Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	U.S. Natural Resources Conservation Service
RIDEM	R.I. Department of Environmental Management
RIDOT	R.I. Department of Transportation
RIEDC	R.I. Economic Development Corporation
RIEMA	R.I. Emergency Management Agency
RIEPC	R.I. Economic Policy Council
RIHPHC	Rhode Island Historical Preservation & Heritage Commission
RIMTA	Rhode Island Marine Trades Association
RIRRC	R.I. Resource Recovery Corporation
RISAA	Rhode Island Saltwater Anglers Association
RISG	Rhode Island Sea Grant
SRICD	Southern Rhode Island Conservation District
URI	University of Rhode Island
URI-CE	University of Rhode Island Cooperative Extension
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
WSA	Warwick Sewer Authority

Chapter 2

The Framework for Collaboration to Implement the Greenwich Bay Special Area Management Plan

Table of Contents

Tables

Figure

Section 200
Summary

1. This chapter traces the background of the Greenwich Bay Special Area Management Plan (SAMP), provides an outline of the legal and administrative framework for management, and proposes collaborative actions that:

- Increase permitting efficiency and improve feedback to applicants
- Ensure that development projects conform with SAMP goals
- Monitor SAMP progress to articulate successes and make corrections as needed

Section 210
Management authorities for regulation, planning, and implementation

1. Different agencies administer the federal, state, and local laws that govern most of the Greenwich Bay ecosystem. These laws are not based primarily on an ecosystem approach. SAMPs, however, are ecosystem-based management plans conceived by public officials and resource users to improve resource management and build on existing laws. SAMPs entail improving existing government rather than creating additional management structures.

210.1 Federal mandate for Special Area Management Planning

1. The SAMP is part of CRMC's ongoing responsibility under the Federal Coastal Zone Management Act (16 U.S.C. §1451). The SAMP is an examination of watershed resources, uses, problems, and institutions. SAMP policies, regulations, and actions are designed to insure the preservation of the vital elements of the ecosystem, to guide future development within land and water limitations, and to resolve existing and anticipated problems. CRMC has the authority to require that proposed development of dry land and submerged land consider impacts on surface and groundwater resources, wetlands, coastal features, and other sensitive and fragile natural resources. The Coastal Zone Management Act (CZMA) (16 U.S.C. §1452) declares that it is the nation's policy:

> to encourage the preparation of special area management plans which provide for increased specificity in protecting significant natural resources, reasonable coastal-dependent economic growth, improved protection of life and property in hazardous areas, including those areas likely to be affected by land subsidence, sea level rise, or fluctuating water levels of the Great Lakes, and improved predictability in governmental decision making (16 U.S.C. §1452).

2. CRMC also has authority over the entire watershed for various federal and federally licensed or supported activities through the federal consistency process. This process is executed according to the provisions set forth in the R.I. Coastal Resources Management Plan, Section 400, and the most recent version of the CRMC Federal Consistency Manual.

210.2 State mandate from the Rhode Island General Assembly to CRMC for Special Area Management Planning

1. CRMC has authority pursuant to Rhode Island General Law (R.I. Gen. Law) §46-23-15 to administer land- and water-use regulations as necessary to fulfill its responsibilities under the Federal CZMA, as amended. CRMC has direct authority over Greenwich Bay, its shoreline, and associated coastal resources. The state legislative mandate for ecosystem-based planning describes the resource management process as follows:

- Identify all state coastal resources including water, submerged lands, air space, finfish, shellfish, minerals, physiographic features

- Evaluate these resources in terms of their quantity, quality, usability, and other key characteristics
- Determine the current and potential uses and problems of each resource
- Formulate resource management plans and programs and identify permitted uses, locations, and protection measures
- Carry out these resource management programs through implementing authority and coordination of state, federal, local, and private activities
- Formulate new standards and evaluate existing standards

CRMC will initiate resource management activities through this process and evaluate these activities to modify its resource management programs (R.I. Gen. Law §46-23-1).

2. CRMC, in partnership with RIDEM, is responsible for developing and implementing the Rhode Island Coastal Nonpoint Pollution Control Program under Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990. This section, "Protecting Coastal Waters," requires each coastal state to develop a Coastal Nonpoint Pollution Control Program (CNPCP). The central purpose of Section 6217 is to strengthen the coordination between federal and state coastal and water quality management programs. Based on federal guidance (EPA 1993, NOAA and EPA 1993), the R.I. CNPCP was developed and submitted in 1995 to the National Oceanic and Atmospheric Administration (NOAA) and the Environmental Protection Agency (EPA). It was conditionally approved in 1997. The R.I. CNPCP contains economically achievable and technology-based management measures for pollution control from new and existing categories and classes of nonpoint pollution sources. Management measures apply to agriculture, forestry, urban development and infrastructure, marinas, and hydrologic modifications. There are also management measures to protect wetlands and riparian areas, and to promote the use of vegetative treatment systems (EPA 1993a). Implementation of management measures in the R.I. CNPCP occurs through CRMC and RIDEM.

3. SAMPs adopted by CRMC are to be adopted as elements of the state guide plan pursuant to R.I. Gen. Law §42-11-1.

210.3 State and local authorities and programs

210.3A Working with municipalities and state agencies

1. Through the SAMP, CRMC has worked with inland state and municipal regulatory authorities, including but not limited to RIDEM, the R.I. Statewide Planning Program, the town of East Greenwich, the city of Warwick, and users, to comprehensively manage the Greenwich Bay watershed.

210.3B The Statewide Planning Program

1. The Statewide Planning Program within the R.I. Department of Administration, Division of Planning, administers the comprehensive planning

program and helps to address the cumulative and secondary impacts of development. The key relevant laws include the Rhode Island Comprehensive Planning and Land Use Act of 1988 (Land Use Act) (R.I. Gen. Law §45-22-2) and the State of Rhode Island Land Development and Subdivision Review Enabling Act of 1992, also known as the Development Review Act (R.I. Gen. Law §45-23). Together, the acts integrate state oversight of local land-use planning. At a minimum, under the Land Use Act, the towns must consider the allocation of land for residences, businesses, industries, municipal facilities, public and private recreation, major institutional facilities, mixed uses, open space, and natural and fragile areas. Optimum intensities and standards of development must be established for each use classification and location, based on current development; natural land characteristics; and projected municipal, regional, and state services and facilities. Land-use allocations must reflect impacts on surface and groundwater resources, wetlands, coastal features, and other sensitive and fragile natural resources. The Development Review Act allows the state agencies to provide review of development applications to the towns before the towns make their series of reviews. This improves regulatory coordination and corresponds with the joint cooperative review envisioned under the SAMP.

210.3C The Land Development and Subdivision Review Enabling Act

1. The Development Review Act went into effect in December 1995. The act requires the towns to administer three levels of review for any subdivision of land, regardless of the number of units: level one, the master plan; level two, the preliminary plan; and level three, the final plan. The Development Review Act requires the towns to designate an administrative officer to administer the act and to coordinate all joint reviews.

2. CRMC has a preliminary determination process that is independent of the town's review process but meets the requirements of the master plan review under the Development Review Act. CRMC's preliminary determination gives applicants up-front information pertaining to a specific site and activity. The preliminary determination review process enables applicants or municipalities to request a preliminary application meeting with all applicable boards, commissions, and where appropriate, state agencies for information on CRMC standards and regulatory processes. Likewise, at the town's master plan level, the town can collect local, state, and federal agency comments and provide a public forum prior to any planning board action. The CRMC preliminary determination process allows CRMC to:

- Minimize the number of failed applications by alerting applicants to potential permitting problems early on in the regulatory process
- Evaluate development proposals on the basis of shared expertise from permitting agencies and municipalities
- Evaluate major ecosystem impacts at the beginning of the permitting process to identify as early as possible the issues applicants need to address

3. At the town's preliminary (second) plan level, all state approvals (including CRMC, RIDEM Wetlands, and ISDS) required prior to construction must be in place, and a formal public hearing must be held. Decisions on local regulatory requirements and any mitigation through public improvements take place during final plan approval.

210.3D Harbor Management Plans

1. Chapter 4 of Title 46 of the R.I. Gen. Laws authorizes coastal municipalities to regulate certain activities in their public waters through Harbor Management Plans with guidance and approval from CRMC. These plans ensure municipal programs, ordinances, and regulations are consistent with state law. Among other criteria, the plans must meet state requirements for fair and consistent access to harbor activities.

210.3E Other state and local land-use controls and programs

In addition to local zoning ordinances, municipalities can implement other land-use management controls and request technical assistance under the following programs and legislation:

- 1990 Erosion and Sediment Control Act (R.I. Gen. Law 45-46) enables municipalities to adopt erosion and sediment control ordinances
- Septic System Maintenance Act of 1987 (R.I. Gen. Law 45-24.5) enables municipalities to adopt waste water management districts
- Rhode Island Sea Grant College Program at the University of Rhode Island conducts research and outreach programs that promote better understanding, conservation, and use of coastal resources
- U.S. Geological Survey Water Quality Initiative and Natural Resources Conservation Service (NRCS) cooperate to address nonpoint pollution
- The Rhode Island Bays, Rivers, and Watersheds Coordination Team, created in 2004 by the Rhode Island General Assembly, coordinates policies and plans to protect, preserve, and restore the state's bays, rivers, and watersheds

Section 220
Implementing the SAMP: Collaboration for action

220.1 The need for collaboration

SAMP implementation requires coordination among local, state, and federal authorities and collaboration with bay users in setting priorities, making decisions on bay use, implementing actions, and assessing progress.

220.2 Progress and lessons from the Greenwich Bay Initiative, 1993-1996

1. Progress in agency coordination and citizen engagement has been achieved in Greenwich Bay. The Greenwich Bay Initiative, launched in 1993, involved cooperative efforts in coordination, research, remediation, and public education among Warwick and East Greenwich, state and federal governmental agencies, university researchers, and non-profit environmental organizations.

2. The early accomplishments of the initiative highlight the benefits of collaboration. A key parcel of land, Chepiwanoxet Point, was purchased with the cooperation of The Nature Conservancy, The Champlin Foundations, CRMC, Save The Bay, and the R.I. Shellfishermen's Association. The Warwick City Council ratified a new zoning ordinance, which allowed for a stormwater ordinance and a watershed protection overlay district. Warwick voters passed a $130-million-bond referendum for wastewater management improvements; a $5-million Bay Bond was also approved in 1994.

3. The R.I. Department of Transportation (RIDOT) approved a joint plan with the Warwick Sewer Authority (WSA) to extend sewer lines to 1,000 homes and apartments as part of a $3-million road reconstruction project. EPA and RIDEM funded the Oakland Beach Project, which paid for connecting about 130 homes to an existing sewer line. WSA has also offered more than $675,000 in grants and $820,000 in loans to upgrade failing septic systems as part of the On-Site Rehabilitation Program. RIDEM Division of Water Resources grants facilitated the installation of marine pump-out facilities for eight of Warwick's 10 marinas. The National Sea Grant College Program awarded $800,000 to Rhode Island Sea Grant to monitor bay pollution concentrations, and to model hydrologic flushing patterns.

220.3 Progress and lessons from the Special Area Management Planning effort, 2002-2004

1. The process for creating the Greenwich Bay SAMP built on the accomplishments of the Greenwich Bay Initiative. The initiative focused on priority measures to address the most pressing concerns at the time, but the need remained for a more comprehensive examination of issues and possible solutions. CRMC secured a $250,000 federal grant in 2002 with the support of the Rhode Island General Assembly to oversee the creation of the Greenwich Bay SAMP with East Greenwich, Warwick, Rhode Island Sea Grant, and the

University of Rhode Island Coastal Resources Center. Additional partners included RIDEM, R.I. Emergency Management Agency,

Rhode Island Historical Society, R.I. Department of Health (HEALTH), R.I. Economic Development Corporation (RIEDC), WSA, Rhode Island Marine Trades Association, Rhode Island Shellfishermen's Association, Save The Bay, NRCS, and the Southern Rhode Island Conservation District.

2. The planning process was structured to consider the watershed and bay ecosystem, and this plan includes new regulations and recommended protection actions that can be undertaken through a collaborative effort with government partners, technical experts, community members and the business community.

3. The Technical Advisory Committee (TAC) provided data and expertise to the SAMP. TAC members included government agencies, municipal officials, and universities (See Appendix A). The TAC met 14 times to collect data, to identify current activities by various organizations, and to draft specific findings and policies. Draft chapters drew from this input and were then reviewed by the Citizens Advisory Committee (CAC). TAC meetings were public, and experts from the TAC often spoke at CAC meetings to ensure communication between the two committees.

4. The CAC was formed in October 2003 to provide Warwick and East Greenwich community organizations with the opportunity to help shape the SAMP (Table 1). Each organization designated one representative to serve on the CAC. In 2003 and 2004, the CAC met over twenty times, including nine joint meetings with the Greenwich Bay Subcommittee of the Coastal Resources Management Council (See Appendix B). The CAC provided guidance for drafting the SAMP chapters, promoted public awareness, and helped select implementation strategies.

5. Early actions took place as the plan was drafted. A rights-of-way study has provided information and recommendations for improving public access. *Greenwich Bay: An Ecological History*, published in 2004, has educated citizens and organizations on Greenwich Bay issues. The municipalities have used the Land Development Act to engage the state in local land-use decisions, improving coordination. CRMC has modified water use classifications in Apponaug and Warwick coves to protect natural resources.

Table 1. Greenwich Bay Citizens Advisory Committee Members

Organization
Buckeye Brook Coalition
Buttonwoods Bay Committee
Buttonwoods Beach Association
Buttonwoods Garden Club
Cedar Tree Point Association
Chepiwanoxet Neighbor Association
Defenders of Greenwich Bay
East Greenwich Chamber of Commerce
Rhode Island Marine Trades Association
Rhode Island Shellfishermen's Association
Rhode Island Saltwater Anglers Association
Warwick Harbor Commission
Warwick Marina Alliance
Warwick Watershed Action Team

220.4 Improving management through the SAMP

1. SAMP implementation may be accelerated by strengthening Greenwich Bay partnerships. For example, progress on issues such as public access requires the cooperation of several groups, such as CRMC, RIDOT, and the municipalities to recognize rights-of-way, allow parking, and provide maintenance.

2. Streamlining permitting can lead to smoother decision-making, for instance, by combining CRMC's preliminary determination process with the Land Development Act's pre-application and master plan review procedures.

3. Key agencies such as CRMC, RIDEM, RIEDC, and RIDOT can expand their learning network, for example, by incorporating Greenwich Bay from the beginning in discussions of projects with regional economic and environmental impacts. No new government agencies or boards need to be created to carry out SAMP activities.

4. Local and state government should monitor, assess, and report on SAMP progress and challenges. The results of monitoring will be used to further improve SAMP activities. Progress indicators should include the condition of the bay environment and the capability of government, businesses, and citizens to collaborate on the SAMP.

Section 230
Actions for implementing the Greenwich Bay SAMP

230.1 Management measures to improve regulation in Greenwich Bay

1. Successfully implementing the SAMP will require adjustments to federal, state, and local regulations and a high degree of compliance. Regulators will provide clear, consistent guidance, — including consolidated guidance documents, training sessions, and improved coordination of the regulatory permitting process — to each other and to applicants for permits and assents.

230.1A Policies and recommendations

1. A CRMC preliminary determination process will be provided to applicants who desire initial regulatory information prior to filing a full application, with detailed activity or construction plans, to municipalities and to CRMC.

2. CRMC will continue to participate in the preliminary review process when initiated by the municipalities or any other state agency under the Development Review Act.

3. CRMC and other state and municipal departments in the Greenwich Bay Implementation Team (see 230.2A.2 below) will jointly review their current regulations and procedures to increase clarity; eliminate unnecessary confusion, overlap, and delays; and work toward more seamless decision making.

4. Warwick and East Greenwich could further support state policies incorporated in the SAMP, for example through a coastal overlay zone. The town of Narragansett has already implemented this idea.

5. The scope of Harbor Commissions in each municipality can be expanded to assist in key management tasks.

230.2 Management measures to improve collaboration during implementation

1. The Rhode Island General Assembly recognized the need for coordination and continuity in bay management in 2004 when it created the Rhode Island Bays, Rivers, and Watersheds Coordination Team, which will report to, and initially be chaired by the governor. This statewide team's focus is on creating a plan for Narragansett Bay and its watershed. SAMP activities should coordinate with the plan for Narragansett Bay.

230.2A Policies and recommendations

1. Local and state agencies and organizations should create and sustain inter-organizational partnerships to raise funds and carry out SAMP projects. Partners

should incorporate SAMP implementation into their work plans to stay focused on essential actions.

2. SAMP implementation will be guided by a Greenwich Bay Implementation Team (GBIT), composed of municipal and state government bodies with the planning and regulatory authority to implement aspects of the SAMP. The GBIT will include the Mayor of Warwick or his or her designee, the Town Manager of East Greenwich or his or her designee, the Town Manager of West Warwick or his or her designee, a member of the Warwick City Council appointed by that body, a member of the East Greenwich Town Council appointed by that body, a member of the West Warwick Town Council appointed by that body, and representatives from CRMC, RIDEM, HEALTH, RIEDC, and the Rhode Island Rivers Council. This team will meet at least once per year to assess progress and formulate an annual implementation work plan that team members can use to guide their budgeting and programming. It will also organize, summarize, and incorporate the results of an annual public forum into progress assessment and work plan preparation.

3. To carry out its responsibilities as a member of the GBIT, CRMC will create a permanent working group or subcommittee to oversee SAMP implementation and will maintain the Greenwich Bay SAMP as a regular item on its agenda. This group will provide relevant information on implementation progress to the Rhode Island Bays, Rivers, and Watersheds Coordination Team.

4. CRMC will seek a legislative appropriation to hire staff for the specific purpose of coordinating and implementing the SAMP.

5. The GBIT will examine the budgetary and administrative requirements of each priority action included in the yearly work plan and identify potential sources of external and internal funding as well as capacity building resources needed to implement each activity in the SAMP. Scientific monitoring equipment needs should be incorporated in the funding proposal of the biennial work plan to help track progress in wastewater management.

6. The Rhode Island General Assembly has demonstrated its leadership and strong commitment to supporting bay and watershed management and will need to continue to play oversight, progress monitoring and addressing legislation to carry out elements of the SAMP. Special efforts should be made to keep legislators from the Greenwich Bay region informed and engaged as part of the work of the GBIT and Public Forum.

230.3 Establish the Greenwich Bay Public Forum for public involvement

230.3A Policies and recommendations

1. Establish a mechanism that helps create an active constituency for implementing the SAMP. To this end, a Greenwich Bay Public Forum will be held annually, cosponsored by the GBIT, Greenwich Bay watershed organizations, Greenwich Bay Citizens Advisory Committee, and other civic, educational, scientific, and business groups.

2. The public forum will feature reports and discussions of bay condition and use, note progress toward goals, and recognize community contributions to implementing the SAMP. The forum will highlight projects underway and provide opportunities for exchanging information, ideas, and strategies to strengthen implementation. The forum will address emerging issues and identify potential revisions of the SAMP. The GBIT will use this information to prepare its work plan. The forum may be followed up by other bay-wide meetings during the year that provide continuing opportunities to discuss progress, focus on specific issues, and coordinate ongoing actions by member groups.

3. The public forum will be supported throughout the year by the Greenwich Bay SAMP website and information systems maintained by Rhode Island Sea Grant and CRMC. Special efforts should be made to work with the school systems of East Greenwich and Warwick to engage students and teachers in the scientific, historic, cultural, communication, and management aspects of the SAMP.

230.4 Prepare a Greenwich Bay work plan

230.4A Policies and recommendations

1. The GBIT should maintain the focus on priority projects from the list of essential short- and medium-term actions needed to achieve key results that have broad support. A work plan will be prepared that describes high-priority projects and programs that the GBIT needs to carry out to implement the SAMP. The work plan will also acknowledge the relevant activities of other government, private sector, and nongovernmental organization efforts.

230.5 Prepare progress assessments

230.5A Policies and recommendations

1. The GBIT should assess progress by determining indicators that show whether SAMP goals and objectives have been achieved to provide feedback to tax payers and rate payers on how their investment is leading to cleaner water and other improvements.

2. A progress assessment and monitoring document will be maintained and revised in concert with the public forum and work plan. The document can include recommendations for addressing problems, especially those of bay coves. This periodically updated document will record decisions, lessons learned, achievements,

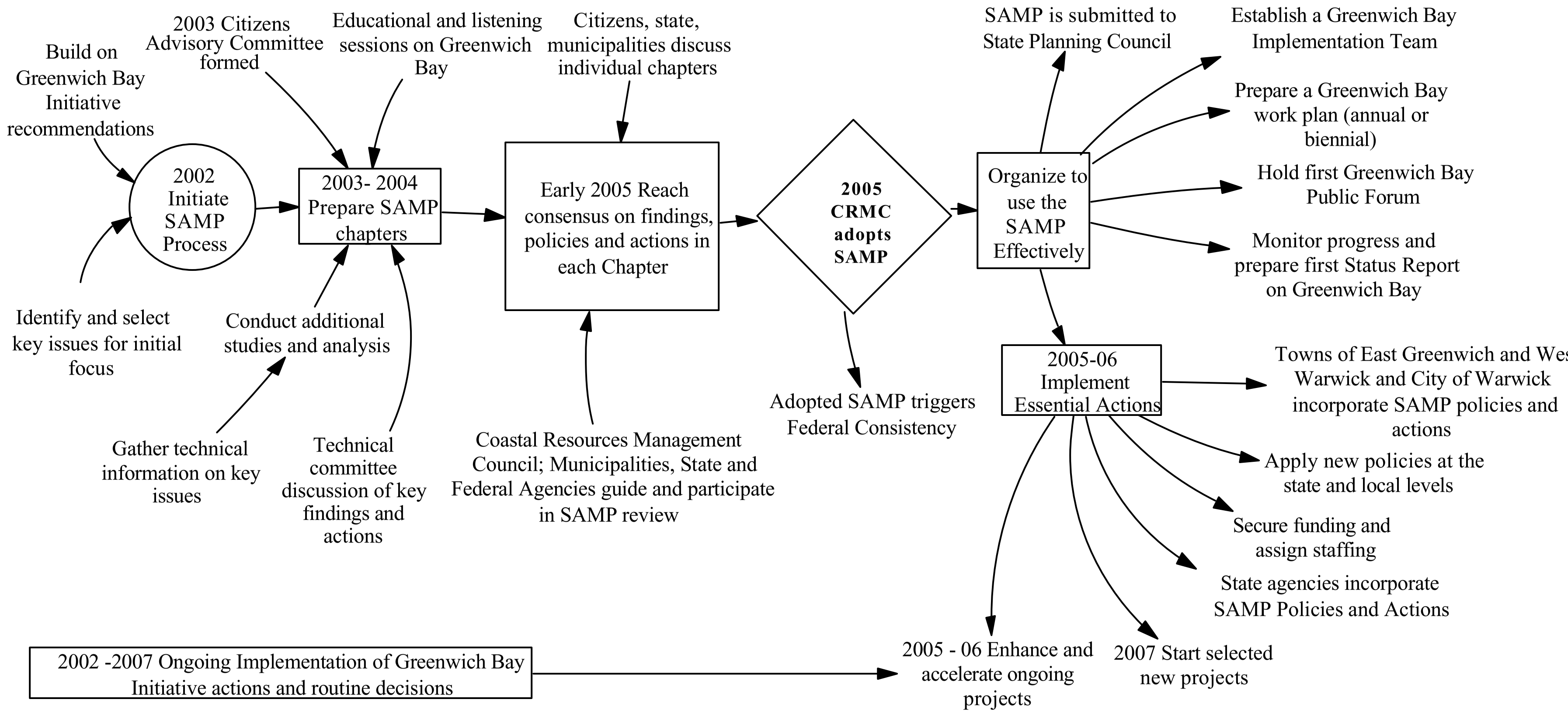
and adaptations of the work plan. Agencies and other implementers will be contacted on a regular basis to obtain updates.

3. Priority collaborations and agreements to implement the Greenwich Bay SAMP, drawn from the individual chapters of the SAMP, are suggested in Table 2. The sequence followed to prepare the SAMP is summarized in Figure 1, which also indicates implementation actions.

Table 2. Issues, essential actions, and priority collaborations to implement the Greenwich Bay SAMP

Key SAMP issue	Essential actions	Priority collaborations
Habitat and Environmental Assets	• Restore tidal and freshwater wetlands and streams • Increase coastal and riparian buffers • Acquire priority lands • Create quahog resource preserves	CRMC, RIDEM, Warwick, East Greenwich, NRCS, EPA, USACE, NGOs
Water Quality	• Complete sewer tie-ins, storm water control and management programs • Phase-out cesspool use • Inspect and maintain ISDS systems with focus on Potowomut region • Secure funding for clean water and habitat restoration • Reduce nitrogen loading from East Greenwich Wastewater Treatment Facility (WWTF) • Increase coastal and riparian buffers • Strengthen Clean Marina and Boating Program • Provide public education • Enhance water quality monitoring	CRMC, RIDEM, RIDOT, HEALTH, WSA, Warwick, East Greenwich, West Warwick, URI Cooperative Extension, RIMTA, NRCS
Cultural and Historical Assets	• Clarify procedures to protect cultural sites • Incorporate sites into buffer zones • Acquire priority sites • Protect and research sub-aquatic sites	CRMC, RIHPC, Warwick, East Greenwich, Narragansett Indian Tribe
Economic Assets	• Grandfather quahog facilities on Greenwich Cove • Expand aquaculture opportunities • Consider developing a comprehensive tourism strategy	CRMC, Warwick, East Greenwich, RIMTA, RI Shellfishermen's Association
Recreational Use	• Prevent encroachment and loss of existing public access • Increase maintenance of access sites and parking at sites • Designate and mark public access sites • Increase funding to maintain and enhance public access • Inform public of access rights to shore • Maintain lateral access along shore • Develop a sediment management plan • Dredge new Warwick Cove channel • Employ a full-time harbormaster	CRMC, RIDEM, Warwick, East Greenwich, RISAA, RIMTA, USACE
Natural Hazards	• Ensure in-water structures meet design and building standards • Facilitate debris clean-up by working with marinas • Identify locations for boat storage outside of flood zones and temporary debris disposal	CRMC, RIEMA, Warwick East Greenwich, RIMTA, Chamber of Commerce

Figure 1. Greenwich Bay SAMP process summary and next steps



Section 240

Literature Cited

City of Warwick. (1996). *National Intergovernment Service Award Nomination Document for the Greenwich Bay Initiative.*

Coastal Zone Management Act. (1972). 16 U.S.C. §1451 et seq.

Federal Water Pollution Control Act (Clean Water Act). (33 U.S.C. §1251 - 1376; Chapter 758; P.L. 845, June 30, 1948; 62 Stat. 1155). As amended.

Federal Emergency Management Agency. *National Flood Insurance Program Description.* (2002). FEMA, Washington, D.C.

Governor's Narragansett Bay and Watershed Planning Commission. (2004). *Phase I Strategic Work Plan and Short Term Recommendations to Governor Carcieri and the Rhode Island General Assembly.* http://www.ci.uri.edu/GovComm/Documents/Phase1Rpt/default.htm

Imperial, M. (2004). *Collaboration and Performance Management in Network Settings: Lessons from Three Watershed Governance Efforts. Collaboration Series.* Washington, D.C.: IBM Center for the Business of Government.

Rhode Island Comprehensive Planning and Land Use Act. (1988). R.I. Gen. Laws §45-22-2.

Rhode Island Farm Forest and Open Space Act. R.I. Gen. Laws §44-27.

R.I. Coastal Resources Management Council. (1998). *Guidelines for the Development of Municipal Harbor Management Plans.* http://www.crmc.state.ri.us/pubs/programs/muniharbors.pdf

R.I. Coastal Resources Management Council, R.I. Department of Environmental Management, and R.I. Department of Administration. (1995). *Rhode Island's Coastal Nonpoint Pollution Control Program.* Providence, R.I.

Rhode Island Erosion and Sediment Control Act. (1990). R.I. Gen. Laws §45-46.

Rhode Island General Assembly. (2003). An Act Relating to Special Development Districts—East Providence. Senate Bill S 1187.

Rhode Island General Assembly. (2004). An Act Relating to Waters and Navigation—The Rhode Island Bays, Rivers, and Watersheds Coordination Team. Senate Bill 2004 S 3113.

Rhode Island Land Development and Subdivision Review Enabling Act. (1992). R.I. Gen. Laws §45-23.

Rhode Island Septic System Maintenance Act. (1987). R.I. Gen. Laws §45-24.5.

Rhode Island Special Development Districts. R.I. Gen. Laws §45-24.4.

U.S. Environmental Protection Agency. (1993). *Guidance Specifying Management Measures For Nonpoint Pollution in Coastal Waters.* U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

U.S. Environmental Protection Agency and the National Oceanic and Atmospheric Administration. (1993). *Coastal Nonpoint Pollution Control Program Development and Approval Guidance.* Washington, D.C.

Chapter 3

Habitat and Environmental Assets

Table of Contents

Tables

Figures

Section 300
Introduction

1. Greenwich Bay and its watershed encompass a diversity of interconnected habitats. Open waters, tidal and freshwater wetlands, beaches, mudflats, rivers, freshwater ponds, and other open areas provide habitat for numerous species of shellfish, finfish, birds, rare plants, and other plant and animal species. Two-thirds of Greenwich Bay's watershed is highly developed, so protection and management of the bay's remaining natural resources is important.

2. Many Greenwich Bay habitats are highly productive, supporting fish and wildlife and contributing to Rhode Island's shellfishing industry. Greenwich Bay and its coves remain a haven for finfish. Horseshoe crabs spawn on the beaches. Tidal wetlands provide important habitat for migratory birds, wintering waterfowl, and juvenile finfish. Some areas of the Greenwich Bay watershed shelter populations of rare and endangered species.

3. Water quality and increasing development impact natural habitats in Greenwich Bay. Large fish kills, shellfish closures, and the lack of eelgrass beds indicate a degraded open water ecosystem. New development has disturbed tidal and freshwater wetlands, diminished natural services, and promoted the colonization of invasive species. To protect tidal wetlands, the R.I. Coastal Resources Management Council (CRMC) has a "no net loss" policy. Current CRMC policies prohibit most development in tidal wetlands and require mitigation in instances where activities are approved.

Table 1. Important federal and state agencies for habitat protection and restoration

Agency	Duties
Federal agencies	
U.S. Fish and Wildlife Service (FWS)	FWS conserves, protects, and enhances fish and wildlife and their habitats for the benefit of present and future generations. http://www.fws.gov/
National Marine Fisheries Service (NMFS)	NMFS is dedicated to the stewardship of living marine resources through science-based conservation and management, and the promotion of healthy ecosystems. http://www.nmfs.noaa.gov/
U.S. Army Corps of Engineers (USACE)	USACE regulates dredge and fill activities in waters of the United States, including wetlands. USACE also regulates the construction of any structures that affect navigable waters. Finally, USACE is involved in environmental restoration, wetlands conservation, fish and wildlife mitigation, and environmental protection. http://www.nae.usace.army.mil/
Natural Resources Conservation Service (NRCS)	NRCS works to conserve soil, water, and other natural resources through a variety of voluntary, incentive-based programs. NRCS partners with state and local agencies and organizations as well as landowners to provide technical and financial assistance for natural resource protection and habitat restoration. http://www.nrcs.usda.gov/
U.S. Environmental Protection Agency (EPA)	EPA responsibilities related to habitat protection and restoration include oversight of the federal wetlands program administered by ACOE, control of non-indigenous aquatic species, and administration of the National Estuary Program. http://www.epa.gov/
U.S. Food and Drug Administration (FDA)	FDA sets allowable levels of contaminants in fish and shellfish for human consumption. Its sanitation standards for shellfish are the basis for state pollution closures of shellfish beds. http://www.fda.gov/
State agencies	
Rhode Island Coastal Resources Management Council (CRMC)	CRMC is responsible for coastal zone management—preserving, protecting, developing, and where possible, restoring the state's coastal areas. CRMC jurisdiction extends from the territorial sea limit (3 miles offshore) to 200 feet inland from any coastal feature, such as a beach, but its jurisdiction may be larger for certain activities. CRMC regulates activities on coastal features and in coastal waters, such as aquaculture operations and dredging. http://www.crmc.state.ri.us/

Agency	Duties
Rhode Island Department of Environmental Management (RIDEM)	RIDEM assists individuals, businesses, and municipalities; conducts research; and enforces laws created to protect the environment. Among other habitat-related activities, RIDEM manages Rhode Island's fisheries and wildlife; regulates activities in freshwater wetlands; conducts research and monitoring of fish, wildlife, and their habitats; and works to restore fish and wildlife habitat. RIDEM also regulates the possession, movement, and sale of animals used at aquaculture operations. http://www.state.ri.us/dem/

Section 310
Greenwich Bay's natural history

310.1 Geology

1. Glaciers have shaped the geology of the Greenwich Bay watershed. Over the last 3 million years, glaciers have frequently retreated and advanced across North America. At the end of the last Ice Age (16,000 years ago), the melting Laurentide ice sheet caused sea level to rise and flood the land, creating coastal plain estuaries, such as Narragansett Bay and the Sakonnet River. Narragansett Bay and parts of the surrounding delta plain were flooded as sea level rose from a mean low water of 330 feet below present sea level. Sediment deposited from the melting ice sheet shaped much of the land and coastal features of Narragansett Bay, including Greenwich Bay and its watershed.

2. Greenwich Bay is inhabited by various species due largely to the geologic and topographic features of the land. These habitats include mud and fine sediments; hard sand, rocky and cobbled areas; marsh and estuarine areas; as well as tidal deltas and mud flats. Sediments around the bay are predominantly glacial outwash and till. Glacial outwash consists of well-sorted sand and gravel, whereas glacial till is poorly sorted and lies across shallow bedrock.

310.2 Climate

1. The temperate climate in Greenwich Bay is moderated by the Atlantic Ocean. Precipitation and temperature data is collected at T.F. Green Airport. Average annual temperatures range between 21°F and 37.5° F in the winter and 63.5°F and 82.5° F in the summer. July is generally the warmest month of the year and February is usually coldest. Precipitation in the area can be as low as 0.4 inches per month and as high as 12.7 inches per month, with an average of 41.7 inches per year. Prevailing winds during the summer are from the south-southwest, changing to the north-northwest during the winter months.

310.3 Land use

1. Greenwich Bay's watershed is highly developed and covers approximately 13,550 acres with approximately 25.8 miles of shoreline. Portions of Warwick, East Greenwich, and West Warwick are in the watershed. Approximately 48,000 people lived in the watershed in 2000, representing 4.5 percent of Rhode Island's population. In general, the development in the watershed parallels suburban growth in many other areas of the northeast. Colonial farming patterns were changed by the impact of the Industrial Revolution's mills, promoting growth of surrounding local economies by the beginning of the 20th century. Over the past 100 years, neighborhoods of single-family homes have characterized much of the development and led to an increase in population, transportation infrastructure, and commercial growth.

2. As of 1995, more then a quarter of the watershed was still covered by forests and wetlands (Table 2). Management of these areas is important not only for direct use by wildlife and waterfowl, but also to intercept pollutants as they drain from the watershed into Greenwich Bay. Between 1988 and 1995, developed areas in the watershed increased by approximately 354 acres (1.5 km^2). New development was focused along the Rte. 2 corridor, along Love Lane near the Warwick/East Greenwich line, and off Warwick Neck Avenue (Figure 1). The increases in developed areas came primarily at the expense of forested land (Table 2). Over this seven-year period, no significant loss of water, wetland, or sandy areas was indicated. Table 2 provides land-use coverage.

3. Coastal land use can have a direct influence on the fish and wildlife that live in Greenwich Bay. The Narragansett Bay Estuary Program (NBEP) and its partners conducted a study on the land use around coastal wetlands, degraded salt marshes, and hardened shoreline in Narragansett Bay using 1996 aerial photographs and field investigations (Tiner et al., 2003). Figure 2 provides a view of the photo-interpreted land use and cover within a 500-foot zone of shoreline features. Table 3 presents the acres of land use cover types clipped to the Greenwich Bay watershed. Much like the watershed as a whole, some pockets of wetlands and beaches remain, but much of the shoreline is impacted by residential development.

Table 2. Land-use change in Greenwich Bay watershed between 1988 and 1995

Land use	**Area (acres)**		**Percentage**	
	1988	**1995**	**1988**	**1995**
Developed				
Residential	6,037 (24.4 km^2)	6,227 (25.2 km^2)	44.6%	46.0%
Commercial and industrial	2,021 (8.2 km^2)	2,185 (8.9 km^2)	14.9%	16.1%
Subtotal	*8,058 (32.6 km^2)*	*8,412 (34.1 km^2)*	*59.5%*	*62.1%*
Undeveloped				
Forest	2,585 (10.5 km^2)	2,426 (9.8 km^2)	19.1%	17.9%
Water, wetlands, and sandy area	1,217 (4.9 km^2)	1,215 (4.9 km^2)	9.0%	9.0%
Recreation and cemeteries	885 (3.6 km^2)	943 (3.8 km^2)	6.5%	6.9%
Agriculture	450 (1.8 km^2)	395 (1.6 km^2)	3.3%	2.9%
Urban open space	355 (1.4 km^2)	159 (0.6 km^2)	2.6%	1.2%
Subtotal	*5,492 (22.2 km^2)*	*5,138 (20.7 km^2)*	***40.5%***	***37.9%***

Total	**13,550 (54.8 km^2)**	**100%**

Source: RIGIS

Table 3. Coastal land use and land cover in Greenwich Bay watershed within 500 feet of coastal wetlands and shoreline features

Land use	Area (acres)	Percentage
Developed		
Residential	834	47%
Industrial	71	4%
Marinas/shipyards	53	3%
Other	42	2%
Paved	6	<1%
Subtotal	*1,006*	*57%*
Undeveloped		
Forest	470	26%
Wetlands	148	8%
Vegetated	66	4%
Vacant	36	2%
Water	35	2%
Sandy	17	1%
Subtotal	*772*	*43%*
Total	**1,778**	**100%**

Source: Geographic Information System Data from the Narragansett Bay Estuary Program; Tiner et al. 2003

Figure 1. Greenwich Bay land use and change from 1988 to 1995

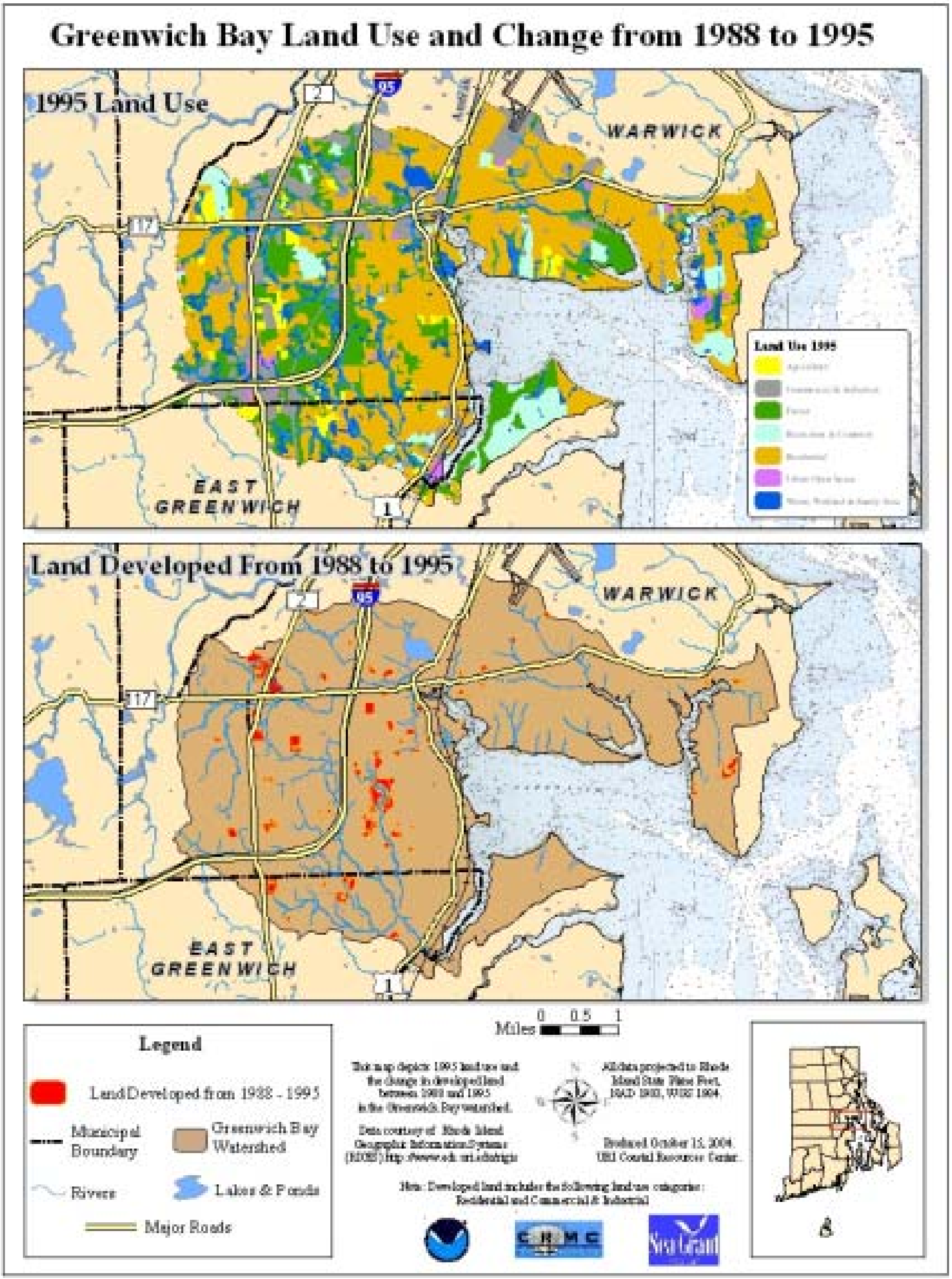
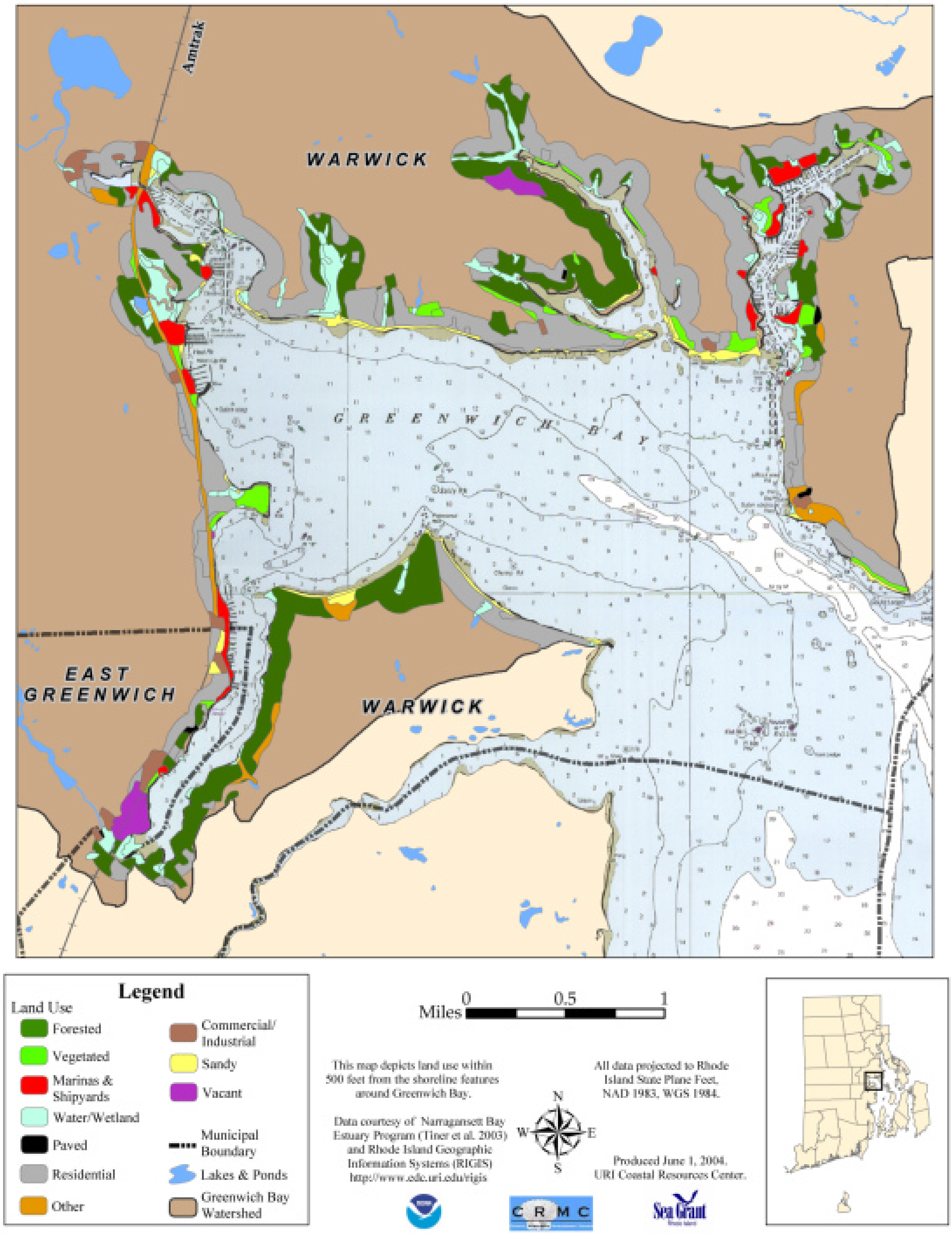


Figure 2. Coastal land use and land cover in the Greenwich Bay watershed within a 500-foot buffer zone of coastal wetlands and features

Coastal Land Use and Land Cover in the Greenwich Bay Watershed within a 500-foot Buffer Zone of Coastal Wetlands and Features



Section 320

Open waters

320.1 Shellfish habitat

1. Greenwich Bay shellfish include northern quahog (*Mercenaria mercenaria*), soft-shelled clam (*Mya arenaria*), oyster (*Crassostrea virginica*), and mussel (*Mytilus edulis*). The physiological and biological distinctions among these species determine their habitat demands. The northern quahog is the most commercially and recreationally important shellfish within Greenwich Bay. According to the R.I. Department of Environmental Management (RIDEM), the value of statewide quahog commercial landings was just under $5 million in 2001.

2. Greenwich Bay was declared a shellfish management area for conservation purposes by RIDEM in the late 1970s. This allows RIDEM, through the R.I. Marine Fisheries Council, to implement measures to prevent overfishing and maintain sustainable commercial harvests. These include opening Greenwich Bay to shellfishing only during the winter months, limiting maximum possession, and carrying out a rotational transplant/harvest system. In addition, Greenwich, Apponaug, and Warwick coves are not designated for direct harvesting of shellfish and are closed year-round because of actual or potential pollution sources, although these areas are used for transplanting shellfish to fishable areas. Brush Neck and Buttonwoods coves are permanently closed to shellfishing because of water pollution. Conditional pollution closures occur for a minimum of seven days in most of Greenwich Bay proper after wet-weather events.

320.1A Quahog habitat

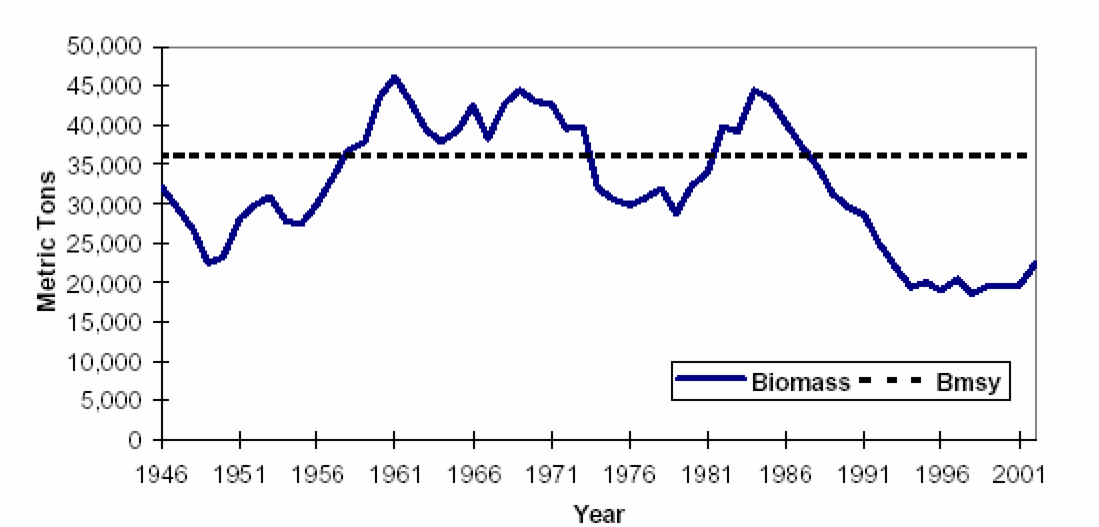
1. Greenwich Bay serves as an important habitat for juvenile and adult quahogs. The northern quahog inhabits shallow coastal waters from the Gulf of St. Lawrence in Canada to Florida. The quahog inhabits the waters of Rhode Island throughout Narragansett Bay from the low tide mark to a depth of 60 feet (Olsen et al., 1980). In general, quahog distribution in Greenwich Bay is patchy, and abundance varies widely. Quahogs are most abundant in sandy substrate mixed with some larger particles that may aid in protection from predation (Rice, 1992).

2. Dispersal and eventual distribution of adult quahog is largely dependent on larval settlement and metamorphosis. Larval spawning is triggered by water temperatures approaching 68°F. In Rhode Island, spawning occurs in June and July. During the 2-week larval period, tidal currents and wind-generated surface currents disperse the larvae several miles from the adult spawner. Larvae settlement is affected by substrate choice, bottom currents, sediment size, and other benthic biota. Greenwich Bay has a high number of quahogs due to a lower number of the competing benthic species *Ampilisca* (Rice, 1992).

3. Various surveys of quahog abundance and distribution have shown evidence of a fisheries decline during the 1950s and again in 1980 (Ganz et al., 1994). Quahog in Narragansett Bay has been in decline since the early 1990s with an estimated biomass below that necessary to produce maximum sustainable yield (Figure 3; RIDEM, 2003). The overall decline in Narragansett Bay has been attributed to past overfishing exacerbated by the increase in predators of benthic invertebrates (RIDEM, 2003). The increased abundance

of predatory species has also been indicated in a review of historic fishery data for the state (Oviatt et al., 2003).

Figure 3. Estimated quahog biomass in Narragansett Bay [1]



1 Dotted line represents estimated maximum sustainable yield.

Source: RIDEM 2003

4. In response to declines in quahog, RIDEM implemented management measures including, in 1981, opening Greenwich Bay waters to commercial harvest from a boat only during winter months for four hours per day, three days per week. The program also included transplanting adult quahogs from the closed coves into Greenwich Bay proper.

5. The Narragansett Bay Project initiated a program in the early 1990s to develop procedures for quantifying quahog populations in Narragansett Bay to use in conjunction with landing data. Once Greenwich Bay was reopened to harvesting after the 1992 pollution closure, RIDEM Division of Fish and Wildlife sampled Greenwich Bay to develop maps of shellfish distribution, abundance, and size.

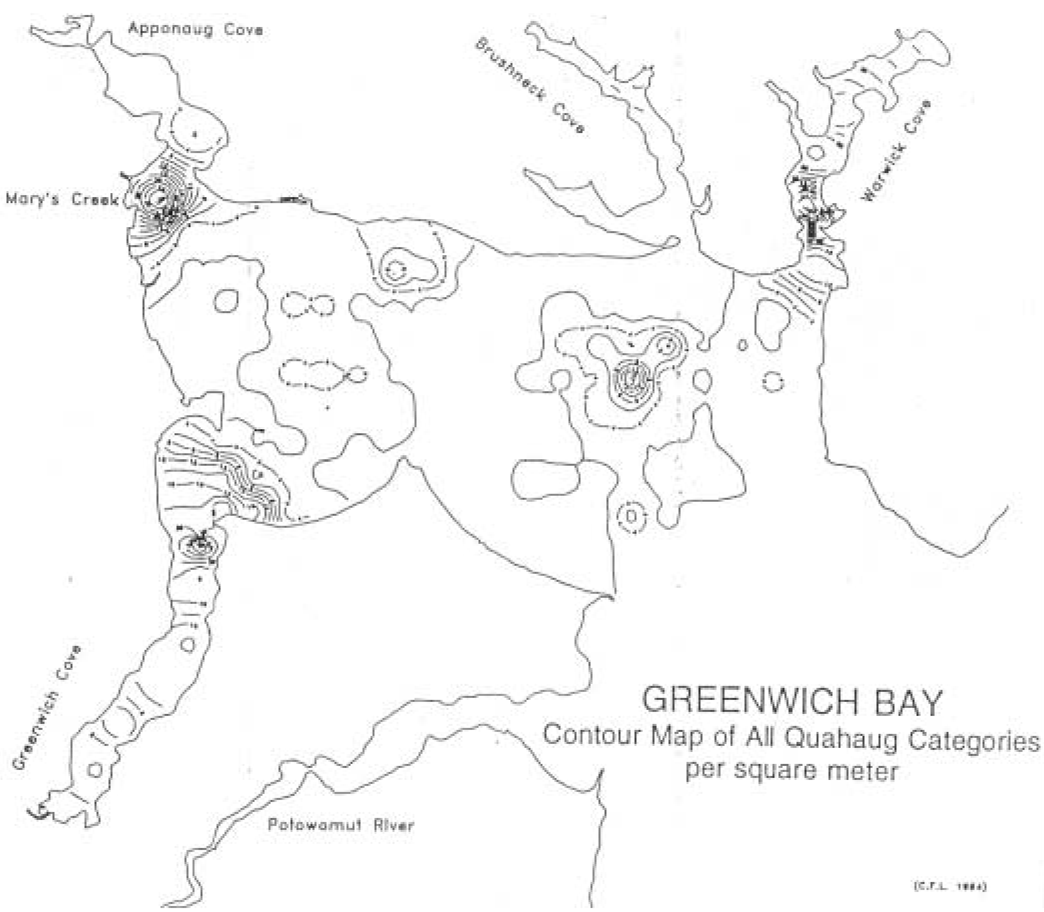
6. Quahog abundance of all size classes measured during the 1993 survey is mapped for Greenwich Bay in Figures 4 and 5 (Ganz et al. 1994) The mouths of Greenwich, Apponaug, and Warwick coves contain large populations of quahogs and represent significant spawning stocks. These stocks develop in natural, stable, conditions where larger individuals tend to dominate populations. In these areas with high densities of adult quahogs, few juvenile quahogs are seen. Possible explanations for this low recruitment include juvenile starvation due to high competition, increased predation of juveniles because of slowed growth, prevention of larval settlement or direct filtration of larvae by adults (Rice 1992). Based on the size, abundance, and distribution data communicated in Figures 4 and 5, Ganz et al. (1994) calculated a total minimum estimated biomass of 68.3 million quahogs (± 16.7 million) with an estimated weight of 9.76 million pounds (± 2.4 million pounds) shell weight in Greenwich Bay. At the time, these numbers represented 75

percent of the state's average yearly landings of quahogs. Approximately 59 percent of this biomass is behind pollution lines where shellfishing is prohibited.

7. The growth rate of quahogs varies widely. It has been found that in areas with coarser sediments, quahog growth rate is higher than in areas with finer, silty sediments. It is believed that the finer sediments clog the quahog filtering apparatus and lead to less efficient feeding (Rice 1992).

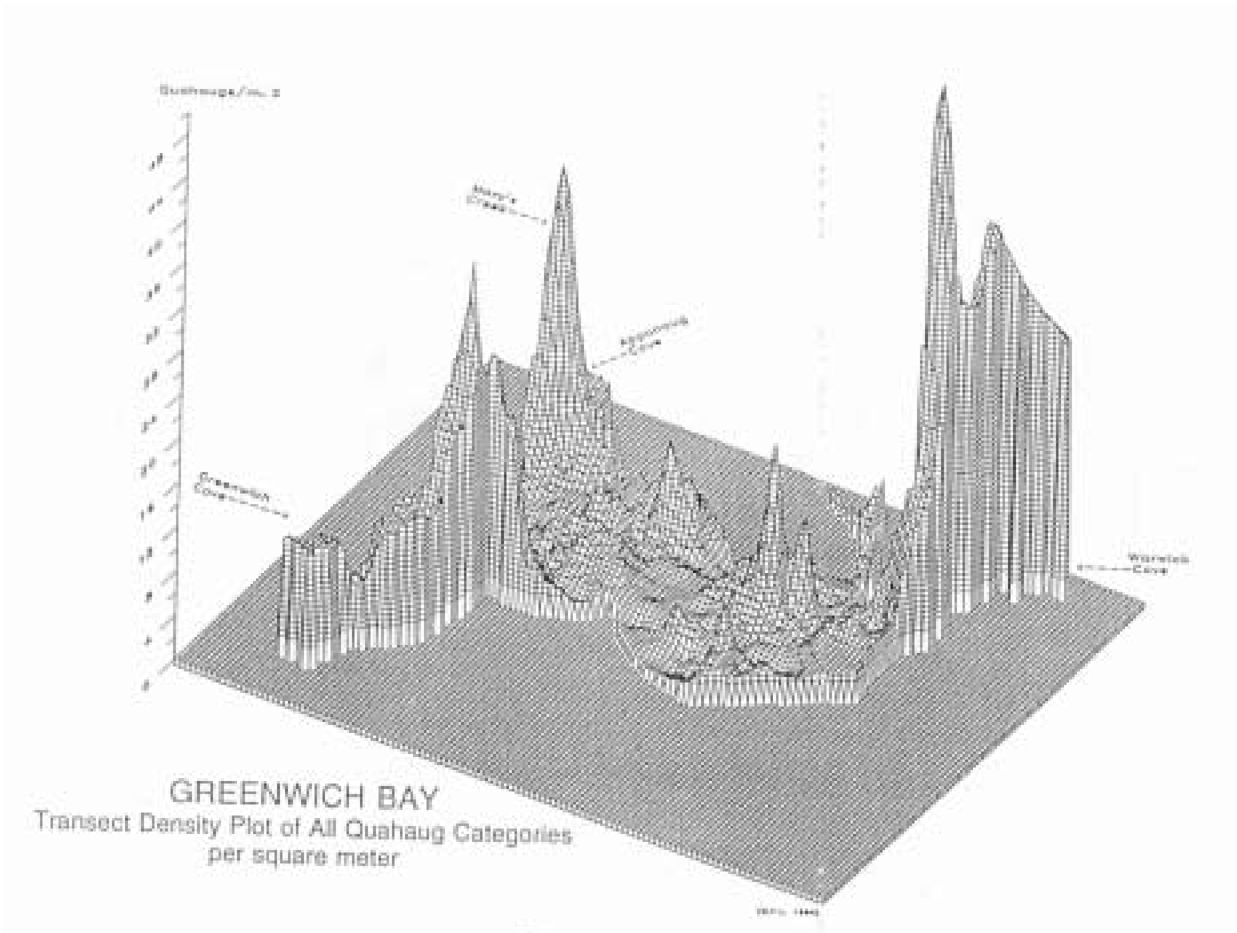
8. Quahog may be lost during dredging. Dredging ensures boat access to marinas and the coves, and in some cases, promotes habitat and biological viability. Quahogs may be removed from these areas prior to dredging and transplanted to spawner sanctuaries or other areas until they can be legally harvested. Quahogs not removed from the sediments prior to dredging are lost. Turbidity, the major potential offsite dredging impact on quahog, is limited by required dredging windows and physical barriers.

Figure 4. Contour map of quahog density in Greenwich Bay



Source: Ganz et al. 1994

Figure 5. Transect density plot of quahogs in Greenwich Bay



Source: Ganz et al. 1994

320.1B Soft-shelled clam habitat

1. Soft-shelled clams (*Mya arenaria*), also known as steamers, inhabit intertidal to subtidal zones to a depth of about 30 feet. This species is found along the perimeter of Greenwich Bay where the tidal range is between 4 to 5 feet, providing the soft-shelled clams a habitat band 75 to 100 feet wide. Soft-shelled clams will often be found on muddier sediment than quahogs. Areas that are especially good for the clams include Chepiwanoxet Point, Nausauket, areas around Oakland Beach, and the entrance to Brush Neck Cove (Beutel pers. comm., Ganz pers. comm.). Soft-shelled clams are preyed upon by ducks, swans, and raccoons, among others.

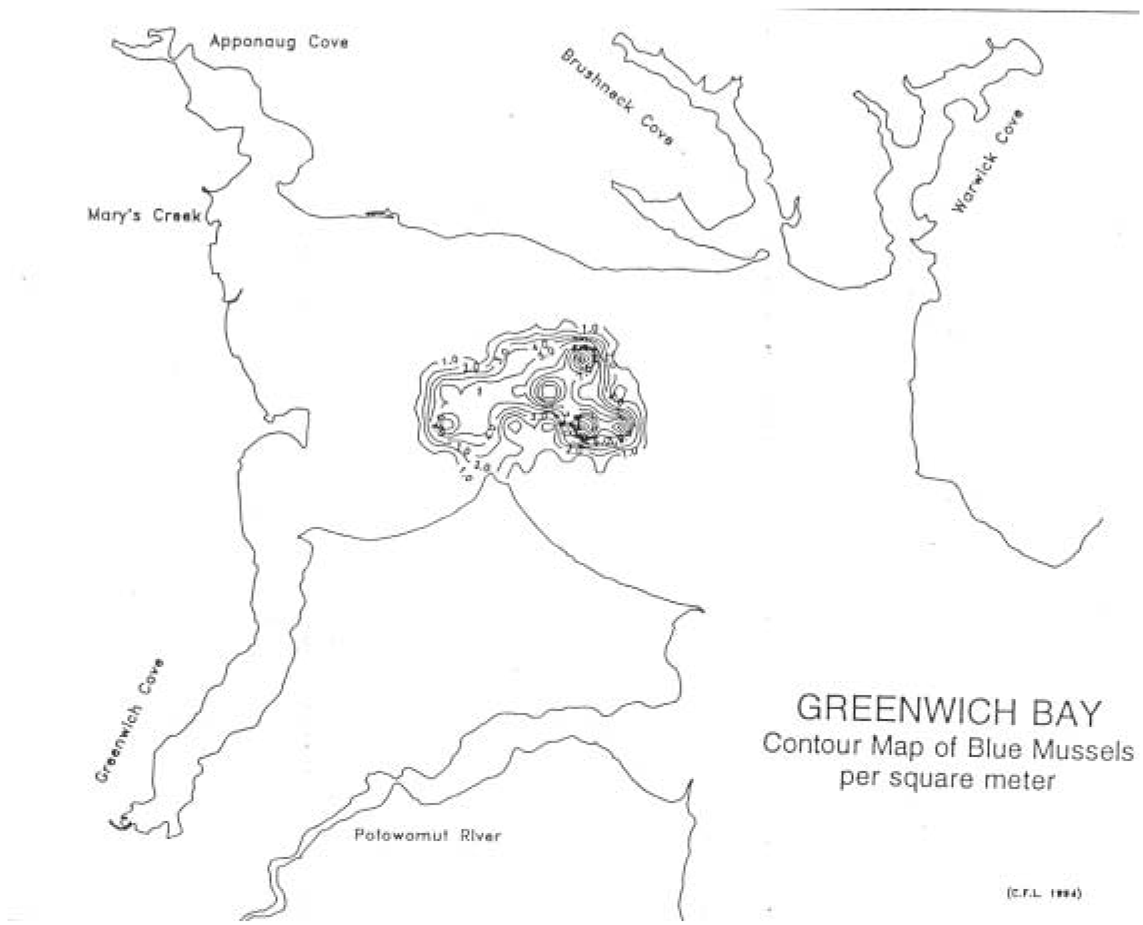
320.1C Oyster habitat

1. Oysters are not common in Greenwich Bay. Unlike quahogs, the common oyster (*Crassostrea virginica*) requires a substrate on which to attach and, therefore, prefers cobbles, hard sand, shell, and rock bottoms. Oysters are generally found in intertidal to subtidal zones at shallow depths. In addition, oysters thrive in areas with a lower salinity (between 5 and 30 parts per thousand) than do quahogs and are intolerant to prolonged exposure to freshwater (Gosner, 1978). Oysters are widely preyed upon and susceptible to disease and do not naturally set well within Greenwich Bay. However, small pockets can be found along the eastern coast at the mouth of Warwick Cove and in the offshore areas from Sally Rock where they are interspersed with mussels (Beutel pers. comm.).

320.1D Mussel habitat

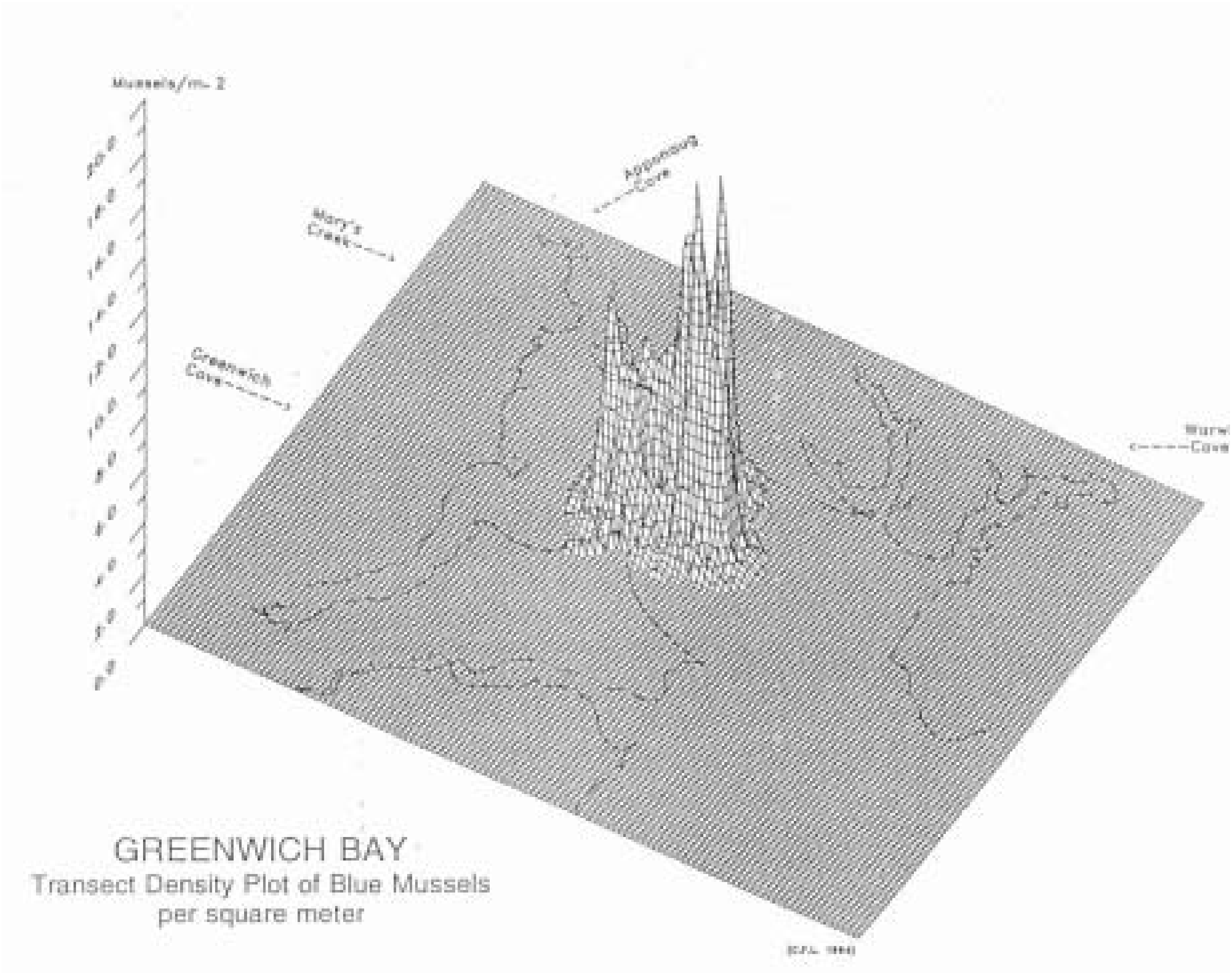
1. Blue mussel (*Mytilus edulis*) also prefer a hard substrate upon which to attach by byssal threads. Abundance of these shellfish varies through the years, but a mussel bed can be found in the area off Sally Rock. (Figures 6 and 7).Given prime habitat, mussel will fully mature in one year, although maturation in three to five years is not uncommon.

Figure 6. Contour map of blue mussel density in Greenwich Bay



Source: Ganz et al. 1994

Figure 7. Transect density plot of blue mussels in Greenwich Bay



Source: Ganz et al. 1994

<u>*320.1E Shellfish bed closures*</u>

1. Shellfish beds in Greenwich Bay may be closed to protect public health or to maintain sustainable shellfish population. Shellfish beds in Greenwich Bay have been subject to permanent and periodic closures to protect public health since 1946. In response to an extreme wet weather event in 1992, all of Greenwich Bay was closed to shellfishing. Since then, Greenwich Bay proper has opened to shellfishing on a conditional basis based on the amount and duration of wet weather that cause high surface run-off and bacterial contamination. The five coves remain permanently closed to shellfishing due to actual or potential pollution but are used for transplanting shellfish to fishable areas. In the past, areas of Greenwich Bay have also been closed to prevent overfishing (Ganz pers. comm.). Currently, a seasonal shellfishing closure for commercial boat harvesting is used to allow for a time-regulated sustainable harvest.

2. RIDEM is responsible for determining polluted areas for shellfishing under R.I. Gen. Laws §20-81. The standards in this law are consistent with U.S. Food and Drug Administration (FDA) sanitation standards established through the National Shellfish Sanitation Program (NSSP) and the Interstate Shellfish Sanitation Conference (ISSC). To enter into interstate commerce, shellfish must be harvested and handled in accordance with the FDA sanitary requirements. These standards are based on current water quality and potential water pollution sources. The standards consider wastewater treatment facilities, mooring fields, and marinas to be potential pollution sources incompatible with direct shellfish harvesting. RIDEM monitors Greenwich Bay waters to determine the location of polluted areas and establish pollution closure lines.

3. RIDEM is also responsible for establishing the state water use goals, known as water-quality classifications, and evaluating whether the current conditions support these goals. Establishment of the goals and current conditions may limit shellfish harvesting and must be consistent with the federal Clean Water Act and the FDA/NSSP sanitation standards for direct shellfish harvesting. Due to actual or potential pollution threats, Greenwich, Apponaug, and Warwick coves are classified as SB or SB1 waters and are designated for controlled relay or transplants but not for direct shellfish harvesting. Therefore, shellfish harvesting is not a goal for these coves, and it is not likely that they will be opened to shellfishing even if water quality were to improve drastically (Liberti pers. comm.). Areas that are presently closed due to potential impacts from marinas could be re-opened when the marinas are not in operation during the winter season. Buttonwoods and Brush Neck coves are designated as SA waters to allow for direct shellfish harvesting.

4. Even if actual water quality were to improve above sanitation standards, the presence of potential pollution sources in would keep at least portions of Greenwich, Apponaug, and Warwick coves closed to direct harvesting. The coves would only open to direct shellfish harvesting if:

a. FDA modified its sanitation standards to disregard these potential pollution sources;
b. Water quality improved above the remaining sanitation standards; and
c. RIDEM reclassified the coves as SA waters.

5. Permanent pollution closures in the coves inadvertently protect the brood stock of quahogs (Ganz et al. 1994) and enables large commercial quahog transplants. Transplants are governed by FDA regulations that include testing transplanted quahogs for contaminants and ensuring a minimum depuration period. The quahogs are transplanted in two sites just outside the mouth of the bay in Potowomut and High Banks. The quahogs depurate within 15 days but are not harvested for two years so they can spawn twice. This program successfully maintained both a healthy stock and fishery.

320.1F Shellfish aquaculture

1. Shellfish aquaculture is the cultivation of shellfish under natural or artificial conditions. Shellfish can be cultivated on the sea floor, in cages, or suspended from

structures in the water. Currently, there are limited opportunities in Greenwich Bay for privatized aquaculture on the bay bottom because of pollution closures and Greenwich Bay's status as a shellfish management area.

2. Quahog aquaculture in Greenwich Bay is in its early, experimental stages with two projects underway. The first project is sponsored by Roger Williams University and the Rhode Island Shellfishermen's Association in cooperation with the CRMC and the University of Rhode Island (URI). It involves a study of quahog substrate selection as well as quahog density versus survivability. The Brush Neck Cove study site was chosen for its shallow depth and its relative protection from recreational fishing. The experiment area consists of a grid with either a shell or natural bottom, usually sand. This will help guide possible reseeding of the bay under the auspices of the Cape Oil spill restoration project (Beutel pers. comm.).

3. The second project, sponsored by the Rhode Island Shellfishermen's Association with Greenwich Bay Marina South, grows quahogs using an upweller -- a box-like device placed under a dock that supplies a constant nourishing flow of oxygenated water to the crop for faster growth. The quahogs will eventually be transplanted for commercial harvesting.

4. Several diseases affect quahogs in aquaculture facilities and in the wild. These include bacterial disease caused by *Vibrio*, fungal infections by *Sirolpidium zoophthorum*, *Chlamydia*-like organisms that attack adults, and various parasites (Rice, 1992). While these diseases do not represent a serious risk for human consumption, they can quickly devastate aquaculture populations. To limit the disease, RIDEM requires that all shellfish for culture imported to Rhode Island have a certificate of disease inspection.

320.2 Finfish habitat

1. Greenwich Bay is a protected, highly productive estuarine environment for finfish (Table 4). The species found in Greenwich Bay are both local populations and migratory species. The abundance and diversity of finfish in Rhode Island vary seasonally and annually, and depend on the life history of individual species as well as changing environmental conditions (Jeffries and Johnson, 1974). Over the past 200 years, finfish distribution and biomass have also been affected by commercial fisheries. Rhode Island fisheries have used various techniques over time with the use of fish traps becoming prevalent in the 1800s, followed by trawling in the mid-1900s (Oviatt et al. 2003, Olsen et al., 1980). A recent review of over 100 years of Rhode Island fisheries data revealed a decline in the abundance of anadromous species, winter flounder, migratory species (such as menhaden), and scup, among others (Oviatt et al., 2003). Much of this decline has been attributed to fishing pressure, although warming water temperatures and pollution may also affect populations.

Table 4. Common finfish species found in Greenwich Bay

Common name *Scientific name*	**Life history characteristics**	**Common habitat**	**Presence in Greenwich Bay**			**Spawning period**	**Migratory pattern**
			Eggs [1]	**Larvae [1]**	**Juveniles [2]**		
Alewife *Alosa pseudoharengus*	Anadromous Planktivorous	Salt marsh Open water Freshwater rivers River mouths	YES	YES	YES	Late spring (May-June)	
American eel *Anguilla rostrata*	Catadromous	Tidal wetlands Eelgrass beds Rivers	-	YES	YES	Fall	Spawn offshore – Fall (Sargasso Sea)
American sand lance *Ammodytes americanus*	Demersal	Shallow coastal waters	-	-	YES	N/A	
American shad *Alosa sapidissima*	Anadromous		-	-	YES	N/A	
Atlantic mackerel *Scomber scombrus*	Pelagic		-	-	YES	Spring	Northward – Spring Southward - Fall
Atlantic menhaden *Brevoortia tyrannus*	Pelagic Migratory Planktivorous	Open water Eelgrass beds	YES	YES	YES	Spring (June) and Fall	Northward – Spring Southward – Fall
Atlantic rainbow smelt *Osmerus mordax*	Anadromous Pelagic	Coastal	-	-	YES	N/A	
Atlantic silverside *Menidia menidia*	Pelagic Omnivorous	Sandy and gravelly shores Salt marsh	-	YES	YES	Late spring (May/June)	Exhibit site fidelity
Atlantic tomcod *Microgadus tomcod*	Anadromous Demersal		-	-	YES	N/A	
Bay anchovy *Anchoa mitchilli*	Pelagic Migratory Planktivorous	Sandy beaches River mouths	YES	YES	YES	Summer (June – Sept.)	Cape Cod is northern range limit.
Black sea bass *Centropristes striatus*	Demersal Benthic predators	Structured bottom Hard bottoms Wharf pilings	-	YES	-	Late Spring (May – June)	Inshore – Spring Offshore – Fall
Blueback herring *Alosa aestivalis*	Anadromous		-	-	YES	N/A	
Bluefish *Pomatomus saltatrix*	Pelagic Important predators	Open water Juveniles nearshore	-	YES	YES	Summer (June-August)	Northward – Spring Southward – Fall

Common name ***Scientific name***	**Life history characteristics**	**Common habitat**	**Presence in Greenwich Bay**			**Spawning period**	**Migratory pattern**
			Eggs [1]	**Larvae [1]**	**Juveniles [2]**		
Cunner *Tautogolabrus adspersus*	Demersal Omnivorous Scavengers	Rock and cobbles Wharf pilings Eelgrass beds	YES	YES	YES	Spring and Summer (April – Sept.)	Exhibit site fidelity
Four-spotted flounder *Paralichthys oblongus*	Demersal	Open water Sandy and muddy bottoms	YES	YES	-	Spring and Summer (May – Aug.)	
Hogchoker flounder *Trinectes maculatus*	Demersal	Coastal	YES	YES	-	Spring and Summer (June –Aug)	
Mummichog *Fundulus heteroclitis*	Omnivorous Scavengers	Eelgrass beds Salt marsh Tidal creeks Brackish waters	YES	YES	YES	Summer (June-Aug)	Small-scale coastal
Northern kingfish *Menticirrhus saxatilis*	Demersal	Coastal Sand to sandy mud bottoms Tidal rivers and creeks	-	-	YES	N/A	
Northern pipefish *Syngnathus fuscus*	Demersal	Seagrass beds	-	-	YES	N/A	
Northern puffer *Sphoeroides maculatus*	Demersal	Protected coastal waters	-	-	YES	N/A	
Oyster Toadfish *Opsanus Tau*		Coastal, brackish, and freshwaters	-	-	YES	N/A	
Permit *Trachinotus falcatus*	Demersal	Sandy beaches	-	-	YES	N/A	
Scup *Stenotomus chrysops*	Demersal Benthic predators	Open Water Sandy Bottom Rocky Bottom	YES	YES	YES	Spring and Summer (May – Sept.)	Inshore – May Offshore – October
Sea robin *Prionotus* spp.	Demersal Benthic generalist predator	Hard benthic substrates	YES	YES	YES	Spring and Summer (June – Aug.)	Inshore – Summer Offshore – Fall
Squeteague (Weakfish) *Cynoscion regalis*	Demersal, Semi-pelagic	Shallow water along open sandy shores Tidal creeks	YES	-	YES	Summer	Inshore – Summer Offshore – Fall
Striped bass *Morone saxatilis*	Coastal, Semi-pelagic	Sandy beaches Rocky areas	-	-	YES	N/A	Northward – Spring Southward – Fall

Common name *Scientific name*	**Life history characteristics**	**Common habitat**	**Presence in Greenwich Bay**			**Spawning period**	**Migratory pattern**
			Eggs [1]	**Larvae [1]**	**Juveniles [2]**		
Tautog (Blackfish) *Tautoga onitis*	Demersal	Structured bottom Rock and cobbles Wharf pilings Eelgrass beds	YES	YES	YES	Spring and Summer (April –Aug.)	Small-scale coastal; Exhibit site fidelity
Windowpane flounder *Scophthalmus aquosus*	Demersal	Open water- Sand and muddy bottoms	YES	YES	YES	Spring and Summer (April –Aug.)	Relatively sedentary; some seasonal movement
Winter flounder *Pseudopleuronectes americanus*	Demersal	Open water- Sand and muddy bottoms	-	YES	YES	Winter-Spring (Dec. – April)	Inshore – Winter Offshore – Summer

1 Presence of ichthyoplankton (as eggs or larvae) taken from Keller et al. 1999
2 Presence of juvenile fish based on Narragansett Bay Juvenile Fish Survey data courtesy of J.C. Powell, RIDEM - Division of Fish and Wildlife.
N/A = Not applicable to Greenwich Bay

Source: Bigelow and Schroeder 1953, Keller et al. 1999; RIDEM 2002; www.fishbase.org

320.2A Predominant Greenwich Bay species

1. The protected coves of Greenwich Bay are an important habitat where several finfish species mature and spawn (Table 4). RIDEM has identified at least 42 species in sampling conducted for the Narragansett Bay Juvenile Fish Survey at Chepiwanoxet Point. Anadromous and catadromous species, migratory populations, and year-round residents are included in this group. Many of the species believed to spawn in Greenwich Bay rely on near-shore areas and salt marshes inundated at high tide. These may include mummichog (*Fundulus heteroclitis*) and silverside (*Menidia menidia*), which are also food for bluefish, striped bass, and shorebirds.

2. A comparison of Narragansett Bay-wide ichthyoplankton data collected in 1972-1973 and 1989-1990 indicates an overall decline in fish eggs and larvae in the Bay. This was true in Greenwich Bay, although the abundance of ichthyoplankton at this site was high when compared with other sites (Keller et al., 1999). These results suggest that Greenwich Bay remains an important spawning area despite large-scale processes that appear to affect fish egg and larvae abundance everywhere. This study also noted a significant correlation between phytoplankton biomass and ichthyoplankton abundance.

3. The RIDEM Narragansett Bay Juvenile Fish Survey indicates that Greenwich Bay is a valuable habitat for juvenile and small adult finfish, particularly juvenile winter flounder, juvenile river herring, and various killifish species. Figure 8 presents survey data from the Greenwich Bay station at Chepiwanoxet Point compared to the 14 other Narragansett Bay stations regularly sampled by the RIDEM since 1988. Both juvenile winter flounder and bluefish have been found at similar or higher abundances than at other Narragansett Bay stations. In recent years, juvenile tautog have been found at lower abundances in Greenwich Bay than the other Narragansett Bay stations. In contrast, juvenile river herring have been found at higher abundances in Greenwich Bay in recent years. Killifish species, including *Fundulus heteroclitus*, *Fundulus majalis*, *Fundulus diaphanus*, and other *Fundulus* spp., have been found at higher abundances in Greenwich Bay. Nearby Mary's Creek may help support the higher populations of these important prey species relative to other Narragansett Bay stations. Finally, Atlantic silverside have been consistently found at similar abundances in Greenwich Bay as at other stations in Narragansett Bay.

4. Anadromous fish, such as river herring, must access freshwater from Greenwich Bay to spawn, often in the stream from which they hatched (Bigelow and Schroeder 1953). These fish runs occur during the spring with young fry returning to salt water within a month. The RIDEM Juvenile Fish Survey indicates a river herring population (composed of alewife and blueback herring) within Greenwich Bay. Alewife spawn in the upper reaches of Brush Neck Cove. In addition, RIDEM has documented two river herring fish runs currently obstructed along Hardig Brook and the Maskerchugg River (Figure 9; Erkan 2002). Along Hardig Brook, the Gorton Pond Dam partially blocks fish passage from Apponaug Cove to Gorton Pond. Save The Bay is currently leading efforts to restore this run. In addition, a R.I. Department of Transportation dam and two condominium dams block passage farther up Hardig Brook. Along the Maskerchugg River, the Bleachery Pond Dam and the Las Brisas Park Pond Dam block passage to and past Bleachery Pond. However, RIDEM assigned this run a low restoration priority due to the height of the Bleachery Pond Dam (16 feet). Table 5 summarizes restoration information collected by RIDEM for these two runs.

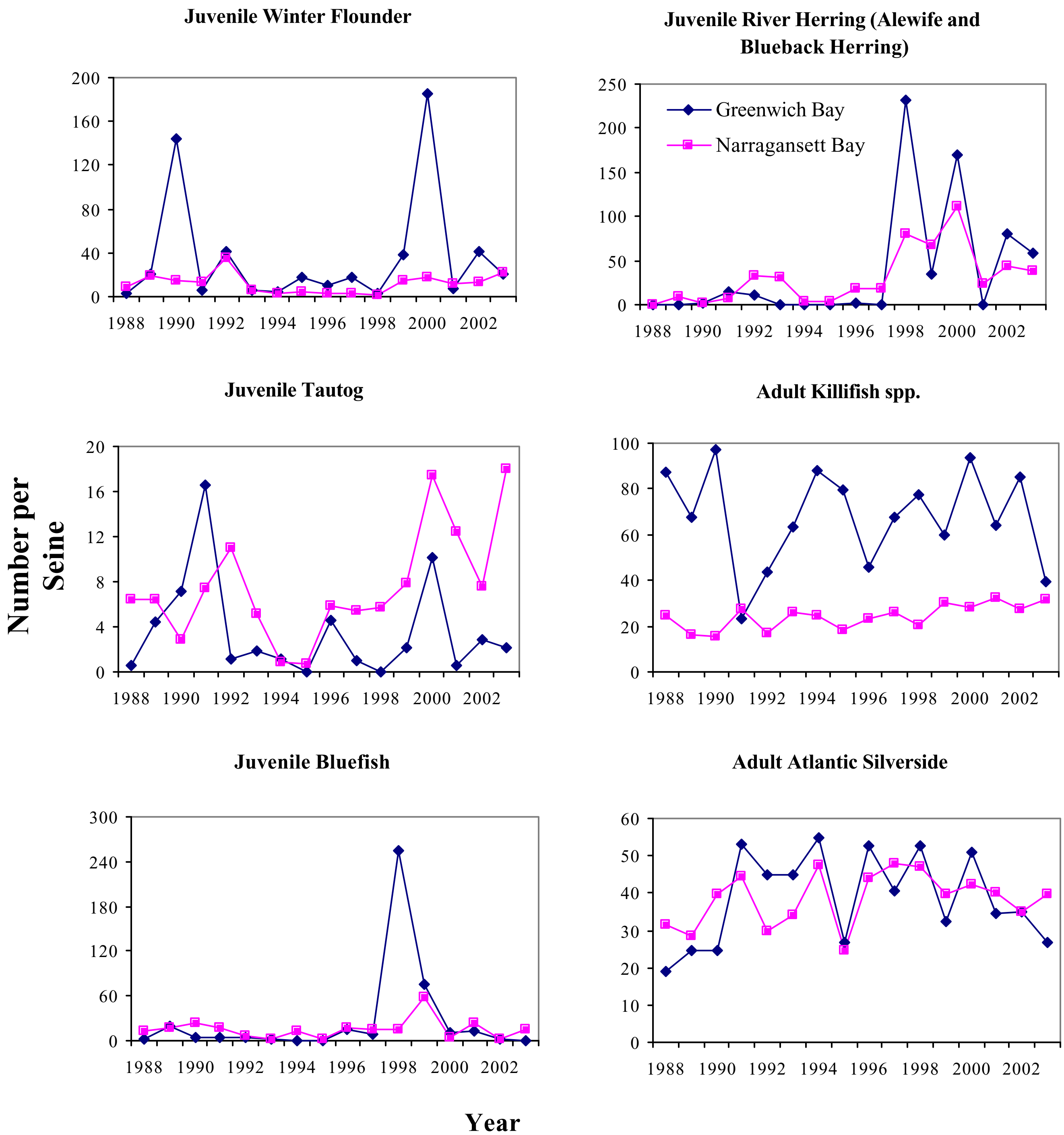
Table 5. Anadromous fish run restoration opportunities in the Greenwich Bay watershed

	Obstruction				Passage sequence to reach obstruction [1]	Existing anadromous population?	Recommended restoration method
	Number [1]	Name	Type	Height			
Hardig Brook	1	Gorton Pond Dam	Earth	7 feet	1	River Herring	Alaska Steeppass Fishway or earthwork
Hardig Brook	2	DOT Dam	Earth, Masonry, Concrete	6 feet	2	No	Slot Fishway/Alaska Steeppass Fishway
Hardig Brook	3	Condominium Dam 1	Earth, Concrete	3 feet	2 3	No	Pool and Weir Fishway
Hardig Brook	4	Condominium Dam 2	Earth, Concrete	3 feet	2 3 4	No	Pool and Weir Fishway
Maskerchugg River	1	Bleachery Pond Dam	Earth, Masonry	16 feet	1	No	Alaska Steeppass Fishway
Maskerchugg River	2	Las Brisas Park Pond Dam	Earth	3.5 feet	1 2	No	Alaska Steeppass Fishway

1 Obstruction numbers and passage sequence refer to Figure 9

Source: Erkan 2002

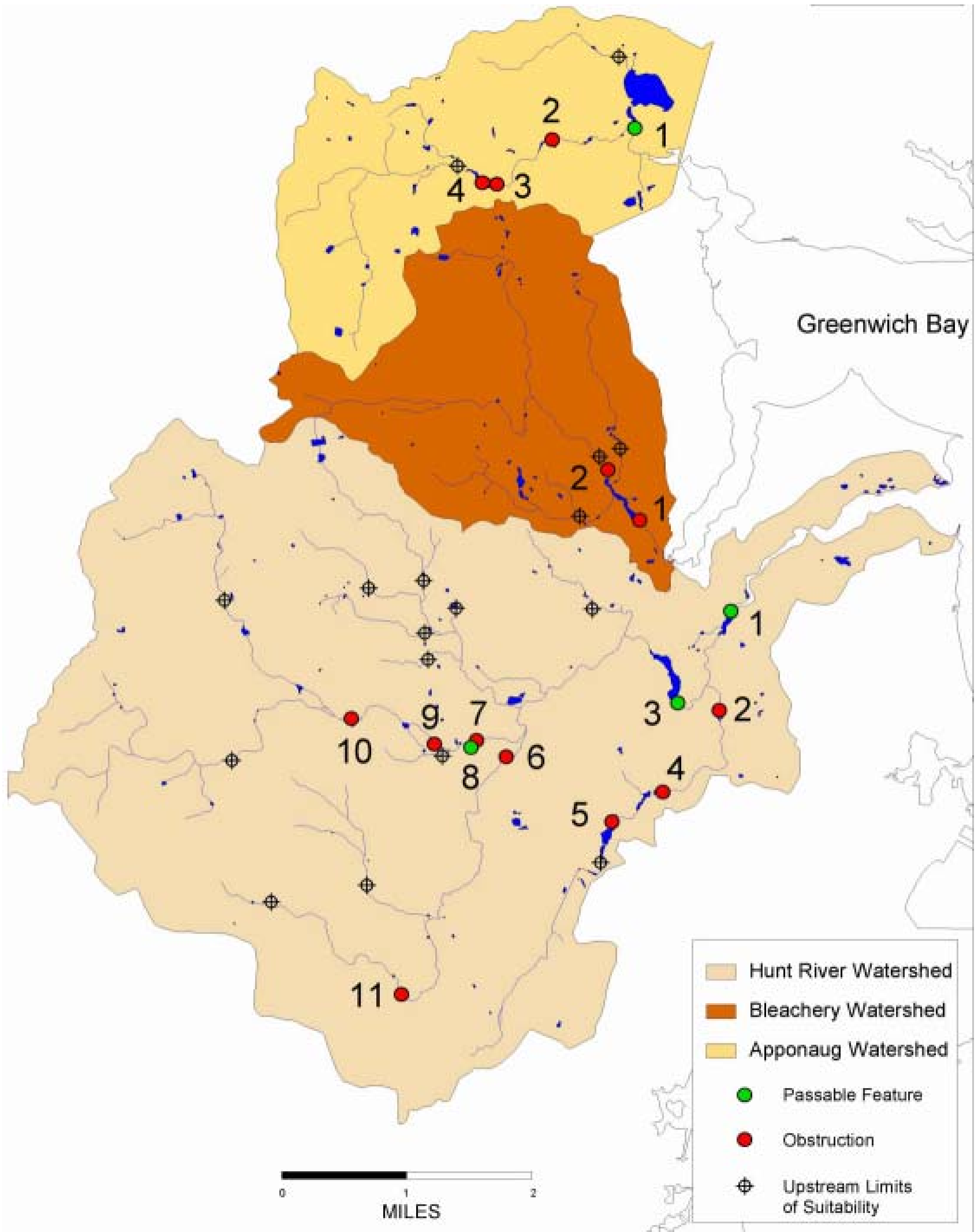
Figure 8. Juvenile and small adult finfish abundance in Greenwich Bay and Narragansett Bay from 1988-2003 [1]



1 Note graph scales are different.

Source: J.C. Powell, Narragansett Bay Juvenile Fish Survey, RIDEM

Figure 9. Anadromous fish restoration opportunities in the Greenwich Bay watershed



Source: Erkan 2002

<u>*320.2B Fish kills*</u>

1. Fish kills occasionally take place in Greenwich Bay and Narragansett Bay. An extensive anoxic event and fish kill was recorded for the summer of 1898 and covered a region from the Providence River south towards the site of the present Jamestown Bridge (Nixon, 1989). In addition, Nowicki and McKenna (1990) reported smaller fish kills in the late 1980s. RIDEM staff also documented small fish kills in 1998 and 2001 (RIDEM, 2003b).

2. On August 20, 2003, an anoxic event prompted an unusually severe fish kill in on the west shore of Greenwich Bay. RIDEM estimated that 1 million organisms died, primarily juvenile menhaden. Other animals that died included small crabs, an occasional blue crab, grass shrimp, tautog, some horseshoe crabs, and a few American eels. The eels appeared to be the largest animal affected. Several weeks later, a large die-off of soft-shelled clams occurred (RIDEM, 2003b).

3. The long-term effects of low oxygen events vary between species. Menhaden stocks are not likely to be significantly affected by the fish kill since they are large and migratory. Shellfish are able to survive short periods of anoxia, but the young are particularly susceptible to periods of low oxygen. Unlike the hard-shelled clam populations, soft-shelled clams are unable to tolerate long periods of low oxygen. Shellfish surveys that were repeated after the fish kill by RIDEM did not indicate a significant difference in population density when compared to the mid-summer sampling data (Ganz pers. comm.).

320.3 Submerged aquatic vegetation

1. Two species of submerged aquatic vegetation (SAV) are found in Rhode Island's marine waters, widgeon grass (*Ruppia maritima* L.) and eelgrass (*Zostera marina* L.). Meadows formed by SAV provide important finfish and invertebrate habitat (Hoss and Thayer, 1993) and stabilize sediment, potentially improving water quality. In 1996, the NBEP and its partners, including Warwick, conducted an inventory of coastal habitats in Narragansett Bay. New aerial photographs and field investigations, were used to update mapping for salt marshes, beaches, rocky shores, tidal flats, brackish marshes, eelgrass beds, pannes, pools, oyster reefs, dunes, and streambeds. The study identified approximately 100 acres of eelgrass in Narragansett Bay.

2. The NBEP inventory detected no eelgrass in Greenwich Bay. Historically, eelgrass habitat was present in many subtidal areas of the bay (Kopp et al., 1995). Throughout the Northeast, a widespread decline (concurrent with global losses) of eelgrass over the past century has been attributed to wasting disease (Short and Mathieson, 1985) or linked more generally to a deterioration in water quality from nitrogen loading and subsequent light attenuation (Valiela et al., 1992; Kopp et al., 1995; Short and Burdick, 1996). Efforts to locate the sites of these former eelgrass meadows were undertaken with support from Rhode Island Aquafund and resulted in a map of historical distribution for Rhode Island, including Greenwich Bay (Figure 10).

3. Several efforts to reestablish eelgrass in Greenwich Bay have taken place over the past 10 years. Adamowicz transplanted eelgrass plants to Buttonwoods and Brush Neck coves in the

spring of 1994 using a staple technique. The transplants failure to survive the summer was attributed to poor water clarity, grazing, high water temperatures, and macroalgae.

4. Save The Bay applied an eelgrass restoration site selection model to select sites for transplant test grids in Narragansett Bay (Lipsky, 2003), with two sites used to test transplants in Greenwich Bay, Sandy Point and an area near Buttonwoods. The results from the model were used to create a map of potential eelgrass restoration areas in Rhode Island (Figure 11). None of the 500 plants transplanted to these sites in 2001 survived the summer.

Figure 10. Historical eelgrass habitats on Greenwich Bay

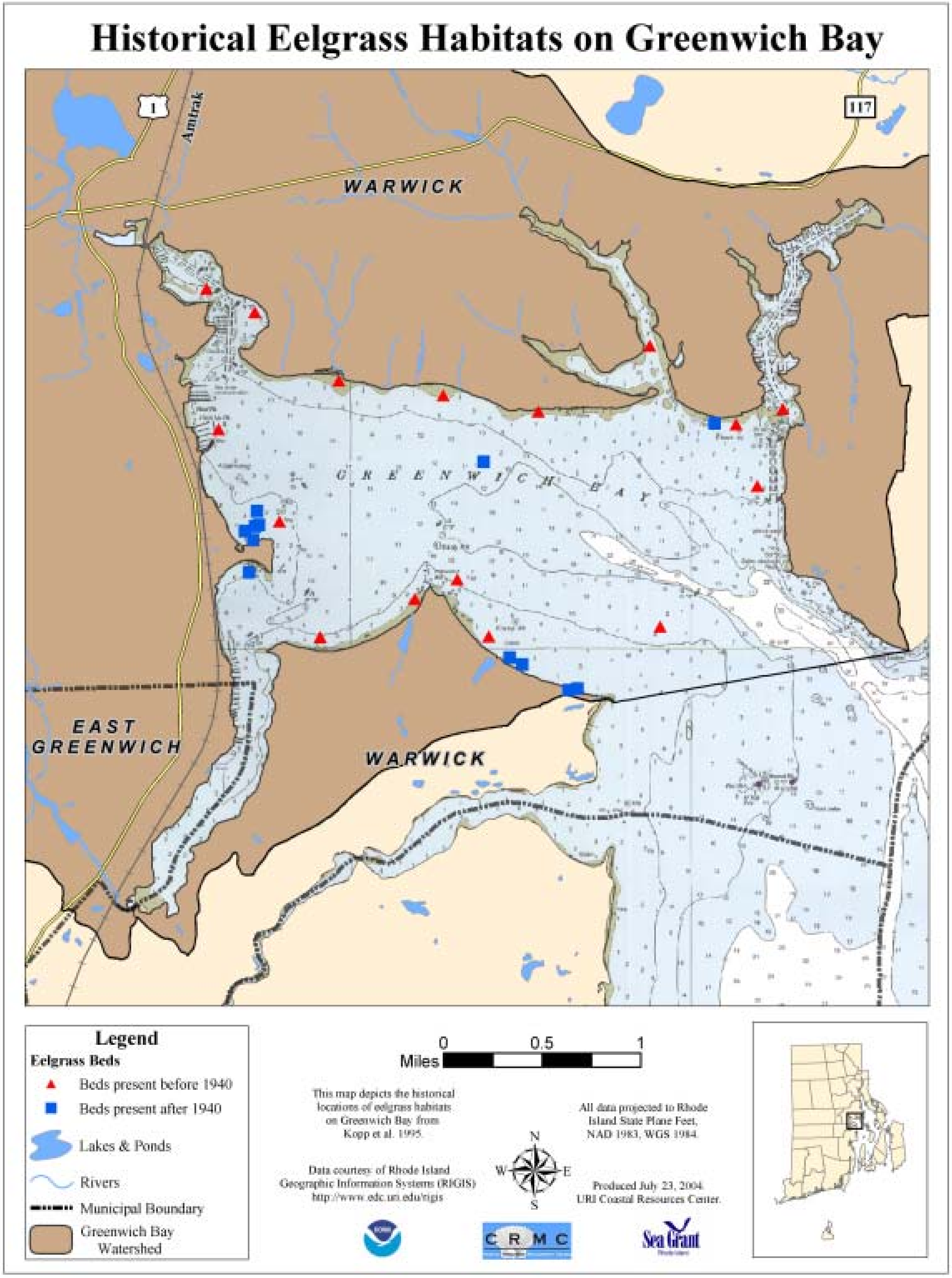
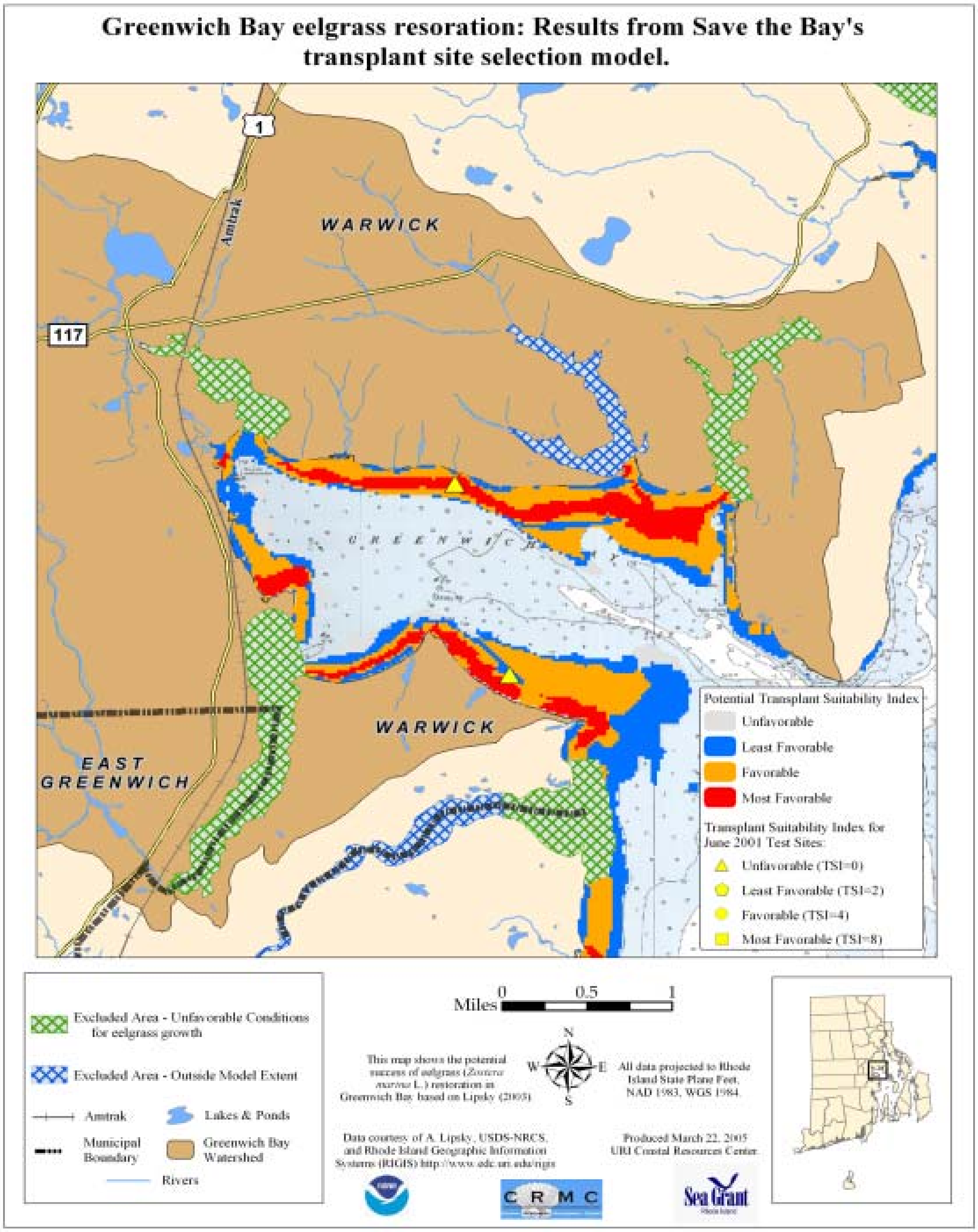


Figure 11. Narragansett Bay eelgrass restoration: Results from Save the Bay's transplant site selection model



Source: Save the Bay

Section 330

Birds

1. Greenwich Bay is along the Atlantic flyway and is an important habitat for many bird species, including migrating birds, wintering waterfowl, and permanent nesting and roosting residents. Habitats for migrating birds include streambeds, woodland patches, tidal creeks, and mudflats. Baker's Creek and Goddard Memorial State Park are important areas for migrating birds and birds that nest late in the season, such as warblers. Wintering waterfowl include the black duck, a species of national interest to the U. S. Fish and Wildlife Service (FWS). There have been high counts in Apponaug and Buttonwoods coves when tidal and mud flats are exposed.

330.1 Waterfowl

1. Greenwich Bay provides limited breeding habitats for waterfowl, though several species, including mallard (*Anas platyrhynchos*), American black duck (*Anas rubripes*), and wood duck (*Aix sponsa*) are known to nest in the watershed. Other wintering birds in Greenwich Bay consistently include pied-billed grebe (fresh water), double-crested cormorant, brant, gadwall, Eurasian wigeon (rare), canvasback, greater scaup, common goldeneye, bufflehead, hooded merganser, and American coot.

2. Wintering habitat for the black duck is a principal focus of the North American Waterfowl Conservation Program in the Atlantic Flyway. Greenwich Bay provides suitable habitat for the black duck due to its shallow water, tidal flats, wetlands, and tidal or permanent ponds and streams within vegetated wetlands. The U.S. Environmental Protection Agency (EPA) has completed two winters of waterfowl surveys at 35 sites in Rhode Island, with four sites in Greenwich Bay. Results are shown in Figure 12 and indicate especially large populations in Apponaug Cove (McKinney pers. comm.).

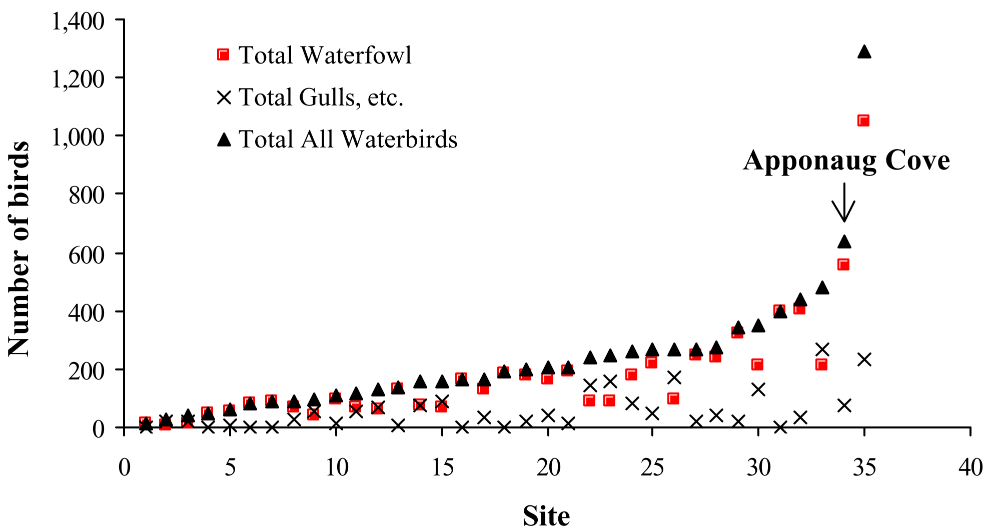
3. Apart from the EPA data, assessment of waterfowl use in Greenwich Bay is based on fairly limited data. Records are compiled by the Rhode Island Ornithological Club and Audubon Society of Rhode Island in the Field Notes of Rhode Island Birds. Compilations of these records for Apponaug Cove are shown in Table 6.

Table 6. Selected waterfowl counts for Apponaug Cove

Species	Date	Number
American black duck	2/11/1987	150
(Anas rubripes)	11/15/1987	348
	1/2/1988	230
	11/29/1988	140
	1/5/1990	160
	1/4/1991	111
	11/20/1992	100
Mallard	1/2/1988	115
(Anas platyrhynchos)	2/6/1994	200
American wigeon	1/6/1990	67
(Anas americana)	1/17/1991	81
	3/15/1995	75
Great blue heron	1/27/1990	5
(Ardea herodias)		

Source: Rhode Island Ornithological Club and Audubon Society; Compiled by R. Enser, RIDEM.

Figure 12. Results of 2003 EPA Narragansett Bay Winter Waterfowl Survey at 35 Rhode Island sites



Source: R. McKinney, US EPA – Atlantic Ecology Division

Section 340

Rare species

1. The historic record for rare species occurrences in Warwick is relatively well known compared to some parts of Rhode Island. Many rare species habitats in the Greenwich Bay area, have been permanently altered or lost due to urbanization, and occurrences are now centered at two specific sites.

2. At Warwick City Park on Brush Neck Cove, a sand plain/pitch pine woodland represents almost the last remnant of the upland natural community that once characterized much of central Warwick. At least two rare plants are found in this remnant community: sickle-leaved golden aster (*Chrysopsis falcata*), a species of concern, and possibly stiff goldenrod (*Solidago rigida*), a state-endangered species that has not been recently verified.

3. The second rare plant site is associated with the aquatic community at Gorton Pond, a natural pond that maintains a shoreline plant community typical of the coastal plain, including regionally rare species. Historically, this pond was one of four sites in Rhode Island for the Plymouth marsh gentian (*Sabatia kennedyana*), a state-endangered species that has not been seen at Gorton Pond for more than 30 years. However, several other endangered or threatened plants persist at the site including awned umbrella sedge, tiny-flowered sedge, and tall beaked rush.

Section 350

Wetlands

1. Wetlands are a diverse group of ecosystems characterized by water-saturated or inundated soils over some portion of the growing season. Marshes, swamps, bogs, fens, and wet meadows are all common names for vegetated wetlands.

2. Tidal and freshwater wetlands comprise the wetlands in the Greenwich Bay watershed. Tidal wetlands are influenced by the tidal cycle and have a salinity above 0.5 parts per thousand. Freshwater wetlands are found along the Greenwich Bay tributaries and in isolated areas.

350.1 Services and values

1. Tidal and freshwater wetlands perform valuable functions, including (Tiner 1989):

   a) *Fish and wildlife values.* Wetlands provide fish and wildlife habitat. Certain fish, shellfish, birds, and mammals spend their entire lives in wetland areas. Wetlands may also export detritus that help support aquatic life elsewhere (Nixon, 1980; Chalmers et al., 1985).

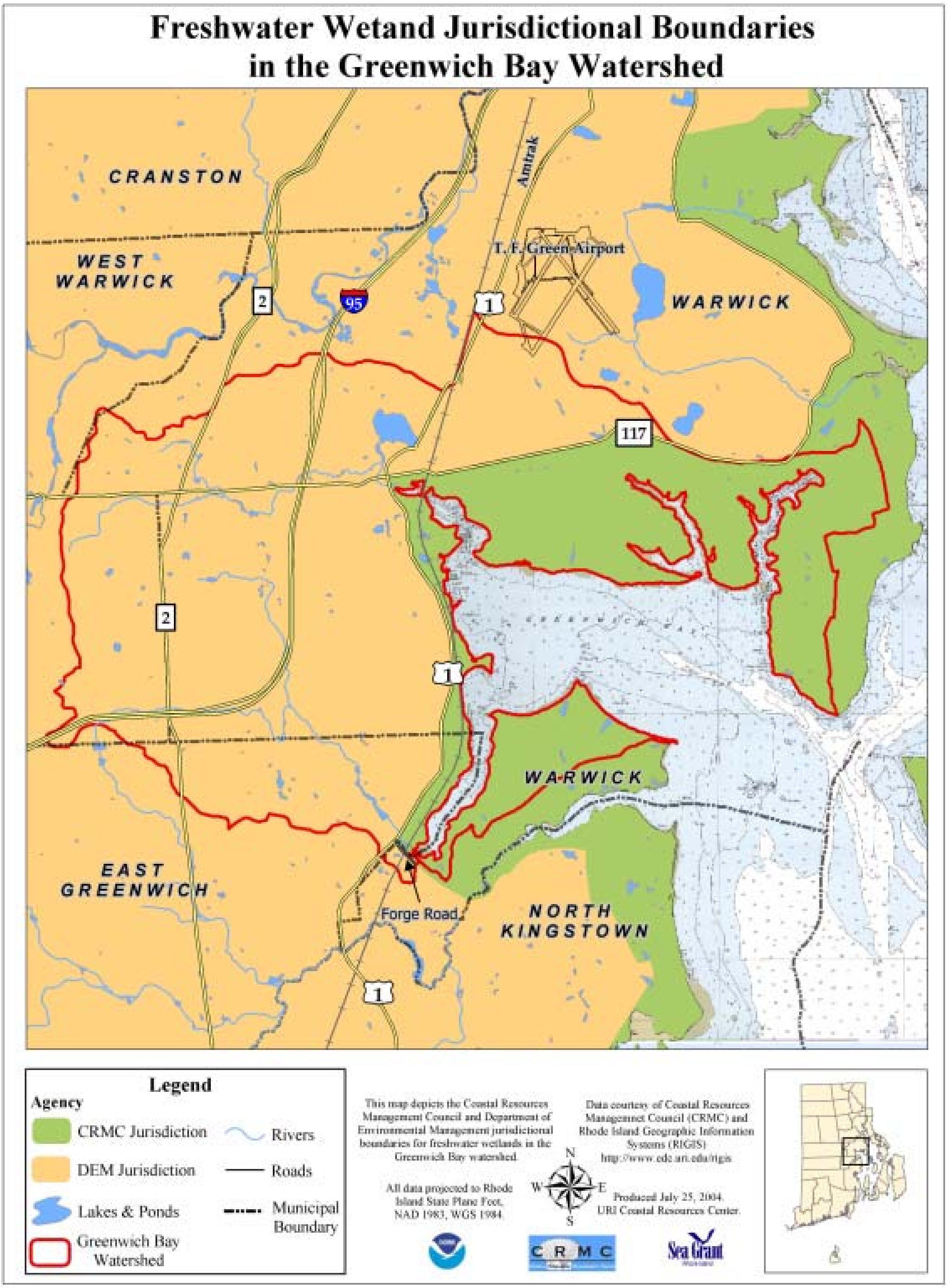
   b) *Water quality values*. Wetland vegetation traps sediments, chemical pollutants, and nutrients. Thus, wetlands may serve as filters, helping to improve water quality in Greenwich Bay and its tributaries. However, not all wetlands filter pollutants. Depending on the type of wetland, the season, and other factors, wetlands may release nutrients to surrounding waters, transform inorganic forms to organic forms (Nixon, 1980), or become overloaded with pollutants and cease to filter them (Kadlec, 1983). In addition, accumulated pollutants may degrade a wetland's value as fish and wildlife habitat (Bertness et al., 2002).

   c) *Socio-economic values*. Tidal wetlands may protect the adjacent terrestrial lands from erosion during storms by binding sediments together and absorbing wave energy (Mitsch and Gosselink, 1993). Freshwater wetlands absorb floodwaters, decreasing storm water runoff and diminishing peak flood discharge down rivers (Novitzki, 1979). Wetland habitat supports hunting, trapping, fishing, shellfishing, bird watching, and other recreational activities.

350.2 Regulations

1. CRMC and RIDEM regulate activities and development in tidal and freshwater wetlands. CRMC has primary permit authority for tidal wetlands. CRMC policies prohibit most development in tidal wetlands and require mitigation in instances where activities are approved. All freshwater wetlands are protected under the Freshwater Wetlands Act. RIDEM has primary authority over freshwater wetlands with the exception of those near the coast, which are in CRMC's jurisdiction (Figure 13).

Figure 13. Freshwater wetland jurisdictional boundaries in the Greenwich Bay watershed



350.3 Tidal

1. Tidal wetlands are wetlands periodically inundated by tidal waters. In the Greenwich Bay watershed, tidal wetlands consist of salt and brackish marshes and shrub swamps. The most common type, salt marshes, is generally separated into two zones based on the duration and frequency of inundation. Low marsh is inundated daily by tidal waters; high marsh is generally inundated during spring tides and storm surges. The upper high marsh may only be inundated during extreme spring tides. The differences between the marshes affect salinity levels, nutrient cycling, and other biogeochemical processes that influence salt marsh vegetation, wildlife habitat, and wetland functions (Tiner, 1989).

350.3A Plant habitat

1. Vegetation in the salt marsh corresponds to the different zones created by tidal flushing and marsh geomorphology. The low marsh along the shoreline and tidal creeks is dominated by the tall form of smooth cordgrass (*Spartina alterniflora*). Smooth cordgrass is found where low marsh transitions into high, and in vegetated salt pannes in the high marsh with saltworts (*Salicornia* spp.), spike grass (*Distichlis spicata*), and mats of blue-green algae. The high marsh is generally dominated by saltmeadow grass (*Spartina patens*) and spike grass at lower elevations. At higher elevations, black rush (*Juncus gerardii*) dominates and is eventually replaced by high-tide bush (*Iva frutescens*) or common reed (*Phragmites australis*), an invasive species, at the terrestrial border (Tiner 1989). Common reed can indicate disturbed estuarine wetlands, particularly from alteration of natural saltwater flushing, or from excess sediment loading(Niering and Warren, 1977). A variety of other plants may be found in the high marsh area at low densities or more disturbed locations and are listed in Table 7.

2. Salt marshes are among the most productive ecosystems anywhere, with productivity nearly as high as subsidized agriculture (Mitsch and Gosselink, 1986). In Rhode Island, salt marshes are highly productive of smooth cordgrass and saltmeadow grass due to tides, nutrient import, and water abundance. Primary productivity supports higher trophic levels either through direct grazing by herbivores or feeding on plant detritus, which may be consumed directly in the salt marsh or exported with tides.

Table 7. Common plants in the high marsh of Rhode Island's salt marshes

Common name	Scientific name
Sea lavender	*Limonium carolinianum*
Marsh orach	*Atriplex patula*
Salt marsh aster	*Aster tenuifolius*
Seaside goldenrod	*Solidago sempervirens*
Seaside arrow grass	*Triglochin maritima*
Seaside gerardia	*Agalinis maritima*

Salt marsh bulrush	*Scirpus robustus*
Seaside plantain	*Plantago maritima*
Sea blite	*Suaeda maritima*
Sand spurrey	*Spergularia maritima*
Switchgrass	*Panicum virgatum*
Slough grass	*Spartina pectinata*
Groundsel tree	*Baccharis halimifolia*

Source: Tiner 1989

350.3B Animal habitat

1. Insects, mollusks, crustaceans, and other invertebrates live in salt marshes. Invertebrate deposit feeders consume detritus and small organisms in the salt marsh sediments. Salt marsh snails (*Melampus bidentatus*) consume detritus in the high marsh. Various insects and crabs, such as the marsh crab (*Sesarma reticulatum*), may graze directly on salt marsh vegetation (Bertness, 1999). Ribbed mussels (*Geukensia demissa*) may form dense beds in the low marsh, where they filter detritus and plankton from the water and help stabilize the marsh edge (Bertness, 1999). In particular invertebrates graze on the cordgrasses (Pelligrino and Carroll, 1974).

2. Many bird species feed and/or nest in salt marshes. Cordgrass seeds serve as food for waterfowl and other birds, while the rhizomes are a major food source for geese (Pierce, 1977). Spike grasses provide nesting sites for waterfowl and food for ducks, marsh birds, and shore birds (Pierce, 1977). The more abundant the supplies of open water and of smooth cordgrass, the more breeding birds that a salt marsh will generally support (Tiner, 1989). Table 8 contains a list of bird species that may use wetland habitats.

3. Salt marshes are also considered important habitat for various fish species, including menhaden, bluefish, flounder, and striped bass. Few fish are permanent salt marsh residents, but many use salt marshes periodically for feeding and shelter (Mitsch and Gosselink, 1993). Species such as mummichog and silverside may feed on the marsh edges during low tide and move up into the marsh during high tide. Mummichogs are deposit feeders during juvenile stages, but prey on salt marsh snails and amphipods as adults. Salt marshes are nurseries for juvenile fish, which seek food and protection there during winter and spring, leaving when they grow larger (Bertness, 1999).

Table 8. Common birds found in Rhode Island's salt marshes

Common name	**Scientific name**
Common tern	*Sterna hirundo*
Clapper rail	*Rallus longirostris*

King rail	*Rallus elegans*
Mallard	*Anas platyrhynchos*
Black duck	*Anas rubripes*
Blue-winged teal	*Anas discors*
Mute swan	*Cygnus olor*
Willet	*Catoptrophorus semipalmatus*
Herring gull	*Larus argentatus*
Great black-blacked gull	*Larus marinus*
Red-winged blackbird	*Agelaius phoeniceus*
Marsh wren	*Cistothorus palustris*
Salt marsh sharp-tailed sparrow	*Ammodramus caudacutus*
Seaside sparrow	*Ammodramus maritimus*
Great blue heron	*Ardea herodias*
Little blue heron	*Egretta caerulea*
Black-crowned night heron	*Nycticorax nycticorax*
Glossy ibis	*Plegadis falcinellus*
Cattle egret	*Bubulcus ibis*
Snowy egret	*Egretta thula*
Great egret	*Ardea alba*
Canada goose	*Branta canadensis*

Source: Tiner 1989

350.3C Tidal wetland areas in Greenwich Bay

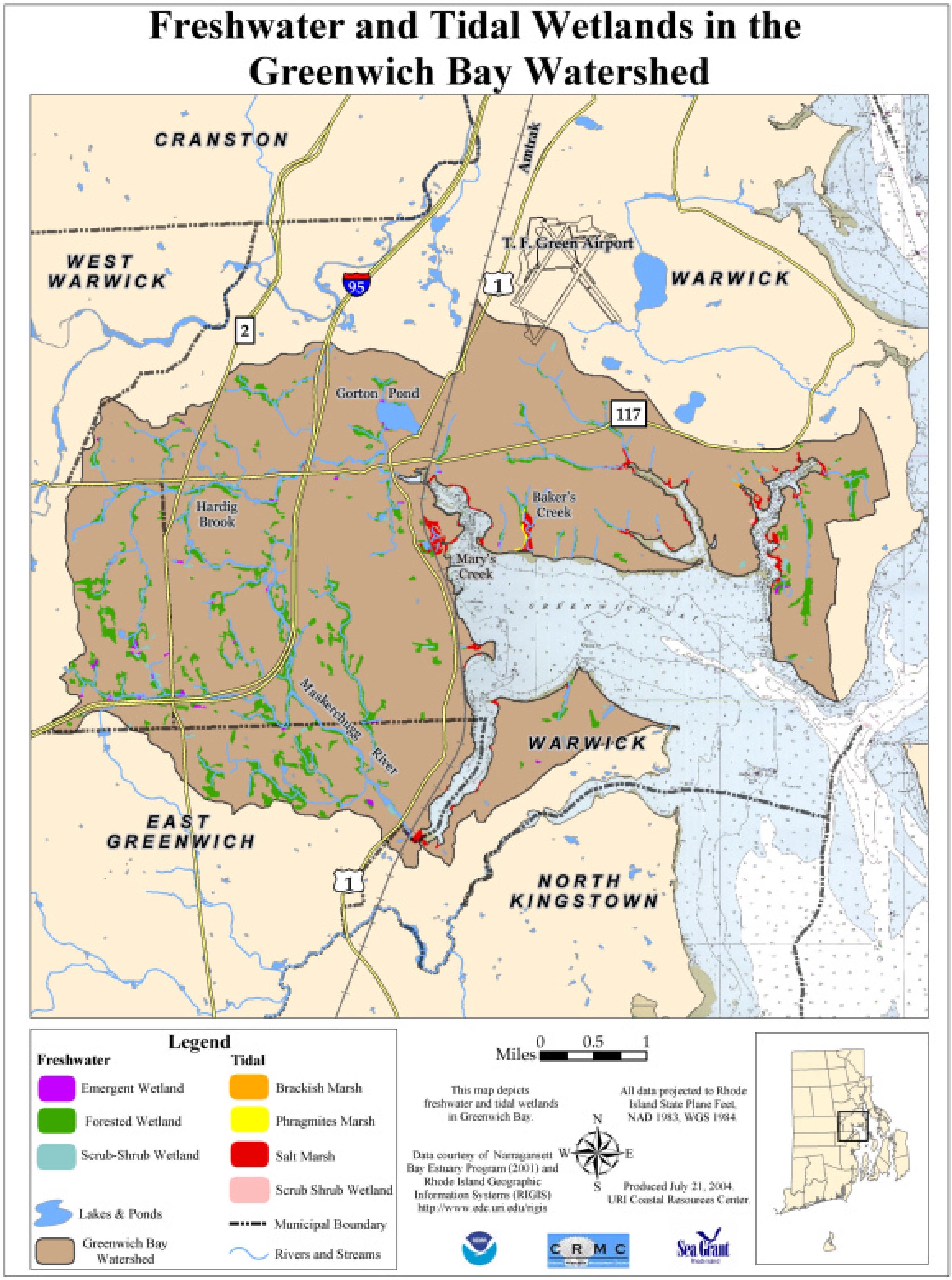
1. Tidal wetlands in Greenwich Bay and its coves primarily consist of salt marshes with a few areas of brackish marshes and salt shrub swamps (Table 9). Nearly 150 acres of tidal wetlands remain in Greenwich Bay and its coves, representing only 4 percent of the remaining tidal wetland areas surrounding Narragansett Bay (NBEP 2001). The largest complexes of tidal wetlands are located along Baker's Creek and Mary's Creek. Smaller areas fringe the shoreline in each of the coves (Figure 14).

Table 9. Tidal and freshwater wetland area in the Greenwich Bay watershed

Wetland type	Area (acres)
Tidal wetlands	
Salt marshes	123
Salt pannes	10
Phragmites marsh	9
Brackish marshes	4
Scrub-shrub wetlands	3
Subtotal	*149*
Freshwater wetlands	
Forested wetlands	423
Scrub-shrub wetlands	50
Emergent marshes	14
Subtotal	*487*
Total	**636**

Source: RIGIS and Narragansett Bay Estuary Program (NBEP 2001)

Figure 14. Freshwater and tidal wetlands in the Greenwich Bay watershed



350.3D Tidal wetland issues

1. Development is the primary threat to tidal wetlands along Greenwich Bay and its coves. Filling, draining, and other activities in tidal wetlands can destroy or degrade the valuable services and functions they provide.

2. Surrounding activities may also degrade tidal wetland habitats. Artificial tidal restrictions, ditching, and dikes modify the hydrology of tidal wetlands. Tidal wetland hydrology drives which plant and animal communities are found in tidal wetlands and ultimately many wetland functions. Mary's Creek and other tidal wetland areas in Greenwich Bay have been impacted by these types of changes. In addition, high levels of nutrient runoff may cause an expansion of smooth cordgrass into the high marsh and promote invasions of common reed (Bertness et al., 2002).

3. Invasive species, such as common reed, can change and potentially degrade tidal wetland services. Common reed has formed large stands in the high marsh of the upland boundary of Baker's Creek. Common reed is generally considered a nuisance plant species because it grows in impenetrable monotypic stands, providing little overall food and cover for waterfowl, and generally out-competing and subsequently replacing more desirable vegetation (Cross and Fleming, 1989). However, common reed is not bereft of value, particularly when it only invades a portion of a tidal wetland (Ostendorp, 1993; Fell et al., 1998; Wainwright et al., 2000). The presence of the common reed is an indicator of disturbed wetlands, particularly where natural flushing by saltwater has been altered, or sediment loading is occurring (Niering and Warren, 1977). Regular tidal flooding, which allows the level of soil water salinity to reach 20 parts per thousand, is necessary to eliminate common reed in favor of more desirable salt marsh vegetation (Howard et al., 1978).

4. Rapidly rising sea levels convert tidal wetlands to open waters. If tidal wetlands are unable to accumulate sufficient organic matter or trap sediments to compensate for sea level rise, they will slowly be inundated. As inundation increases, high marsh zones are lost and converted to low marsh (Donnelly and Bertness, 2001). Any surrounding development may prevent tidal wetlands from migrating landward in response to sea level rise.

350.3E Restoration opportunities

1. Tidal wetlands in Greenwich Bay and its coves have been identified as potential restoration sites. The NBEP and its partners conducted a comprehensive inventory of potential coastal wetland restoration sites in Narragansett Bay (Tiner et al., 2003). Approximately 29 acres of degraded wetlands were identified in Greenwich Bay (Figure 15). Impacts to the wetlands include ditching, restrictions in tidal flow, filling, invasive species, and potential runoff from impervious surfaces (Table 10). Salt marshes with restoration potential are located around Mary's and Baker's creeks, and Apponaug, Buttonwoods, Brush Neck, and Warwick coves.

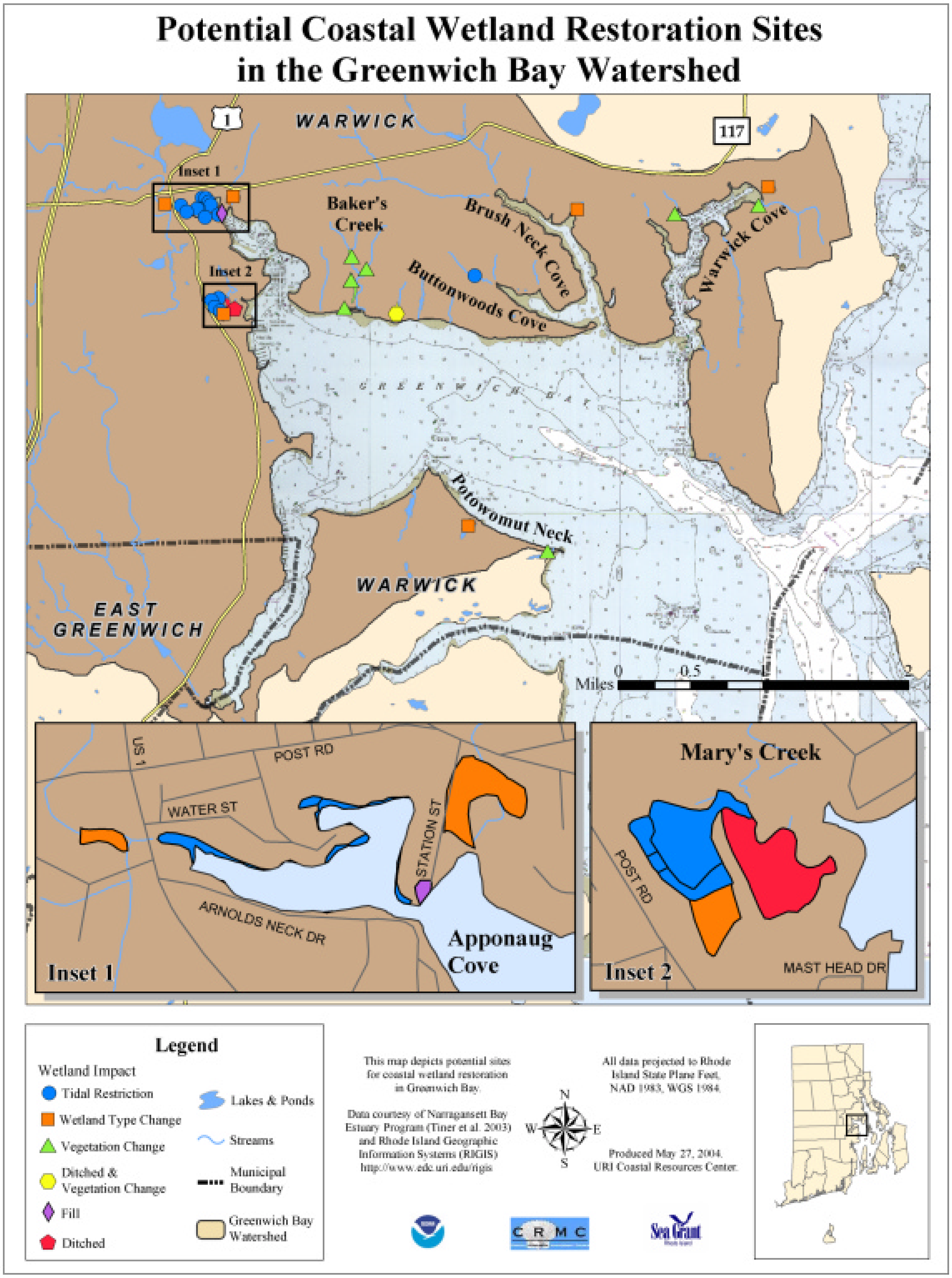
(i)

Table 10. Potential Coastal Wetland Restoration Areas in Greenwich Bay

B. Location		**Size (acres)**	**Impacts**	**Adjacent Land Use**	**Restoration Need**
Greenwich Bay					
Unnamed creek	1	1.32	Vegetation change – *Phragmites* Ditched	Residential Forest buffer	Hydrologic restoration
Baker's Creek	4	4.61	Vegetation change – *Phragmites* Debris	Forest buffer Residential	Buffer management
Mary's Creek	6	11.67	Tidal restriction Ditched Wetland type change – estuarine to palustrine Fill Debris Storm water discharge	Forest buffer Industrial/commercial Marina	Hydrologic restoration Buffer management
Potowomut Neck	2	2.68	Wetland type change – estuarine to palustrine Vegetation change – *Phragmites*	Residential	Buffer management
Apponaug Cove	13	5.94	Wetland type change – estuarine to palustrine Tidal restriction Fill	Industrial/commercial Residential	Hydrologic restoration Buffer management
Brush Neck and Buttonwoods coves	2	0.36	Wetland type change – estuarine to palustrine Tidal restriction	Forest buffer Residential	Buffer management Hydrologic restoration
Greenwich Cove	0	0	-	-	-
Warwick Cove	3 + Numerous small fringe marshes	2.45	Wetland type change – estuarine to palustrine Vegetation change – *Phragmites* Debris	Residential Forest buffer Marina	Buffer management Hydrologic restoration

Source: Geographic Information System Data from the Narragansett Bay Estuary Program; Tiner et al. 2003; Save The Bay

Figure 15. Potential coastal wetland restoration sites in the Greenwich Bay watershed



350.4 Freshwater

1. Freshwater wetlands border lakes, ponds, rivers, and streams and have water salinities below 0.5 parts per thousand. They may also be found in isolated areas where the water table is close to the surface. Freshwater wetlands are the most common and floristically diverse group of wetlands in Rhode Island (Tiner, 1989). The most abundant freshwater wetland type in the state and in Greenwich Bay is forested wetlands, dominated by the presence of woody vegetation 20 feet high or taller.

350.4A Freshwater wetland areas in Greenwich Bay

1. The Greenwich Bay watershed holds more than 500 acres of freshwater wetlands (Figure 13). Forested wetlands cover 423 acres of the watershed (Miller and Golet, 2001). Deciduous trees dominate the majority of these forested wetlands. The remaining freshwater wetlands are marshes and wet meadows (14 acres) and freshwater wetlands dominated by shrubs and other small woody plants (50 acres). More than 90 percent of these freshwater wetlands are privately owned (Miller and Golet, 2001).

2. Freshwater wetlands, while not directly adjacent to Greenwich Bay, still provide functions and services valuable to Greenwich Bay. These wetlands contain hydric soils that can remove nitrogen from groundwater that may eventually drain to Greenwich Bay. In addition, wetlands throughout a watershed naturally soak up storm water, decreasing storm water runoff and diminishing peak flood discharge down rivers. Many of the remaining freshwater wetlands in the watershed are small and located on parcels unsuitable for development (Reis, pers. comm.). Small wetlands still perform valuable functions and services, and cumulatively may be as important as larger wetlands.

350.4B Freshwater wetland issues

1. The primary threat to freshwater wetlands in the Greenwich Bay watershed is draining and filling for development. As uplands are developed, there may be increasing pressure to develop wetlands if populations continue to increase. Small wetlands on parcels of land where new sewer lines will soon be available may be in particular danger (Reis, pers. comm.). Without sewer lines, many of these wetlands could not be developed because individual sewage disposal systems (ISDS) were not an acceptable means of sewage treatment. As these wetland areas diminish, each remaining wetland's functions and services will be more important. For example, as hydric soil areas decrease in a watershed, the remaining areas with hydric soils may remove the same amount of nitrogen as before but are proportionally responsible for a larger percentage of total nitrogen removal (Gold pers. comm.).

350.4C Restoration opportunities

1. Freshwater wetland restoration sites have not been identified in the Greenwich Bay watershed, as of January 2005. However, Miller and Golet (2001) have developed site identification and prioritization methods for freshwater wetland restoration in Rhode

Island. Potential restoration sites are prioritized based on the type of impact, potentially restorable wetland functions, size, and other factors, such as restoration costs and proximity to other proposed restoration sites. RIDEM and URI with support from the U.S. Environmental Protection Agency (EPA) have applied these methods to the Woonasquatucket River watershed (Golet et al., 2002).

Section 360

Beaches

1. Approximately 70 acres sandy beaches dot the shoreline of Greenwich Bay and its coves. (NBEP, 2001), with larger beach areas along the northern, southern and eastern bay shores (Figure 16). Coastal birds, such as the American oystercatcher (*Haematopus palliatus*), the least tern (*Sterna antillarum*), and gulls, use Rhode Island's sandy beaches as nesting and feeding habitats. Harbor seals (*Phoca vitulina*) use beaches, including Sally Rock Point (NBEP, 2001), to haul out for grooming, resting, sunning, and mating from late fall to early winter. Horseshoe crabs use Greenwich Bay beaches as spawning sites, particularly west of Sandy Point, northern Chepiwanoxet Point, and Buttonwoods Cove (Figure 17). Beaches also protect shoreline homes and structures from damage during storms.

Figure 16. Greenwich Bay recreational beaches

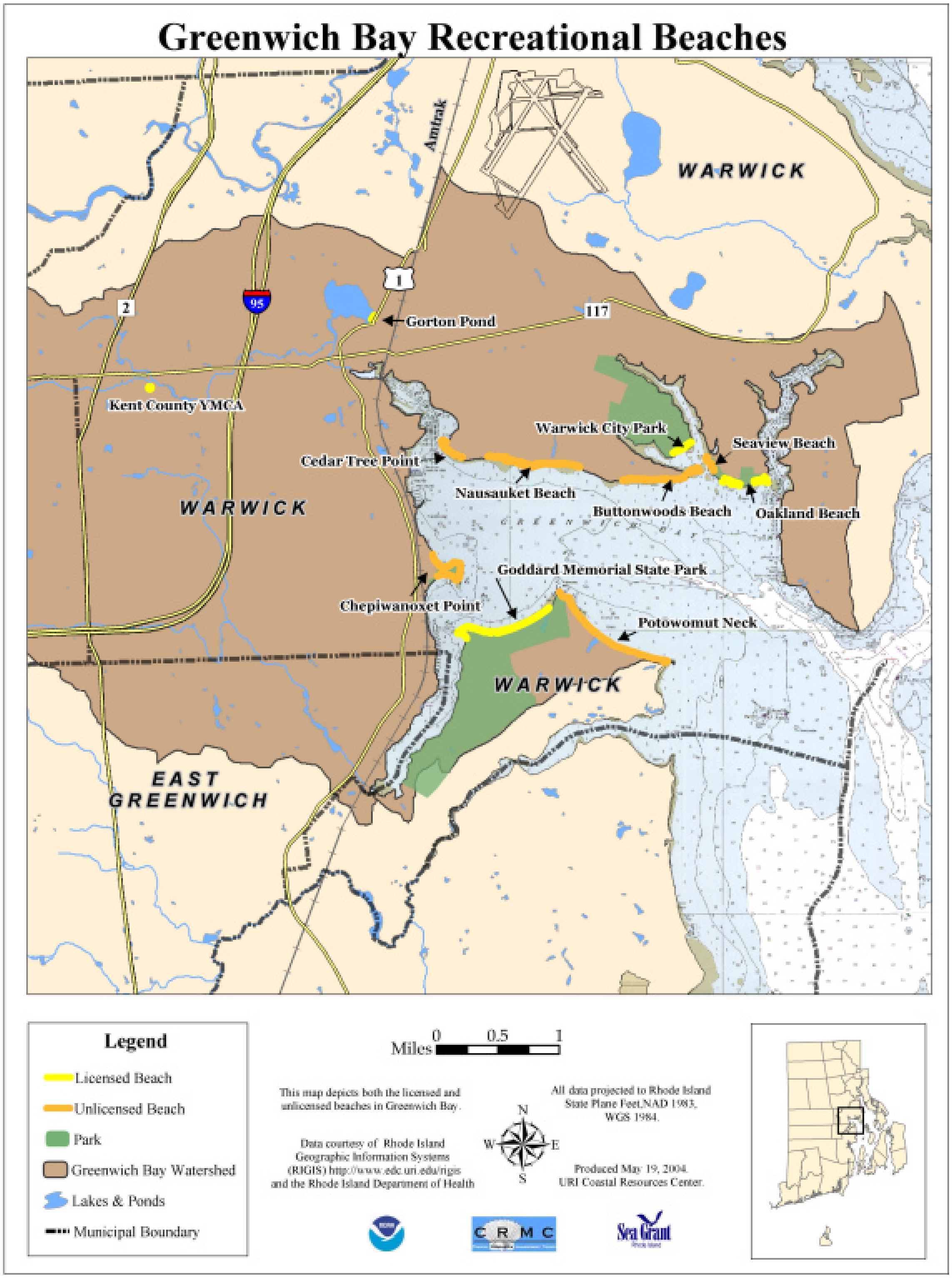
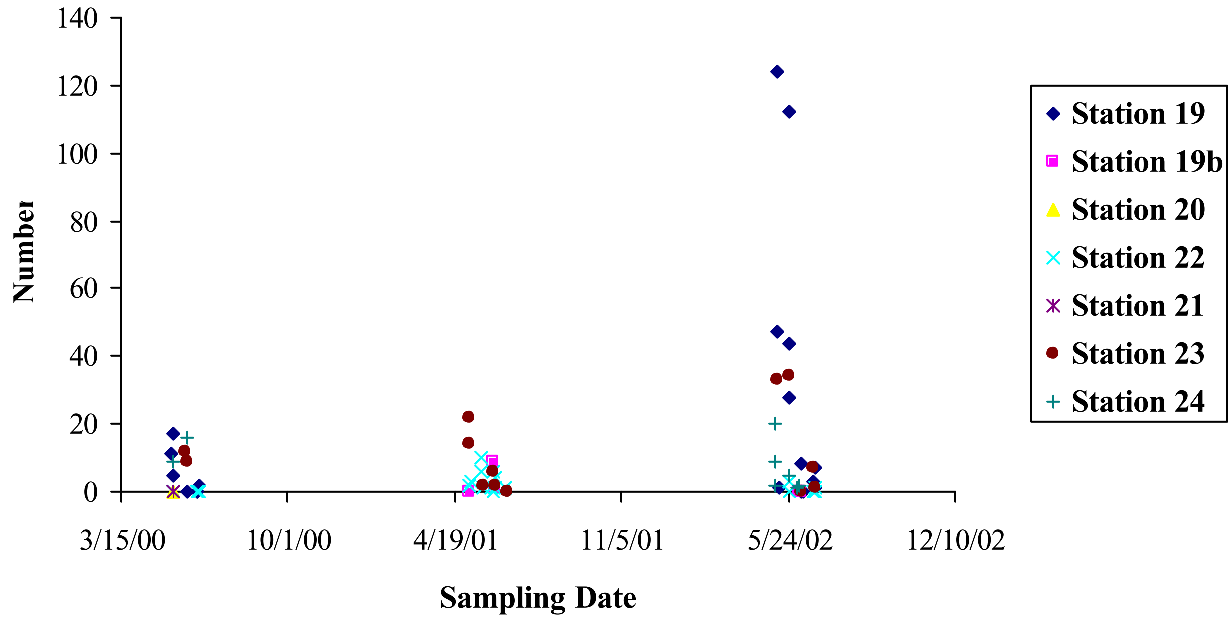
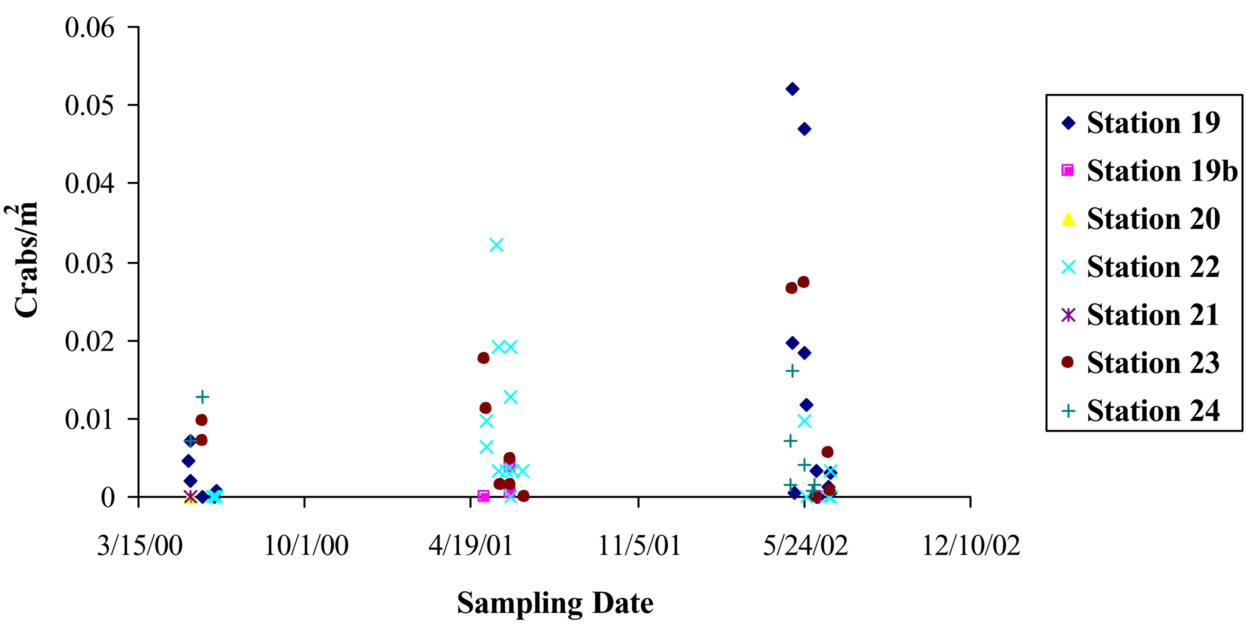


Figure 17. Horseshoe crab abundance and density in Greenwich Bay

Horseshoe Crab Abundances in Greenwich Bay



Horseshoe Crab Densities in Greenwich Bay



Source: RIDEM

360.1 Horseshoe crabs

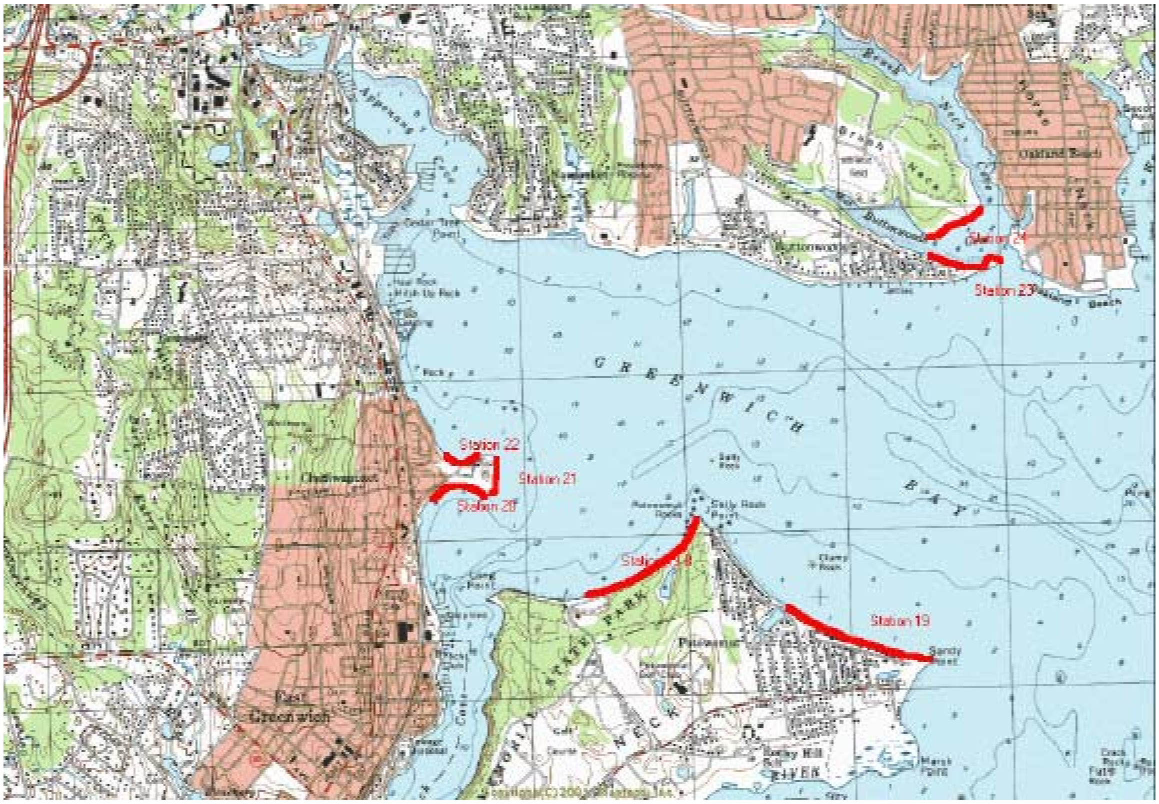
1. Horseshoe crabs (*Limulus polyphemus*) are benthic arthropods found along the Atlantic seaboard. Adult horseshoe crabs feed and spawn in estuaries during the summer and may migrate to the continental shelf during the winter. Spawning occurs from May to July on intertidal beaches in low-energy estuarine environments protected from surf, such as Greenwich Bay. Spawning reaches its peak during high tides associated with full and new moons. Upon hatching, juvenile horseshoe crabs spend two years in shallow subtidal flats near the shore (Atlantic States Marine Fisheries Commission (ASMFC), 1998).

2. Horseshoe crabs are a valuable resource for three reasons. First, horseshoe crabs are used as bait in the American eel and conch fisheries. Second, Limulus amoebocyte lysate (LAL), a clotting agent, is derived from horseshoe crab blood. LAL testing is the standard for ensuring medical equipment and drugs are not contaminated. No alternatives are currently available with similar accuracy. Finally, horseshoe crab eggs and larvae are part of the diet of shorebirds and finfish (ASMFC, 1998).

3. RIDEM coordinates horseshoe crab monitoring along Greenwich Bay with Save The Bay and local volunteers (Figure 18). Horseshoe crabs have been recorded on beaches along Potowomut Neck, northern Chepiwanoxet Point, and Buttonwoods and Brush Neck coves (Figure 17). Approximately 30 to 50 percent of the horseshoe crabs recorded were observed to be spawning. Spawning also occurs on the bay's north shore (Robinson, pers. comm.). Higher abundances and densities have been reported near Sandy Point (Station 19), northern Chepiwanoxet Point (Station 22), and Buttonwoods Cove (Stations 23 and 24).

4. A reported decline in Narragansett Bay's horseshoe crab population led RIDEM to restrict commercial and recreational harvests in 2000 (Gibson and Olszewski, 2001). Regulations were also designed to comply with the ASMFC management plan for horseshoe crabs. A quota system limits the number of animals that can be taken, and harvest is prohibited during a four-day period surrounding new and full moons during the spawning season from May to July, and a spawning sanctuary has been established around Prudence and Patience islands.

Figure 18. Locations of RIDEM horseshoe crab monitoring stations in Greenwich Bay



Source: S. Olszewski, RIDEM

360.2 Beach habitat issues

1. The primary threats to Greenwich Bay's beaches are erosion and shoreline structures that affect coastal processes and sand movement. Erosion processes in Greenwich Bay have been at work along the coastline since the basin first flooded. The effects of erosion are exacerbated by storm waves and elevated storm surges. Sand and gravel beaches and glacial till bluffs have eroded slowly over time. Efforts, such as the Oakland Beach Renourishment Project, work to address such erosion. However, beach nourishment projects are constantly needed to address erosion.

2. Shoreline protection structures, such as revetments, can be used to modify the erosional forces affecting beaches. Many shoreline protection structures are designed to limit erosion and retain beach areas. Groins at Oakland, Buttonwoods, and Cedar Tree Point beaches trap sand and help slow sand loss from these areas. However, groins save some beaches at the expense of others, because sand swept from some beaches accrete on others (Nordstrom, 2000). In addition, structures, such as seawalls, used to protect buildings and other structures above the beach can hasten erosion (Nordstrom, 2000). Shoreline protection structures must be implemented carefully to minimize these impacts.

3. Human activity can disturb animals along the beach or destroy nests and plants. Damaging vehicle activity has been reported on Baker's Creek and the beaches from Baker's Creek to Budlong Farm Road during the winter months (Langseth, pers. comm.). The ASMFC recommends limiting all-terrain vehicle (ATV) access and personal watercraft use in horseshoe crab spawning areas during the spawning season (ASMFC 1998).

4. CRMC regulates vehicle use on beaches. CRMC requires vehicles to display a decal indicating CRMC permission to operate on beaches. Violators are subject to a fine from $25 to $75 that may be enforced by the municipality (R.I. Gen. Laws §31-8-1.1). CRMC offers signs to municipalities to post at access points explaining the need for this permit. In addition, CRMC prohibits all vehicles on vegetated areas of barrier beaches at the mouth of Baker's Creek and Buttonwoods Cove or on dunes (R.I. Coastal Resources Management Program §210.2 and §210.7).

5. Recreational vehicles, such as ATVs, are prohibited on publicly owned beaches, except for authorized management-related vehicles, and other specific areas in the Greenwich Bay watershed by CRMC and Warwick. Only vehicles registered by the R.I. Department of Motor Vehicles (RIDMV) are eligible for CRMC beach vehicle permits. Recreational vehicles are not registered by the RIDMV, and therefore, are not allowed on publicly owned beaches, except for authorized management-related vehicles (R.I. Coastal Resources Management Program §210.1). (Recreational vehicles are registered by the RIDEM.) In addition, Warwick prohibits recreational vehicle activity on a "city-owned or operated beach or waterfront area" (Warwick City Ordinance §76-89) as well as "private property, whether posted or not, without the permission of the owner" (Warwick City Ordinance §76-92). Violators of either city ordinance can be fined $30.

Section 370

Vegetated buffers

1. Vegetated buffers are land areas that are retained or restored to a vegetated condition in order to:
   a) Protect adjacent land areas from the impacts of surrounding activities
   b) Separate incompatible land development and alterations
   c) Maintain important wildlife habitat

Vegetated buffers may protect wetlands, steep bluffs or banks, estuarine shorelines and their tributaries, shoreline homes, or critical wildlife habitats. They may also protect cultural and historical resources. Finally, they may preserve scenic views and the shoreline aesthetics. Ideally, vegetated buffers are maintained in their natural and undisturbed condition or restored to a natural condition, but they also may be actively managed or engineered areas.

2. Vegetated filter strips are a subset of vegetated buffers. Filter strips are generally engineered or managed vegetated areas that help filter pollutants from storm-water runoff (Desbonnet et al., 1994). They are not necessarily composed of natural vegetation and may be managed to optimize erosion control and trap sediments, nutrients, and other contaminants. To a lesser extent, filter strips may also provide cover and food for wildlife, protect shores from erosion, and preserve scenic quality (CRMC, 2000). Filter strips are commonly used in agricultural settings around fields (Wenger, 1999). For the purposes of this SAMP, a filter strip is defined as an area of natural vegetation maintained along the shoreline for a width of less than 25 feet.

370.1 Services and values

1. An undisturbed vegetated buffer zone can provide habitat itself for a diverse wildlife population or shield valuable habitats from human activities. Establishment of a buffer can prevent human encroachment on wildlife habitat. Loss of any one population can have a dramatic effect on species that may have been dependent on that population, either as a food source or for population control. Vegetated buffer zones may be linked to create corridors for wildlife to travel between larger habitat areas, or isolated buffers may provide refuge to wildlife in largely developed areas. Buffers can help maintain rare and endangered species populations by reducing the potential of human intervention and contact. Rare and endangered species can be easily lost due to activities such as inadvertent collection of plant species, or establishment of footpaths through nesting grounds (Clark, 1977). In addition, vegetated buffers along coasts and riparian areas can moderate adjacent water temperatures and provide inputs of organic material necessary for many aquatic animals (Wenger, 1999). The primary limitation on a vegetated buffer's habitat value is its size. Buffers must be fairly large to provide valuable habitat for wildlife (Desbonnet et al., 1994).

2. Vegetated buffers can reduce storm-water volume that directly reaches Greenwich Bay and its tributaries. Storm water flowing from nonvegetated areas, and particularly impervious surfaces, reaches surface waters faster and at larger volumes and can lead to flash flooding as well as increased streambank erosion. In addition, pollutants carried in the storm water reach surface waters faster and bypass natural filters. A natural, densely vegetated buffer zone slows

the rate at which water flows over the land, allowing percolation into the soils (Karr and Schlosser, 1977). Buffers have been shown to reduce runoff volume in some instances by 28 percent (Wong and McCuen, 1982). A number of factors affect the efficiency of volume reduction, primarily slope, soils, vegetation type and density, water table, and buffer width (Desbonnet et al., 1994).

3. A vegetated buffer zone can decrease the amount of sediment carried by storm water runoff to Greenwich Bay and its tributaries. Sediment carried in runoff can increase the need for channel dredging and alter benthic habitats. In addition, pollutants attached to sediments are often carried to surface waters. Vegetated buffers decrease sediment loads absorbing the impact of rain, preventing sediments from dislodging from the ground (Palfrey and Bradley, 1982), and by slowing runoff movement through the buffer, and allowing heavier sediment to settle out before entering adjacent waters. Maryland's Coastal Zone Management Program has determined that the use of buffers may decrease sediment transport loads by 90 percent to Chesapeake Bay (Wong and McCuen 1982). However, flow through the buffer must be slow, shallow, and uniform to remove sediments effectively (Desbonnet et al. 1994). Therefore, sheet flow must be promoted and the water's tendency to channelize discouraged. Steep slopes are also not conducive to the slow water movement through the buffer.

4. Vegetated buffer zones can aid in the removal of nutrients, such as phosphorous and nitrogen, from surface water and groundwater. High nitrogen loads to coastal saltwaters and high phosphorus loads to freshwater lead to eutrophication in adjacent surface waters. Phosphorus generally is adsorbed on to sediment particles and removed from runoff when sediments settle out (Karr and Schlosser, 1977; Palfrey and Bradley, 1982). However, nitrogen is generally dissolved in surface water and groundwater that move through the buffer. Dissolved nitrogen can be removed when storm-water runoff percolates into the buffer soil or when shallow horizontal groundwater flows pass through the buffer. In the soils, dissolved nitrogen may be converted to nitrogen gas or nitrous oxide gas either through denitrification or via uptake by vegetation. Denitrification provides a permanent nitrogen removal from the system, whereas vegetative assimilation may only for a time shift nitrogen inputs to adjacent waters. Not all vegetated buffers will necessarily remove nitrogen effectively. Vegetation can only take up dissolved nitrogen when it passes through plant root zones. Denitrification also requires an anaerobic environment and sufficient organic carbon supply (Hill, 1996). The efficiency of nutrient removal by vegetative buffers has been found to vary from 0 percent to 99 percent depending on vegetation, soil type, volume of runoff, concentration of nutrients, and slope (Desbonnet et al., 1994). Trees are particularly helpful, as their roots aerate the soils by penetrating the ground (Palfrey and Bradley, 1982).

5. Vegetated buffer zones along shorelines and other riparian areas can protect surface waters from pathogen contamination. Birds, such as Canada geese, may contribute to high indicator bacteria counts in Greenwich Bay and its coves and tributaries. Canada geese prefer to feed and rest on grassy areas, such as golf courses, residential lawns, and public parks. Naturally vegetated buffers along riparian areas discourage geese from congregating directly on the shoreline and diminish bacterial inputs from their feces (Smith et al., 1999).

6. Shoreline homes and businesses may be flooded or undercut by erosion when they are constructed too close to the shoreline. Vegetated buffers can protect structures by pushing them

away from severe flooding and erosion areas. Vegetation can also absorb wave and floodwater energy, and roots can help hold soils together and resist erosion. Rainfall and runoff intensity, soil characteristics, hydrologic regime, slope, vegetation, and the size of adjacent waters influence how effective a vegetated buffer may be at reducing flooding and erosion (Desbonnet et al., 1994).

7. Vegetated buffers can protect archaeological sites and other historical and cultural assets from inadvertent damage. Many sites in Rhode Island are within 200 feet of the coast (Desbonnet et al., 1994). Shoreline vegetated buffers may protect known sites from damage or preserve unstudied and undiscovered sites for future archaeological work.

8. Vegetated buffers can provide a screen of natural growth between developed and undeveloped areas, providing privacy and aesthetic appeal (Desbonnet et al., 1994).

370.2 Vegetated buffer design

1. Vegetated buffers may be designed to provide one service, such as pollutant filtering, or multiple services, such as pollutant filtering, habitat, and streambank stabilization. Multiple-use buffers provide more value but can be difficult to implement in areas, such as Greenwich Bay, where land parcels can be small. In general, a buffer that provides more services must be bigger than a single service buffer. Land areas can be prioritized for buffer establishment based on their potential to provide multiple services.

2. Multiple-use buffers in riparian areas often incorporate a design where the buffer is separated into three distinct zones (Chase et al., 1997; Palone and Todd, 1998; Fischer and Fischenich, 2000). The zone directly adjacent to the water is essentially unmanaged native vegetation. Its primary purpose is as wildlife habitat and bank stabilization. The second zone is generally managed forest and provides enhanced water quality, recreation, and habitat value. Within this zone, trees and shrubs may be pruned or selectively harvested. The third zone is farthest inland and is generally a grassy area maintained for water quality protection. Property owners' use of this area is generally unrestricted (Palone and Todd, 1998). The three-zone buffer design provides multiple services while maintaining some use by property owners. However, this design also covers a relatively large area adjacent to the water.

3. Buffer width is one of the most important variables in designing effective vegetated buffers. The desired buffer width depends on the services that the buffer is expected to provide. Under ideal conditions, buffers as small as a few feet can remove some nutrients and sediments from runoff water (Neibling and Alberts, 1979). However, small buffers may provide limited value for other services. As buffer width increases, the buffer generally provides greater service and value (Table 11). Once the buffer widens beyond 30 feet, however, there is a diminishing return in water quality value for each additional foot (Fischer and Fischenich, 2000). Wildlife value and other values do continue to grow as buffer width increases, although some studies indicate that there is minimal increased benefit in buffers wider than 300 feet for bird, reptile, and amphibian habitat (Hodges and Krementz 1996; Burbrink et al., 1998). Buffer widths may need to be larger depending on specific site conditions, such as slope and adjacent water size, to

provide expected services. For example, Trimble and Sartz (1957) suggest an additional 2- to 4-foot buffer width for each 1 percent increase in slope to maintain water quality value.

4. Vegetation type is another important variable in buffer design. Grasses, shrubs, and trees can be planted or maintained on vegetated buffers. Each vegetation type can provide more or less benefit depending on the desired service. Grasses efficiently trap sediments and remove nutrients from water flowing through the buffer (Chase et al., 1997). Shrubs help stabilize banks and prevent erosion (Fischer and Fischenich, 2000). Trees are also good bank stabilizers and benefit aquatic habitat by shading streams and helping keep water temperatures low. In general, a mix of native species of the three major vegetation types is more desirable for maintaining wildlife habitat (Palone and Todd, 1998; Fischer and Fischenich, 2000). CRMC provides guidance on recommended plant species in its "Guide to Landscape Management in the Rhode Island Coastal Zone" (CRMC, 2000).

5. Buffer design, especially for water quality protection, must also account for how water flows through the buffer. Natural processes that remove sediment, nutrients, and other pollutants from storm-water runoff take time. If runoff moves through a buffer too quickly or in channels, the buffer will not have an opportunity to remove pollutants. Furthermore, rapid, channelized flow can lead to erosion within a shoreline buffer. Vegetation and engineered structures, such as spacers, can be used to promote sheet flow (Palone and Todd, 1998).

Table 11. Vegetated buffer values at various widths

Buffer width (feet)	Progressive habitat values	Water quality value[1]		
15	Poor – Useful for temporary activities of wildlife (Desbonnet et al. 1994)	= 50%		
30	Poor – Minimal protection of stream habitat from temperature changes (Davies and Nelson 1994)	= 60%	Recommended width (Fischer and Fischenich 2000)	
50	Minimal – Minimal protection of stream habitat for woody debris inputs (Davies and Nelson 1994). Protects ~90% plant species (Spackman and Hughes 1995)	= 60%		
65	Minimal – Minimal use as a wildlife travel corridor as well as general avian habitat (Desbonnet et al. 1994)	= 70%		Recommended width (Fischer and Fischenich 2000)
100	Minimal – Protects ~10% of wetland-dependent reptile species (Boyd 2001) Protects ~20% of wetland-dependent amphibian species (Boyd 2001)	= 70%		
175	Minimal – Protects ~30% of wetland-dependent reptile species (Boyd 2001) Protects ~40% of wetland-dependent amphibian species (Boyd 2001)	= 75%		
250	Fair-to-good – Protection of small mammal habitat (Cross 1985)	= 80%		
325	Good – Recommended protection for neotropical bird habitat (Keller et al. 1993)	= 80%		
500	-	= 85%		
650	Excellent – Likely to support a diverse community (Desbonnet et al. 1994)	= 90%		
2,000	Excellent – Supports a diverse community; protection of significant species (Desbonnet et al. 1994)	= 99%		

[1] Approximate percentage of sediment and nutrient removal. Based on Desbonnet et al. 1994

Source: Adapted from Desbonnet et al. 1994; Wenger 1999

370.3 Site identification

1. Not all locations in a watershed will provide equal service as vegetated buffers. For water quality protection, establishing vegetated buffers in the headwaters of a watershed can have a greater impact on water quality than buffers along the coast (Fischer and Fischenich, 2000). In coastal and riparian areas, buffers in areas with hydric soils provide greater nitrogen removal from shallow groundwater flow than non-hydric soils provide (Gold et al., 2001). However, Gold et al. (2001) noted that seeps in glacial tills, filling and artificial drainage in the riparian zone, and river downcutting and bank erosion can all decrease a vegetated buffer's effectiveness at removing nitrogen. For wildlife habitat, vegetated buffers that are continuous and connect larger natural areas, such as parks, provide greater habitat value than fragmented buffers (Fischer and Fischenich, 2000). In addition, not all areas in a watershed have equal need for vegetated buffers. For example, some areas may be more at risk of flooding or shoreline erosion. Critical habitats, such as wetlands, or historical sites may be more important to protect with buffers than other areas.

370.4 Buffer regulations

1. CRMC regulates coastal vegetated buffers in Rhode Island (R.I. Coastal Resources Management Program §150). Generally, CRMC requires that new residential developments or existing residential developments where a structure's foundation is increased by more than 50 percent maintain a native vegetated buffer along the shoreline feature, such as a wetland or beach. The buffer width is dependent on the residential lot size and adjacent CRMC water-use classification. Commercial and industrial developments are evaluated on a case-by-case basis for required coastal buffers. Variances are available from CRMC. Alterations or management to approved coastal buffers or any coastal area with natural vegetation must follow CRMC standards and may require CRMC approval.

2. Freshwater riparian buffers are regulated under the Freshwater Wetlands Act (R.I. Gen. Laws §2-1-18 et seq.). Under the Act, riparian buffers are part of the 50-foot perimeter wetland, 100- and 200-foot riverbank wetlands, or regulated floodplain. RIDEM regulates these buffers along most tributaries and freshwater wetlands in Rhode Island. CRMC regulates them along those tributaries and freshwater wetlands in the vicinity of the coast. In general, a wetland permit is required from RIDEM or the CRMC to make alterations to these riparian buffers, although some activities may be exempted (RIDEM, 2000).

3. Despite attempts to clarify the regulatory boundary by CRMC and RIDEM, public confusion remains as to whether the CRMC coastal buffer regulations or Freshwater Wetlands Act apply in a particular area and who is the responsible permitting agency, according to the Greenwich Bay Citizens Advisory Committee.

370.5 Application in the Greenwich Bay watershed

1. Establishment and restoration of vegetated buffers in the Greenwich Bay watershed could help improve habitat availability, water quality, hazard mitigation, and historical preservation. Migratory bird habitat, such as Baker's Creek, rare and endangered species habitat, such as Gorton Pond, and wetlands, such as Mary's Creek, are critical areas that vegetated buffers could

protect. Vegetated buffers in both coastal and riparian zones, particularly where hydric soils are present, can help mitigate water pollution.

2. Vegetated buffer establishment is limited in the Greenwich Bay watershed by small lot sizes. Small lots may not be able to accommodate both a vegetated buffer and a home or business. Required municipal setbacks from the road may further limit the space available for vegetated buffers (Boothroyd, pers. comm.). CRMC receives numerous requests for variances from coastal buffer policies along the Greenwich Bay shoreline because current CRMC policies do not take small-lot sizes into consideration (Reis, pers. comm.). In another situation, municipal authorities trying to protect riparian buffers are often frustrated when applicants receive variances from RIDEM after the municipality has told the applicant that they cannot develop in a buffer.

3. Vegetated buffer restoration is limited in the Greenwich Bay watershed by existing development and policies. Many areas needing vegetated buffers are private properties with existing residential, commercial, or industrial structures, but these properties are grandfathered, and do not require the creation of buffers, unless the footprints of their existing structures are increased by 50 percent or more. In addition, property owners have expressed concern that if they voluntarily restore a vegetated buffer on their property, then regulatory agencies such as CRMC, will not allow them to manage the new buffer or choose to remove it in the future (Ferguson, pers. comm.).

4. The RIDEM received U.S. Forest Service funding to identify and implement coastal and riparian vegetated buffers in the Greenwich Bay watershed (Presley, pers. comm.). The focus of this effort is to establish forested buffers for water quality protection and habitat value. Buffer restoration sites were identified and prioritized on the Greenwich Bay coast and streams and ponds in the watershed, using a combination of 2002 U.S. Geological Survey digital color orthophotography and 1995 RIGIS land use data (Mulé and Golet, 2005). On Greenwich Bay's coastline, most areas could accommodate either a buffer of less than 25 feet or a buffer of greater than 100 feet. Mulé and Golet (2005) identified more than 14 miles of potential buffer restoration sites on Greenwich Bay's shoreline with 50 feet or less riparian vegetation. The identified sites were prioritized based on the current width of riparian vegetation, adjacent land use intensity, and the continuous shoreline length with restoration potential. Potowomut Neck and the Greenwich Bay shore of Cedar Tree Point were areas identified as having a high restoration potential. Actual buffer restoration would be funded using state and local restoration funds as well as up to $100,000 from the U.S. Natural Resources Conservation Service (NRCS) Wildlife Habitat Incentives Program (WHIP).

Section 380
Priority lands and acquisition

380.1 Priority lands analysis

1. Using geographic information system (GIS) data, the Conservation Agency, under the direction of the University of Rhode Island Coastal Resources Center, conducted a priority lands analysis to help identify critical land areas for natural resources in the Greenwich Bay watershed. Areas were scored based on the number of resources the land area provides and then were grouped into three priority categories.

380.1A Natural resources

1. The analysis prioritized watershed areas based on the following land characteristics:

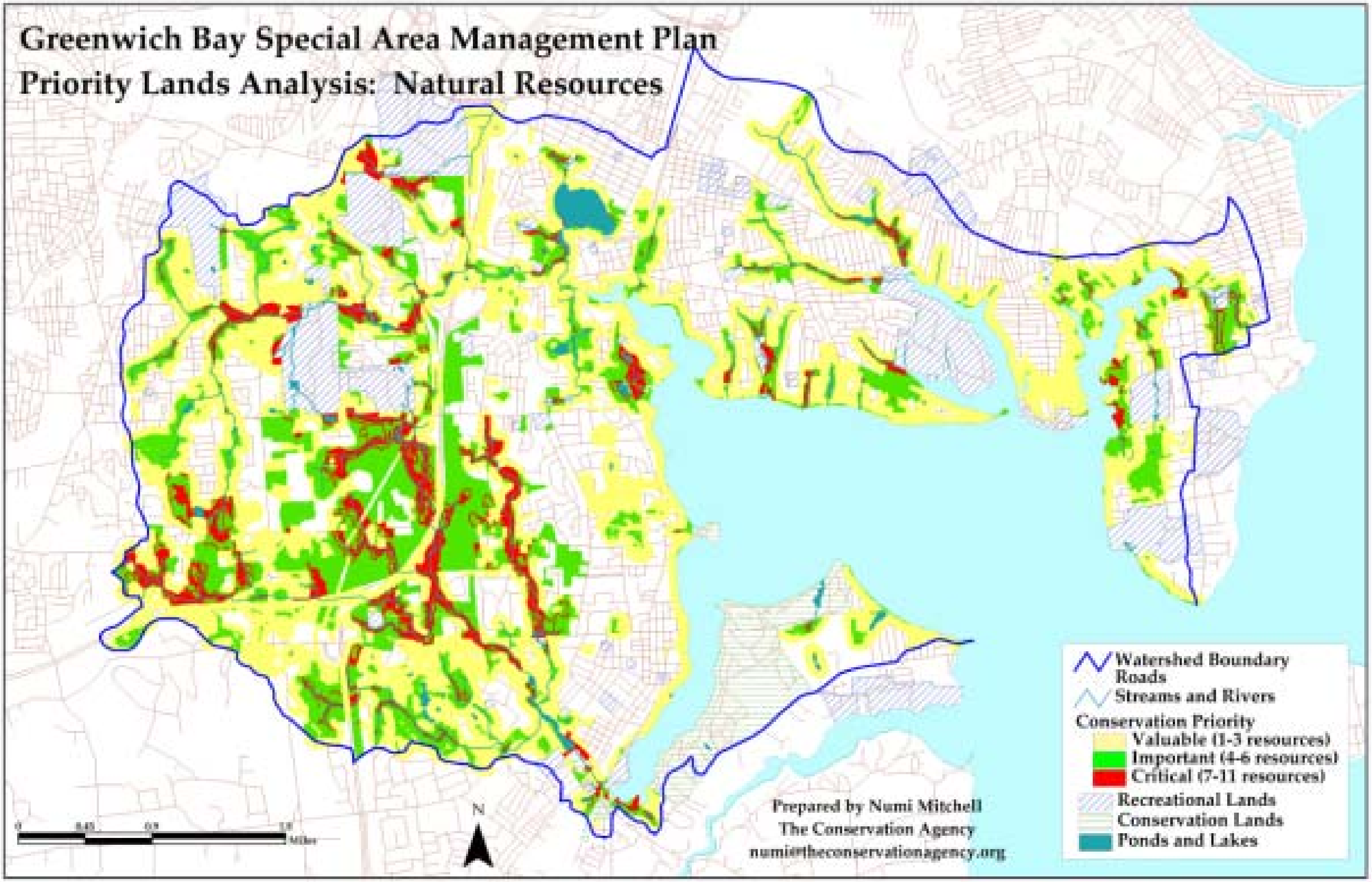
- Wetlands
- Forest and brushland
- Rare species habitat
- Undeveloped areas
- Areas undeveloped and contiguous to protected or recreational land
- Areas within the 50-foot buffer of the shoreline, river, lake, or wetland where vegetated buffers are most valuable for water quality protection
- Areas within the 300-foot buffer of the shoreline, river, lake, or wetland where vegetated buffers are most valuable as habitat
- Hydric soils
- Federal Emergency Management Agency flood zones
- Wellhead protection areas

All lands were scored equally for each characteristic with the exception of wetland, forest, and brushland areas that received twice the weighting of other characteristics. Lands receiving a score of 1 to 3 were classified as “valuable,” 4 to 6 as “important,” and 7 to 11 as “critical.”

2. Approximately 7,600 acres of land with value for natural resources were identified in the Greenwich Bay watershed (Figure 19). Critical lands cover more than 700 acres and are generally found in freshwater wetland areas along Hardig Brook and the Maskerchugg River, or in tidal wetlands, such as Mary’s and Baker’s creeks. Important areas cover around 2,000 acres and generally encompass unprotected forested areas. Valuable areas cover nearly 4,900 acres and generally encompass the 300-foot vegetated buffer as well as undeveloped land contiguous to protected or recreational lands.

3. The priority lands analysis provides a broad, objective watershed-wide analysis of priority land areas based on multiple resource values. The analysis does not differentiate areas based on resource quality and is limited by the resolution of the geographic data available. Further work is needed to identify additional local areas that may not have been captured by this analysis, and differentiate between the resource value of specific land parcels within each category.

Figure 19. Natural resource priority lands identified in the Greenwich Bay watershed



380.2 Land acquisition

1. Acquisition of land or conservation easements can protect valuable lands in perpetuity. Current federal, state, and local laws can protect valuable lands, such as wetlands, but as long as these lands remain private property with intact development rights, regulatory changes may lead to their development. Federal, state, and local agencies, as well as certain nongovernment organizations, may directly acquire land or easements to provide additional protection.

2. The primary limit on land or easement acquisition is funding, which cannot generally meet the demand for lands worthy of protection. In 2004, the R.I. General Assembly and voters approved a $70 million Open Space, Recreation, Bay, and Watershed Protection Bond that is leveraging $65 million dollars for protecting open space and farmland.

3. Additional funding may also become available through the federal Coastal and Estuarine Land Conservation Program. This program will make federal funding available to acquire coastal lands for habitat, recreational, historical, or aesthetic purposes. CRMC is completing Rhode Island's Coastal and Estuarine Land Conservation Plan (CELCP). Once the CELCP is approved by the National Oceanic and Atmospheric Administration (NOAA), Rhode Island will become eligible for federal funding. Lands in the Greenwich Bay watershed could be acquired using these grants when funding becomes available. At this time, there is no federal funding for the program.

4. Potential acquisitions must be prioritized carefully to maximize the use of limited funds. For instance, vacant land could be easier and cheaper to acquire, while preserving unsewered areas can decrease development pressure, and tax status could allow certain properties to be acquired for less money.

Section 390

Regulations, recommended actions, and research needs

1. Regulations, recommended actions, and research are needed to protect, restore, and enhance Greenwich Bay's habitat and environmental assets. In regulatory sections, plain text indicates current R.I. Coastal Resources Management Program regulations whereas underlined text indicates new regulatory language and strikethrough text indicates deleted regulatory language. Recommended actions and research needs may apply to federal agencies, state agencies, local governments, and nongovernment organizations. Recommended actions are presented in plain text.

390.1 General

390.1A Regulations

Policies

1. CRMC supports local efforts to adopt wetlands, streams, and shorelines by providing technical and permitting assistance when needed.

390.1B Recommended Actions

1. Warwick, East Greenwich, and nongovernment organizations should examine the feasibility of partnering with other groups to develop adopt-a-wetland, adopt-a-stream, and adopt-a-shoreline programs. Adoption agreements should include:

a. Applicant contact information
b. Identification of adopted area
c. Description of activities to be conducted by the local group
d. Landowner permission if applicable
e. Description of municipal services to be provided, such as training, safety and informational materials, technical support, and equipment
f. Activity timeframe
g. Liability waiver signed by participants

Adoption programs should be designed to allow school groups to qualify for CRMC Adopt-a-Wetland, Adopt-a-Stream, or Adopt-a-Shoreline recognition certificates. In addition, municipalities should design Adopt-A-Wetland programs to reflect the requirements of the EPA Region 1 Adopt-a-Wetland Program.

2. CRMC should award certificates to school groups to recognize their completion of actions that monitor, protect, or improve the quality of a wetland, stream, or shoreline in the Greenwich Bay watershed. These actions include but are not limited to:

a. Education campaigns
b. Litter pickups
c. Water quality monitoring
d. Monitoring for illegal dumping or activities
e. Non-native vegetation removal
f. Planting native vegetation
g. Habitat restoration

390.2 Open waters

390.2A Regulations

Policy

1. The following areas are designated as quahog resource preserves:
   a. Mary's Creek and the area delineated by the northern and southern edge of the Mary's Creek salt marsh due east to the federal navigation channel
   b. The area delineated by the shoreline and lines from Long Point due west and the southernmost point of Chepiwanoxet Point due south

Prohibitions

1. New structures and facilities are prohibited within quahog resource preserves.

Standards

1. Prior to any improvement dredging project, applicants shall be required to remove any significant shellfish in the sediments and transplant the shellfish to a RIDEM/CRMC–approved site. Appropriate sites include spawner sanctuaries, quahog resource preserves, or sites deemed appropriate by the RIDEM Division of Fish and Wildlife and CRMC.

2. Prior to any maintenance dredging project, applicants shall be required to make the proposed dredging area available for RIDEM, CRMC, or other groups, such as the Rhode Island Shellfishermen's Association, to remove any significant shellfish present in the sediments and transplant them to a RIDEM/CRMC–approved site. Appropriate sites include spawner sanctuaries, quahog resource preserves, or sites deemed appropriate by the RIDEM Division of Fish and Wildlife and CRMC.

390.2B Recommended actions

1. CRMC should change the water-use classification from Type 3 waters (High Intensity Boating) to Type 1 (Conservation Areas) or Type 2 (Low Intensity Use) in quahog resource preserve.

2. Pursuant to R.I. Gen. Laws §20-8.1-2, RIDEM should prohibit the taking of shellfish from quahog resource preserves, and the knowingly selling of shellfish taken from resource preserves, except pursuant to a transplant program authorized by and conducted under the direct supervision of the RIDEM director and the CRMC.

3. CRMC and RIDEM should consider allowing marinas to use mechanical dredges to transplant shellfish resources more efficiently and economically, potentially providing a higher percent of the stock for transplanting.

4. CRMC, in conjunction with RIDEM, should investigate the potential for biologically compensating for lost shellfish resources during maintenance dredging.

5. RIDEM, CRMC, Warwick, East Greenwich, and other management authorities should pursue restoration efforts or support efforts of nongovernment organizations, such as Save The Bay, to restore anadromous fish runs along Hardig Brook, in particular, and the Maskerchugg River, as recommended by RIDEM. Warwick and East Greenwich should amend their comprehensive plans as appropriate to support these restoration efforts.

390.2C Research needs

1. Research should be conducted to determine if anoxia is affecting shellfish recruitment.

390.3 Birds

Also see regulations and recommended actions for vegetated buffer regulations.

390.3B Recommended actions

1. Warwick should consider posting signs at access points to Mary's Creek and Baker's Creek explaining that unleashed dogs could disturb nesting birds.

390.4 Rare species

See vegetated buffer regulations and recommended actions.

390.5 Wetlands

Also see regulations and recommended actions for vegetated buffers.

390.5A Regulations

Policies

1. CRMC supports wetland restoration programs in salt marshes and contiguous freshwater or brackish wetlands adjacent to coastal waters if significant degradation of wetland functions and values can be demonstrated.

2. CRMC shall pursue restoration efforts or support efforts of Warwick or nongovernment organizations to restore tidal wetland areas identified by the SAMP or the State Habitat Restoration Plan. These efforts will help achieve the Governor's Narragansett Bay and Watershed Planning Commission goal of restoring 100 acres of coastal wetland by 2008.

390.5B Recommended actions

Definition

1. *Buildable land* is defined as a land area that satisfies all federal, state, and municipal requirements for the intended development. To be defined as buildable land, the intended development should also satisfy the requirements in the Greenwich Bay SAMP and meet all RIDEM regulations and requirements for ISDS in "Critical Resource Areas."

Recommended actions

1. To promote consistency in wetland and vegetated buffer regulations, the Rhode Island General Assembly should consider extending the boundaries of CRMC's jurisdiction over Greenwich Bay's freshwater wetlands to the boundaries of the Greenwich Bay watershed approximated by major roads and provide sufficient resources to administer the increased area, as requested by the Greenwich Bay Citizens Advisory Committee. In the event the General Assembly does extend CRMC's jurisdiction, the CRMC should become the lead agency on the recommended actions that follow.

2. The RIDEM should prohibit the filling, removing, or grading of non-coastal freshwater wetlands along tributaries to the Greenwich Bay watershed or of wetlands that provide significant storm water drainage. RIDEM should provide relief from this prohibition only in instances where filling is required to access otherwise buildable land, when no other reasonable alternatives for access exist, and when the applicant has satisfied the following burdens of proof:

a. The proposed alteration conforms to applicable goals and policies in Parts Two and Three of the Rhode Island Coastal Resources Management Program (RICRMP).
b. The proposed alteration will not result in significant adverse environmental impacts or use conflicts, including but not limited to, cumulative impacts.
c. Due to conditions at the site in question, the applicable standard cannot be met.

d. The modification requested by the applicant is the minimum variance to the applicable standard necessary to allow a reasonable alteration or use of the site.
e. The requested modification to the applicable standard is not due to any prior action of the applicant's predecessors in title.
f. Due to the conditions of the site in question, the standard will cause the applicant an undue hardship. In order to receive relief from an undue hardship an applicant must demonstrate the nature of the hardship and that the hardship is shown to be unique or particular to the site. Mere economic diminution, economic advantage, or inconvenience does not constitute a showing of undue hardship that will support the granting of a variance.

3. In cases where RIDEM approves filling of a tributary freshwater wetland or freshwater wetland that provides treatment of storm water drainage from the surrounding area in order to access otherwise buildable land in the Greenwich Bay watershed, RIDEM should require the applicant to:

a. Replace the altered wetlands with on-site wetlands of a similar type (in-kind), which provide ecological functions and values equal to or greater than that of the altered wetland and are hydrologically connected to the altered wetland.
b. Consider off-site options if on-site replacement is not feasible or environmentally preferable. In this situation, replacement wetlands should first be considered with a hydrologic connection. Out-of-kind mitigation within the Greenwich Bay watershed may be considered once options for on-site and in-kind mitigation are exhausted. In such cases, every effort shall be made to replace the primary functions and values of the altered wetland.
c. Restore or create wetlands at a minimal compensation ratio of 2:1 (area of wetland restored or created to area permanently altered or lost). Specific replacement requirements shall be determined on a case-by-case basis, taking into account such factors as size, type and functions and values of the existing wetland, and the probability of achieving fully functional replacement at the proposed mitigation site.
d. Abide by setback and buffer requirements for the wetland replacement area.
e. Receive preliminary comments on any proposed mitigation project from the state restoration authority that the proposed location and wetland mitigation type and methods are appropriate for further investigation prior to the applicant proceeding with an application to alter the wetland and design the compensatory mitigation project.

NOTE:

a. Enhancement of existing wetlands shall not be an acceptable form of mitigation under this section unless the wetland has been identified by the state as a degraded wetland in need of restoration.

b. If an offsite contribution to an ongoing restoration project is deemed appropriate by the State, the contribution must be toward a specific work phase (e.g., planting or dredging) of an ongoing wetland restoration or creation project shall be an acceptable form of mitigation under this section. The specific physical compensation shall be determined on a case-by-case basis, taking into account such factors as the size, type, and ecological value of the existing wetland, and at least equivalent to the minimum compensation requirements.

4. CRMC and RIDEM should use the coordinated application review process developed under their 2001 Memorandum of Agreement to review proposed projects in freshwater wetlands landward of the freshwater wetland jurisdictional boundary and within the Greenwich Bay watershed.

5. The Rhode Island Airport Corporation should examine the impacts from any expansion proposal on Greenwich Bay's tidal and freshwater wetlands and mitigate for any impacts within the watershed. Due to surficial geology and potential groundwater flow impacts from the airport may extend beyond the surface watershed (See Appendix C).

6. The RIDEM, in conjunction with CRMC, Warwick, East Greenwich, EPA, NRCS, and nongovernment organizations should identify and prioritize freshwater wetland restoration sites in the Greenwich Bay watershed, using methods developed and refined by Miller and Golet (2001) and Golet et al. (2002). RIDEM should pursue restoration efforts or provide technical and financial support to restoration efforts by Warwick, East Greenwich, other government agencies, or non-government organizations.

7. Because wetland restoration areas are often on private property (Golet et al. 2002), CRMC and RIDEM, in conjunction with other federal and state agencies, should explore incentives for private property owners to restore wetlands, such as state tax incentives and corporate merit awards.

8. Warwick, East Greenwich, and nongovernment organizations, in conjunction with the CRMC, RIDEM, EPA, and NRCS should work with private property owners to restore tidal and freshwater wetlands by promoting and providing outreach for these efforts.

9. CRMC and the U.S. Army Corps of Engineers (USACE) should identify potential areas within Greenwich Bay where tidal wetlands could be created or restored when CRMC grants a special exception for alterations to tidal wetlands.

390.5C Research needs

1. RIDEM should conduct or fund research to document and evaluate the potential impacts and solutions to shoaling around storm drains, such as sediment removal. However, some of these newly shoaled areas may be suitable habitat for vegetation and could provide some stormwater treatment capability.

390.6 Beaches

390.6A Definitions

1. *Recreational vehicle* is defined as a non-municipal motor vehicle, including minibikes, designed to travel over unimproved terrain and which has been determined by the Division of Motor Vehicles as unsuitable for operation on the public way and not eligible for registration for such use. This shall not be construed to include golf carts, riding lawn mowers, garden tractors, which are not registered as farm vehicles, but shall include any three (3) wheel driven vehicle and any other four (4) wheel driven vehicle, regardless of type or design, including all classes of all-terrain vehicles.

390.6B Regulations

Policy

1. It is CRMC's policy to protect horseshoe crab spawning areas. Beaches along Potowomut Neck from Sandy Point to Beachwood Drive, the northern shore of Chepiwanoxet Point, the southern shore of Buttonwoods Cove from the cove entrance to Ode Court, and at Warwick City Park are recognized as horseshoe crab spawning areas.

Prohibitions

1. Shoreline structures and activities that directly disturb horseshoe crab spawning or contribute to beach erosion along horseshoe crab spawning areas are prohibited.

Requirements

1. Applicants for shoreline structure construction and maintenance and beach nourishment in the vicinity of horseshoe crab spawning areas shall limit activities during the months of May through July that may impact spawning.

390.6C Recommended actions

1. Warwick should consider increasing awareness and enforcement of current restrictions on recreational vehicle use on public and private property, such as by posting signs at areas where illegal recreational vehicle use has been documented, increasing the response priority to recreational vehicle complaints, or increasing the penalty for violations. CRMC has signs available noting the need for a beach vehicle permit.

2. CRMC should evaluate if water-use classifications adjacent to certain Greenwich Bay beaches, such as off of the Baker's Creek barrier beach, could be changed from Type 2 waters (Low Intensity Use) to Type 1 waters (Conservation Areas).

390.6D Research needs

1. RIDEM should identify critical habitat areas for horseshoe crabs along the shoreline of Greenwich Bay and its coves.

390.7 Vegetated buffers

390.7A Definitions

1. A *coastal buffer zone* is a land area adjacent to a shoreline (coastal) feature, tributary to Greenwich Bay, or freshwater wetland in the Greenwich Bay watershed that is, or will be, vegetated with native shoreline species and which acts as a natural transition zone between the coastal and riparian areas and adjacent upland development. A coastal buffer zone differs from a construction setback (RICRMP Section 140) in that the setback establishes a minimum distance between a shoreline feature and construction activities, while a buffer zone establishes a natural area adjacent to a shoreline feature that must be retained in, or restored to, a natural vegetative condition. The coastal buffer zone is generally contained within the established construction setback.

2. *Land trusts* are organizations incorporated pursuant to R.I. Gen. Laws §7-6-1, et. seq., or organizations meeting the definition of "charitable trust" set out in R.I. Gen. Laws §18-9-4, or organizations duly existing as private nonprofit organizations in other states or the District of Columbia among whose purposes is the preservation of open space, as the term is defined in the SAMP. Further, all organizations must have been granted preliminary status as tax-exempt corporations under Section 501 (c) (3) of the Internal Revenue Code and its regulations, as they now exist or may hereafter be amended.

3. A *native vegetated area* is a previously landscaped area or lawn adjacent to a shoreline (coastal) feature, tributary to Greenwich Bay, or freshwater wetland in the Greenwich Bay watershed where native coastal or riparian species have been restored voluntarily.

4. Mary's Creek and Baker's Creek are *critical areas* in the Greenwich Bay coastal zone. Mary's Creek is a coastal wetland complex feeding one of the most productive quahog grounds in Greenwich Bay (Figures 4 and 5). Baker's Creek is a coastal wetland complex that provides valuable habitat for migratory birds. Gorton Pond's shoreline provides habitat for at least three regionally rare plant species.

390.7B Regulations

Policies

1. CRMC will update and develop standards for coastal buffer zone management specifically within suburban areas. Once completed, the CRMC will amend the Special Area Management Plan to adopt the new standards.

2. CRMC encourages the establishment of native vegetated areas along shorelines, tributaries, and wetlands in the Greenwich Bay watershed where designated coastal buffer zones or areas of existing undisturbed natural vegetation (non-landscaped areas) are not present. CRMC shall issue a certificate to property owners recognizing that they have voluntarily planted a native vegetated area on their property. Property owners holding a certificate may make alterations to the native vegetated area and will not be subject to the coastal buffer zone regulations unless these regulations are triggered by alterations to existing structures or new development on the lot.

3. It is the CRMC's policy to develop conservation easements for the Greenwich Bay watershed that permanently restrict development, such as docks, in coastal buffers.

4. No land shall be subdivided unless it can accommodate the required coastal buffer zone.

Prohibitions

1. New structures are prohibited within the coastal buffer zone required around critical areas unless part of a buffer management plan.

2. Alterations to an existing structure or structures on a residential lot that result in the expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more are prohibited without the establishment of the coastal buffer zone required in that area.

Standards

1. All coastal buffer zones shall be measured from the inland edge of the most inland shoreline (coastal) feature. In instances when the coastal feature accounts for

50 percent or more of the lot, CRMC may grant a variance to the required buffer width.

2. *Coastal buffer zone requirements for new residential development.* The minimum coastal buffer zone requirements for new residential development bordering Rhode Island's shoreline are contained in Table 2a. The Coastal Buffer Zone requirements are based upon the size of the lot and the CRMC's designated Water Types (Type 1 - Type 6). Where the buffer zone requirements noted above cannot be met, the applicant may request a variance in accordance with this SAMP A variance to 50 percent of the required buffer width may be granted administratively by CRMC's executive director if the applicant has satisfied the burdens of proof for the granting of a variance. Where it is determined that the applicant has not satisfied the burdens of proof, or the requested variance is in excess of 50 percent of the required width, the application shall be reviewed by the full council.

3. *Coastal buffer zone requirements for alterations to existing structures on residential lots.* All calculations for the requirements of a coastal buffer zone shall be made on the basis of structural lot coverage. Structural lot coverage shall mean the total square foot area of the structure(s) on a lot or parcel (RICRMP §300.3.A.5).

a. Where alterations to an existing structure or structures result in the expansion of the structural lot coverage such that the square footage of the foundation increases by less than 50 percent, no new coastal buffer zone shall be required.
b. Where alterations to an existing structure or structures result in the expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more, the coastal buffer zone requirement shall be established with a width equal to the percentage increase in the structural lot coverage as of August 8, 1995, multiplied by the value contained in Table 2a.
c. Coastal buffer zones shall not be required when a structure is demolished and rebuilt on the existing footprint. Where a structure is demolished and rebuilt and will result in an expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more, a coastal buffer zone shall be established with a width equal to the percentage increase in a structure's footprint, multiplied by the value contained in Table 2a.
d. Where the applicant demolishes a structure, any contemporary or subsequent application to rebuild must meet applicable setback requirements.
e. Structures that are less than 200 square feet in area are excluded from these requirements.

In addition, the CRMC executive director shall have the authority to grant a variance to this requirement for category "A" assents in accordance with the burdens of proof for variances contained in the SAMP .

Variances

1. Applicants desiring a variance from the coastal buffer zone standards shall make such request in writing and address in writing the six criteria below. The application shall then be granted an assent only if CRMC finds that:

a. The proposed alteration conforms to applicable goals and policies in parts two and three of the RICRMP.
b. The proposed alteration will not result in significant adverse environmental impacts or use conflicts, including but not limited to, cumulative impacts.
c. The applicable standard cannot be met due to conditions at the site in question.
d. The modification requested by the applicant is the minimum variance to the applicable standard necessary to allow a reasonable alteration or use of the site.
e. The requested variance to the applicable standard is not due to any prior action of the applicant's predecessors in title.
f. The standard will cause the applicant an undue hardship due to the conditions of the site in question. In order to receive relief from an undue hardship, an applicant must demonstrate, among other things, the nature of the hardship and that the hardship is shown to be unique or particular to the site. Mere economic diminution, economic advantage, or inconvenience does not constitute a showing of undue hardship that will support the granting of a variance. For a new residential development or alterations to existing structures on residential lots, the inability to construct a residential home larger than 1,400 square feet, which is the average square footage of a single-family Warwick home, or expand a residential home beyond 1,400 square feet does not constitute an undue hardship.

2. Relief from a standard does not remove the applicant's responsibility to comply with all other RICRMP requirements.

3. In those instances where a variance would be rendered unnecessary if a variance for a setback were acquired from the local municipality, the applicant must first approach the municipality and exhaust his remedies there prior to requesting approval for a CRMC variance.

390.7C Recommended actions

1. When restoring native vegetated areas, property owners should follow standards for managing shoreline vegetation developed by CRMC for suburban areas. Until these standards are developed, property owners should use CRMC's "Guide to Landscape Management in the Rhode Island Coastal Zone," Save The Bay's "Coastal Property and Landscape Management Guidebook" or similar publications, or follow guidance from URI Cooperative Extension or NRCS.

2. Warwick, East Greenwich, and West Warwick should evaluate the feasibility of establishing vegetated buffers on municipally owned properties within the Greenwich Bay watershed.

3. Local garden clubs and nongovernment organizations should create volunteer opportunities to participate in planting buffer zones on public and private properties.

4. The Rhode Island General Assembly should consider amending the Freshwater Wetlands Act (R.I. Gen. Laws §2-1-18 et seq.) to require more stringent setbacks or buffers adjacent to riparian areas, such as tributaries, ponds, and freshwater wetlands in the Greenwich Bay watershed. Warwick and East Greenwich should adopt these setback and coastal buffer requirements into local ordinances if passed by the General Assembly.

5. CRMC and RIDEM should form an interagency team, in conjunction with the Rhode Island Rivers Council, to establish performance standards for projects and activities proposed within the 50-foot perimeter wetland or 100- and 200-foot riverbank or riverbank wetland areas regulated by CRMC and RIDEM under the Freshwater Wetlands Act (R.I. Gen. Laws §2-1-18 et seq.).

6. Warwick and East Greenwich should consider adopting vegetated buffer ordinances, in accordance with CRMC regulations, that would require buffer maintenance or restoration prior to issuing building permits.

7. Warwick and East Greenwich should consider variances to current road setback requirements when these setbacks may force a structure to infringe on coastal buffer zones.

8. CRMC should encourage the Rhode Island Mortgage Banker's Association to enact policies that make mortgage approval in the Greenwich Bay watershed conditional on establishment of required buffers.

9. CRMC, in conjunction with RIDEM and NRCS, should consider developing an education and outreach program that explains the benefits of coastal and riparian vegetated buffers.

10. Warwick and East Greenwich should evaluate developing a plan with local groups and CRMC to monitor coastal buffer zones and native vegetated areas. Monitoring could be coordinated with adopt-a-shoreline programs.

390.8 Priority lands and acquisition

390.8A Recommended actions

1. CRMC, RIDEM, and R.I. Department of Health should explore revenue enhancement options to help fund efforts to preserve wildlife habitat and historical areas, protect water quality, improve public access, or mitigate natural hazards in the Greenwich Bay watershed.

2. The Rhode Island General Assembly should create dedicated funding for direct acquisition of coastal open space or easements in the Greenwich Bay watershed to preserve wildlife habitat and historical areas, protect water quality, improve public access, or mitigate natural hazards. The General Assembly should pass a $10 million bond proposal for this purpose. The General Assembly should establish a restricted fund to hold state monies, as well as potential fee in lieu payments from wetland and buffer mitigation in the Greenwich Bay watershed, and appropriate restricted funds to Warwick and East Greenwich for land or easement acquisition or habitat restoration in the Greenwich Bay watershed.

3. The Greenwich Bay Implementation Team (GBIT) should make it a priority task to build on the priority land analysis in this SAMP and identify additional priority lands in the Greenwich Bay watershed. The GBIT should prioritize parcels identified as critical for direct or easement acquisition taking into consideration current land vacancy, tax status, the sewer construction schedule, and other factors. The NRCS and URI should help the GBIT evaluate the relative ecological value of particular land parcels or compare the value of land parcels identified in the priority lands analysis and proposed for acquisition.

4. Contingent on federal and state funding, Warwick and East Greenwich should pursue the acquisition of land parcels or permanent conservation easements on land parcels to preserve wildlife habitat and historical areas, protect water quality, improve public access, or mitigate natural hazards in the Greenwich Bay watershed. To support these actions, the municipalities should amend their comprehensive plans to include priority lands identified in this SAMP (Figure 19) and create a restricted fund for the acquisition of open space or permanent conservation easements. Furthermore, the municipalities should investigate using local bond revenues to leverage federal, state, and private grant dollars.

5. The Warwick Sewer Authority should consider granting a deferment or abatement of the sewer assessment fee for currently undeveloped land parcels of any size if the property owner agrees to sell her development rights to a land trust or a municipal or state agency among whose purposes is the preservation of open

space and having the operational capability and legal authority to effect this purpose.

6. CRMC, in conjunction with Warwick, East Greenwich, and West Warwick, should explore the feasibility of reducing property taxes when the development rights to a portion of the property have been sold or donated to a land trust or a municipal or state agency among whose purposes is the preservation of open space and having the operational capability and legal authority to effect this purpose.

7. Warwick and East Greenwich, in conjunction with CRMC, should consider public safety, security, and the environment prior to improvements to or creation of facilities that encourage physical access to the shoreline or wetlands. In the Greenwich Bay watershed, areas including, but not limited to, salt and brackish marshes, such as Mary's Creek, Baker's Creek, and upper Brush Neck Cove; barrier beaches; and shallow, silty waters are not appropriate for facilities that encourage physical access.

Section 391
Literature Cited

Adamowicz, S.C. (1994). *1994 Eelgrass transplant project to Brushneck and Buttonwoods Coves, Greenwich Bay.* R.I. Department of Environmental Management, Narragansett Bay Project Final Report. Providence.

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. (1976). *A land use and land cover classification system for use with remote sensor data.* U.S. Geological Survey Professional Paper 96A. Washington, D.C.: U.S. Government Printing Office.

Atlantic State Marine Fisheries Commission. (1998). Interstate marine fishery management plan for horseshoe crab. *Fishery Management Report No. 32.*

Bertness, M.D. (1999). *The ecology of Atlantic shorelines.* Sunderland: Sinauer Associates, Inc.

Bertness, M.D., P.J. Ewanchuk, and B.R. Silliman. (2002). Anthropogenic modification of New England salt marsh landscapes. Proceedings of the *National Academy of Sciences 99*, 1395-1398.

Bigelow, H.B. and W.C. Schroeder. (1953). Fishes of the Gulf of Maine. *Fishery Bulletin of the Fish and Wildlife Service, 53.* Washington D.C.: U.S. Government Printing Office.

Boyd, L. (2001). *Buffer zones and beyond: wildlife use of wetland buffer zones and their protection under the Massachusetts wetland protection act.* Wetland Conservation Program, Department of Natural Resources and Conservation, University of Massachusetts, Amherst, Mass.

Burbrink, F.T., C.A. Phillips, and E.J. Heske. (1998). A riparian zone in southern Illinois as a potential dispersal corridor for reptiles and amphibians. *Biological Conservation 86*, 107-115.

Chalmers, A.G., R.G. Wiegert, and P.L. Wolf. (1985). Carbon balance in a salt marsh: interactions of diffusive export, tidal deposition, and rainfall-caused erosion. *Estuarine and Coastal Shelf Science, 21*, 757-771.

Chase, V., L. Deming, and F. Latawiec. (1997). Buffers for wetlands and surface waters: a guidebook for New Hampshire municipalities. Audubon Society of New Hampshire.

City of Warwick. (2003). Comprehensive plan for Warwick, R.I.

Clark, J. (1977). *Coastal ecosystem management*. Malabar: Robert E. Krieger Publishing Co.

Cowardin, L.M., V. Carter, F.C. Golet, and T. Laroe. (1992). *Classification of wetlands and deepwater habitats of the United States*. Washington, D.C.: U.S. Fish and Wildlife Service.

Cross, D.H. and K.L. Fleming. (1989). Control of *Phragmites* or common reed. *Waterfowl Management Handbook*. Washington, D.C.: U.S. Fish and Wildlife Service.

Cross, S.P. (1985). Responses of small mammals to forest riparian perturbations. In: *Riparian Ecosystems and their Management: Reconciling Conflicting Uses (First North American Riparian Conference)*. Ft. Collins: Rocky Mountain Forest and Range Experimentation Station.

Davies, P.E. and M. Nelson. (1994). Relationships between riparian buffer widths and the effects of logging on stream habitat, invertebrate community composition and fish abundance. *Australian Journal of Marine and Freshwater Resources, 45*, 1289-1305.

Desbonnet, A., P. Pogue, V. Lee, and N. Woolf. (1994). *Vegetated buffers in the coastal zone.* Narragansett: University of Rhode Island Coastal Resources Center and Rhode Island Sea Grant.

Donnelly, J.P. and M.D. Bertness. (2001). Rapid shoreward encroachment of salt marsh cordgrass in response to accelerated sea-level rise. *Proceedings of the National Academy of Sciences, 98*, 14218-14223.

Erkan, D.E. (2002). Strategic plan for the restoration of anadromous fishes to Rhode Island coastal streams. *Completion Report in Fulfillment of Federal Aid in Sportfish Restoration Project F-55_R.* Jamestown: R.I. Department of Environmental Management, Division of Fish and Wildlife.

Fell, P.E., S.P. Weissbach, D.A. Jones, M.A. Fallon, J.A. Zeppieri, E.K. Faison, K.A. Lennon, K.J. Newberry, and L.K. Reddington. (1998). Does invasion of oligohaline tidal marshes by reed grass, *Phragmites australis* (Cav.) Trin. ex Steud., affect the availability of prey resources for the mummichog, *Fundulus heteroclitus* L.? *Journal of Experimental Marine Biology and Ecology, 222*, 59-77.

Fischer, R.A. and J.C. Fischenich. (2000). Design recommendations for riparian corridors and vegetated buffer strips. *EMRRP Technical Notes Collection.* Vicksburg: U.S. Army Engineer Research and Development Center.

Ganz, A., N. Lazar, and A. Valliere. (1994). *Quahaug management project, phase I–Greenwich Bay.* Wakefield: R.I. Department of Environmental Management, Division of Fish, Wildlife, and Estuarine Resources, Coastal Fisheries Lab.

Gibson, M. and S. Olszewski. (2001). *Stock status of horseshoe crabs in Rhode Island in 2000 with recommendations for management.* R.I. Division of Fish and Wildlife.

Gold, A.J., P.M. Groffman, K. Addy, D.Q. Kellogg, M. Stolt, and A.E. Rosenblatt. (2001). Landscape attributes as controls on ground water nitrate removal capacity of riparian zones. *Journal of the American Water Resources Association, 37*(6): 1457-1464.

Golet, F.C., D.H.A. Myshrall, N.A. Miller, and M.P. Bradley. (2002). *Wetland restoration plan for the Woonasquatucket River watershed, Rhode Island (draft).* Prepared for R.I. Department of Environmental Management, Office of Water Resources, and U.S. Environmental Protection Agency, Region 1. Kingston: University of Rhode Island, Department of Natural Resources Science.

Gosner, K.L. (1978). *A field guide to the Atlantic seashore*. New York: Houghton Mifflin Company.

Grant, R.R. and R. Patrick. (1970). Tinicum marsh as a water purifier. In: J. McCormick, R.R. Grant, Jr., and R. Patrick (eds.), *Two Studies of Tinicum Marsh, Delaware and Philadelphia Counties, Pa.* Washington, D.C.: The Conservation Foundation.

Hill, A.R. (1996). Nitrate removal in stream riparian zones. *Journal of Environmental Quality, 25,* 743-755.

Hodges, M.F., Jr. and D.G. Krementz. (1996). Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Georgia. *Wilson Bulletin, 108(3)*, 495-506.

Hoss, D.E. and G.W. Thayer. (1993). The importance of habitat to the early life history of estuarine dependent fishes. *America Fisheries Society Symposium, 14*, 147-158.

Howard, R., D.G. Rhodes and J.W. Simmers, (1978). A review of the biology and potential control techniques for *Phragmites australis*.

Jeffries, H.P. and W.C. Johnson. (1974). Seasonal distributions of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (*Pseudopleuronectes americanus*). *J. Fish. Res. Board Can. 31*, 1057-1066.

Kadlec, R.H. (1983). The Bellaire wetlands: wastewater alteration and recovery. *Wetlands, 3*, 44-63.

Karr, J.R. and I.J. Schlosser. (1977). *Impact of nearstream vegetation and stream morphology on water quality and stream biota.* Washington, D.C.: U.S. Environmental Protection Agency.

Keller, A.A., G. Klein-MacPhee, and G. St. Onge Burns. (1999). Abundance and distribution of ichthyoplankton in Narragansett Bay, Rhode Island, 1989-1990. *Estuaries, 22*(1), 149-163.

Keller, C.E., C.S. Robbins, and J.S. Hatfield. (1993). Avian communities in riparian forests of different widths in Maryland and Delaware. *Wetlands, 13*(2),137-144.

Kleinschmidt Associates. (2001). *Woonasquatucket River riparian buffer restoration project.* Prepared for the R.I. Department of Environmental Management, Sustainable Watersheds Office, and the Woonasquatucket River Watershed Council.

Kopp, B., A.M. Doherty, and S.W. Nixon. (1995). *A guide to site-selection for eelgrass restoration projects in Narragansett Bay, Rhode Island*. Report to Aqua fund.

Lipsky, A. (2003). Development of an eelgrass restoration site selection model for Narragansett Bay. *Appendix D: Wildlife Habitat Incentive Program Technical Guidance Document*. Warwick, RI: USDA-Natural Resources Conservation Service.

Lewis, J.C. and R.L. Garrison. (1984). *Habitat suitability index models: American black duck (wintering).* Washington, D.C.: U.S. Fish and Wildlife Service.

Long Island Sound Study. (2003). *Long Island Sound habitat restoration initiative: technical support for coastal habitat restoration.*

Miller, N.A. and F.C. Golet. (2001). *Development of a statewide freshwater wetland restoration strategy: site identification and prioritization methods.* Prepared for R.I. Department of Environmental Management, Office of Water Resources, and U.S. Environmental Protection Agency, Region 1. Kingston: University of Rhode Island, Department of Natural Resources Science.

Mitsch, W.J. and J.G. Gosselink. (1986). *Wetlands*. New York: Van Nostrand Reinhold Company.

Mitsch, W.J. and J.G. Gosselink. (1993). *Wetlands* (2nd ed.) New York: Van Nostrand Reinhold Company.

Mulé, M.F. and F.C. Golet. (2005). *Inventory of prioritization of potential riparian buffer restoration sites in the Greenwich Bay and Buckeye Brook Watersheds, Rhode Island - DRAFT*. Prepared for R.I. Department of Environmental Management, Office of Sustainable Watersheds. Kingston: University of Rhode Island, Department of Natural Resources Science.

Narragansett Bay Estuary Program. (2001). *Atlas of Narragansett Bay Coastal Habitats.*

Neibling, W.H. and E.E. Alberts. (1979). Composition and yield of soil particles transported through sod strips. *American Society of Agricultural Engineers Paper No. 79-2065*. St. Joseph: American Society of Agricultural Engineers.

Niering, W.A. (1988). Endangered, threatened, and rare wetland plants and animals of the continental United States. In: Hook, D.D. et al. (eds.), *The Ecology and Management of Wetlands, Vol. 1: Ecology of Wetlands*.

Niering W.A. and R.S. Warren. (1977). Salt Marshes. In: Clarke, J. (ed.) *Coastal Ecosystem Management: A Technical Manual for the Conservation of Coastal Zone Resources*. The Conservation Foundation.

Nixon, S.W. (1980). Between coastal marshes and coastal waters—a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry. In: P. Hamilton and K.B. MacDonald (eds.), *Estuarine and wetland processes*, New York: Plenum.

Nixon, S. W. (1989). An extraordinary red tide and fish kill in Narragansett Bay. In: *Coastal and Estuarine Studies*. E. M. Cosper, V. M. Bricelj, and E. J. Carpenter (Eds.) New York: Springer-Verlag.

Nixon, S.W. and C.D. Oviatt. (1973). Ecology of a New England salt marsh. *Ecological Monographs 43*(4), 463-498.

Nordstrom, K.F. (2000). *Beaches and dunes of developed coasts.* Cambridge: Cambridge University Press.

Novitzki, R.P. (1979). Hydrologic characteristics of Wisconsin's wetlands and their influence on floods, stream flow, and sediment. In: Greeson, P.E., J.R. Clark, and J.E. Clark (eds.), *Wetland Functions and Values: The State of Our Understanding*. Minneapolis: American Water Resources Association.

Nowicki, B.L. and J.H. McKenna. (1990). *A preliminary assessment of environmental quality in Greenwich Bay, Rhode Island.* Final Report to the Narragansett Bay Project.

Olsen, S., D. D. Robadue Jr., and V. Lee. (1980). *An interpretive atlas of Narragansett Bay.* Narragansett: University of Rhode Island Coastal Resources Center.

Ostendorp, W. (1993). Reed bed characteristics and significance of reeds in landscape ecology. *Limnologie Aktuell 5*, 149-161.

Oviatt, C., S. Olsen, M. Andrews, J. Collie, T. Lynch, K. Raposa. (2003). A century of fishing and fish fluctuations in Narragansett Bay. *Reviews in Fisheries Science, 11,* 221-242.

Palfrey, R. and E. Bradley. (1982). *The buffer area study*. Annapolis: Maryland Department of Natural Resources, Coastal Resources Division, Tidewater Administration.

Palone, R.S. and A.H. Todd. (1998). *Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers.* Radnor: U.S. Department of Agriculture Forest Service.

Pelligrino, P.E., and A.T. Carroll, (1974). The distribution of invertebrates in Connecticut salt marshes. In: Neiring W.A. and R.S. Warren (eds.), *Tidal Wetlands of Connecticut: Vegetation and Associated Animal Populations, Vol. 1.* State of Connecticut, Department of Environmental Protection and Bureau of Sports, Fisheries, and Wildlife. Washington, D.C.: U.S. Department of the Interior.

Peters, D.S., D.W. Ahrenholz, and T.R. Price. (1979). Harvest and value of wetland associated fish and shellfish. In: Greeson, P.E., J.R. Clark, and J.E. Clark (eds.), *Wetland Functions and Values: The State of Our Understanding*. Minneapolis: American Water Resources Association.

Phillips, R.C. and C.P. McRoy (eds.). (1990). Seagrass research methods. Paris: United Nations Educational, Scientific and Cultural Organization.

Pierce, R.J., (1977). *Wetland plants of the eastern United States.* New York: U.S. Army Corp of Engineers, North Atlantic Division.

Rice, M.A. (1992). *The northern quahog: the biology of* Mercenaria mercenaria. Narragansett: Rhode Island Sea Grant.

R.I. Coastal Resources Management Council. (2000). *A guide to landscape management in the Rhode Island coastal zone.*

R.I. Department of Environmental Management. (2000). *What's the scoop on wetlands?: frequently asked questions about DEM's freshwater wetland program.*

R.I. Department of Environmental Management. (2002). Stock status of marine resources and summary of fisheries management in Rhode Island: a report to the Rhode Island General Assembly. Jamestown: R.I. Department of Environmental Management, Division of Fish and Wildlife, Marine Fisheries Section.

R.I. Department of Environmental Management. (2003). *Management plan for the shellfish fishery sector.* Jamestown: R.I. Department of Environmental Management, Division of Fish and Wildlife, Marine Fisheries Section.

R.I. Department of Environmental Management. (2003b). *The Greenwich Bay fish kill, August 2003: causes, impacts and responses.* Providence: R.I. Department of Environmental Management, Office of Water Resources.

R.I. Department of Environmental Management. (2004). Question 8: $70,000,000 open space, recreation, bay and watershed protection bond. *Rhode Island Department of Environmental Management Fact Sheet*.

Short, F.T. and A.C. Mathieson. (1985). Wasting disease: eelgrass decline in the Great Bay Estuary. *Estuaries, 8*(2B), 49A.

Short, F.T. and D.M. Burdick. (1996). Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries, 19*, 730-739.

Short, F.T., R.C. Davis, B.S. Kopp, C.A. Short and D.M. Burdick. 2002. Site-selection model for optimal transplantation of eelgrass *Zostera marina* in the northeastern U.S. *Marine Ecology Progress Series, 227*, 269-273.

Smith, A.E., S.R. Craven, and P.D. Curtis. (1999). *Managing Canada geese in urban environments.* Ithaca: Jack Berryman Institute and Cornell University Cooperative Extension.

Spackman, S.C. and J.W. Hughes. (1995). Assessment of minimum corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont, USA. *Biological Conservation 71*, 325-332.

Tiner, R.W., (1989). *Wetlands of Rhode Island.* Newton Corner: U.S. Fish and Wildlife Service, National Wetlands Inventory.

Tiner, R.W., I.J. Huber, T. Nuerminger, and A.L. Mandeville. (2003). *An inventory of coastal wetlands, potential restoration sites, wetland buffers, and hardened shorelines for the Narragansett Bay estuary.* Hadley: U.S. Fish and Wildlife Service, Northeast Region. In cooperation with the University of Massachusetts, Amherst, the University of Rhode Island, and the Narragansett Bay Estuary Program. National Wetlands Inventory Cooperative Interagency Report.

Town of East Greenwich. (2003). Comprehensive plan for East Greenwich, R.I.

Trimble, G.R., Jr. and R.S. Sartz. (1957). How far from a stream should a logging road be located? *Journal of Forestry, 55*, 339-341.

Valiela, I., K. Foreman, M. LaMontagne, D. Hersh, J. Costa, P. Peckol, B. Demeo-Anderson, C. D'Avanzo, M. Babione, C.H. Sham, and K. Lajtha. (1992). Couplings of watersheds and coastal waters: sources and consequences of nutrient enrichment in Waquoit Bay, Massachusetts. *Estuaries, 15,* 443-457.

Valiela, I., J.M. Teal, S. Volkmann, D. Shafer, and E.J. Carpenter. (1978). Nutrient and particulate fluxes in a salt marsh ecosystem: tidal exchanges and inputs by precipitation and groundwater. *Limnology and Oceanography, 23*, 798-812.

Wainwright, S.C., M.P. Weinstein, K.W. Able, and C.A. Currin. (2000). Relative importance of benthic macroalgae, phytoplankton and the detritus of smooth cordgrass *Spartina alterniflora* and the common reed *Phragmites australis* to brackish-marsh food webs. *Marine Ecology Progress Series, 200*, 77-91.

Wenger, S. (1999). *A review of the scientific literature on riparian buffer width, extent and vegetation.* Athens: Office of Public Service & Outreach, Institute of Ecology, University of Georgia.

Wong, S.L. and R.H. McCuen. (1982). *Design of vegetative buffer strips for runoff and sediment control*. Annapolis: Maryland Department of Natural Resources, Coastal Resources Division, Tidewater Administration.

Chapter 4
Water Quality

Table of Contents

Tables

Figures

Section 400
Introduction

1. Greenwich Bay water quality is characterized by high fecal bacteria levels, low dissolved oxygen levels, and high nitrogen inputs. Fecal bacterial contamination forces closure of shellfish beds and swimming beaches. Low dissolved oxygen levels can lead to fish kills. High nitrogen inputs to Greenwich Bay contribute to phytoplankton blooms, localized macroalgae blooms, the loss of eelgrass meadows, and other effects associated with eutrophication. When phytoplankton and macroalgae die and decay, they can contribute to low dissolved oxygen levels and cause odor problems. Due to these problems, the R.I. Coastal Resources Management Council (CRMC) and the R.I. Department of Environmental Management (RIDEM) have determined that Greenwich Bay, its coves, and many of its tributaries need restoration plans developed to improve water quality, as required and authorized under federal and state law.

2. Point and nonpoint sources of fecal bacteria and nitrogen degrade Greenwich Bay water quality. From a regulatory standpoint, the significant point sources to Greenwich Bay and its tributaries are storm drains and any channelized conveyances of runoff, such as ditches or swales, subject to Phase I and II U.S. Environmental Protection Agency (EPA) storm water regulations (whether on developed or undeveloped land) as well as the East Greenwich wastewater treatment facility (WWTF). RIDEM regulates point source discharges under the Rhode Island Pollution Discharge Elimination System (RIPDES). Significant nonpoint sources are unregulated and unchannelized stormwater runoff, groundwater, tidal waters flowing into Greenwich Bay from Narragansett Bay, and atmospheric deposition. Stormwater and nonpoint sources may carry pollutants originating both from within and outside the watershed to Greenwich Bay.

3. Storm water is the primary means that fecal bacteria originating within the watershed reaches Greenwich Bay (Food and Drug Administration (FDA), 1993; DeMelo et al., 1997; Herron et al., 1998; Wright et. al., 1998; Southern Rhode Island Conservation District (SRICD), 1999; Wright and Viator, 1999; SRICD, 2003; RIDEM, 2004a). Impervious surfaces cover a large percentage of the Greenwich Bay watershed and contribute to increased surface runoff and the washing of pollutants from individual sewage disposal systems (ISDS), pets, wildlife, and other sources into stormwater drains. Storm water and groundwater also transport nitrogen from ISDS and other sources to the bay. The East Greenwich WWTF is another major nitrogen source within the watershed.

4. A primary goal of the Greenwich Bay Special Area Management Plan (SAMP) is to restore and protect Greenwich Bay's water quality. New management initiatives and monitoring of Greenwich Bay's waters and pollution sources will help improve water quality, which will promote better and safer swimming opportunities, increase access to commercial and recreational fishing areas, and increase property values. Due to the fact that Greenwich Bay's watershed is characterized by urban and suburban development, much of the effort to restore water quality will require remedial, rather than preventative, actions.

5. Nitrogen originating from outside the Greenwich Bay watershed is transported to Greenwich Bay in the air and with tidal waters from Narragansett Bay. In addition, tidal waters with low dissolved oxygen levels entering from Narragansett Bay may contribute to low dissolved oxygen levels in Greenwich Bay. In contrast, there are no significant sources of bacteria to Greenwich Bay that originate outside the Greenwich Bay watershed.

6. The SAMP is not the only water quality restoration plan being developed for areas in the Greenwich Bay watershed. RIDEM is required under Section 303(d) of the federal Clean Water Act to list all water bodies that are not meeting water quality standards (33 USC §1313(d)). Water quality standards are established in accordance with national guidance and vary depending on the RIDEM water quality classification, also known as a designated use, for a water body. Greenwich Bay, its coves, and its tributaries are composed of five RIDEM–designated water quality classifications (Figure 1). Class SA waters and Class A waters correspond to the highest water quality standards for seawater and freshwater, respectively (Table 2). Greenwich Bay, its coves, and many of its tributaries appear on the 2002 303(d) list primarily because of problems with bacterial contamination (referred to as pathogens), nutrients, or low dissolved oxygen (Table 3). Under the federal Clean Water Act, RIDEM must develop a Total Maximum Daily Load (TMDL) or equivalent restoration plan for each water body that does not meet water quality standards for a particular pollutant. RIDEM has developed a draft TMDL for bacterial contamination in the Greenwich Bay watershed (RIDEM, 2004a). It is RIDEM's intention that this SAMP will serve as an equivalent restoration plan for low dissolved oxygen and other nutrient-related impairments.

7. The SAMP and TMDLs build upon efforts to improve Greenwich Bay's water quality under the Greenwich Bay Initiative. The conditional closure of Greenwich Bay's open waters to shellfishing in 1992 prompted an intense decade of monitoring and analysis of Greenwich Bay's waters. The Greenwich Bay Initiative was an effort to coordinate government and private agencies concerned with restoring the ecological health of Greenwich Bay. The groups involved in this work included CRMC, RIDEM, Warwick, East Greenwich, the Warwick Sewer Authority (WSA), the R.I. Department of Transportation (RIDOT), the University of Rhode Island (URI), EPA, SRICD, the Rhode Island Sea Grant College Program, Save The Bay, the Rhode Island Shellfishermen's Association, and concerned citizens.

Table 1. Important federal and state agencies for water quality issues

Agency	Duties
Federal agencies	
EPA	EPA has authority to regulate and manage nationwide water quality. The EPA develops policy and guidance under the Clean Water Act and monitors state compliance with requirements, such as TMDL development. Among other things, the EPA can establish minimum requirements for point source discharge permits, recreational water quality standards for beaches, and standards for vessel sewage discharge. The EPA administers oil and hazardous substance spill programs, toxic pollutant and pretreatment programs, and numerous low-interest loan and grant programs to improve water quality. http://www.epa.gov/
FDA	FDA sets allowable levels of contaminants in fish and shellfish for human consumption. Its sanitation standards for shellfish are the basis for state pollution closures of shellfish beds. http://www.fda.gov/
National Oceanic and Atmospheric Administration (NOAA)	NOAA is the lead federal agency on coastal, ocean, and weather issues. NOAA, with EPA, develops guidance for state coastal nonpoint pollution control programs, and reviews and approves state programs. http://www.ocrm.nos.noaa.gov/czm/6217/
NRCS	NRCS works to conserve soil, water, and other natural resources through a variety of voluntary, incentive-based programs. NRCS partners with state and local agencies and organizations as well as landowners to provide technical and financial assistance to implement BMPs to limit nonpoint source water pollution. http://www.nrcs.usda.gov/

Agency	Duties
State agencies	
CRMC	CRMC is the lead state agency for coastal zone management in Rhode Island. Its primary responsibilities are for the preservation, protection, development and where possible the restoration of the coastal areas of the state via coastal planning and the issuance of permits for work within the state's coastal zone. CRMC's core jurisdiction extends from the territorial sea limit (3 miles offshore) to 200 feet inland from any coastal feature, such as a beach, but its jurisdiction may be larger for certain activities. CRMC regulates the treatment of stormwater and sewage discharges that could affect coastal waters. CRMC reserves the right to review any activity proposed within the watershed of a poorly flushed estuary, like Greenwich Bay, through the development and adoption of a SAMP. http://www.crmc.state.ri.us/
RIDEM	RIDEM is the lead state agency for environmental protection statewide. Together with many partners, RIDEM offers assistance to individuals, businesses and municipalities; conducts research; and enforces laws created to protect the environment. RIDEM administers numerous programs to protect and improve water quality in Rhode Island, such as: - Adopting state water quality standards - Issuing RIPDES permits to point sources of pollution - Regulating the installation and replacement of ISDS - Developing TMDL water quality restoration plans for water bodies that are not meeting water quality standards - Monitoring water quality to support program efforts - Enforcing boat no discharge requirements - Issuing water-quality certifications for activities that can impact water quality, such as marina expansions and dredging - Administering low-interest loan and grant programs to improve water quality http://www.state.ri.us/dem/
HEALTH	HEALTH is the lead state agency for bathing beach monitoring statewide. HEALTH is responsible for the protection of public health by minimizing the public's exposure to disease causing bacteria in bathing waters. HEALTH licenses and regulates 119 beaches statewide. Through an EPA grant, HEALTH collects water quality samples at all coastal beaches and, when appropriate, closes these facilities when standards are violated. http://www.health.state.ri.us/environment/beaches/index.html

Table 2. Water quality classifications and standards for fecal coliform bacteria, dissolved oxygen, and nutrients

	Water Quality Standards			
Classification – use [1]	Fecal coliform [1]	Dissolved oxygen [1]	Nutrients	Applicable waters [2]
Seawaters				
Class SA - Shellfish harvesting for direct human consumption, primary and secondary contact recreation, and fish and wildlife habitat, and shall have good aesthetic value.	Not to exceed a geometric mean most probable number (MPN) value of 14 and not more than 10 percent of the samples shall exceed an MPN value of 49 for a 3-tube decimal dilution.	Not less than 6 mg/L at any place or time, except as naturally occurs. Normal seasonal and diurnal variations which result in *in situ* concentrations above 6 mg/L not associated with cultural eutrophication will be maintained.	None in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication [3]. Shall not exceed site- specific limits if deemed necessary by the RIDEM director to prevent or minimize accelerated or cultural eutrophication. Total phosphorus, nitrates and ammonia may be assigned site- specific permit limits based on reasonable Best Available Technologies. Where waters have low tidal flushing rates, applicable treatment to prevent or minimize accelerated or cultural eutrophication may be required for regulated nonpoint source activities.	Greenwich Bay proper Brush Neck Cove Buttonwoods Cove Mouth of Warwick Cove Baker's Creek
Class SB - Primary and secondary contact recreation, fish and wildlife habitat, shellfish harvesting for controlled relay and depuration, and shall have good aesthetic value.	Not to exceed a geometric mean MPN value of 50 and not more than 10 percent of the samples shall exceed an MPN value of 500.	Not less than 5 mg/L at any place or time, except as naturally occurs. Normal seasonal and diurnal variations which result in *in situ* concentrations above 5 mg/L not associated with cultural eutrophication will be maintained.		Apponaug Cove Warwick Cove Mouth of Greenwich Cove Mary's Creek

	Water Quality Standards			
Classification – use [1]	**Fecal coliform [1]**	**Dissolved oxygen [1]**	**Nutrients**	**Applicable waters [2]**
Class SB1 - Primary and secondary contact recreation, fish and wildlife habitat, and shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. All Class SB criteria must be met.	Not to exceed a geometric mean MPN value of 50 and not more than 10 percent of the samples shall exceed an MPN value of 500.			Greenwich Cove
Freshwaters				

	Water Quality Standards			
Classification – use [1]	Fecal coliform [1]	Dissolved oxygen [1]	Nutrients	Applicable waters [2]
Class A - Primary and secondary contact recreation and fish and wildlife habitat, and shall have good aesthetic value.	Not to exceed a geometric mean value of 20 and not more than 10 percent of the samples shall exceed a value of 200.	*Cold Water Fish Habitat* - Dissolved oxygen content of not less than 75 percent saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5 mg/l. For the period from October 1st to May 14th, where in areas identified by the R.I. Division of Fish and Wildlife as cold water fish spawning areas the following criteria apply: For species whose early life stages are not directly exposed to the water column (i.e., early life stages are intergravel), the 7 day mean water column dis solved oxygen concentration shall not be less than 9.5 mg/l and the instantaneous minimum dissolved oxygen concentration shall not be less than 8 mg/l. For species that have early life stages exposed directly to the water column, the 7 day mean water colum dissolved oxygen concentration shall not be less than 6.5 mg/l and the instantaneous minimum dissolved oxygen concentration shall not be less than 5.0 mg/l. *Warm Water Fish Habitat* - Dissolved oxygen content of not less than 60 percent saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5.0 mg/l. The 7 day mean water column dissolved oxygen concentration shall not be less than 6 mg/l.	a. Average Total Phosphorus shall not exceed 0.025 mg/l in any lake, pond, kettlehole or reservoir, and average Total P in tributaries at the point where they enter such bodies of water shall not cause exceedance of this phosphorus criteria, except as naturally occurs, unless the RIDEM director determines, on a site-specific basis, that a different value for phosphorus is necessary to prevent cultural eutrophication [1]. b. None in such concentration that would impair any usages specifically assigned to said Class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion of 10(a) above in a downstream lake, pond, or reservoir. New discharges of wastes containing phosphates will not be permitted into or immediately upstream of lakes or ponds. Phosphates shall be removed from existing discharges to the extent that such removal is or may become technically and reasonably feasible.	Baker's Creek Tuscatucket Brook Southern Creek (Carpenter Brook) Unnamed Brook – Buttonwoods Cove
Class B - Primary and secondary contact recreation and fish and wildlife habitat, and shall have good aesthetic value.	Not to exceed a geometric mean value of 200 and not more than 20 percent of the samples shall exceed a value of 500.			Hardig Brook Mill Brook Gorton Pond and Tributary Cedar Brook Dark Entry Brook Greenwood Creek Maskerchugg River Fosters Brook Oakside Street Brook Pequot Street Brook

1 These classifications and standards reflect current rules, as of January 2005. Draft rule changes may change these classifications and standards at a future date.

2 Waters that are not specifically mentioned in the RIDEM Water Quality Regulations are generally classified the same as the water body into which they drain.

3 "Cultural eutrophication" means the human-induced acceleration of primary productivity in a surface water body resulting in nuisance conditions of algal blooms and/or dense macrophytes [RIDEM Water Quality Regulations, August 6, 1997 (Amended June 23, 2000) Rule 7].

Source: RIDEM Water Quality Regulations, August 6, 1997 (Amended June 23, 2000), Rule 8

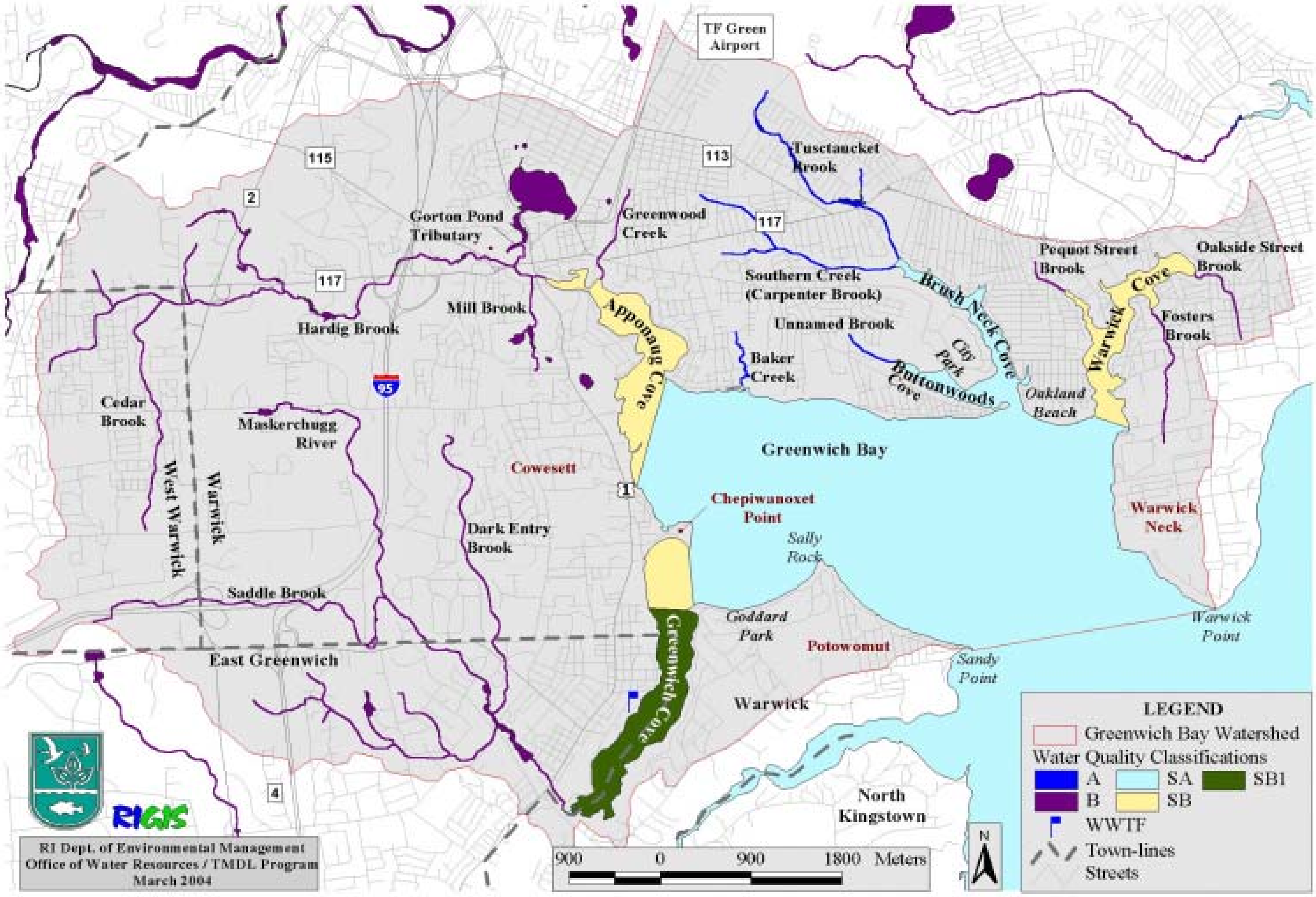
Table 3. Impaired waters in the Greenwich Bay watershed

Waterbody ID	Name	RIDEM water quality classification	Pollution problem [1]
RI0007025E-01	Apponaug Cove	SB	P, N, DO, AG
RI0007025R-01	Hardig Brook	B	P, Pb, Bio
RI0007025L-01	Gorton Pond	B	N, DO, AG
RI0007025R-12	Gorton Pond Tributary	B	P
RI0007025R-02	Cedar Brook	B	P
RI0007025R-14	Mill Brook	B	P
RI0007025R-11	Greenwood Creek	B	P
RI0007025E-02	Brush Neck Cove	SA	P, N, DO
RI0007025R-05	Tuscatucket Brook	A	P
RI0007025R-09	Southern Creek	A	P
RI0007025E-03	Buttonwoods Cove	SA	P, N, DO
RI0007025E-04A	Greenwich Bay	SA	P, N, DO
RI0007025E-04B	Greenwich Bay	SA	P, N, DO
RI0007025R-06	Baker's Creek	A	P
RI0007025E-05A	Greenwich Cove	SB1	P, N, DO
RI0007025E-05B	Greenwich Cove	SB	P, N, DO
RI0007025R-03	Maskerchugg River	B	P, Pb, Cd, Cu
RI0007025R-04	Dark Entry Brook	B	P
RI0007025E-06A	Warwick Cove	SB	P, N, DO
RI0007025E-06B	Warwick Cove	SA	P, N, DO
RI0007025R-07	Fosters Brook	B	P

1 P = Pathogens (fecal coliform/bacteria); N = Nutrients; DO = Low Dissolved Oxygen; AG = Excess Algal Growth / Chlorophyll a; Bio = Biodiversity Impacts; Pb = Lead; Cd = Cadmium; Cu = Copper

Source: RIDEM, 2003a; RIDEM, 2004a

Figure 1. RIDEM water quality classifications in the Greenwich Bay watershed



Source: RIDEM, 2004a

Section 410
Greenwich Bay and watershed characteristics

1. Greenwich Bay is a shallow embayment located in Narragansett Bay, partially sheltered by Warwick Neck to the north and Potowomut Neck to the south (Figure 2). The bay covers approximately 4.6 square miles (12 km^2) and includes five major coves: Warwick, Brush Neck, Buttonwoods, Apponaug, and Greenwich (Brush, 2002). These coves constitute an estimated 8.4 percent of the total volume of Greenwich Bay (Brush, 2002). The average depth of Greenwich Bay is 8.5 feet (2.6 m). Semidiurnal tides in Greenwich Bay have amplitudes of 1.8 feet (0.55 m) and maximum current speeds of 0.5 feet per second (15 cm/s; Spaulding, 1998). The estimated water residence time of Greenwich Bay is approximately 8.8 days (Erikson, 1998). Residence times of the smaller coves are shorter (Table 4). However, recent maintenance dredging at Greenwich Bay's marinas may have modified local water depths, volume, and residence times in Greenwich Bay since Brush (2002) estimated these factors (Deacutis, pers. comm.). Because Greenwich Bay is a part of Narragansett Bay, it should also be noted that Narragansett Bay waters have a residence time of approximately 25 days (Pilson, 1985). Basic geographic features for Greenwich Bay's different areas are summarized in Table 4.

2. Greenwich Bay is an estuary (where freshwater mixes with saltwater). The largest freshwater inputs to Greenwich Bay are Hardig Brook, flowing to Apponaug Cove, and the Maskerchugg River, flowing to Greenwich Cove (Wright pers. comm.). These inputs represent more than 60 percent of the freshwater inputs to Greenwich Bay. The remaining 40 percent come from smaller tributaries, the East Greenwich WWTF, direct surface runoff, groundwater flow, and storm water outfalls to Greenwich Bay (Table 5). Saltwater flows into Greenwich Bay from Narragansett Bay and mixes with the freshwater. Vertical density stratification develops in Greenwich Bay, particularly during low-energy conditions, such as neap tides and low winds (Granger et al., 2000; RIDEM, 2003e).

3. The most recent land use maps available indicate that the Greenwich Bay watershed, covering approximately 13,550 acres or 21.2 square miles (54.8 km^2), encompasses a diversity of land uses (Rhode Island Geographic Information System (RIGIS), 1995). Residential and commercial development cover more than 60 percent of the land area.

4. Historically, the three municipalities encompassing the Greenwich Bay watershed grew most dramatically between 1920 and 1970 (Figure 3). During that period, the population grew by 85,362 people or 265 percent, primarily in Warwick. From 1970 to 2000, the growth rate slowed to 9 percent in both East Greenwich and Warwick. Over the next 30 years, population growth is projected to grow even more slowly, at 3 percent (Rhode Island Statewide Planning Program, 2004a). However, only a portion of each municipality is within the Greenwich Bay watershed, and population changes within the watershed may be larger or smaller than the municipal-wide numbers. It is estimated that in 2000, nearly 47,952 people lived in the Greenwich Bay watershed. Between 1990 and 2000, the estimated population increased by 5 percent, while total households increased by 12 percent[1]. From 1970 to 2000, most areas directly along the

[1] Housing and population densities were first calculated per census block for the 1990 and 2000 Census data and then multiplied by the proportion of the census block covered by the watershed.

Greenwich Bay shoreline experienced population losses or minimal growth (Figure 4), which may indicate that these areas are nearly built-out.

5. The population in the Greenwich Bay watershed is serviced by ISDS or sewers leading to three WWTFs. Warwick and the West Warwick WWTFs discharge to the Pawtuxet River, outside of the Greenwich Bay watershed. The East Greenwich WWTF discharges to Greenwich Cove. The remaining homes and businesses in the Greenwich Bay watershed are on ISDS. Sanitary sewers are or will be available to a large portion of the developed areas in the Greenwich Bay watershed (Figure 5). After sewer expansions are complete, Potowomut, Warwick Neck, and Cowesett will be the only major population areas in the Greenwich Bay watershed still relying on ISDS.

Each census block contains 1,000 people, providing the greatest resolution in the U.S. Census database.

Table 4. Geographic features of the Greenwich Bay watershed

	Area (acres)		Water depth (feet)		Water volume (million gallons)	Mean residence time (days)
	Land	Water	Mean	Maximum		
Warwick Cove	919 ($3.7\ km^2$)	95 ($0.4\ km^2$)	3.3 (1.0 m)	9.8 (3.0 m)	98 ($3.7 \times 10^5\ m^3$)	3.6
Brush Neck & Buttonwoods coves	1,847 ($7.5\ km^2$)	65 ($0.3\ km^2$)	1.6 (0.5 m)	7.9 (2.4 m)	36 ($1.4 \times 10^5\ m^3$)	0.9
Apponaug Cove	4,316 ($17.5\ km^2$)	75 ($0.3\ km^2$)	2.6 (0.8 m)	7.9 (2.4 m)	61 ($2.3 \times 10^5\ m^3$)	0.4
Greenwich Cove	4,484 ($18.1\ km^2$)	252 ($1.0\ km^2$)	6.2 (1.9 m)	16 (4.9 m)	511 ($1.9 \times 10^6\ m^3$)	3.3
Inner Greenwich Bay	497 ($2.0\ km^2$)	225 ($0.9\ km^2$)	6.9 (2.1 m)	-	511 ($1.9 \times 10^6\ m^3$)	0.7
Mid Greenwich Bay	503 ($2.0\ km^2$)	620 ($2.5\ km^2$)	9.2 (2.8 m)	-	1,853 ($7.0 \times 10^6\ m^3$)	1.0
Eastern Greenwich Bay	668 ($2.7\ km^2$)	1,642 ($6.6\ km^2$)	9.8 (3.0 m)	-	5,337 ($2.0 \times 10^7\ m^3$)	1.8
Total	13,234 ($53.5\ km^2$)	2,974 ($12.0\ km^2$)	8.5 (2.6 m)	35.1 (10.7 m)	8,407 ($3.2 \times 10^7\ m^3$)	8.8

Source: Brush, 2002

Table 5. Mean freshwater inputs to Greenwich Bay from 1995-1996

	Streams and groundwater (million gallons/year)	Atmospheric[1] (million gallons/year)	Total freshwater inputs	
			Annual flow (million gallons/year)	Percentage
Warwick Cove *Oakside Street Brook* *Fosters Brook* *Pequot Avenue Stream*	554.8 (2.1 x 10^6 m^3/yr)	-2.6 (-0.01 x 10^6 m^3/yr)	552.1 (2.1 x 10^6 m^3/yr)	5.7 percent
Brush Neck and Buttonwoods Coves *Southern Creek* *Tuscatucket Brook*	1,003.8 (3.8 x 10^6 m^3/yr)	-2.6 (-0.01 x 10^6 m^3/yr)	1,001.3 (3.8 x 10^6 m^3/yr)	10.3 percent
Apponaug Cove *Hardig Brook (Gorton Pond Tributary, Mill Brook)*	3,170.1 (12.0 x 10^6 m^3/yr)	-7.9 (-0.03 x 10^6 m^3/yr)	3,162.2 (12.0 x 10^6 m^3/yr)	32.6 percent
Greenwich Cove *Maskerchugg River (Saddle Brook, Nichols Brook)*	2,932.3 (11.1 x 10^6 m^3/yr)	-2.6 (-0.01 x 10^6 m^3/yr)	2,929.7 11.1 x 10^6 m^3/yr	30.1 percent
E. Greenwich WWTF	317.0 (1.2 x 10^6 m^3/yr)	0	317.0 1.2 x 10^6 m^3/yr	3.3 percent
Inner Greenwich Bay	317.0 (1.2 x 10^6 m^3/yr)	0	317.0 (1.2 x 10^6 m^3/yr)	3.3 percent
Mid Greenwich Bay	343.4 (1.3 x 10^6 m^3/yr)	31.7 (0.12 x 10^6 m^3/yr)	375.1 (1.4 x 10^6 m^3/yr)	3.8 percent
Eastern Greenwich Bay	449.1 (1.7 x 10^6 m^3/yr)	626.1 (2.37 x 10^6 m^3/yr)	1,075.2 (4.0 x 10^6 m^3/yr)	10.9 percent
Total System	**9,087.5** **(34.4 x 10^6 m^3/yr)**	**644.6** **(2.44 x 10^6 m^3/yr)**	**9,732.1** **(36.8 x 10^6 m^3/yr)**	**100 percent**

[1] Atmospheric freshwater inputs = precipitation minus evaporation

Source: Brush, 2002; Wright pers. comm.

Figure 2. Greenwich Bay watershed

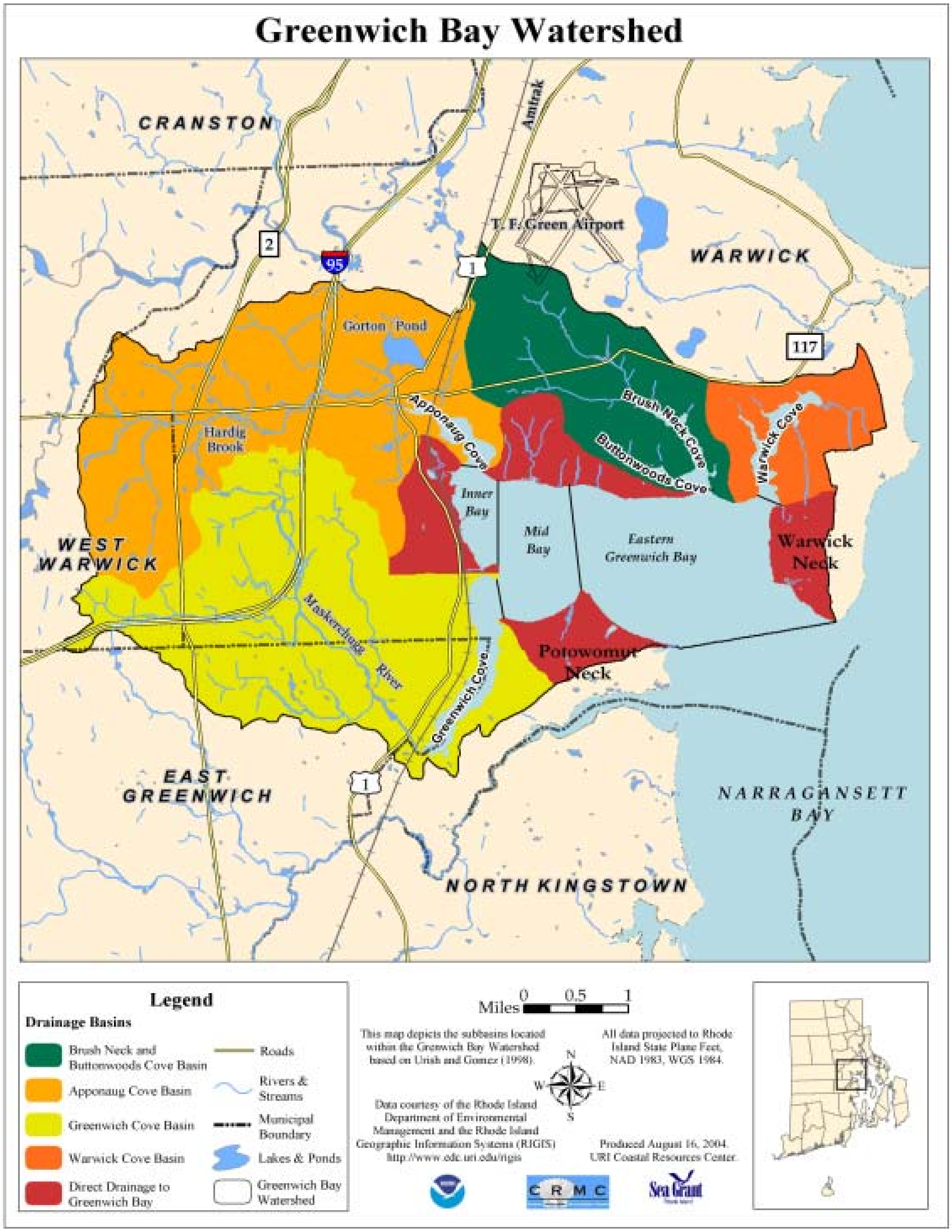
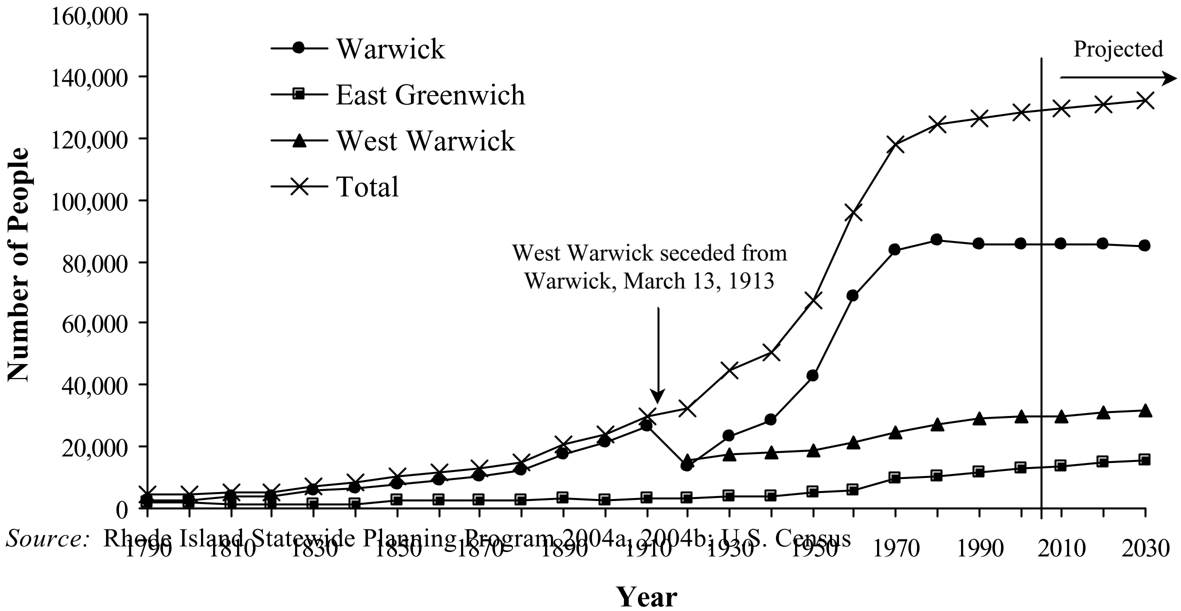
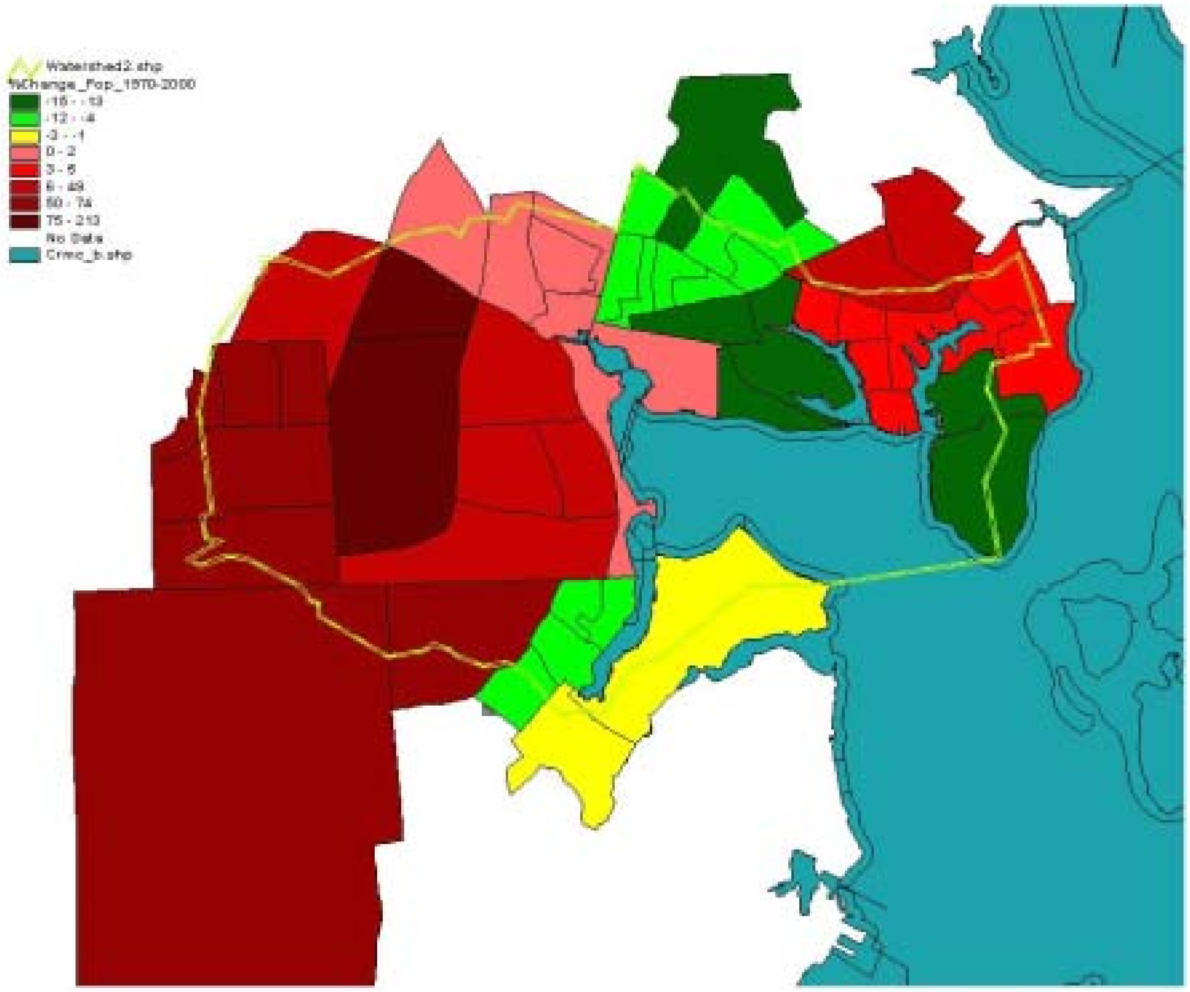


Figure 3. Population trends and projections for Warwick, East Greenwich, and West Warwick



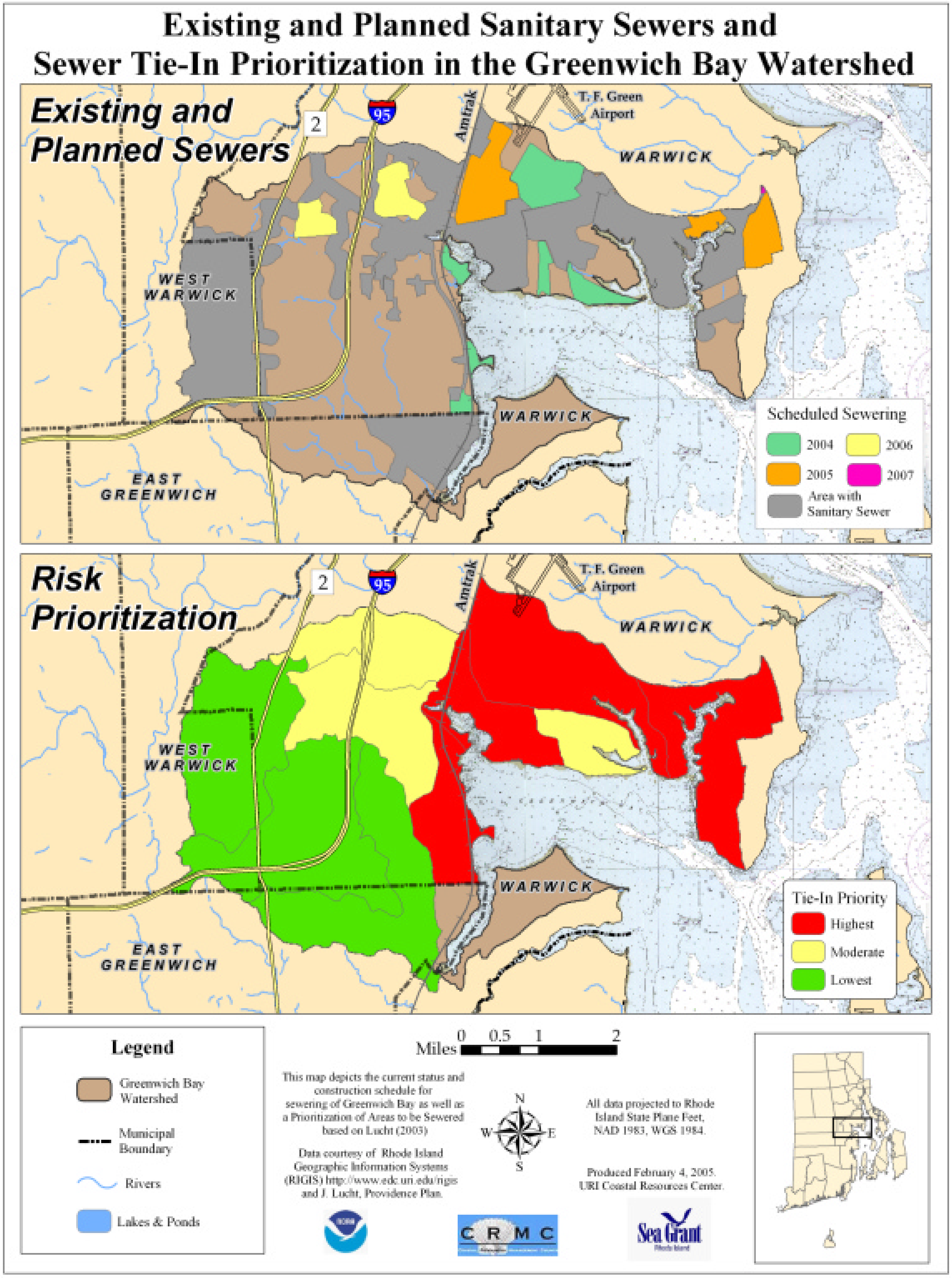
Source: Rhode Island Statewide Planning Program 2004a, 2004b; U.S. Census

Figure 4. Percent change in population growth in the Greenwich Bay watershed, by U.S. Census Tract (1970-2000)



Source: RIGIS, 2004; U.S. Census Bureau, Neighborhood Change Database, 2002; Dema, 2004

Figure 5. Existing and planned sanitary sewers in the Greenwich Bay watershed



Section 420
Bacterial contamination

420.1 Definition of the problem

1. Fecal contamination in waters used for swimming and direct shellfish harvesting is a public health concern. Both human and animal fecal matter contain pathogens that are harmful to humans who ingest them while swimming or eating raw shellfish. Waterborne pathogens include many type of parasites (helminthes and protozoans), infectious bacteria, and more than 140 viruses. While outbreaks of disease caused by contaminated waters rarely cause mortality in the United States, even a mild case of diarrhea may result in loss of productivity and economic costs up to $280 per episode (Rose et al., 1998).

2. Greenwich Bay is monitored for fecal contamination. Because it is expensive and difficult to directly detection pathogens, EPA has recommended the use of bacterial indicators, such as *Escherichia coli,* enterococci, and fecal coliform, to determine the extent and source, if possible, of fecal contamination.

3. Waters with high counts of indicator organisms implies the potential presence of fecal matter and human pathogens. Bacterial contamination does not refer to the natural bacterial community, which is an important part of the ecosystem. In temperate climates, such as New England, most naturally occurring bacteria and viruses do not pose a public health risk and are considered non-pathogenic.

4. RIDEM currently uses fecal coliform as an indicator. RIDEM fecal-coliform water-quality standards are based on health risks associated with swimming in or eating raw shellfish from contaminated waters (Table 2). The RIDEM fecal-coliform standard for SA waters is consistent with FDA standards for shellfish harvesting. The FDA National Shellfish Sanitation Program (NSSP) establishes allowable fecal-coliform concentrations for the direct harvesting of shellfish. In January 2005, RIDEM accepted public comment on rule changes that would adopt the enterococci standard for recreational beaches and all waters where swimming (primary contact) is a designated use as described below.

5. The Rhode Island Department of Health (HEALTH) uses enterococci as an indicator of fecal contamination at licensed bathing beaches. HEALTH follows recreational swimming standards for water quality recommended by EPA under the federal Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 (2000 P.L. 106-284) and with authority granted through the General Laws of Rhode Island (R.I. Gen. Laws §23-21 and §23-21.1) to ensure beach water meets bacteriological standards (HEALTH, 2004a). The enterococci standard states that no single sample can exceed 104 enterococci per 100 milliliters (ml) and the geometric mean, based on a minimum of five samples over a 30-day period, cannot exceed 35 enterococci per 100 ml. Prior to 2004, HEALTH used fecal coliform as the recreational swimming standard for water quality at licensed beaches. The old fecal-coliform standard followed RIDEM's water quality standard of no greater than 50 most probable number (MPN) of fecal coliforms per 100 ml with no more than 10 percent of samples to exceed 500 MPN. HEALTH changed to enterococci in 2004 to comply with the federal BEACH Act.

6. Even though Class SA waters are designated for direct shellfish harvesting, most of Greenwich Bay's Class SA waters are conditionally closed for seven days following a rain and/or snow melt event that exceeds 0.5 inches in 24 hours due to elevated fecal-coliform concentrations. Year-round closures occur in other Class SA waters in Greenwich Bay. Since 1990, harvesting shellfish has been prohibited in Brush Neck Cove (FDA, 1993). In 2002, RIDEM prohibited the harvesting of shellfish in Buttonwoods Cove (RIDEM, 2002). In May 2003, RIDEM expanded the dry-weather closure of Greenwich Bay to include all waters between Chepiwanoxet and the extension of Cooper Road in the Buttonwoods section of Warwick (RIDEM, 2003b). In 2004, based on sampling at shellfish monitoring stations, RIDEM returned dry-weather closure lines to their 2002 limit, reopening 240 acres for shellfishing (RIDEM, 2004b). The 2004 dry-weather closure line runs from Chepiwanoxet Point to the extension of Capron Farm Drive in Nausauket (Figure 6). Finally, the Class SB and SB1 waters of Greenwich Bay are not designated for the direct harvesting of shellfish and are closed year-round, but are used for shellfish transplants. Dry-weather closure areas and Class SB and SB1 waters form the permanent shellfish closure areas on Greenwich Bay. Historical and current shellfish bed closures are shown in Figure 6.

7. Elevated indicator bacteria levels lead to beach closures at the five licensed beaches in the Greenwich Bay watershed, including the three beaches along Greenwich Bay and its coves, during the swimming season, which generally runs from Memorial Day to Labor Day. When a beach does not meet recreational swimming standards, HEALTH can close the beach until bacteria levels are within acceptable limits (HEALTH, 2004a). Greenwich Bay's saltwater beaches have averaged 16 closure days per beach per year since 2000 due to elevated indicator bacteria levels (Table 6). For comparison, Table 6 also includes the number of shellfish bed closure days in the Greenwich Bay conditional closure area and the amount of rain received between May 15 and September 7.

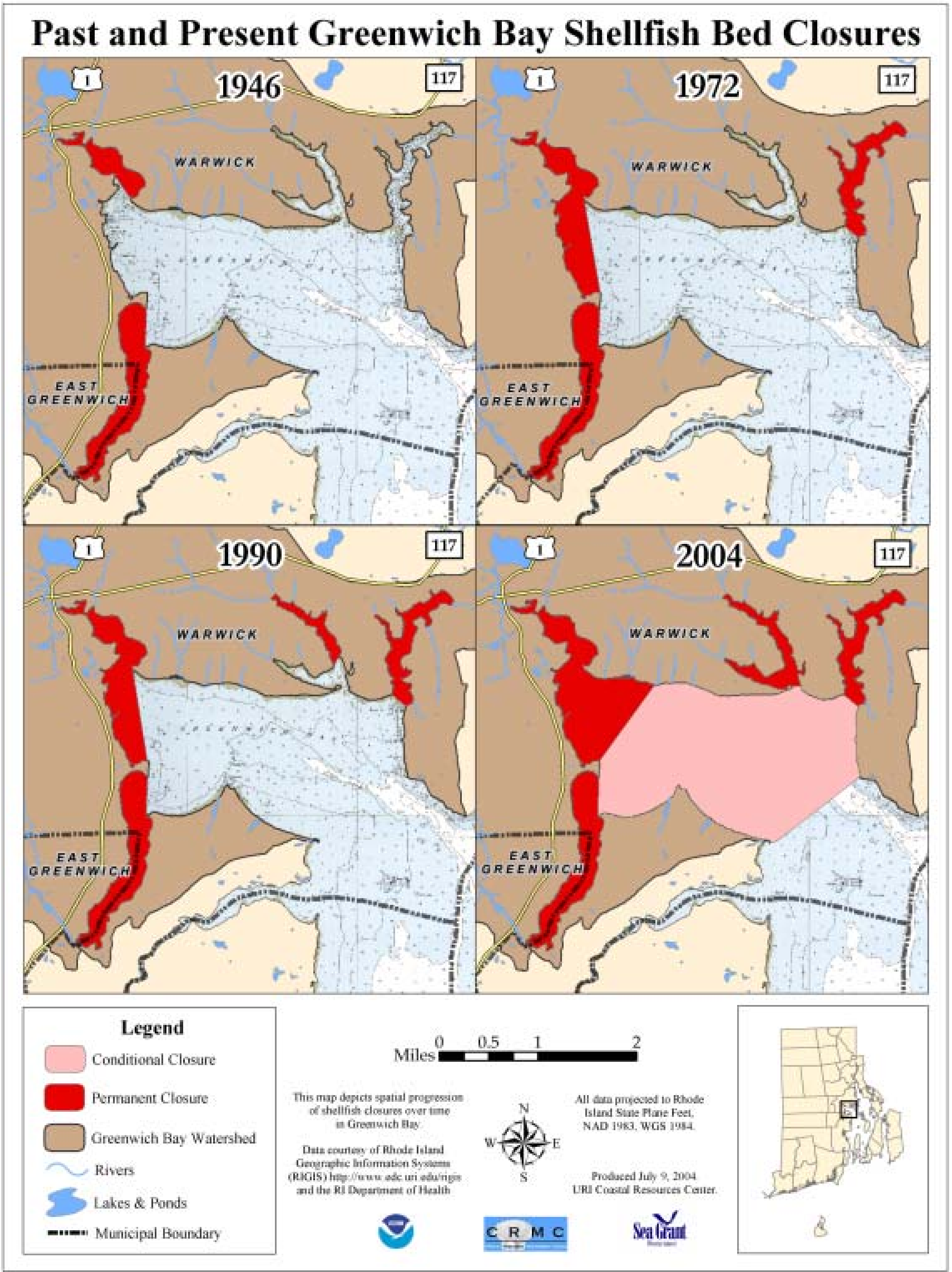
Table 6. Closure days at Greenwich Bay beaches and shellfish grounds

Location	2000	2001	2002	2003	2004
	Number of closure days				
Saltwater Beaches					
Warwick City Park Beach	0	19	15	23	5
Oakland Beach	10	12	12	66	11
Goddard Memorial State Park Beach	16	28	7	21	0
Freshwater Beaches [1]					
Gorton Pond	0	0	13	22	0
Kent County YMCA	0	15	8	11	4
Shellfish Growing Area [2]	*58*	*67*	*41*	*73*	*56*
	Inches of rain				
T.F. Green Airport [2]	13.0	17.3	8.8	19.4	12.5

1 The freshwater beaches at the Kent County YMCA and Gorton Pond were only monitored sporadically prior to 2001 and 2002, respectively.
2 Between May 15 and September 7

Source: HEALTH, 2004a; HEALTH, 2004b; RIDEM, 2002, 2003b, 2004a; Migliore pers. comm.

Figure 6. Past and present Greenwich Bay shellfish bed closures



420.2 Results of bacterial contamination studies in Greenwich Bay

420.2A FDA and RIDEM Greenwich Bay reclassification study

1. Prior to 1992, harvesting shellfish from Greenwich Bay was allowed regardless of precipitation, although pollution closures did exist in Brush Neck Cove, and there were resource management restrictions throughout the entire bay. In December 1992, heavy precipitation (over seven inches of rain and snow) in less than three days resulted in sustained violations of the shellfish fecal-coliform standard in Greenwich Bay. After weeks of temporary closures, Greenwich Bay was permanently closed for shellfish harvesting on January 5, 1993, until a reclassification study could be conducted (RIDEM, 1993).

2. RIDEM and FDA conducted the study (FDA, 1993) to recommend management strategies for the bay and to determine pollution sources. By conducting dry- and wet-weather sampling and examining historical dry and wet-weather data, FDA concluded that the Greenwich Bay shellfish growing area should be classified as "conditionally approved." Greenwich Bay was conditionally reopened on June 27, 1994 (RIDEM, 1994). Dry-weather water quality is acceptable for the direct harvesting of shellfish with exceptions shown in Figure 6.

3. FDA identified Hardig Brook in Apponaug Cove as the largest dry- and wet-weather fecal- coliform source to the watershed. Apponaug Cove had the highest fecal-coliform levels in the entire watershed under wet-weather conditions. As estimated by the FDA report, 95 percent of the overall daily and 99 percent of the wet-weather fecal-coliform inputs to Greenwich Bay came from eight sources (FDA, 1993). These sources included Hardig Brook, Southern Creek, and the Maskerchugg River. The report also established that the East Greenwich WWTF was not a significant source of bacterial contamination.

420.2B URI-CVE Hardig Brook and Northern Watershed studies

1. Throughout the 1990s, researchers from the URI department of civil and environmental engineering (URI-CVE) studied pollutant sources identified by the FDA report. URI-CVE sampled seven Greenwich Bay tributaries during two of its studies. Mitigation activities resulting from the Hardig Brook study included implementing best management practices at a dairy farm along Hardig Brook and eliminating three raw sewage pipes at a mill complex (RIDEM Complaint 94-241) along Gorton Pond tributary (DeMelo et al., 1997). Since the time of the URI-CVE study, the dairy farm has ceased operations and was purchased by Warwick in 2001. In November 2003, RIDEM conducted follow-up sampling in these two streams and documented improvements.

2. URI-CVE sampled five additional streams—Southern Creek, Tuscatucket Brook, Greenwood Creek, Mill Brook, and Baker's Creek—during its northern watershed study. While most streams either met or almost met water-quality standards in dry weather, every stream exhibited elevated fecal-coliform concentrations following wet weather events. In general, concentrations after wet weather events rose from less than 50 fecal coliform (fc)/100 ml to more than 1,000 fc/100 ml (Wright and Viator, 1999). This wet-weather

trend continues today and directly leads to wet weather shellfish restrictions and beach closures.

420.2C URI Cooperative Extension citizen water-quality monitoring

1. A citizen water-quality program monitored the Maskerchugg River with support from URI Cooperative Extension (URI-CE) (Herron et al., 1998). Throughout 1996 and 1997, up to 11 sites were monitored for a variety of water-quality indicators, including fecal-coliform bacteria. In contrast to the findings reported by the FDA study, fecal-coliform counts were low. Geometric means at the sampled sites did not exceed state water-quality standards, although indicator bacterial levels were higher following rainfall events.

420.2D URI-CVE and SRICD direct stormwater-discharges studies

1. The URI-CVE and the SRICD studies of direct stormwater discharges identified stormwater outfalls in the Greenwich Bay watershed. In 1998, the URI-CVE inventoried stormwater outfalls along the Greenwich Bay shoreline and compiled a list of approximately 100 outfalls (Wright et. al., 1998), many of which were previously unidentified. SRICD added to the list by cataloging outfalls in the Brush Neck Cove and Warwick Cove sub-watersheds (SRICD, 1999, 2003).

2. The URI-CVE sampled a limited number of direct stormwater sources and two streams. A single sample was taken during dry weather, and between 16 and 27 samples were taken during wet weather at 20 stormwater and two stream locations in the watershed (Figure 7). Stream data are included in this section because of the limited dry-weather data available. These streams will be treated as other stormwater sources for remediation activities. Available data for the direct stormwater sources, including the Wright and Viator (1999) study, RIDEM Shellfish Program shoreline sanitary survey data, and TMDL data, are listed in Table 7. These data indicate that stormwater is a significant mechanism for fecal-coliform transport to Greenwich Bay and that stormwater abatement activities should be a primary action for restoring water quality. The intensity of land use in the Greenwich Bay watershed and the resulting density and diversity of potential sources appear to indicate that comprehensive stormwater mitigation is needed.

3. The URI-CVE and the SRICD analyzed data to prioritize stormwater discharges for remediation. The URI-CVE developed a stormwater management model. Results from dry- and wet-weather bacterial monitoring of the tributaries and several of the direct stormwater discharge sites were used to rank surveyed areas and identify hot spots. The SRICD analysis of Brush Neck Cove prioritized stormwater systems according to their contribution of untreated runoff to Greenwich Bay (Table 8). This analysis incorporated the area of impervious surfaces, the lack of sewers, and the size of the drainage basin to determine the priority systems and develop a retrofit feasibility plan for stormwater treatment (Table 9).

Table 7. Measured fecal coliform levels in direct stormwater discharges and other sources

Station	Location	Number of samples		Geometric mean (fc/100 ml) Observed		90th percentile[1] (fc/100 ml) Observed		80th percentile[1] (fc/100 ml) Observed	
		Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Potowomut									
WK5A	Beachwood Pond	2	23	12	560	135	24000		
WK5B	Beachwood Pond		24		430		7890		
WK5C	Beachwood Pond		25		1034		8840		
WK5D	Beachwood Pond		25		1532		20800		
Apponaug Cove									
WK09	Post Rd. and Ocean Point Ave. South	1	16	1	5668			1	14000
WK10	Chepiwanoxet Way and Oak Grove	1	16	44	4949	44	11000		
WK13	Masthead Dr. and Fred Humlak Way	1	16	22	11894			22	21000
Brush Neck Cove									
WK30	Shand Avenue	2	17	4	3310	4.9	17800		
WK35	Gordon, Hawksley, Seaview sts.	1	17	1	8000	1	13000		
WK38	Mohawk Avenue	1	17	360	35656	360	270000		
Warwick Cove									
WK46	Samuel Gorton Avenue	1	17	17	3580			17	6880
WK47	Oakside Street Brook	1	2	590	5683			590	15540
WK54	Fosters Brook	1	18	33	6105			33	13600
Warwick Neck									
WK52	Kirby Avenue	1	18	1	484	1	3100		
Greenwich Cove									
EG01	East Greenwich Transfer Station	1	27	400	9665			400	23000
EG06	Division Street	1	27	19	9910			19	31600
EG07	Crompton Ave. at Rocky Hollow	1	27	5	4234			5	8660
WK08	Ladd Street at Norton's Marina	1	27	4600	6444			4600	14600

[1] Stations that discharge to Class SA waters must meet a 90th percentile criterion, while stations that discharge to Class SB/SB1 waters must meet an 80th percentile criterion.

Source: RIDEM, 2004a

Table 8. SRICD list of stormwater priority systems

System #	Associated Road(s)	Subwatershed	Why priority?			Sampled?
			Large drainage area	Highly impervious	Lack of sewers	
139	MacArthur Drive	Lower Carpenter		X		No
127	West Shore Road	Upper Carpenter	X			No
123	West Shore Road	Upper Carpenter	X			No
128	Wesleyan Avenue	Upper Carpenter	X		X	No
87	West Shore Road	Lower Tuscatucket	X	X		No
112	Main Avenue	Lower Tuscatucket	X			No
145	Industrial Drive	Upper Tuscatucket	X		X	No
TB01	Industrial Drive	Upper Tuscatucket	X		X	Yes (Wright & Viator, 1999)
163	Industrial Drive	Upper Tuscatucket	X		X	No
110	Strawberry Field Road	Upper Tuscatucket	X	X		No
38	Mohawk Avenue	Brush Neck East	X	X		Yes (Wright, Fanning & Viator, 1998)
35	Gordon/Hawksley sts.	Brush Neck East	X			Yes (Wright, Fanning & Viator, 1998)
104	Northup Street	Brush Neck East		X		No

Source: SRICD, 2002

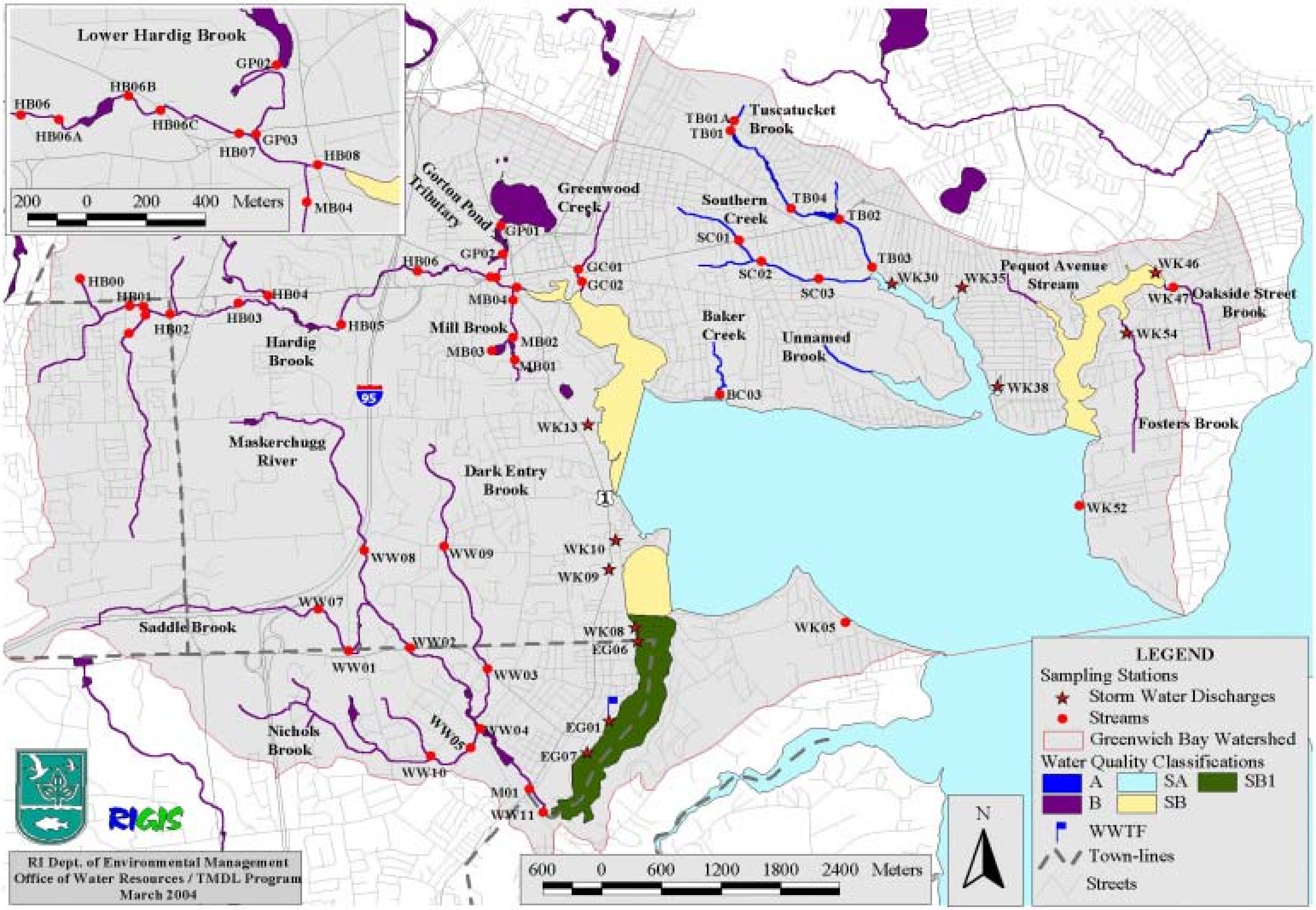
Table 9. SRICD list of potential stormwater retrofits

System Number (Street)	Suggested practice	Effect	Acres treated	Rough estimate implementation cost [1]	Status
131 (White)	Diversion/level spreader/created wetland with infiltration	high	25.5	\$100,000–\$150,000	Project being designed. Money available for construction.
133 (Boyle)	Pocket wetland with infiltration	high	12.0	\$70,000–\$100,000	Project being designed. Money available for construction.
121 (N. Burbank)	In-line practice	some	8.4	\$25,000–\$50,000	Construction Planned Spring 2005
116 (Burgess)	In-line practice	some	4.4	\$25,000–\$30,000	Construction Planned Spring 2005

[1] Cost estimates for wetlands from NRCS, estimates for in-line practices from Warwick

Source: SRICD, 2002

Figure 7. RIDEM and URI-CVE sampling stations for fecal coliform



Source: RIDEM, 2004a

<u>*420.2E HEALTH bathing beach monitoring*</u>

1. In 2002, HEALTH completed sanitary surveys that evaluated Greenwich Bay beaches according to past and present conditions, known or likely sources of pollution, and user characteristics. Graded point classifications used to evaluate beach risk were based on numbers of beach closure days, users, confirmed illnesses, stormwater drains, birds, indicator bacteria concentrations, proximity to point-source discharges, and other relevant parameters. HEALTH classified beaches receiving more than 100 points as high risk. Warwick City Park Beach, Oakland Beach, and Goddard Memorial State Park Beach received 122, 138, and 212 points respectively.

2. HEALTH monitors indicator bacteria levels at these three licensed beaches under its bathing beaches monitoring program (Figure 8). In the summer, Greenwich Bay beaches are sampled at least three times per week with Goddard Memorial State Park Beach sampled four times per week. Recreational swimming standard violations have occurred at each sampling location in at least one year that sampling was conducted, primarily after wet weather (Table 10). Beach closures have occurred nearly every year (Table 6) because decisions to close the beach are based on individual sample results (not seasonal means), the area's water-quality history, and other environmental conditions. HEALTH updates beach conditions on its webpage.

3. Monitoring data from the summers of 2000 and 2001 show that, with a few exceptions, Greenwich Bay beach closures correspond with the wet-weather shellfish closures of Greenwich Bay (RIDEM, 2004a). Figure 9 shows 2001 summer monitoring data for the three licensed beaches. Beach closures that occur during dry weather may be the result of fecal contamination from bathers (especially small children), waterfowl, dogs and other animals along the beach, illegal boat discharges, illegal sewer tie-ins to storm drains, and failed ISDS.

Table 10. Indicator bacteria levels at Greenwich Bay beaches

Location	Station	Weather conditions	Fecal coliform geometric mean (MPN/100 ml)						Enterococci[1] geometric mean (MPN/100 ml)			
			2000	2001	2002	2003	2004	Target[2]	2002	2003	2004	Target
Goddard Memorial State Park	East	Dry	21	23	12	18	13	50	16	30	14	35
		Wet	17	38	18	33	*51*		19	*45*	20	
	Center	Dry	N/A	28	10	26	11		13	34	12	
		Wet	N/A	40	20	33	*53*		16	24	22	
	West	Dry	*77*	35	14	26	11		18	*37*	17	
		Wet	22	*79*	*65*	32	*91*		22	*39*	20	
Oakland Beach	East	Dry	22	*51*	33	39	9		N/A	*37*	13	
		Wet	*54*	*173*	34	*53*	30		N/A	32	27	
	Middle	Dry	30	N/A	N/A	*78*	24		20	*60*	20	
		Wet	*51*	N/A	N/A	*53*	*87*		21	25	29	
	West	Dry	18	10	22	35	23		15	*45*	22	
		Wet	36	*434*	*57*	*102*	*89*		13	*67*	*44*	
Warwick City Park		Dry	16	*69*	28	24	8		16	*55*	13	
		Wet	20	*452*	*58*	*61*	21		27	*84*	21	

N/A Indicates that sampling was not conducted at these sites in those years.
1 Enterococcus is the indicator bacteria used by HEALTH to determine beach closures starting in 2004.
2 Swimming use was evaluated utilizing data collected by HEALTH.

Source: HEALTH Bathing Beach Monitoring Program

Figure 8. Rhode Island Department of Health water quality sampling stations at Greenwich Bay beaches

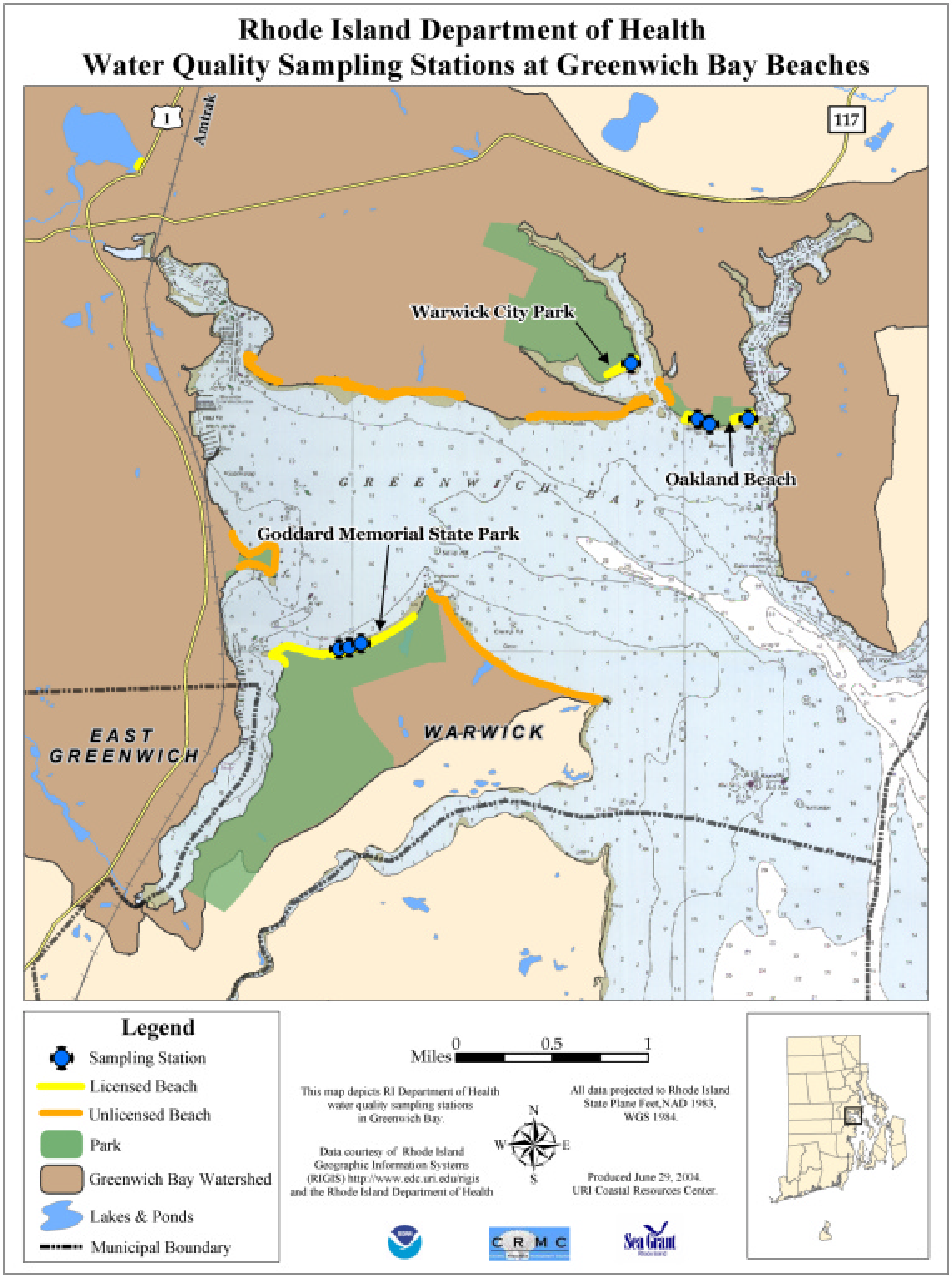
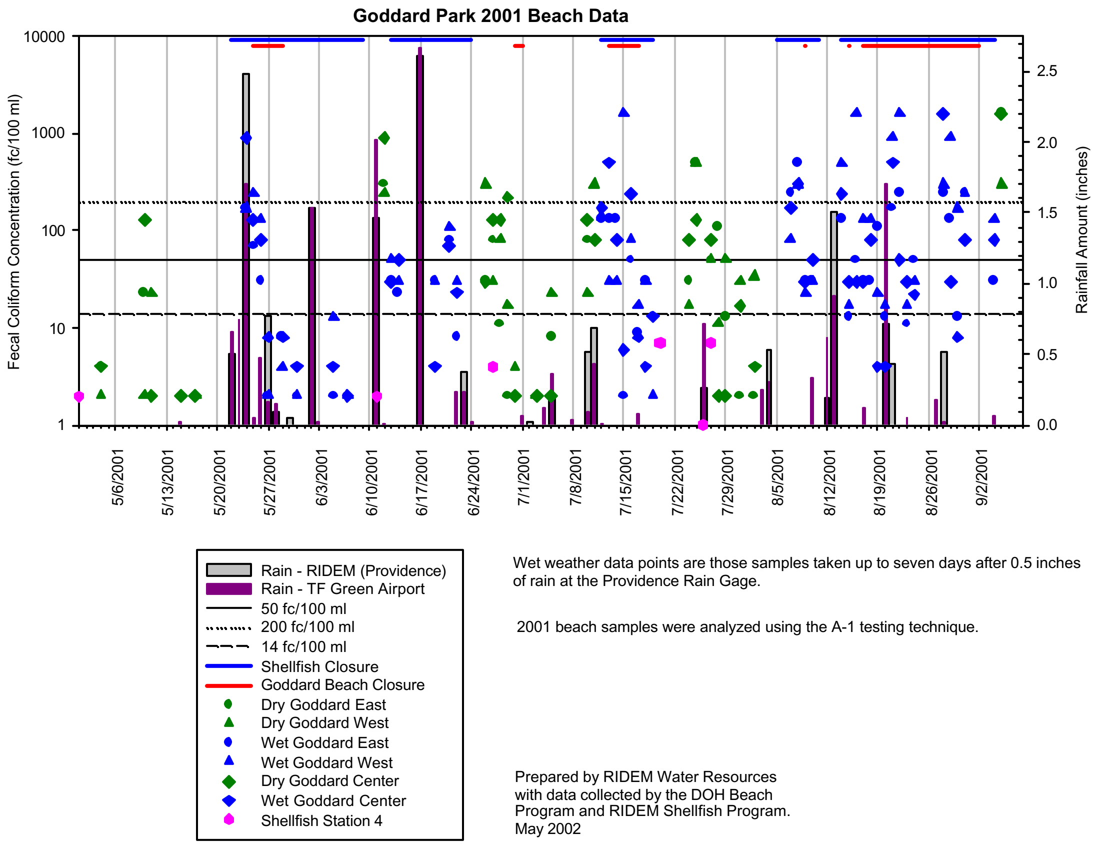
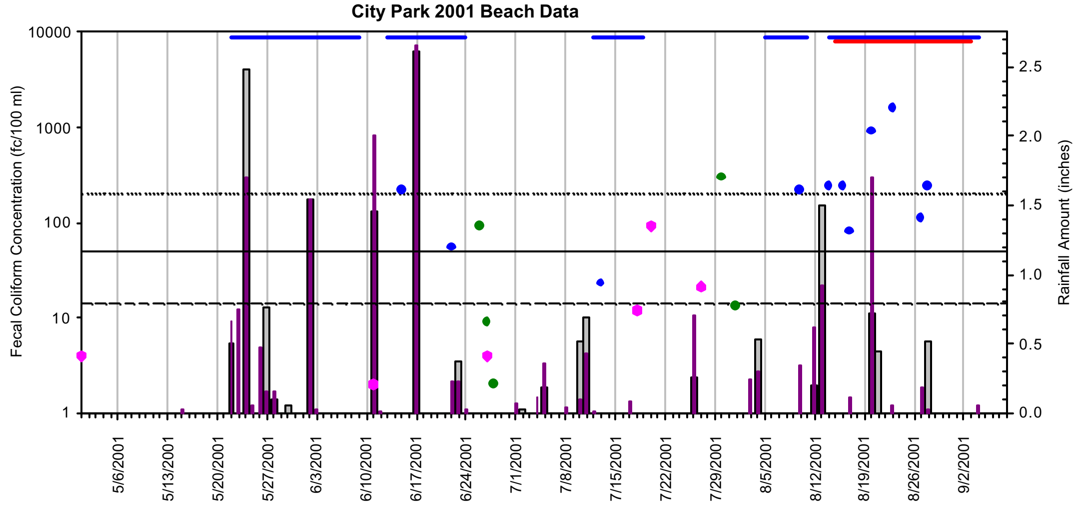


Figure 9. Relationship between beach and shellfish bed closures and wet weather in Greenwich Bay



City Park 2001 Beach Data



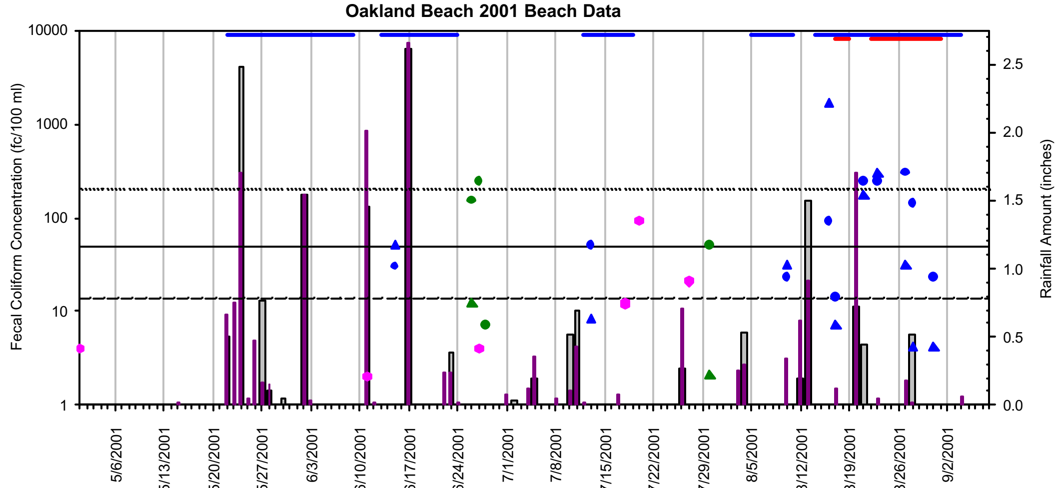
- Rain - RIDEM (Providence)
- Rain - TF Green Airport
- 50 fc/100 ml
- 200 fc/100 ml
- 14 fc/100 ml
- Shellfish Closure
- City Park Closure
- Dry City Park
- Wet City Park
- Shellfish Station 25

Wet weather data points are those samples taken up to seven days after 0.5 inches of rain at the Providence Rain Gage.

2001 beach samples were analyzed using the A-1 testing technique.

Prepared by RIDEM Water Resources with data collected by the DOH Beach Program and RIDEM Shellfish Program. May 2002

Oakland Beach 2001 Beach Data



- Rain - RIDEM (Providence)
- Rain - TF Green Airport
- 50 fc/100 ml
- 200 fc/100 ml
- 14 fc/100 ml
- Shellfish Closure
- Oakland Beach Closure
- Dry Oakland East
- Dry Oakland West
- Wet Oakland East
- Wet Oakland West
- Shellfish Station 25

Wet weather data points are those samples taken up to seven days after 0.5 inches of rain at the Providence Rain Gage.

2001 beach samples were analyzed using the A-1 testing technique.

Prepared by RIDEM Water Resources with data collected by the DOH Beach Program and RIDEM Shellfish Program. May 2002

420.2F RIDEM shellfish growing area water quality monitoring

1. The RIDEM shellfish growing area water-quality monitoring program is part of Rhode Island's agreement with the FDA National Shellfish Sanitation Program, which requires the state to conduct routine bacteriological monitoring and shoreline sanitary surveys of its waters where shellfish are harvested for direct human consumption. The RIDEM shellfish program samples 19 stations in Greenwich Bay each month when the Greenwich Bay conditional area is open (Figure 10). Twelve stations are in Class SA waters. Seven stations are in Class SB/SB1 waters (RIDEM, 2004a).

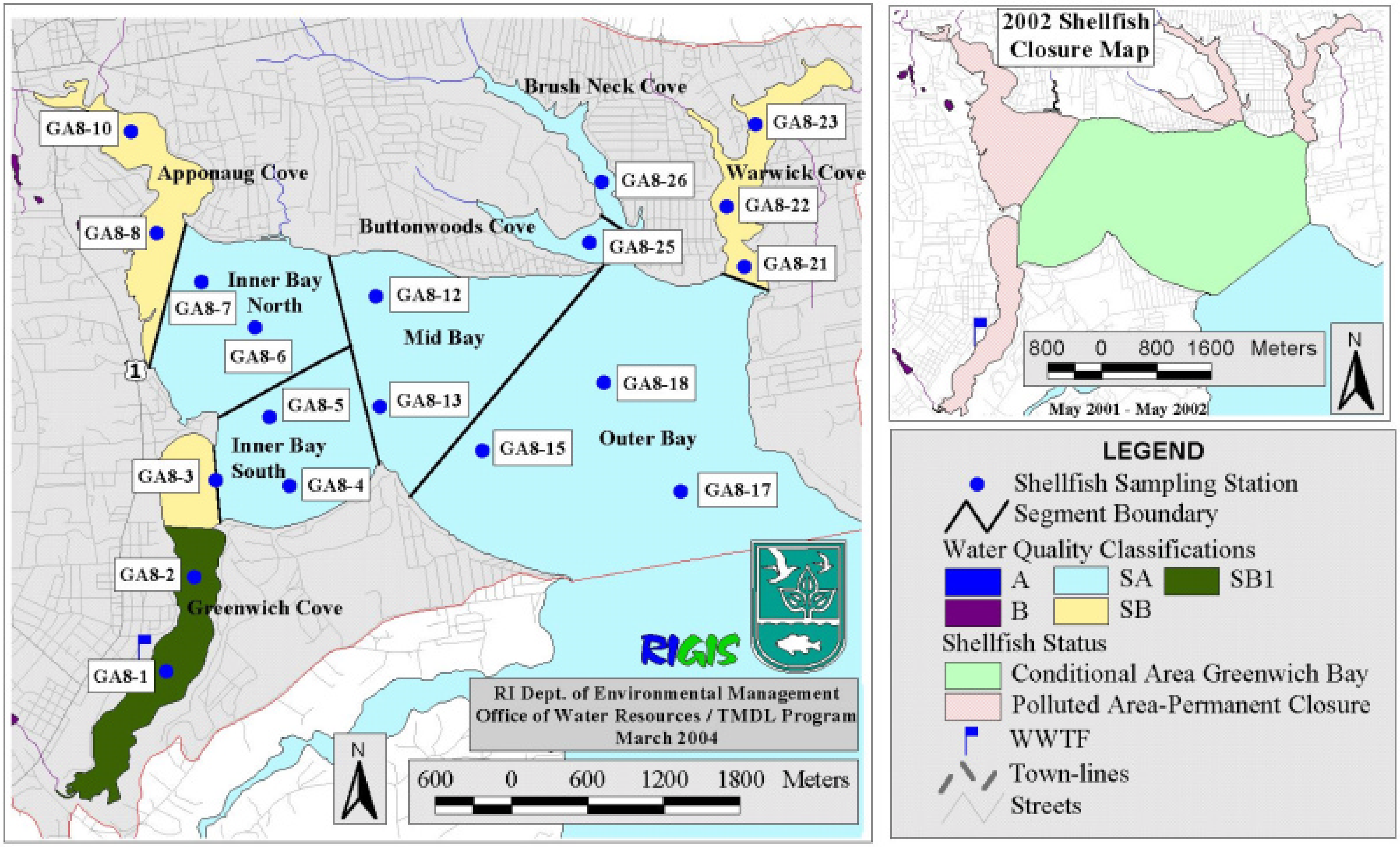
2. RIDEM conducts sanitary surveys of all state shellfish growing areas every 12 years, the last one in 1993. The survey includes walking the shoreline of the growing area to identify all actual and potential pollution sources. Every three years, RIDEM reevaluates actual pollution sources identified during the most recent survey, as well as any new pollution sources. The RIDEM shellfish program issues an annual growing-area evaluation that includes field observations of pollution sources and an update of RIDEM records to reflect any changes in the growing area (NSSP, 1997). The most recent triennial review was completed in 2001 (Figure 11) and updated in 2003. Major sources identified by the 1993 survey were also sampled by URI-CVE. Shoreline survey results have been consistent with Greenwich Bay's permanent and conditional pollution closures for shellfish beds (Table 11).

Table 11. Results of recent Greenwich Bay shoreline sanitary surveys

Description/location	Fecal Coliform Levels (MPN/100 ml)		
	1998	2001	2003
Outflow from marsh at Sandy Point	1,500	2,300	93
18" concrete pipe at end of Robert St.	750	43	-
18" cc pipe in headwall at end of right-of-way	430	-	-
18" concrete pipe at 201 Charlotte Dr.	230	7	-
Outflow from pond at Beachwood St. culvert	9,300	150	-
Stream – 100 yards west of Sally Rock Point	430	23	-
12" CMP at right-of-way at 90 Herbert St.	-	23,000 (minimal flow)	-
Stream at 58 Melbourne St.	2,300	1,200	-
Baker's Creek	2,100	43	-
Stream at end of Capron Farm Dr.	930	930	-
Stream east of previous	4,300	150	-
Stream west of Andrew Comstock Rd.	93	430	-
24" cc culverted stream at 339 Promenade Ave.	75	93	-
18" cc end of Claflin Rd.	9	9,300	1,100
12" iron pipe at end of Cooper Ave. and beside ramp	-	3-	-
Outflow from marsh south of Randall Ave.	430	4,300 at 100 gpm	23
12" cc south of community dock	23	430 at 100 gpm	9
18" cc 100 yards south of previous	-	2,300 at 80 gpm	23
Drainage from retention pond at Warwick Country Club	4	-	-
18" cc pipe in riprap east of Warwick Country Club	230	-	-
18" cc pipe in riprap 100 feet east of previous	2,300	-	-

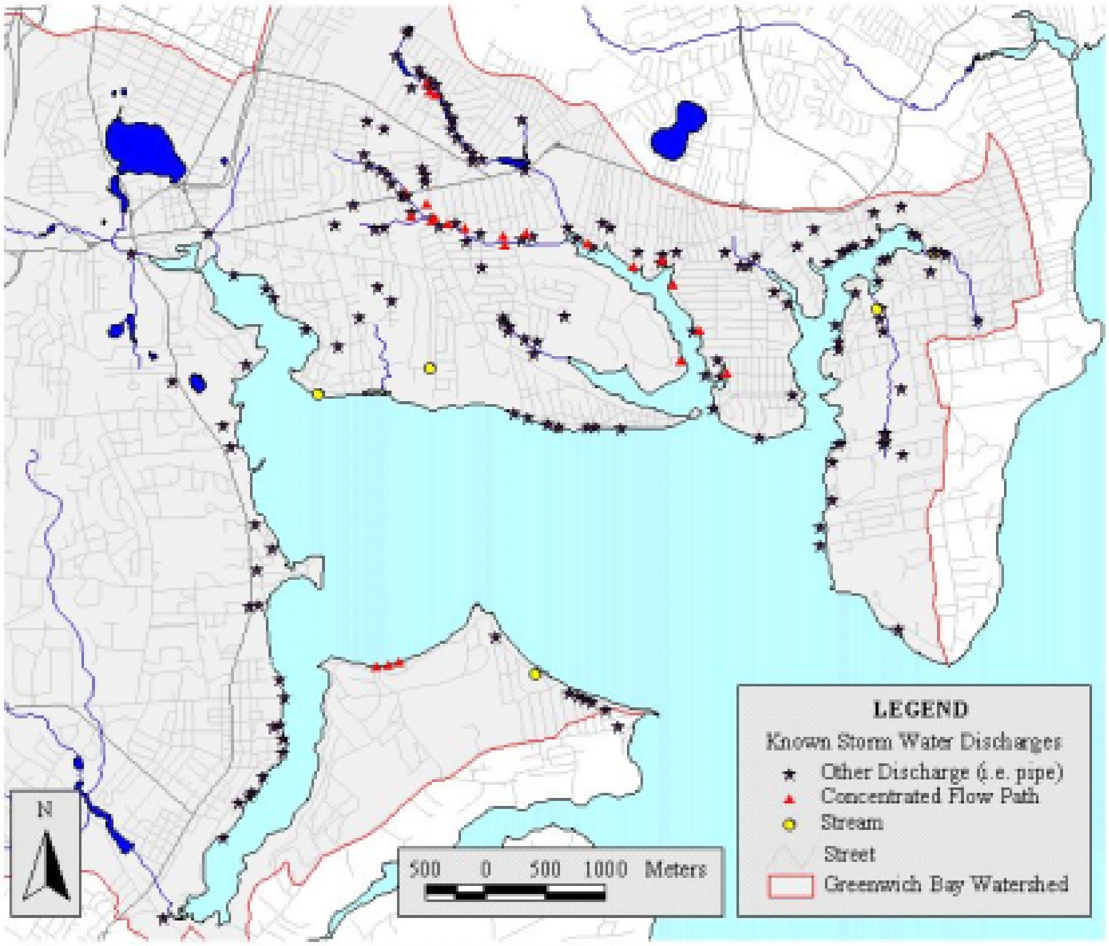
Source: RIDEM, 1998; RIDEM, 2001; RIDEM, 2003c

Figure 10. RIDEM shellfish sampling stations in Greenwich Bay



Source: RIDEM, 2004a

Figure 11. Approximate locations of stormwater outfalls



Source: RIDEM, 2004a

420.2G RIDEM Total Maximum Daily Load (TMDL)

1. The RIDEM Total Maximum Daily Load (TMDL) program developed a draft water-quality restoration plan for fecal-coliform contamination, based on data they collected that demonstrated that water quality in Greenwich Bay and its coves and freshwater tributaries does not meet fecal-coliform standards, primarily during wet-weather events.

2. Because no recent wet weather data was available, RIDEM sampled the marine waters of Greenwich Bay six times directly following storm events during 2001 and 2002 (RIDEM, 2004a). These data were used along with 15 dry-weather surveys conducted by the RIDEM shellfish program between October 2000 and December 2001 to define the dry- and wet-weather status at each monitoring station. Results show that water quality at most of the shellfish growing-area monitoring stations (Figure 10) meets standards in dry weather, but exceeds standards following wet-weather events (Tables 12 and 13). Although the TMDL analysis used data and procedures from the RIDEM shellfish program, the analysis to determine the closure of shellfish grounds is based solely on the NSSP requirements and is not identical to the TMDL analysis.

3. The RIDEM draft fecal-coliform TMDL plan also determined Greenwich Bay's tributaries do not generally meet fecal-coliform water-quality standards during wet weather. RIDEM used data from the URI-CVE Hardig Brook, Northern Watershed, and Direct Storm Water Discharges studies; the URI-CE Maskerchugg River Study; and the RIDEM shellfish and TMDL programs to establish the current condition of the freshwater tributaries to Greenwich Bay (RIDEM, 2004a) (Table 14 and Figure 7). Stations on or close to a border with a different water quality classification default to the higher standard. It should be noted that while the URI-CE data did not indicate a problem along the Maskerchugg River, additional RIDEM data for the Maskerchugg River indicates the station closest to Greenwich Cove does not meet wet-weather bacteria standards.

4. The areas with the highest concentrations of fecal coliform were Brush Neck, Apponaug, and Warwick coves and Baker's Creek.

5. The TMDL sampling documented water-quality improvements due to the elimination of a dairy farm along Hardig Brook and removal of sewage pipes along the Gorton Pond tributary since the URI-CVE Hardig Brook Study. RIDEM completed its sampling of Hardig Brook in late 2003. Since the URI-CVE study, dry-weather geometric-mean concentrations and bacteria loads dropped by half at station HB01, the first regularly sampled station downstream of the former dairy farm. Wet-weather concentrations at HB01 also appeared to be lower. Dry-weather bacteria concentrations on the Gorton Pond tributary downstream of the eliminated sewage pipes were significantly reduced, resulting in a 94 percent reduction in fecal-coliform loads to Apponaug Cove between 1995 and 2003. The Gorton Pond tributary still occasionally exhibits elevated bacteria concentrations in dry weather.

6. Bacteria concentrations in the Hardig Brook headwaters remain among the highest in the watershed in both dry and wet weather. With the exception of some reductions in the Gorton Pond tributary, Hardig Brook wet-weather bacteria concentrations in the vicinity of

Apponaug Cove showed no improvement since the URI-CVE study. This reflects the lack of significant mitigation activities in this area to address wet-weather bacteria sources (RIDEM, 2004a).

Table 12. Greenwich Bay TMDL fecal coliform data at shellfish stations

Station	Location	Class	Number of samples		Geometric mean (fc/100 ml)			90th percentile (fc/100 ml)			Required percent reduction
			Dry [1]	Wet [2]	Dry [1]	Wet [2]	Target	Dry [1]	Wet [2]	Target	
1	Greenwich Cove	SB1	15	3	9	58	50	73	169	500	85.8
2		SB1	15	6	9	202		43	930		
3		SB [3]	15	6	3	49	14	8	680	49	
4	Inner bay south	SA	15	6	3	16	14	7	210	49	71.1
5		SA	15	6	4	34		9	330		
6	Inner bay north	SA	15	6	8	33	14	93	230	49	81.3
7		SA	15	5	8	71		65	430		
8	Apponaug Cove	SB [3]	15	6	9	97	14	73	2615	49	96.4
10		SB	15	6	22	423	50	93	12650	500	
12	Mid-bay	SA	15	6	4	17	14	9	387	49	75.7
13		SA	15	6	4	10		17	127		
15	Outer bay	SA	15	6	3	25	14	4	162	49	46.2
17		SA	15	6	3	4		19	26		
18		SA	15	6	4	11		20	137		
21	Warwick Cove	SA	15	6	5	57	14	19	535	49	94.1
22		SB [3]	15	6	12	148	14	43	1615	49	
23		SB	15	3	11	373	50	62	3496	500	
25	Buttonwoods Cove	SA	15	5	8	116	14	93	354	49	78.1
26	Brush Neck Cove	SA	15	6	14	228	14	73	8758	49	98.9

1 RIDEM shellfish program samples taken during dry weather between October 2000 and December 2001. Violations in the variability portion of the water quality standard may not be reflected in the 90th percentile value calculation.
2 Wet-weather samples were taken following storm events in 2001 and 2002.
3 These stations are on or close to the Class SA line and need to meet Class SA standards.

Source: RIDEM, 2004a; Speaker, 2003

Table 13. 2003 dry weather fecal-coliform data at Greenwich Bay shellfish stations [1]

Station	Location	Class	Number of samples	Geometric mean (fc/100 ml)		90th percentile (fc/100 ml)	
				Result	Target	Result	Target
1	Greenwich Cove	SB1	12	14.1	50	242.3	500
2			14	20.5		340.9	
3		SB [2]	15	9.8	14	59.3	49
4	Inner bay south	SA	15	5.5	14	28.6	49
5			15	5.3		18.7	
6	Inner bay north	SA	15	4.9	14	22.7	49
7			15	14.5		184.9	
8	Apponaug Cove	SB [2]	15	24.1	14	311.3	49
10		SB	14	36.8	50	297.3	500
12	Mid-bay	SA	15	5	14	27.6	49
13			15	3.8		11.1	
15	Outer Greenwich Bay	SA	15	5.4	14	37.6	49
17			15	3.4		8.8	
18			15	3.3		7.8	
21	Warwick Cove	SA	15	8.5	14	57.1	49
22		SB [2]	14	11.9	14	98.3	49
23		SB	14	12.3	50	93.7	500
25	Buttonwoods Cove	SA	14	10.7	14	91.1	49
26	Brush Neck Cove	SA	13	16.6	14	102.7	49

1 Violations in the variability portion of the water-quality standard may not be reflected in the 90th percentile value calculation.

2 These stations are on or close to the Class SA line and need to meet Class SA standards.

Source: RIDEM Shellfish Growing Area Water Quality Monitoring Program

Table 14. Measured fecal coliform levels in Greenwich Bay's tributaries

Station	Location		Number of Samples		Geometric Mean (fc/100 ml)				90^{th} Percentile (fc/100 ml)				Required Percent Reduction
			Dry	Wet	Observed Dry	Observed Wet	Target	Segment Weighted[1]	Observed Dry	Observed Wet	Target	Segment Weighted[1]	
Apponaug Cove													
HB00	Hardig Brook	B	7	0	458	NA	200	NA	1290[4]	NA	500	NA	NA[5]
HB01	Hardig Brook	B	13	14	400	6859	200	3630	748[4]	22700[4]	500	11724	96
HB02	Hardig Brook	B	12	12	418	6436	200	3427	884[4]	16800[4]	500	8842	94
HB03	Hardig Brook	B	11	12	344	7706	200	4025	540[4]	15700[4]	500	8120	95
HB04	Hardig Brook Trib.	B	6	12	114	3165	200	1640	1100[4]	10460[4]	500	5780	91
HB05	Hardig Brook	B	12	11	161	2835	200	1498	360[4]	14000[4]	500	7180	93
HB06	Hardig Brook	B	14	14	109	5019	200	2564	220[4]	14000[4]	500	7110	93
HB06A	Hardig Brook	B	4	3	163	7882	200	4022	246[4]	12840[4]	500	6543	95
HB06B	Hardig Brook	B	12	12	82	5742	200	2912	156[4]	11000[4]	500	5578	93
HB06C	Hardig Brook	B	12	12	116	6117	200	3116	190[4]	11800[4]	500	5995	94
HB07	Hardig Brook	B[3]	18	21	120	4225	50	2172	389	12000	500	6195	98
HB08	Hardig Brook	B[3]	6	7	291	3796	50	2044	647	13460	500	7053	98
GP01	Gorton Pond Trib.	B	8	17	135	465	200	261	194[4]	1000[4]	500	528	33
GP02	Gorton Pond Trib.	B	12	28	16	320	200	177	40[4]	4080[4]	500	2069	76
GP03	Gorton Pond Trib.	B[3]	16	17	210	3780	50	1995	705	10480	500	5593	97
MB01	Mill Brook	B	8	30	177	3993	200	2085	542[4]	10000[4]	500	5271	91
MB02	Mill Brook	B	8	28	18	655	200	336	91[4]	5720[4]	500	2905	83
MB03	Mill Brook	B	8	28	16	1787	200	901	42[4]	10600[4]	500	5321	91
MB04	Mill Brook	B[3]	25	48	158	1952	50	1404	550	19600	500	7176	95
GC01	Greenwood Creek	B[3]	8	30	7	1138	50	573	126	20600	500	10363	95
GC02	Greenwood Creek	B[3]	7	8	6	360	50	183	188	2400	500	1294	73
Northern Shoreline													
BC03	Baker Creek	A[2]	7	10	44	607	14	326	1432	3090	49	2261	98
Brush Neck Cove													
SC01	Southern Creek	A	8	28	3	1875	20	939	166	25000	200	12583	98
SC02	Southern Creek	A	8	30	2	876	20	439	148	17100	200	8624	98
SC03	Southern Creek	A[2]	10	30	11	1928	14	969	471	19200	49	9836	100
TB01	Tuscatucket Brook	A	8	28	9	157	20	83	41	6240	200	3141	94
TB01A	Tuscatucket Brook	A	8	28	6	723	20	365	87	4860	200	2473	95
TB04	Tuscatucket Brook	A	0	2	NA	1406	20	NA	NA	3472	200	NA	NA[5]
TB02	Tuscatucket Brook	A[2]	10	30	19	1881	14	950	84	14200	49	7142	99
TB03	Tuscatucket Brook	A[2]	7	8	39	448	14	244	257	1470	49	864	94
Greenwich Cove													
WW08	Maskerchugg River	B	4	3	8	44	200	26	24[4]	423[4]	500	223	0
WW02	Maskerchugg River	B	4	3	29	443	200	236	84[4]	2814[4]	500	1449	65
WW04	Maskerchugg River	B	4	2	104	362	200	233	163[4]	1534[4]	500	848	41
M01	Maskerchugg River	B[3]	10	5	39	336	50	188	581	1920	500	1101	73
WW11	Maskerchugg River	B[3]	2	1	32	75	50	53	91	75	500	83	6
WW07	Saddle Brook	B	3	2	31	79	200	55	287[4]	713[4]	500	500.1	0.02
WW01	Saddle Brook	B	5	3	95	85	200	90	424[4]	858[4]	500	641	22
WW09	Dark Entry Brook	B	3	3	99	50	200	74	184[4]	78[4]	500	131	0
WW03	Dark Entry Brook	B	3	3	42	270	200	156	65[4]	1092[4]	500	578	14
WW10	Nichols Brook	B	3	1	43	36	200	40	214[4]	36[4]	500	125	0
WW05	Nichols Brook	B	5	1	106	32	200	69	710[4]	32[4]	500	371	0

[1]Using 50% wet weather and 50% dry weather.
[2]These stations are on or close to the Class SA line. They need to meet Class SA standards.
[3]These stations are on or close to the Class SB line. They need to meet Class SB standards.
[4]These values are 80^{th} percentile concentrations.
[5]Surrounding stations adequately characterize the water quality conditions and required reductions at these locations.

Source: RIDEM, 2004a

420.3 Sources and transport of bacterial contamination

1. Sources of fecal bacterial contamination that exist within the watershed include failed, poorly sited, and malfunctioning ISDS as well as fecal material from domestic animals and wildlife. Storm water acts as the major transport pathway for these bacteria (Weiskel et al., 1996; Mallin et al., 2000; Noble et al, 2003). Therefore, contamination of receiving water bodies is more likely following wet-weather events. Reducing these wet-weather fecal-bacteria sources from Greenwich Bay will decrease indicator bacteria concentrations, allowing the shellfish beds and beaches to remain open following precipitation. However, other smaller sources of fecal-coliform bacteria could prevent direct shellfish harvesting in certain areas because shellfish fecal-coliform standards are stringent. Addressing illegal sewer tie-ins to storm drains and illegal boat discharges in Greenwich Bay may resolve any remaining fecal bacterial contamination problem during dry weather.

420.3A Storm water: the most significant transport pathway for bacterial contamination

1. The most significant transport pathway of bacteria to Greenwich Bay waters was found to be urban stormwater runoff from the surrounding watershed. Tables 12 and 14 show that the highest fecal-coliform concentrations in Greenwich Bay and its watershed are found during and directly following wet-weather events. Fecal-coliform concentrations follow a gradient, with the highest levels in the tributaries, lower levels in the coves, and the lowest levels in Greenwich Bay proper. This gradient continues to decrease from west to east in the bay itself. For example, high bacteria concentrations in Hardig Brook enter Apponaug Cove, causing impairments to both the cove and to adjacent areas of Greenwich Bay. The same trend can be seen in Brush Neck Cove with Southern Creek and Tuscatucket Brook. The stations with the lowest bacteria concentrations are located near where Greenwich Bay borders Narragansett Bay (RIDEM, 2004a).

2. The large amount of impervious area in the Greenwich Bay watershed causes significant increases in the amount of water and fecal bacteria entering Greenwich Bay directly following rain events (RIDEM, 2004a). During a 1995 storm event, flow in Southern Creek more than doubled after less than 0.5 inches of rain (Wright and Viator, 1999). Flow data from all tributaries reflect this trend. These increased stormwater flows throughout the watershed carry large amounts of bacteria from animals and failed ISDS into the bay. In comparative estuarine studies in North Carolina, Mallin et al. (2000) found that the most important human influence on fecal-coliform concentrations and transport to an estuary was the percentage of impervious surfaces, such as roads, parking lots, and roofs, within the watershed. Illegal sewer tie-ins may also transport untreated sewage into storm drains.

3. Urban storm water enters Greenwich Bay and its coves and tributaries directly through stormwater discharge outfalls. More than 150 direct stormwater discharges have been identified along Greenwich Bay, its coves, Tuscatucket Brook, Southern Creek, and along tributaries to Brush Neck, Buttonwoods, and Warwick coves (Figure 11). Most outfalls that discharge directly to Greenwich Bay have been identified, but stormwater discharges along tributary streams, such as Hardig Brook and the Maskerchugg River, have not been identified.

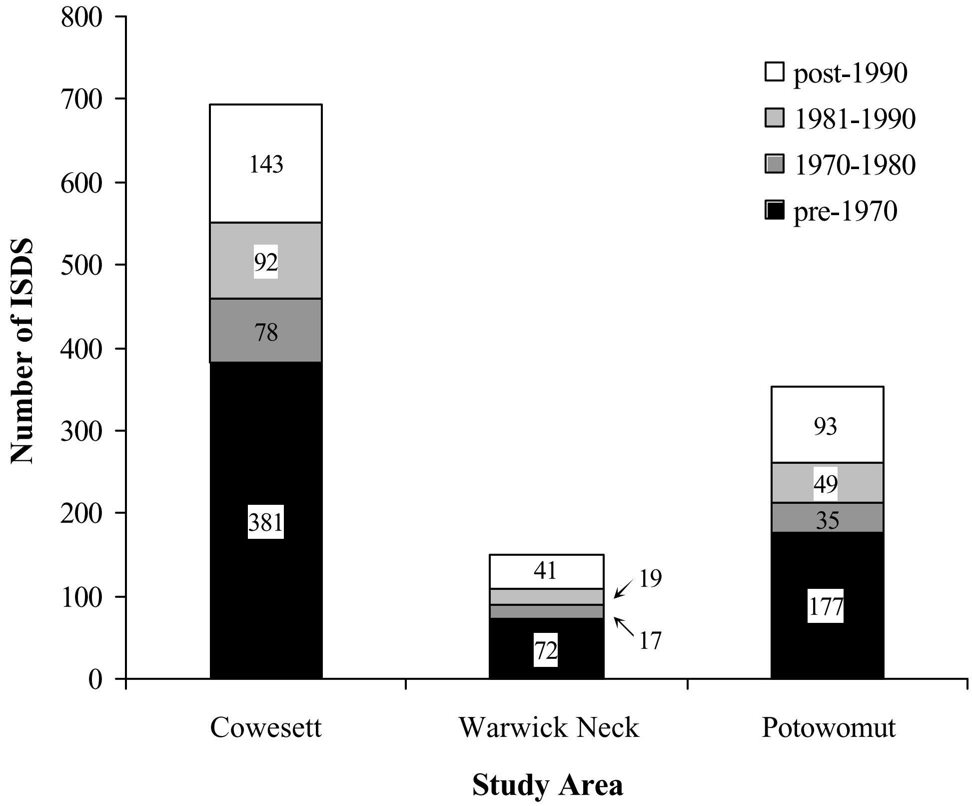
<u>*420.3B ISDS*</u>

1. ISDS that are poorly sited, malfunctioning, or failing can contaminate receiving waters with sewage and fecal pathogens (Canter and Knox, 1985; Postma et al., 1992). Faulty installation, cracks or leaks, general misuse, lack of maintenance, and clogging of the soil in the leachfield with organic material can shorten system life (Canter and Knox, 1985). When the soils clog, the effluent from a system cannot filter through the soil substrate and may pool at or near the surface. While ISDS are designed to operate indefinitely, poorly maintained conventional systems have an average 20-year lifespan (EPA, 1999). During or after a rainstorm, the effluent from a failed ISDS, already near the surface, surges upward with the water table and flows downslope with minimal infiltration (Jarrett et al., 1985). This type of bacterial input to coastal waters is significant in many areas (Weiskel et al., 1996).

2. Hundreds of failing or substandard ISDS continue to operate in the Greenwich Bay watershed and are a potential source of fecal contamination (Sinnamon, 2004). In 1993, sewers were not available to most of the Greenwich Bay watershed. Beginning in late 1993, RIDEM inspected ISDS in Warwick, East Greenwich, South Kingstown, and Charlestown. The vast majority of the inspected systems were in the Greenwich Bay watershed. Visual outside inspections resulted in reported violations primarily for water pooling at ground level and for illegal graywater or laundry discharges. The highest violation rates were in Potowomut and Brush Neck Cove (O'Rourke, 1995). Today, although sewers are available or are planned for large areas within the Greenwich Bay watershed, including the Brush Neck Cove area, ISDS remain a potential source of fecal contamination in these areas.

3. Certain developed areas in the Greenwich Bay watershed will remain unsewered, with sewage primarily treated by ISDS (Figure 5). Sinnamon (2004) evaluated the bacterial contamination risk to Greenwich Bay from ISDS, particularly cesspools, in three watershed areas where sewers are not planned. Sewers are not currently planned for Potowomut, Cowesett, and Warwick Neck. Sinnamon (2004) estimated that 53 percent of the ISDS—or 630 systems—in these areas are potentially cesspools (Figure 12). Cesspools are substandard ISDS that do not provide adequate treatment to remove pathogens. Based on housing density, soil conditions, slope, distance to Greenwich Bay, and the estimated number of cesspools, Sinnamon concluded that Potowomut is the highest risk area to Greenwich Bay, especially where ISDS serve shoreline homes (Figure 13). Large portions of Warwick plats 219, 220, 234, and 235 in Cowesett also represent a high-medium risk (Figure 14). The remaining areas in Cowesett and Warwick Neck represent a medium to low risk. ISDS in unsewered areas will remain a potential fecal contamination source until cesspools are eliminated, and until enforceable ISDS maintenance and inspection procedures are in place for homes and businesses not connected to the municipal sanitary sewer system.

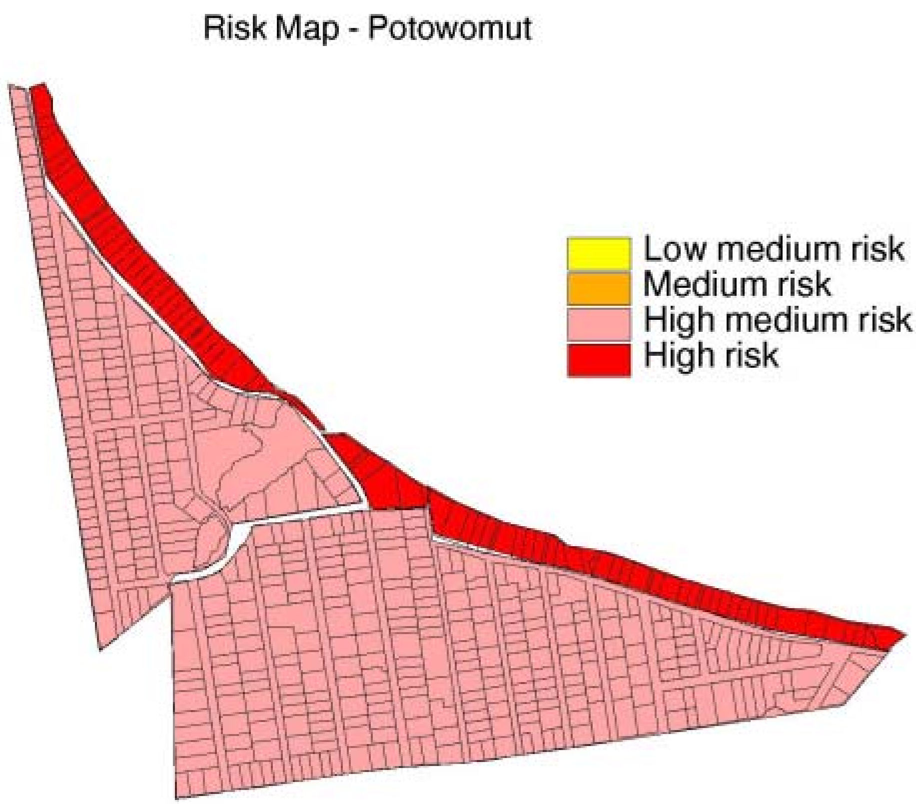
Figure 12. Approximate age of ISDS in three Warwick neighborhoods without sanitary sewers [1]



1 Pre-1970 ISDS are potential cesspools.

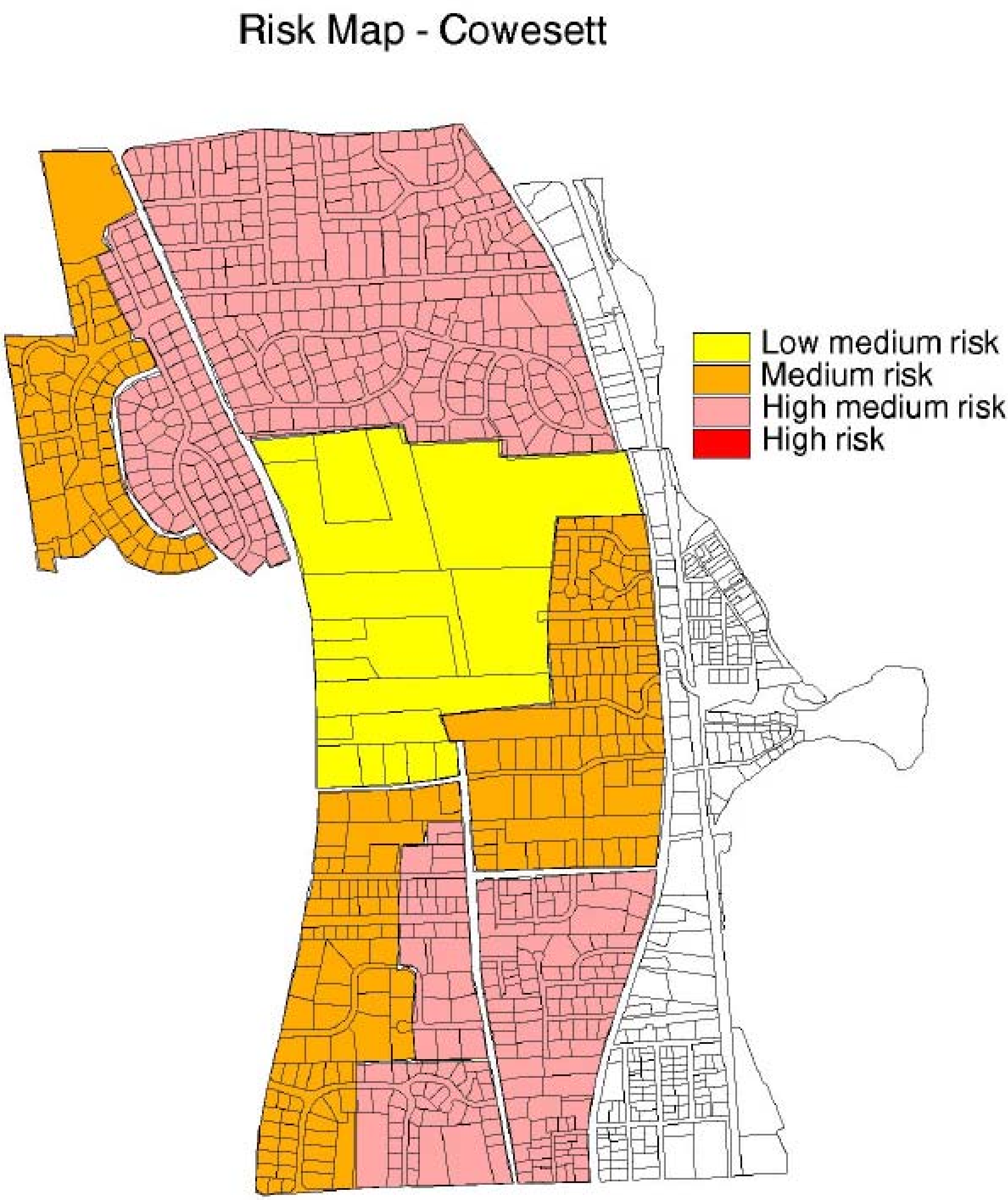
Source: Sinnamon, 2004

Figure 13. Relative fecal contamination risk from ISDS to Greenwich Bay - Potowomut



Source: Sinnamon, 2004

Figure 14. Relative fecal contamination risk from ISDS to Greenwich Bay - Cowesett



Source: Sinnamon, 2004

420.3C Pets and wildlife

1. Past studies have shown that waterfowl, wildlife, and pets contribute significantly to elevated indicator bacteria concentrations in surface water. A 2002 bacteria source tracking study conducted by RIDEM in Green Hill Pond, South Kingstown identified non-human animal sources as significant bacteria contributors (RIDEM, 2003d). In Greenwich Bay, waterfowl gather at beaches, in the coves, and along upland freshwater ponds and streams, depositing feces directly in the water body, or on land in the watershed, from where it enters receiving waters through runoff or groundwater (Weiskel et al., 1996). RIDEM maintains equestrian stables at Goddard Memorial State Park and has implemented a manure management plan to control pollution from these facilities (Mouradjian, pers. comm.). In the case where sources are widespread and diverse (for example, Greenwich Bay bacteria transported by storm water from the watershed), bacteria source tracking studies may not be useful. However, potential bacteria source tracking studies in Greenwich Bay could focus on specific areas, such as swimming beaches.

420.3D Boats

1. Boats operating on Greenwich Bay are a minor potential contributor to fecal contamination. On August 18, 1998, the EPA designated Rhode Island's marine waters as a federal no-discharge area. Boats with installed toilets must have an operable U.S. Coast Guard–approved marine sanitation device designed to hold sewage for pump-out or for discharge in the ocean beyond the three-mile limit. Figure 15 shows marine pumpout facilities in Greenwich Bay. Even with the no-discharge designation, boats remain a potential sewage source, depending on compliance rates. Data from RIDEM monitoring during dry weather (Table 12 and 13), do not indicate that marinas are a significant source of fecal contamination, relative to stormwater discharges.

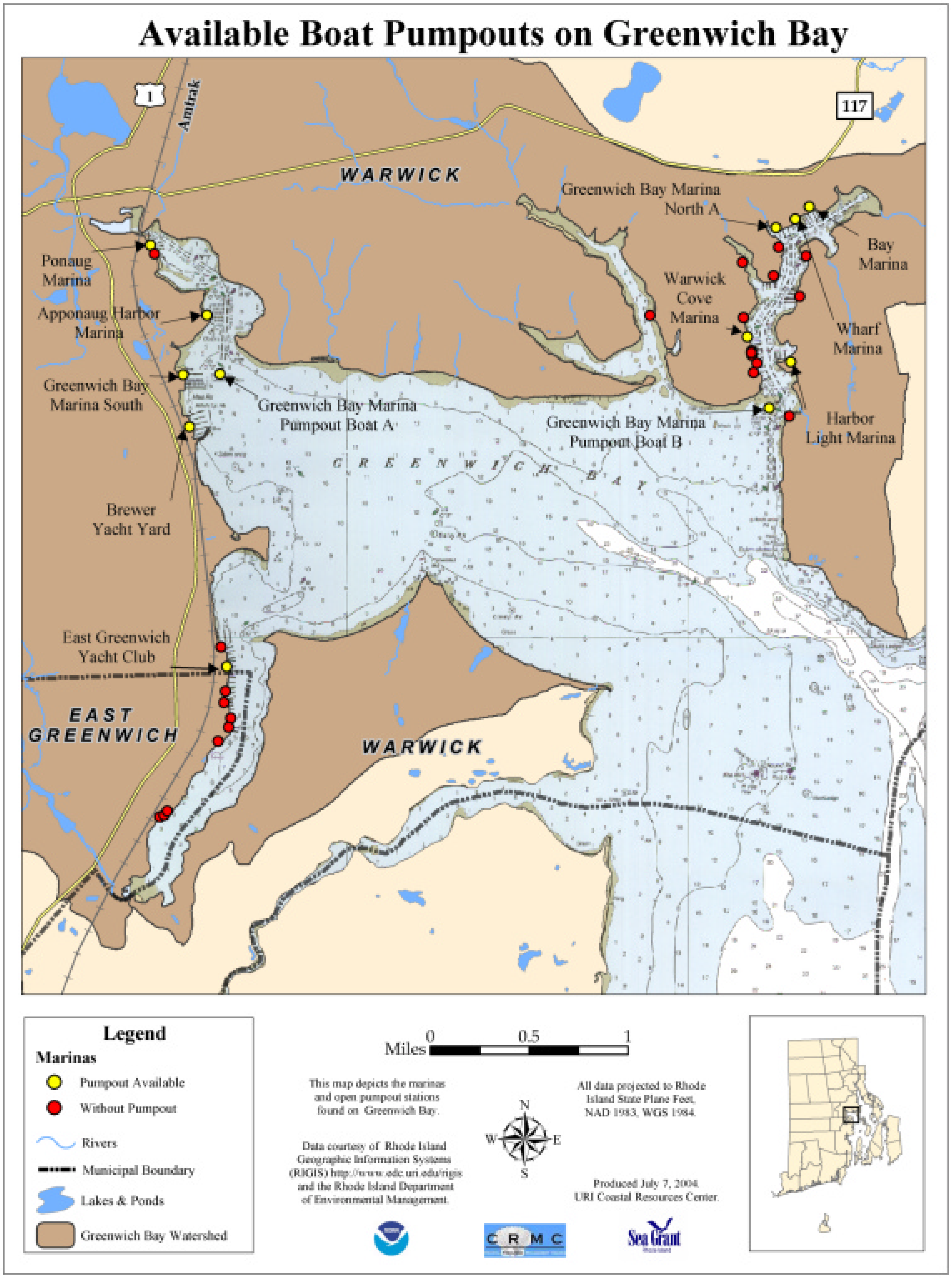
420.3E WWTF

1. Studies have concluded that the East Greenwich WWTF is not a significant contributor to bacterial contamination in Greenwich Cove or Greenwich Bay (FDA, 1993; RIDEM, 2004a).

420.3F Combined sewer overflows (CSOs)

1. Wet-weather sampling studies performed in the upper portions of Narragansett Bay indicate that CSOs from the Narragansett Bay Commission system in Providence have little, if any, effect on bacterial contamination in Greenwich Bay. Studies conducted by URI in 1990 and 1992 show that bacteria concentrations drop significantly as CSO-impacted waters move south, with little or no discernable impact in the waters adjacent to Rocky Point, approximately 1.5 miles north of Greenwich Bay (Reitsma, 2003). RIDEM shellfish station data show that bacteria levels outside the mouth of Greenwich Bay meet shellfish harvesting standards during both dry weather and following wet-weather events (RIDEM, 2004a).

Figure 15. Available boat pumpouts on Greenwich Bay



Section 430

Low dissolved oxygen levels

430.1 Definition of the problem

1. Low dissolved oxygen levels impair fish and wildlife habitat, potentially affecting commercial and recreational fisheries and leading to nuisance conditions, such as foul smelling odors. Fish, shellfish, and other aquatic animals require dissolved oxygen for survival. EPA conducted tests to determine the sensitivity of 23 saltwater species to reduced levels of dissolved oxygen. They found that juveniles and adults tolerate a limited number of brief exposures to dissolved oxygen concentrations as low as 2.3 mg/L, but lethal effects on larvae occur after extended exposure to concentrations below 4.8 mg/L (Thursby et al., 2000). In addition, growth effects were observed in both juveniles and larvae at concentrations between 2.3 mg/L and 4.8 mg/L. EPA concluded that 4.8 mg/L is suitable for early life stage development and will preserve biodiversity. Lower concentrations have increasingly adverse effects that are dependent on exposure durations. As dissolved oxygen falls below 4.8 mg/l for extended periods, residents should expect to see reduced abundance and diversity in the aquatic community. Fish and shellfish kills may be expected when dissolved oxygen concentrations drop below 1.0 mg/L. Other conditions associated with hypoxia (generally less than 3 mg/L) or anoxia (less than 0.1 mg/L) include bacterial slimes, foul smelling odors, and in extreme cases, generation of toxic levels of hydrogen sulfide (Nixon, 1995b; Goldberg, 1995). Over time, fish and shellfish populations decline, the bottom accumulates organic sediments, and anoxic events occur that are toxic to aquatic life. Low dissolved oxygen levels do not lead to beach or shellfish bed closures. These closures are caused by elevated fecal bacteria levels.

2. Greenwich Bay and its coves do not meet Rhode Island water quality standards for dissolved oxygen (Table 3). The dissolved oxygen level needed to meet water quality standards depends on that water body's water quality classification (Table 2). Greenwich Bay proper and Brush Neck and Buttonwoods coves must have oxygen concentrations of at least 6.0 mg/L at any place or time to meet water quality standards, except as naturally occurs. Greenwich, Apponaug, and Warwick coves have a less stringent standard of 5 mg/L. As noted in the following section, bottom water in Greenwich Bay and its coves frequently do not meet the 5 mg/L or 6 mg/L of dissolved oxygen standards during the summer months. In addition, surface waters can also fall below 5 mg/L or 6 mg/L of dissolved oxygen under certain conditions. In January 2005, RIDEM accepted public comments on rule changes that, if adopted, would change these standards to be consistent with proposed EPA standards.

3. Low dissolved oxygen levels drop below the 5 and 6 mg/L water quality standards on a regular basis in the bottom waters and occasionally in the surface waters of Greenwich Bay and its coves during the summer months. Low levels generally occur in the bottom waters of Greenwich and Apponaug coves and Greenwich Bay west of Sally Rock Point (Granger et al., 2000; Applied Science Associates (ASA), 2001; RIDEM, 2003e; Sullivan et al., unpublished data; Narragansett Bay Estuary Program (NBEP), 2004). Low levels occur less frequently in eastern Greenwich Bay (Nowicki and McKenna, 1990; Granger et al., 2000; ASA, 2001). With recent more intensive monitoring, low dissolved oxygen levels have been observed every year since 1996 somewhere in Greenwich Bay (Granger et al., 2000; ASA, 2001; RIDEM, 2003e; Sullivan et al., in preparation; Prell et al., 2004). Dissolved oxygen measurements prior to 1996

are sparse, although anecdotal reports and limited data prior indicate that hypoxic and anoxic conditions are not confined to recent years (Pratt and Seavey, 1981; Nixon, 1989; Nowicki and McKenna, 1990). The frequency, extent, and causes of past events may not be the same as current problems.

4. In recent years, low dissolved oxygen conditions have been associated with fish kills in Greenwich Bay. Small fish kills were reported in July 1998, July 1999, and June 2001 (RIDEM, 2003e). On August 20, 2003, an unusually severe fish kill took place in Greenwich Bay. An estimated 1 million organisms died, primarily juvenile menhaden. Other animals included small crabs, an occasional blue crab, grass shrimp, tautog, some horseshoe crabs, and a few American eels. The eels appeared to be the largest animal affected. Several weeks later, a large die-off of soft-shelled clams occurred, including a reported 1.05 billion dead juveniles, between Cedar Tree Point and Baker's Creek (RIDEM, 2003e; Ganz pers. comm.). The last reported Greenwich Bay fish kill of this size may have occurred in 1898 (Nixon, 1989). Most reported fish kills occur in Apponaug Cove and western Greenwich Bay, and do not necessarily occur during every hypoxic or anoxic event. Fish must be in the area and unable to escape low dissolved oxygen conditions for a fish kill to occur. Shellfish cannot move out of hypoxic and anoxic areas. Soft-shelled clams can survive short periods of low dissolved oxygen, but hard-shelled clams can survive long periods of low dissolved oxygen.

430.2 Results of dissolved oxygen studies

1. Monitoring studies have been conducted to measure dissolved oxygen levels in Greenwich Bay and its coves, although data are generally limited to certain areas of the bay and its coves or specific years. Recent technological advances have greatly improved the quality of the monitoring data being collected by providing continuous measurements that capture daily peaks and valleys in dissolved oxygen levels.

430.2A Rhode Island Sea Grant Greenwich Bay Collaborative Study

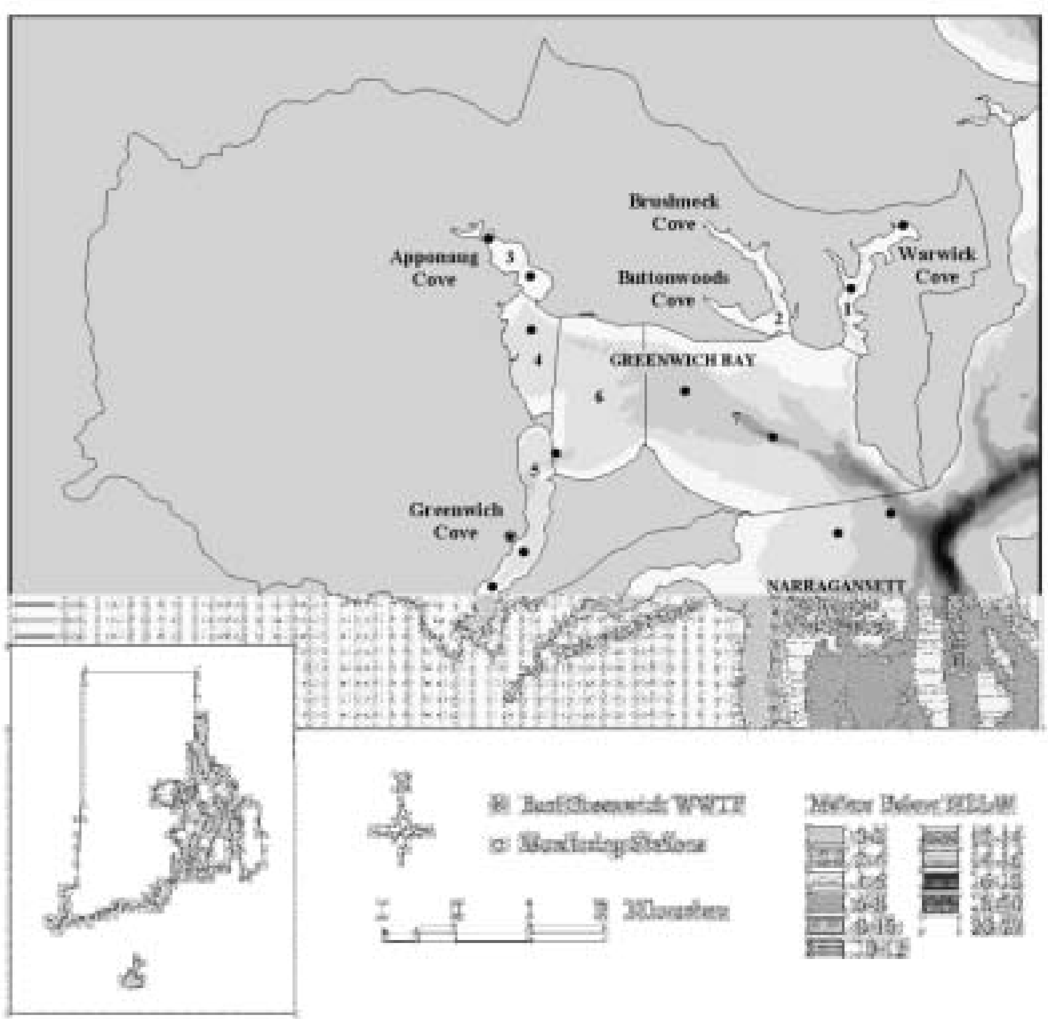
1. Granger et al. (2000) measured dissolved oxygen levels in Greenwich Bay over the course of a two-year study from August 1995 to May 1997 (Figure 16). Over 1,900 measurements were made, although shallow depths excluded data collection in Brush Neck and Buttonwoods coves. Low dissolved oxygen levels were found in bottom waters throughout Greenwich Bay and its coves (Table 15). These conditions were limited to the summer months between June and September when vertical density stratification was present. The most severe conditions were detected in the bottom waters of Greenwich and Apponaug coves and western Greenwich Bay. Between June and September 1996, 67 percent of the samples collected from bottom waters in these areas showed hypoxic conditions, with dissolved oxygen conditions less than 1 mg/L detected on certain dates. Conditions were less severe in Warwick Cove and eastern Greenwich Bay with 21 percent of the samples collected from June to September indicating hypoxic conditions. However, 85 percent of these samples still did not meet water quality standards. The Granger et al. (2000) data captured one widespread hypoxic event in July 1997. During this event, over 40 percent of the Greenwich Bay bottom waters sampled contained less than 3 mg/L of dissolved oxygen and 25 percent contained less than 2 mg/L. Within five days, most bottom waters in the bay had returned to levels above 2 mg/L of dissolved oxygen.

Table 15. Dissolved oxygen levels in Greenwich Bay bottom waters between June and September 1996

Location	Number of Measurements	Percentage of Measurements with Dissolved Oxygen Measurements Less Than:	
		3 mg/L	RIDEM Water Quality Standard
Greenwich Cove	11	73 percent	91 percent
Apponaug Cove	12	50 percent	83 percent
Warwick Cove	12	17 percent	75 percent
Western Greenwich Bay	13	77 percent	100 percent
Eastern Greenwich Bay	22	23 percent	91 percent

Source: Data from Granger et al. 2000

Figure 16. Water Quality Monitoring Stations used in 1995-1997 by Granger et al. (2000)



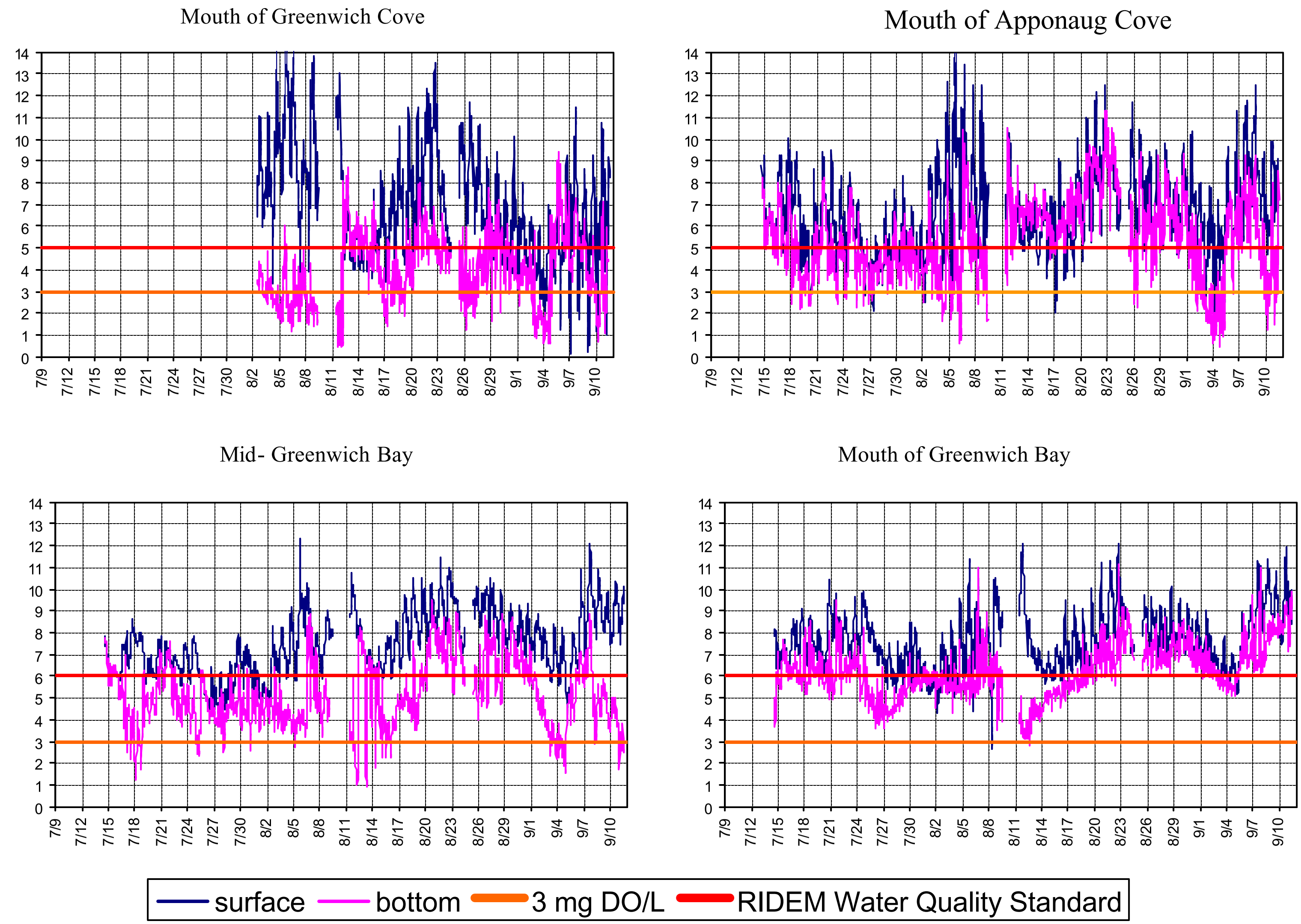
Source: Brush, 2002

<u>*430.2B ASA/RIDEM study*</u>

1. ASA and RIDEM conducted continuous oxygen monitoring at four locations throughout Greenwich Bay in 2000 (ASA, 2001). Measurements were taken at mid-Greenwich Bay and the mouths of Greenwich Bay and Apponaug and Greenwich coves. At each location, temperature, salinity, and dissolved oxygen were measured at both the surface and bottom of the water column at 15-minute intervals (Figure 17). The equipment was deployed for two months beginning in mid-July, with the exception of Greenwich Cove, where the equipment was deployed for only one month. Dissolved oxygen levels at the mouth of Greenwich Bay and the surface of mid-Greenwich Bay were generally good. Bottom-water dissolved oxygen at the mouth of the coves and the middle of the bay exhibited signs of hypoxia. Almost 30 percent of the bottom measurements taken at the mouth of Greenwich Cove were hypoxic. Hypoxia was recorded on 31 of the 40 days when measurements were taken in Greenwich Cove. Continuous near-surface and near-bottom measurements at the mouth of the Bay, north of Sally Rock, and at the entrance to Apponaug Cove show a consistent gradient of decreasing dissolved oxygen from east to west in Greenwich Bay.

2. In addition to the continuous oxygen measurements, ASA and RIDEM took dissolved oxygen profiles of the water column at locations throughout Greenwich Bay and just outside the bay. The oxygen levels from stations within Greenwich Cove were less than 3 mg/L at depths below the surface for some of the August surveys. An Apponaug Cove station also showed signs of hypoxia at the bottom during the mid-August survey.

Figure 17. ASA/RIDEM dissolved oxygen measurements during summer of 2000



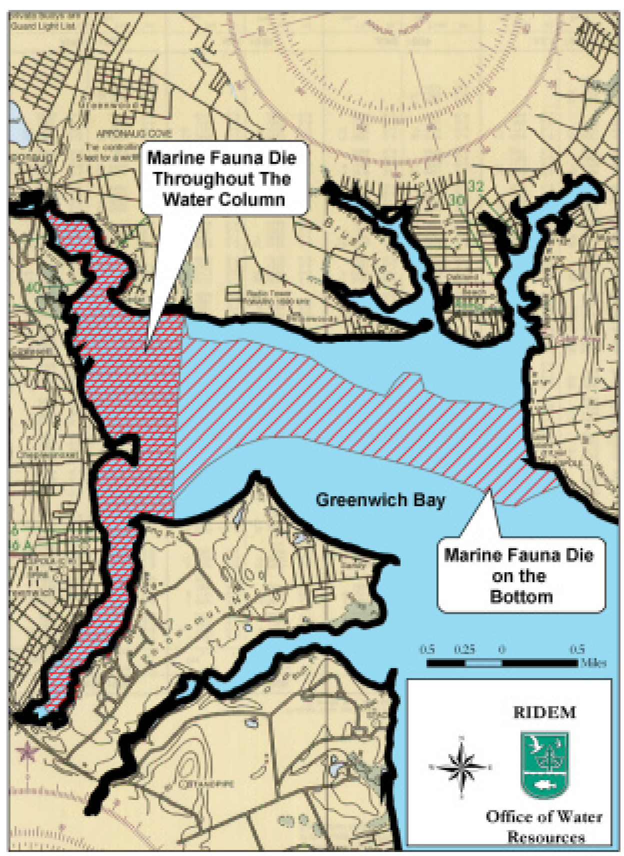
Source: Applied Science Associates, 2001

430.2C RIDEM Greenwich Bay Fish Kill Study

1. The RIDEM report, "The Greenwich Bay Fish Kill – August 2003: Causes, Impacts, and Responses," documented dissolved oxygen conditions during the unusually severe hypoxic and anoxic event that occurred in August 2003. RIDEM measured hypoxic and anoxic conditions in surface and bottom waters in Greenwich and Apponaug coves and western Greenwich Bay (RIDEM, 2003e). Sampling indicated that these conditions lasted for weeks in some areas. Hypoxic and anoxic conditions were present in bottom waters all the way to the mouth of Greenwich Bay as well (Figure 18). Bottom waters in eastern Greenwich Bay remained below 3 mg/L for almost 10 days.

2. The RIDEM fish kill report also cited hypoxic and anoxic events affecting these areas in July 1998, July 1999, and June 2001 (RIDEM, 2003e). The 1999 event affected Greenwich Cove and western Greenwich Bay while the 2001 event affected western Greenwich Bay near the mouth of Apponaug Cove.

Figure 18. Hypoxic and anoxic areas in Greenwich Bay based on RIDEM measurements of August 20, 2003



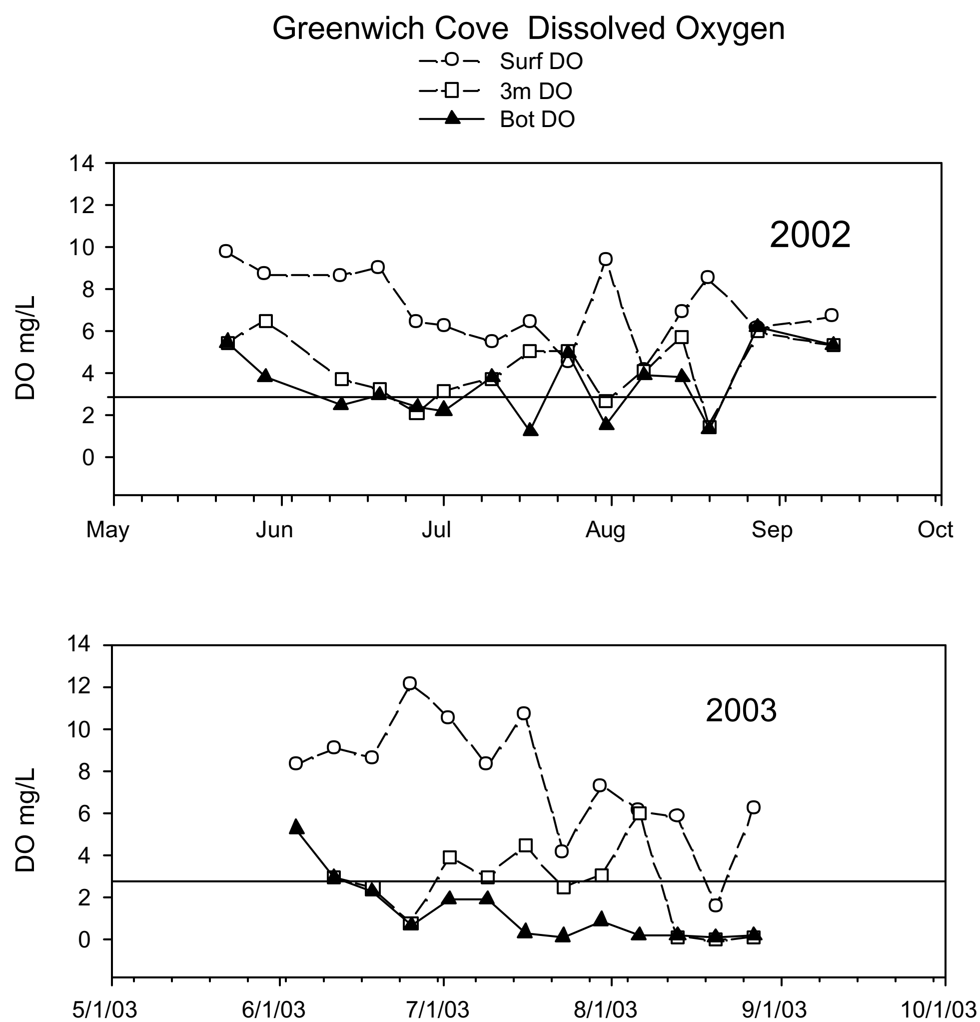
Anoxic / Hypoxic Areas in Greenwich Bay
Based on DEM Measurements of August 20, 2003

Source: RIDEM, 2003e

430.2D URI Graduate School of Oceanography and Providence College study

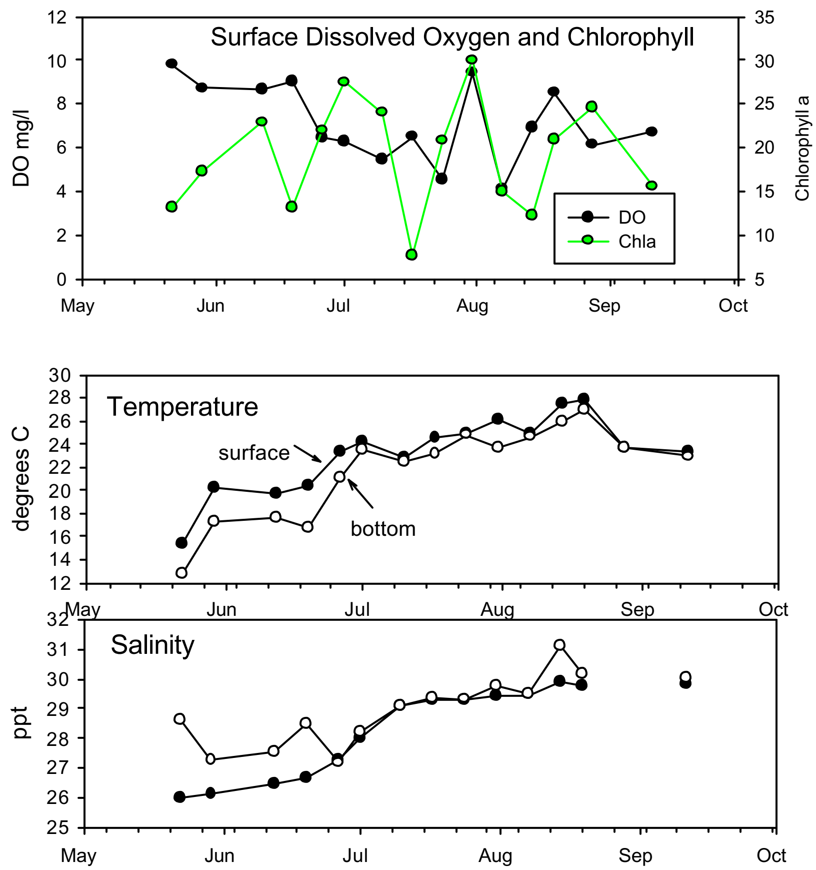
1. Weekly monitoring of dissolved oxygen, chlorophyll, temperature, and salinity during the summers of 2002 and 2003 took place off the outermost dock at Norton's Shipyard and Marina in Greenwich Cove (Sullivan et al., unpublished data). Hypoxic conditions in bottom waters were documented regularly during the summer of 2002 and were consistently below 3 mg/L in 2003 (Figure 19). On August 20, 2003, during the 2003 Greenwich Bay fish kill, both bottom and surface water dissolved oxygen levels were below 3 mg/L. Minimum values of dissolved oxygen generally followed documented chlorophyll maximum concentrations, especially during August. Stratification of the water column, as evidenced by differences in surface and bottom temperature and salinity, was most pronounced during the first half of the summers of 2002 and 2003 (Figures 20 and 21).

Figure 19. 2002 and 2003 Surface and Bottom Dissolved Oxygen Levels in Greenwich Cove



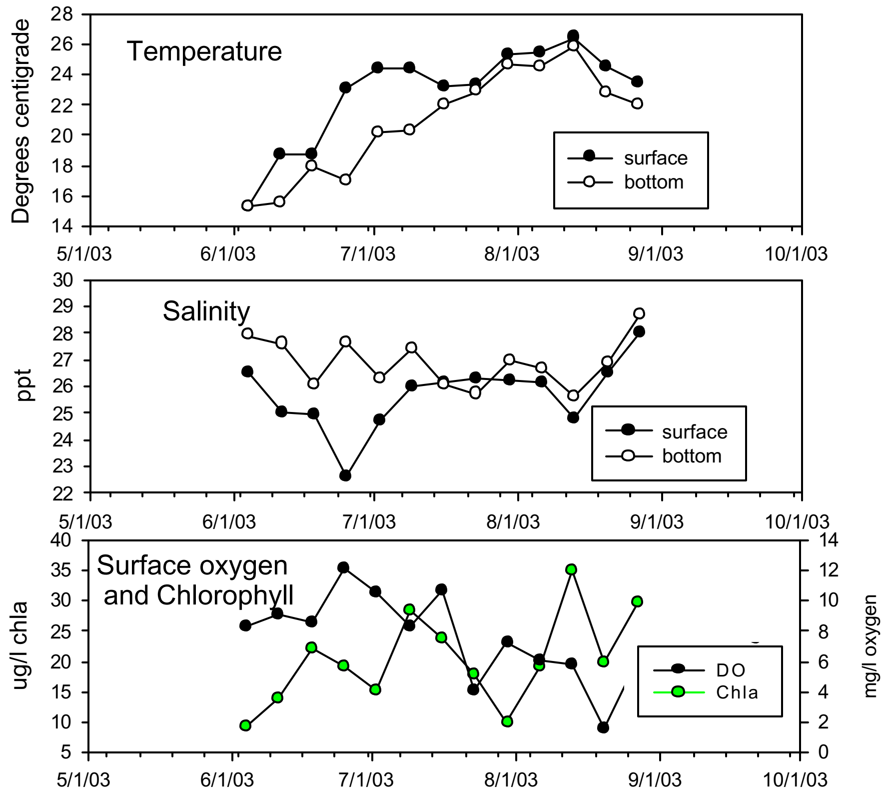
Source: Data courtesy of Sullivan et al.

Figure 20. 2002 dissolved oxygen levels relative to chlorophyll a, temperature, and salinity



Source: Data courtesy of Sullivan et al.

Figure 21. 2003 dissolved oxygen levels relative to chlorophyll a, temperature, and salinity



Source: Data courtesy of Sullivan et al.

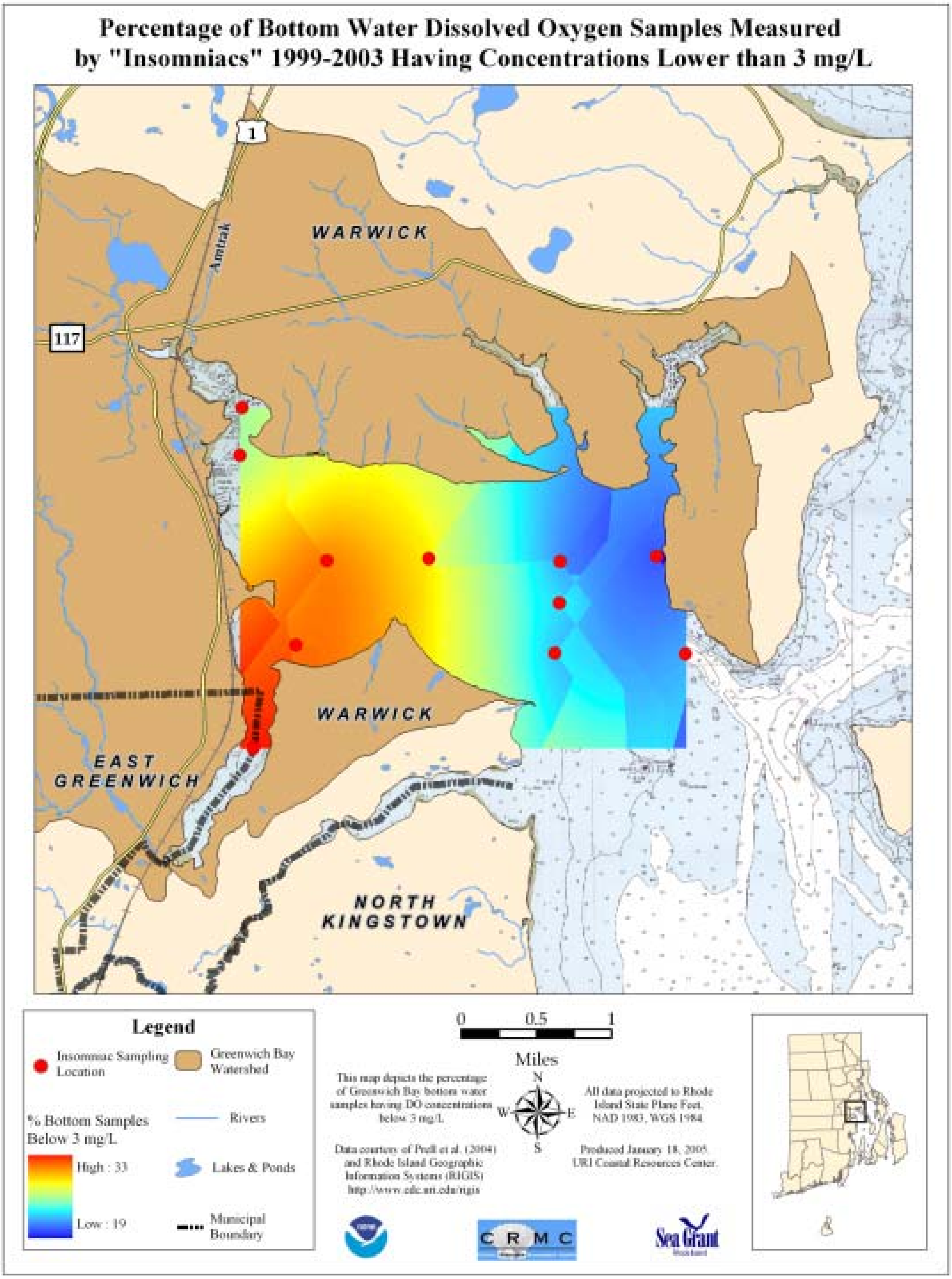
430.2E NBEP volunteer monitoring

1. Surveys carried out by volunteers and coordinated by Chris Deacutis (NBEP) measured evening dissolved oxygen between 1999 and 2003 at locations throughout Narragansett Bay, including Greenwich Bay (Prell et al., 2004). Evening neap tides during the summer months were targeted in an attempt to capture worst oxygen conditions.

2. The lowest dissolved oxygen concentrations measured during these surveys (often = 2 mg/l, sometimes = 1 mg/l) usually occurred in the lower Providence River, between Fields Point and Conimicut Point just below the pycnocline, and also in bottom waters on the western side of Greenwich Bay at the entrances to Apponaug and Greenwich coves. To generate a map of predicted low oxygen areas, the percentage of bottom water samples below 3 mg/L for each station was calculated for all 11 Greenwich Bay stations. A map was created of predicted percentages across most of the bay (Figure 22). It is evident that low dissolved oxygen in bottom waters is most common in Greenwich and Apponaug coves and along the western shore of Greenwich Bay, a pattern reinforced by the other studies described in this section.

3. Volunteer monitoring was also conducted in 2004. Due to a change in the monitoring program, different stations were monitored during 2004, and the total number of stations increased to 15. Hypoxia was much less common in 2004 compared to 2003. However, the pattern of lowest dissolved oxygen values in the bottom waters on the western side of Greenwich Bay was comparable to other years and surveys.

Figure 22. Percentage of bottom water dissolved oxygen samples measured by "Insomniacs" 1999-2003 having concentrations less than 3 mg/L

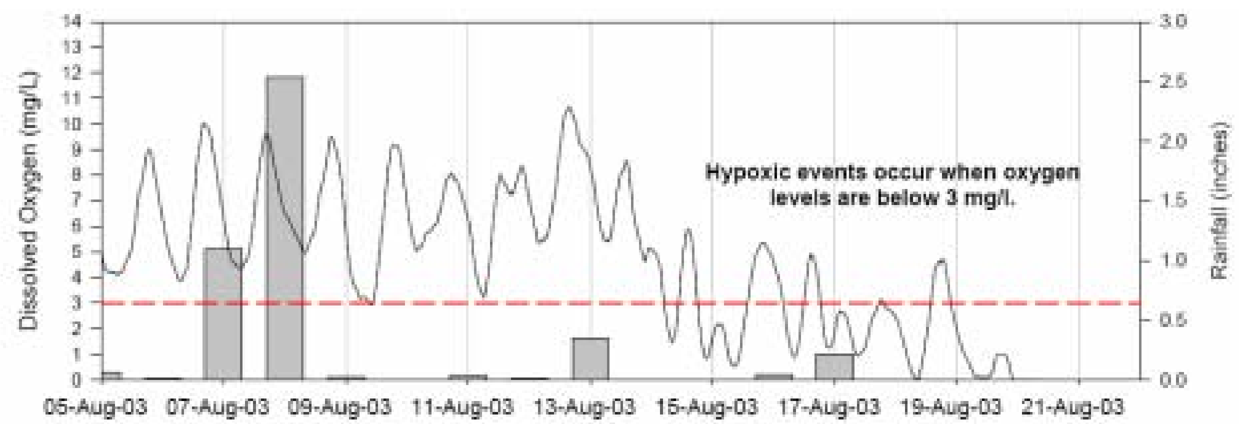


<u>*430.2F RIDEM and NBNERR Dissolved Oxygen Data*</u>

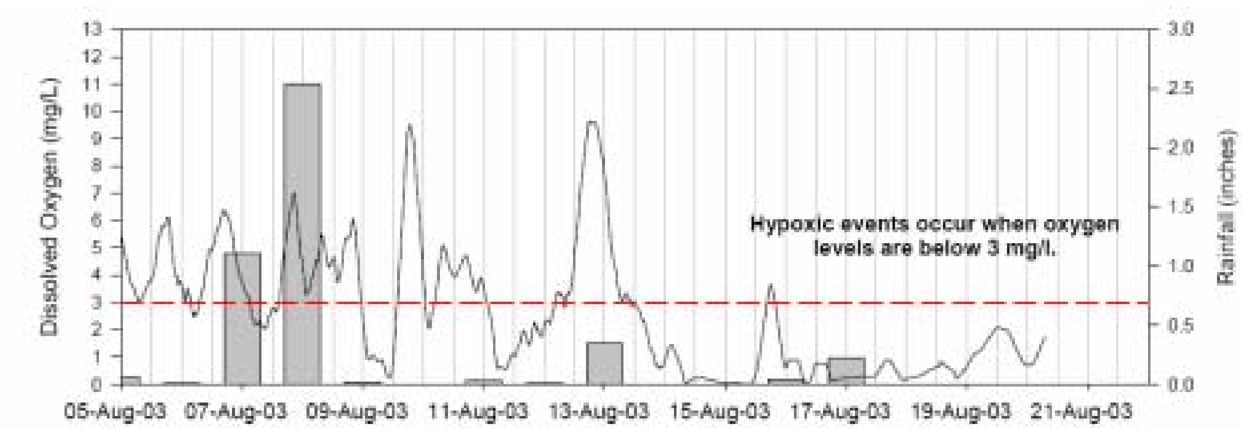
1. The Narragansett Bay National Estuarine Research Reserve (NBNERR) and RIDEM have maintained data sondes (a device for testing physical conditions) off of a dock at Greenwich Bay Marina South near the mouth of Apponaug Cove. In the summer of both 2003 and 2004, dissolved oxygen levels in bottom and surface waters dipped below current water quality standards (5 mg/L) on a nearly daily basis. In 2003, bottom waters in this area experienced hypoxic and anoxic conditions from August 14 through at least August 25 when the last measurements were taken (Figure 23; RIDEM, 2003e), corresponding to the 2003 fish kill. Surface waters also were hypoxic for periods of the day during this time. In July and August 2004, bottom waters were again hypoxic at times but for no period longer than four days (Figure 24 and 25). Surface waters were hypoxic only for brief periods on certain days.

Figure 23. Dissolved oxygen levels recorded by the Greenwich Bay Marina sonde in August 2003

a) Surface Sonde (Depth ~0.5 meters)



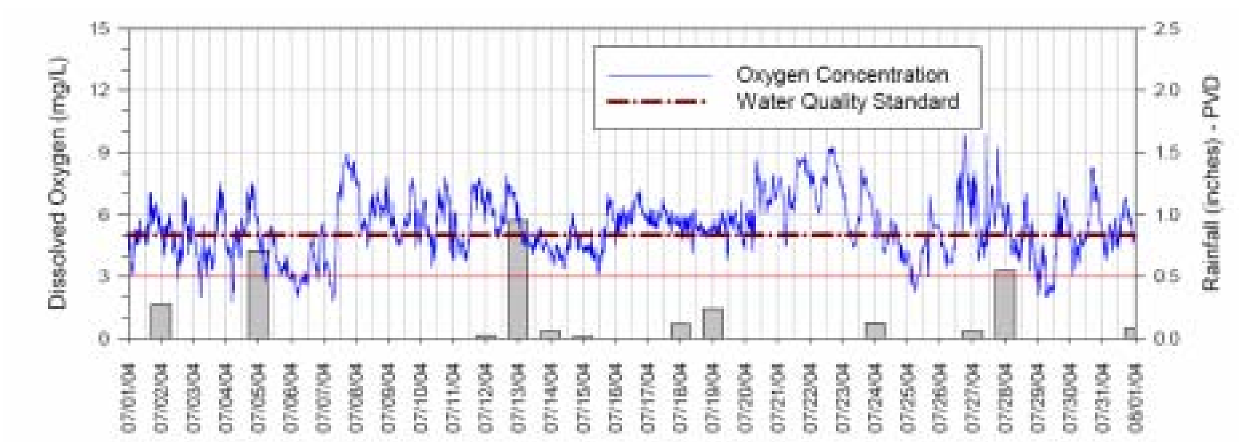
b) Bottom Sonde (Depth ~2 meters)



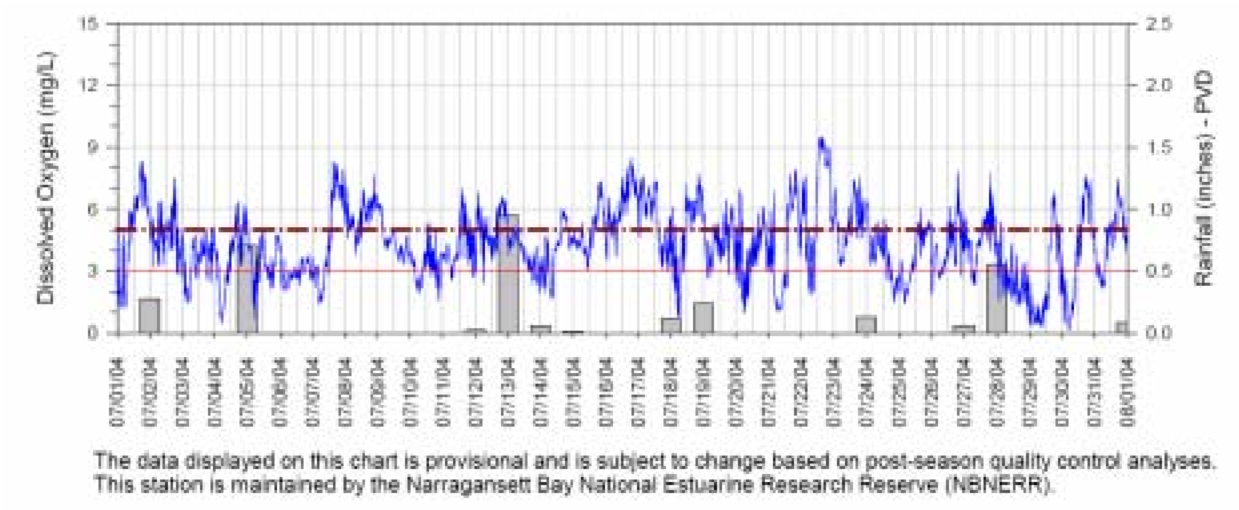
Source: RIDEM, 2003e

Figure 24. Dissolved oxygen levels recorded by the Greenwich Bay Marina sonde in July 2004

a) Surface Sonde (Depth ~0.5 meters)



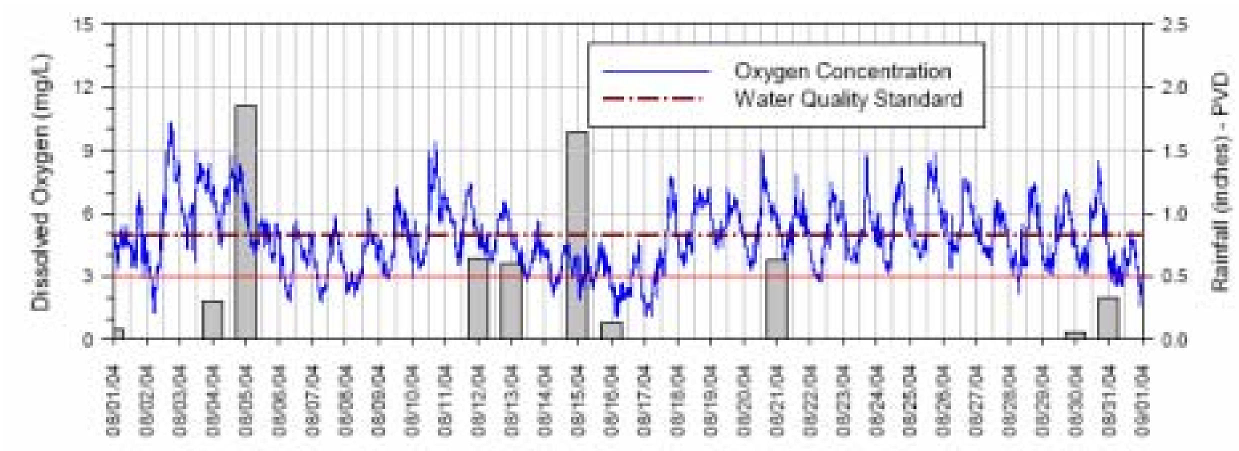
b) Bottom Sonde (Depth ~2 meters)



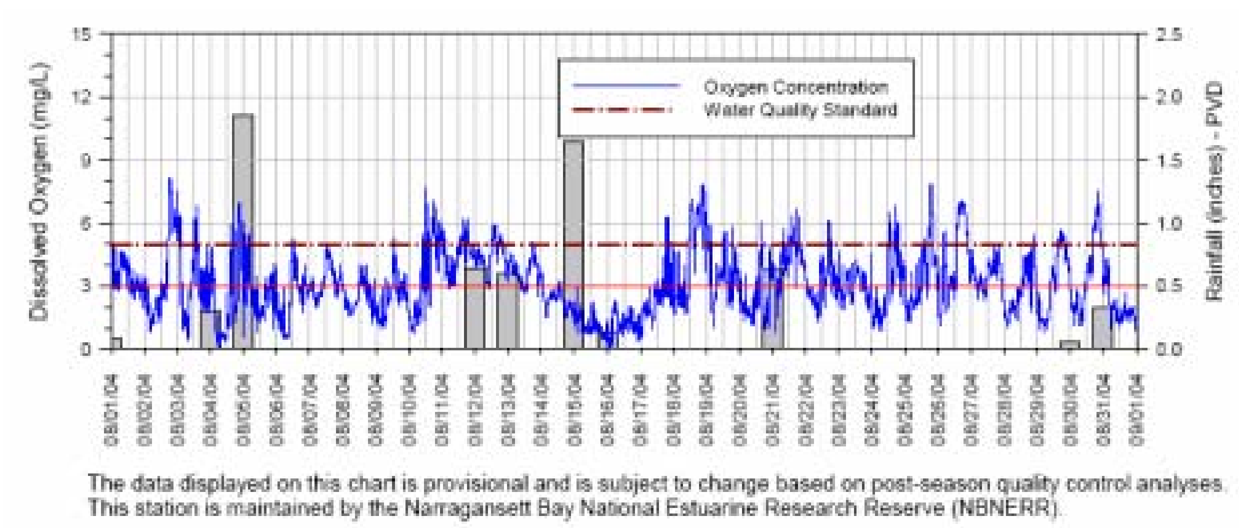
Source: Narragansett Bay National Estuarine Research Reserve, Bay Assessment and Response Team, http://www.state.ri.us/dem/bart/stations.htm

Figure 25. Dissolved oxygen levels recorded by the Greenwich Bay Marina sonde in August 2004

a) Surface Sonde (Depth ~0.5 meters)



b) Bottom Sonde (Depth ~2 meters)



Source: Narragansett Bay National Estuarine Research Reserve, Bay Assessment and Response Team, http://www.state.ri.us/dem/bart/stations.htm

430.3 Historic dissolved oxygen conditions

1. Data and reports on historic dissolved oxygen conditions in Greenwich Bay and its coves prior to 1996 are limited. The information that is available suggests that low dissolved oxygen conditions have occurred in Greenwich Bay prior to 1996, primarily in Apponaug Cove. However, limited sampling and data reporting make it difficult to determine the frequency or extent of past hypoxic and anoxic conditions relative to current conditions. The factors and pollution sources, such as high organic matter inputs, that caused hypoxic and anoxic events in the early part of the century may be different from the factors that are currently causing hypoxic and anoxic events.

2. Nowicki and McKenna (1990) summarized data collected on dissolved oxygen levels in Greenwich Bay from the late 1980s. Citing the following limited monitoring studies in eastern Greenwich Bay, they concluded that eastern Greenwich Bay was generally well-mixed and oxygenated. Hunt et al. (1987) sampled one site in eastern Greenwich Bay in October 1985, November 1985, April 1986, and May 1986, and found dissolved oxygen levels from 9.0 to 10.5 mg/L in surface and bottom waters. Doering et al. (1988) sampled the same location in August and found dissolved oxygen levels at approximately 7 mg/L. In Apponaug Cove, Nowicki and McKenna (1990) noted anecdotal reports of hypoxia and anoxia in 1986 and 1989. The 1989 report attributed a June fish kill of 300 to 500 winter flounder at the mouth of Apponaug Cove to low dissolved oxygen conditions.

3. Pratt and Seavey (1981) cite environmental surveys by the U.S. Army Corps of Engineers and RIDEM that found oxygen levels around 60 percent saturation in outer Apponaug Cove past the railroad bridge in 1967, 1972–73, and 1975. There is no indication of the time of year these measurements were taken.

4. During the first half of the 20th century, inner Apponaug Cove experienced hypoxic and anoxic events. Nowicki and McKenna (1990) cite historical records from 1924 that reported low dissolved oxygen levels (30 percent of saturation) in inner Apponaug Cove at and above the railroad bridge. Pratt and Seavey (1981) cite state surveys from 1926 and 1937 also showing hypoxia and anoxia in inner Apponaug Cove during the summer. Pratt and Seavey (1981) note that hypoxia and anoxia were limited to inner Apponaug Cove with oxygen levels in the outer cove above 60 percent saturation. Gage and McGouldrick (1924) report that low dissolved oxygen conditions in inner Apponaug Cove during this period were likely related to organic matter inputs from the Apponaug Bleachery and Dye Works, and that there was no other evidence of excessive pollution in Greenwich Bay outside of this area.

5. Nixon (1989) speculates that the Great Narragansett Bay Algal Bloom and Fish Kill of 1898 may have caused hypoxic and anoxic conditions in Greenwich Bay. Accounts describing the reaction of marine animals from that time are consistent with hypoxia and anoxia, although dissolved oxygen measurements are not available from that period. It is not clear how extensively, if at all, these conditions affected Greenwich Bay's coves at that time.

430.4 Causes of low dissolved oxygen levels

1. Dissolved oxygen levels in Greenwich Bay and its coves are determined by how much dissolved oxygen the water can hold and the relative balance between oxygen consumption in the water column and oxygen replenishment. Low dissolved oxygen levels develop when the oxygen production and replenishment in the water column is less than oxygen consumption. Physical factors, such as temperature, winds, tides, and gravitational circulation, largely determine how much dissolved oxygen the water can hold and how much oxygen is replenished. Aquatic plants and algae also produce oxygen as a waste product during photosynthesis. The rate at which photosynthesis occurs is called primary production. Biological factors largely influence the level of oxygen consumption in the water column. Biological respiration consumes oxygen in the water column and in bottom sediments. Temperature, organic matter inputs, primary production, and nutrient loads affect the intensity of biological respiration and oxygen consumption (Nixon, 1993).

430.4A Physical factors

1. Greenwich Bay and its coves are more susceptible to low dissolved oxygen levels during the summer. Seawater is saturated with oxygen at only 6 to 12 mg/L (2 to 4 percent of that found in air). As seawater warms, the amount of dissolved oxygen it can hold decreases, and biological respiration increases (Nixon, 1993). Therefore, oxygen consumption increases at the same time less dissolved oxygen is available in the water.

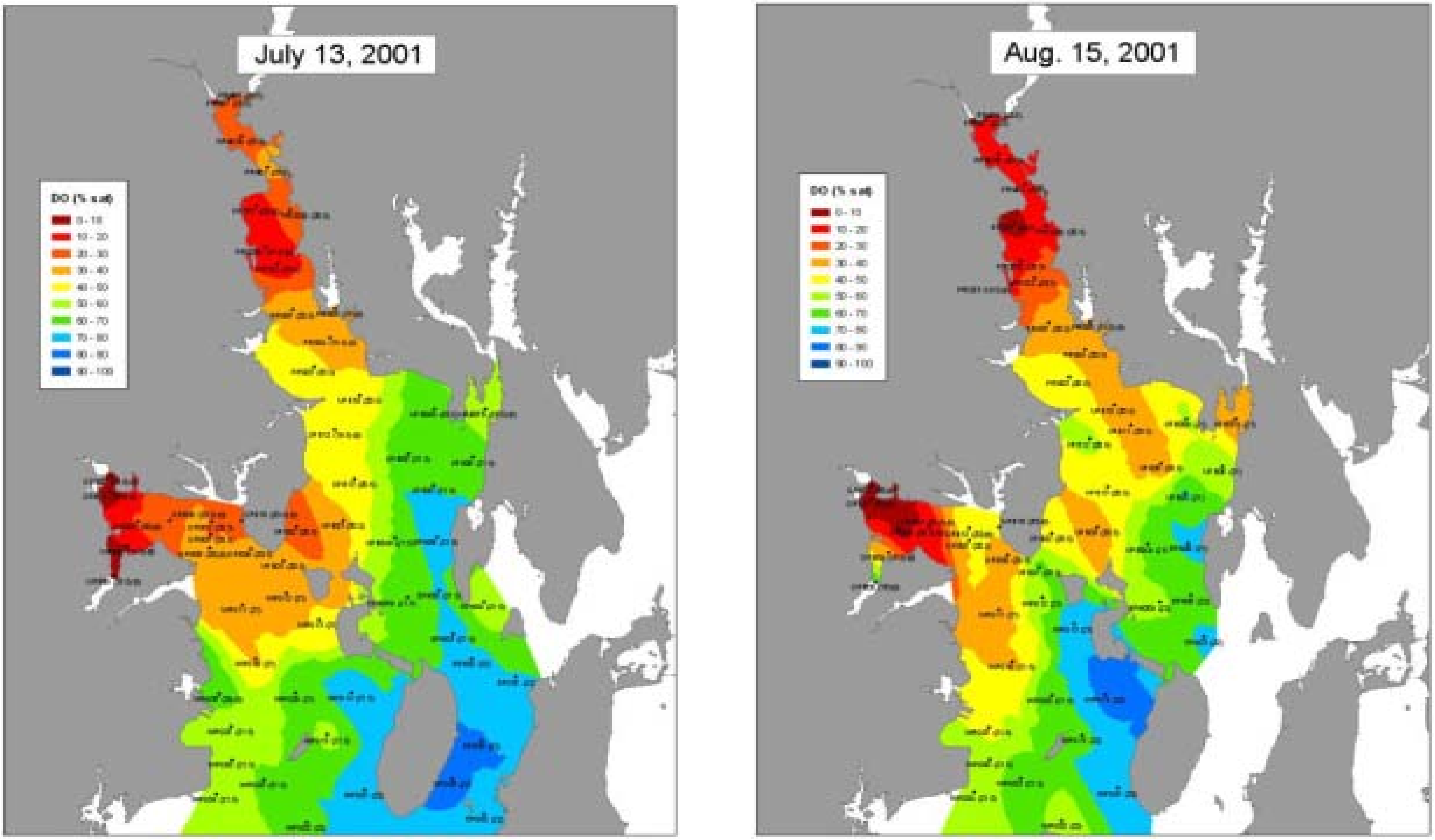
2. Greenwich Bay and its coves are more susceptible to low dissolved oxygen levels when vertical density stratification develops, which may occur when less dense freshwater enters an estuary and floats over the denser seawater, forming a fresher surface layer and a saltier bottom layer. Solar radiation may contribute to stratification as well when the surface layer is warmed, thus increasing its buoyancy. Vertical stratification is more likely to develop when winds and tides that mix the water column are minimal. Therefore, stratification is most likely to form during calm days coinciding with neap tides (Nixon, 1993). When stratification forms, the bottom layer does not have contact with the air and is not directly replenished with oxygen from the atmosphere. However, biological respiration continues to consume oxygen in the bottom layer. The primary remaining sources for oxygen replenishment are new bottom water flowing in from Narragansett Bay and photosynthetic oxygen production, if light can reach the bottom layer. In this situation, the balance between oxygen consumption and oxygen production is tipped towards consumption and low dissolved oxygen levels can develop in bottom waters. Surface waters generally remain well oxygenated because they continue to be replenished by oxygen from the atmosphere.

3. Waters of the West Passage and upper Narragansett Bay that enter Greenwich Bay due to tidal and estuarine flushing during the summer months may contain low oxygen levels. Generally, recent data indicates that the waters inside Greenwich Bay have lower levels of oxygen than waters outside the mouth of Greenwich Bay. Dissolved oxygen data show a general trend of decreasing dissolved oxygen from east to west in Greenwich Bay, particularly near the bottom (ASA, 2001; Brush, 2002; Prell et al., 2004). The NBEP data also periodically show low oxygen waters extending south from the mouth of the

Providence River to Warwick Point (Figure 26). From the earlier NBEP volunteer data, Saarman (2003) concluded that the Providence River and Greenwich Bay are the dominant sources of hypoxic water in Narragansett Bay.

4. The consistent trend indicates that the waters of western Greenwich Bay experience a net oxygen demand that is supplemented by the relatively well-oxygenated waters of the West Passage. Waters containing lower oxygen levels that exit Greenwich Bay with the ebb tide are not entirely transported away from the area by net transport in the bay. As a result, oxygen levels may be depressed outside the mouth of Greenwich Bay, particularly during the summer season. An additional negative influence is likely exerted by the Providence River. Regional Ocean Modeling System (ROMS) simulations indicate that under certain meteorological conditions, water flows primarily from the Providence River down the West Passage of Narragansett Bay (Bergondo, 2004). Model simulations of water movements indicate that some of this water may subsequently enter Greenwich Bay around Warwick Neck. Incomplete removal of waters from the mouth of Greenwich Bay by tidal flushing and transport of hypoxic waters from further up Narragansett Bay depress oxygen levels south of Warwick Point that subsequently contribute to further depressed levels inside Greenwich Bay. An ecosystem model developed for Greenwich Bay indicates that hypoxic events simulated within an annual cycle appear to be linked to these waters entering Greenwich Bay that are already partially depleted in oxygen (Brush, 2002).

Figure 26. Dissolved oxygen concentrations interpolated from sampling survey completed in July and August 2001



430.4B Biological factors

1. Biological activity in Greenwich Bay and its coves is high enough to deplete rapidly dissolved oxygen levels in the water column. Granger et al. (2000) measured oxygen consumption in the water and sediments at summer temperatures. Assuming no oxygen replenishment, they found that hypoxic conditions could develop within 5.8 hours to 3.4 days and anoxic conditions could develop within 8 hours to 4.7 days (Table 16). Hypoxic and anoxic conditions do not develop more often in Greenwich Bay and its coves because mixing from winds and tides allows oxygen in the water column to be replenished from the atmosphere and from seaward waters (Granger et al., 2000). They also concluded that phytoplankton respiration and decomposition had a far greater impact on dissolved oxygen levels than macroalgae in Greenwich Bay and its coves; estimated macroalgae production was only to 2 to 7 percent of estimated phytoplankton production.

Table 16. Estimated Time Needed to Reduce Greenwich Bay Bottom Waters to Hypoxic and Anoxic Conditions[1]

Location	Time to Reach:		Assumptions
	<2 mg/L (Hypoxia)	0 mg/L (Anoxia)	
Apponaug Cove	5.8 hours (0.2 days)	8 hours (0.3 days)	Stratification at 1 m Sediment oxygen uptake = 70 mg m^{-2} h^{-1} Water column respiration = 40 mg m^{-3} h^{-1} Benthic consumption = 96 percent of total
Greenwich Cove	26.4 hours (1.1 days)	36 hours (1.5 days)	Stratification at 1.5 m Sediment oxygen uptake = 100 mg m^{-2} h^{-1} Water column respiration = 45 mg m^{-3} h^{-1} Benthic consumption = 77 percent of total
Mid Greenwich Bay	70 hours (2.9 days)	96 hours (4 days)	Stratification at 2 m Sediment oxygen uptake = 35 mg m^{-2} h^{-1} Water column respiration = 30 mg m^{-3} h^{-1} Benthic consumption = 62 percent of total
Eastern Greenwich Bay	82 hours (3.4 days)	113 hours (4.7 days)	Stratification at 2.5 m Sediment oxygen uptake = 35 mg m^{-2} h^{-1} Water column respiration = 25 mg m^{-3} h^{-1} Benthic consumption = 63 percent of total

1 Based on approximate time needed for water column respiration and benthic oxygen uptake to reduce oxygen concentrations from 7.5 mg/L to 2 mg/L or 0 mg/L at summer temperatures. Assumes darkness, constant rate of respiration, and no oxygen input from surface waters or adjacent areas.

Source: Granger et al. 2000

2. High nutrient loadings increase biological production, oxygen consumption in the water column, and the probability of low dissolved oxygen levels. As nutrient loading increases in enclosed bays like Greenwich Bay, primary production by phytoplankton increases. Nutrient pulses to Greenwich Bay and its coves can lead to intense blooms of phytoplankton. Phytoplankton produce oxygen by photosynthesis during the day, whereas at night they only respire and consume oxygen. When phytoplankton blooms die, these organisms sink to bottom waters and their decomposition by bacteria also consumes oxygen. During the physical conditions described previously, hypoxia and anoxia can develop (Nixon, 1993; National Research Council, 2000). The consensus is that the previous scenario lead to the severe August 2003 fish kill (Pryor et al., 2004).

430.4C 2003 Greenwich Bay fish kill

1. In August 2003, as discussed previously, an unusually severe hypoxic and anoxic event occurred in Greenwich Bay. RIDEM reported that the onset of hypoxia and subsequent anoxia at both the surface and bottom of western Greenwich Bay occurred within hours following the collapse of a large phytoplankton bloom that was recorded by both the surface and bottom instruments in western Greenwich Bay (RIDEM, 2003e). The phytoplankton bloom occurred subsequent to a large rainstorm whose impact on the bay was observed as a decrease in surface and bottom salinity. Nearly simultaneous behavior of salinity, phytoplankton levels, and dissolved oxygen was observed near Bullocks Point in the central Providence River. In contrast, measurements in upper Narragansett Bay did not show the same behavior. In addition to the RIDEM report, URI researchers have emphasized the importance of physical factors, such as water temperature, stratification, winds, water circulation, and tides, in decreasing oxygen replenishment (Schwartz, 2004), and creating the severe hypoxic and anoxic conditions in the summer of 2003 relative to other recent years. They also suspect that Narragansett Bay waters with low dissolved oxygen levels may have contributed to the severity of this particular event in Greenwich Bay (Nixon et al., 2004).

430.5 Limiting hypoxic and anoxic events

1. Eliminating or reducing hypoxic and anoxic events requires addressing the physical and biological factors described previously. Reducing nitrogen inputs to Greenwich Bay and its coves could reduce biological production and the frequency, magnitude, and duration of hypoxic and anoxic events. However, nitrogen-loading reductions may not completely eliminate low dissolved oxygen levels in Greenwich Bay if natural physical conditions occasionally favor hypoxia and anoxia development. Some low-dissolved-oxygen events may be a natural phenomenon in Greenwich Bay and its coves. Reducing nitrogen loadings may have impacts on dissolved oxygen levels in Greenwich Bay. Details may be found in the following section.

2. While biological production can be addressed, controlling physical factors, such as temperature, winds, and tides, is generally infeasible or expensive. On a small scale though, mechanical mixing of the water column during critical summer periods could improve localized dissolved oxygen levels in bottom waters.

Section 440
Eutrophication and nutrient loading

440.1 Definition of the problem

1. Eutrophication is an increase in the rate of supply of organic matter, such as plants and algae, to an ecosystem (Nixon, 1995b). It is most commonly related to increased nutrient loadings to a lake, river, estuary, or other water body and a subsequent increase in aquatic plant and algae growth. Eutrophication has been identified as one of the major emerging problems for the coastal environment in the 21st century (Goldberg, 1995; GESAMP, 1990; Nixon, 1995b). In marine ecosystems, nitrogen is the essential nutrient that stimulates plant growth, while in freshwater ecosystems, phosphorus plays the controlling role (Nixon and Pilson, 1983; Smith, 1989; Taylor et al., 1995). Mesocosm experiments confirm that nitrogen is the most important limiting nutrient in northeastern estuaries (Oviatt et al., 1995).

2. Nutrients act as fertilizers leading to increased organic matter production and consequent impacts symptomatic of eutrophication (Nixon, 1993; 1995b). Symptoms of coastal eutrophication include:

- Reduced biodiversity
- Increased phytoplankton production
- Shifts from large to small phytoplankton
- Shifts in species composition of phytoplankton from diatoms to flagellates
- Shifts from benthic (bottom dwelling) to pelagic (swimming in open water) fish communities
- Increased seaweed/macroalgae biomass
- Decreased eelgrass habitat
- Shifts from filter-feeding to deposit-feeding benthos
- Increased organic content in bottom sediments
- Increased disease in fish, crabs, and lobsters
- Increased extent and frequency of hypoxia and anoxia
- Increased potential for toxic phytoplankton blooms
- Nuisance odor problems
- Decreased aesthetic quality and suitability for recreational use

3. Greenwich Bay exhibits many of the symptoms of eutrophication including high phytoplankton production (Granger et al., 2000), high seaweed/macroalgae biomass (Granger et al., 2000), periods of hypoxia and anoxia during the summer months (Granger et al., 2000; ASA, 2001; RIDEM, 2003e; Sullivan et al. unpublished data; Prell et al., 2004), and loss of eelgrass habitat (Kopp et al., 1995). These conditions often lead to problems such as seaweed or dead fish wash up on beaches, causing a degradation of aesthetic quality and prompting nuisance odor complaints (RIDEM 2003e).

4. Greenwich Bay and all of its coves do not currently meet state water quality standards for nutrients (Table 3). In addition, Apponaug Cove is also listed as impaired by excess algal growth. Nitrogen is the nutrient of concern because it limits primary production. The state water

quality standard does not include a particular numeric criteria for nitrogen, but preventing or minimizing eutrophication is a goal and limits are in place for dissolved oxygen levels (Table 2). When a TMDL is established, RIDEM may establish numeric criteria for nutrients in a particular water body such as Greenwich Bay. Water quality in the coves is of particular concern because the five major coves receive 90 percent of the watershed's nutrient inputs (Brush, 2002). These inputs, combined with the small volumes of cove receiving waters (8.4 percent of total), create significant potential for high concentrations of pollutants in the coves.

440.2 Results of nitrogen and eutrophication symptom studies

1. Over the last 20 years, a number of scientific studies have been conducted that evaluate nitrogen levels and eutrophication symptoms in Greenwich Bay. Ambient nitrogen concentrations have been measured throughout the bay (Granger et al., 2000; Applied Science Associates, 2001). Nitrogen concentrations or loadings have been measured or estimated from groundwater (Urish and Gomez 1998, 2004), storm water (Wright et al. 1998), tributaries (DeMelo, 1996; DeMelo et al. 1997; Herron et al. 1998; Wright and Viator, 1999; Applied Science Associates, 2001), and the East Greenwich WWTF (Applied Science Associates, 2001). Eutrophication symptoms have been characterized in many parts of the bay (Valente et al., 1992; Granger et al. 2000; Sullivan et al. unpublished data). An ecosystem model has been developed to connect nitrogen inputs to euthrophication symptoms and provide insight into potential impacts with load changes (Brush, 2002).

440.2A Science Applications International Corporation Benthic Habitat Study

1. In 1988, Valente et al. (1992) used REMOTS (Remote Ecological Monitoring of the Seafloor) sediment profile photography to evaluate eutrophication symptoms in Greenwich Bay's benthic habitats. Sediment profile photographs were taken at 10 locations in Greenwich Bay. Photographic images were analyzed for sediment type, depth to hypoxic/anoxic sediments, and infaunal successional stage. In addition, samples were analyzed for *Clostridium perfringens* as an indicator of point source sewage discharges. Greenwich Bay sediments, particularly in Greenwich and Apponaug coves, appeared to transition to hypoxic/anoxic conditions at shallow depths and supported benthic communities characteristic of organically-enriched sediments or transitional communities characteristic of benthic habitats moving from oligotrophic to eutrophic conditions. Greenwich Cove images also showed surface mats of anaerobic bacteria. Based on their analysis, Valente et al. (1992) concluded that eutrophication symptoms in Greenwich Cove are related to discharges from the East Greenwich WWTF whereas other areas in Greenwich Bay receive organic enrichment from other sources primarily.

440.2B URI-CVE Hardig Brook and Northern Watershed Studies

1. In 1994 and 1995, the URI-CVE monitored six tributaries to Greenwich Bay for dissolved inorganic nitrogen (DIN) in dry and wet weather (DeMelo, 1996; DeMelo et al. 1997, Wright and Viator, 1999). The largest measured loads in dry weather flowed from Southern Creek (Carpenter Brook), Tuscatucket Brook, and Mill Brook (Table 17). Wet weather measurements suggest that nitrogen pulses following storm events are significant

sources of nitrogen to Greenwich Bay. For example, results indicate that nitrogen loads from Tuscatucket Brook after a single storm event can exceed daily loads measured from the East Greenwich WWTF (Table 18). The positive relationship between flux of nitrogen and river water flow has been found for most of the rivers in Narragansett Bay (Nixon et al. 1995).

440.2C URI-CVE Direct Storm Discharges Studies

1. The URI-CVE sampled a limited number of direct storm water sources during its Direct Storm Water Discharges Study (Wright and Viator, 1999). In general, DIN concentrations were lower from storm water outfalls during wet weather relative to dry weather, but loads were larger because of greater discharge volume (Table 18). Individual storm water outfalls had much smaller loads than measured discharges from the East Greenwich WWTF.

Table 17. Tributary end loadings of dissolved inorganic nitrogen (DIN) to Greenwich Bay

Stations		**Dry Weather**				**Wet Weather**	
		ASA/RIDEM Study		**URI-CVE Hardig Brook and Northern Watershed Studies**		**URI-CVE Hardig Brook and Northern Watershed Studies**	
Location	**ID**	**Concentration (mg/L)**	**Load (kg/day)**	**Concentration (mg/L)**	**Load (kg/day)**	**Concentration (mg/L)**	**Load [1] (kg/event)**
Greenwich Cove							
Maskerchugg River	L5	1.00	2.9	-			
Apponaug Cove							
Hardig Brook at Route 1 [2]	HB08/L2	1.35	15.6	1.17	-	-	-
Hardig Brook at Route 117	HB07/L6	1.15	8.6	1.26	2.5	0.79	22
Gorton Pond Tributary	GP03/L7	0.69	2.3	0.54	0.6	0.82	9.7
Mill Brook	MB04/L8	1.54	1.2	3.67	7.8	1.18	5.3
Greenwood Creek	GC01	-		7.51	5.9	2.37	4.9
Brush Neck Cove							
Southern Creek (Carpenter Brook)	SC03/L3	4.77	8.4	8.42	22.1	2.65	21.2
Tuscatucket Brook	TB02/L4	2.56	4.8	4.66	10.8	1.90	13.8

1 Loading rate per wet weather event above dry weather loadings.
2 Tidally-influenced location. During the ASA/RIDEM Study, samples were only taken during low tides.

Source: DeMelo, 1996; DeMelo et al., 1997; Wright and Viator, 1999; Applied Science Associates, 2001

Table 18. Point source discharges of dissolved inorganic nitrogen (DIN) to Greenwich Bay

Discharge			Dry Weather [1]		Wet Weather	
Location	ID	Type	Concentration (mg/L)	Load (kg/day)	Concentration (mg/L)	Load [2] (kg/event)
Greenwich Cove						
East Greenwich WWTF	L1	Wastewater Treatment Facility	8.57	35.51	No Data	
Division Street	EG06	Storm Water	4.87	0.12	2.05	0.55
Ladd Street at Norton's Marina	WK08	Storm Water	3.52	0.35	3.02	0.78
Crompton Ave at Rocky Hollow	EG07	Storm Water	0.53	0.13	0.62	0.38
East Greenwich Transfer Station	EG01	Storm Water	3.35	0.12	1.30	1.85
Apponaug Cove						
Midget Ave.	WK28		2.28	0.62	No Data	
Buttonwoods and Brush Neck coves						
Shand Avenue	WK30	Storm Water	5.61	1.65	3.50	1.82
Moulton Circle	WK22	Storm Water	3.28	0.96	No Data	
Gordon, Hawksley, Seaview	WK35	Storm Water	5.20	0.89	0.88	0.90
Mohawk Avenue	WK38	Storm Water	1.08	0.005	0.19	0.08
Warwick Cove						
Pequot Ave. and Prior St.	WK43	Storm Water	2.38	1.16	No Data	
Samuel Gorton Avenue	WK46	Storm Water	3.60	0.18	0.49	0.13
Greenwich Bay – Western Shore						
Masthead Dr and Fred Humlak Way	WK13	Storm Water	1.88	0.92	0.42	0.41
Chepiwanoxet Way and Oak Grove	WK10	Storm Water	0.68	0.34	0.35	0.45
Post Rd and Ocean Point Ave South	WK09	Storm Water	1.53	0.17	0.80	0.84
Greenwich Bay - Northern Shore						
Capron Farm Rd.	WK19	Storm Water	1.45	0.54	No Data	
Greenwich Bay - Warwick Neck						
Kirby Avenue	WK52	Storm Water	1.26	0.21	2.41	0.27

1 Dry weather measurements were made on a single sampling day (March 21, 1997).
2 Loading rate per wet weather event above dry weather loadings.
Source: Wright et al., 1998; Applied Science Associates, 2001

440.2D Rhode Island Sea Grant Greenwich Bay Collaborative Study

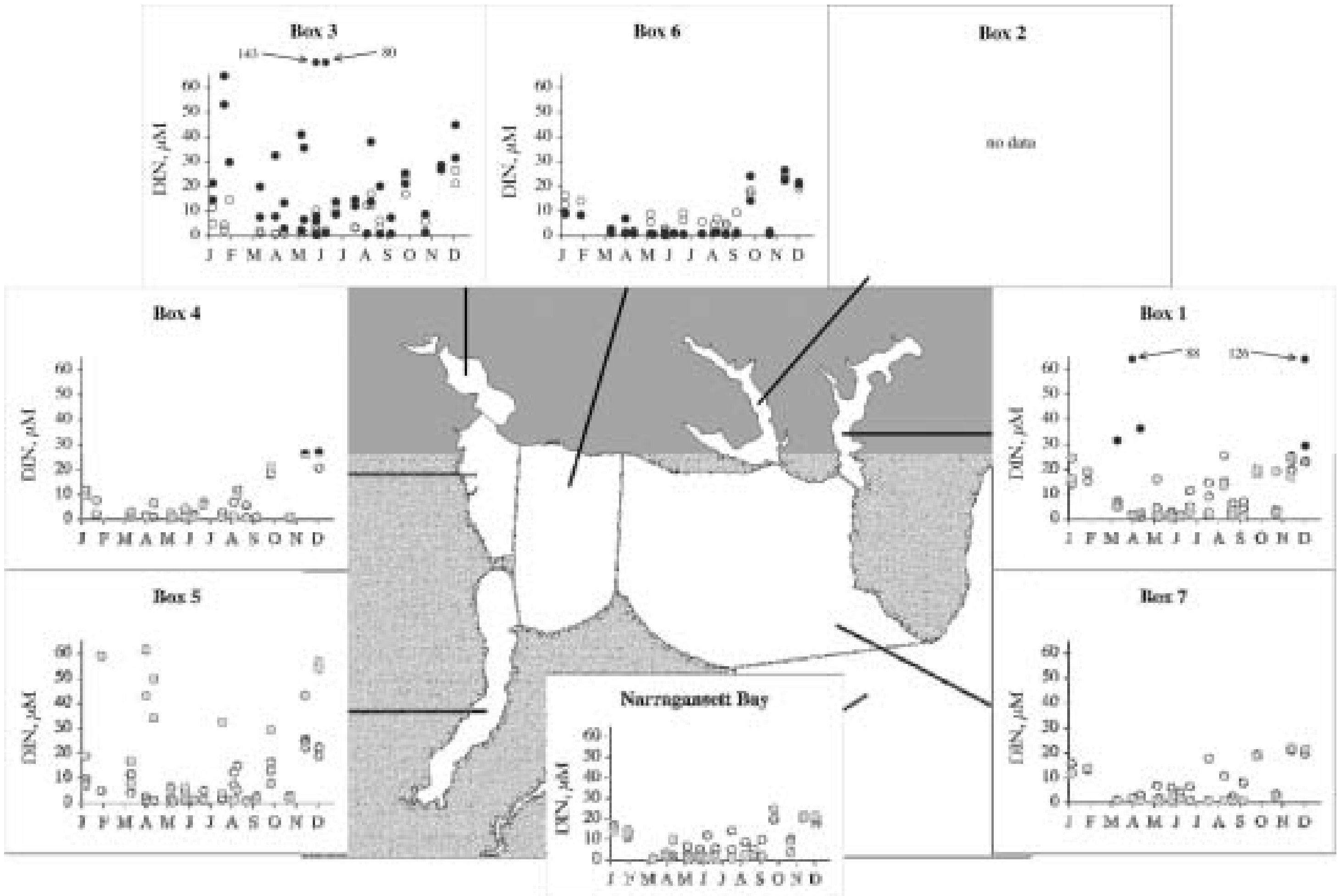
1. Granger et al. (2000) measured dissolved inorganic nitrogen (DIN) and chlorophyll a at 12 stations in Greenwich Bay between May 1996 and May 1997 (Figure 16). In general, the highest DIN concentrations were found within the coves (Figures 27). DIN was generally lower in the summer in Greenwich Bay proper, and higher in bottom waters.

2. Chlorophyll a concentrations were lowest during the late winter and early spring (Figure 28). Bay-wide phytoplankton blooms occurred in June and October, increasing chlorophyll a concentrations. Concentrations remained high in Greenwich Cove and inner Greenwich Bay throughout the summer with more variability in Apponaug and Warwick coves. The measured range of chlorophyll a concentrations was consistent with past studies, as summarized by Nowicki and McKenna (1990), although the timing of blooms varied (Figure 29).

3. While precisely measuring the biomass and distribution of macroalgae is logistically difficult, Granger et al. (2000) worked with Save the Bay volunteers to survey biomass of the two major species of macroalgae commonly found in Greenwich Bay in the summer of 1996. *Ulva lactuca* and *Gracilaria tikvahiae* were collected from rakings in the intertidal zone, then dried and weighed. During periods of peak abundance, up to 400 grams dry weight/m^2 were measured in only a few places in the coves (Granger et al., 2000). The following summer a coring survey was undertaken to map macroalgae in Apponaug, Greenwich, Buttonwood, and Warwick Coves. Maps generated from this study show small areas of dense biomass rather than widespread abundance of the two main species of macroalgae (Figure 30). Granger et al. (2000) estimated that macroalgae produce 5-15 g C m^{-2} $year^{-1}$.

4. Granger et al. (2000) concluded that phytoplankton are the major primary producers in Greenwich Bay and its coves. They estimated that phytoplankton production in Greenwich Bay proper is 210-250 g C m^{-2} $year^{-1}$. Combined with estimates for macroalgae/seaweed production, phytoplankton produce 93-98% of total primary production while macroalgae/seaweed produce 2-7%. Theoretically, estimates for phytoplankton and macroalgae production place Greenwich Bay in a mesotrophic state (Nixon, 1995b). However, total phytoplankton production for Greenwich Bay and its coves and its proportion of primary production is underestimated since the estimates did not include phytoplankton production in the coves.

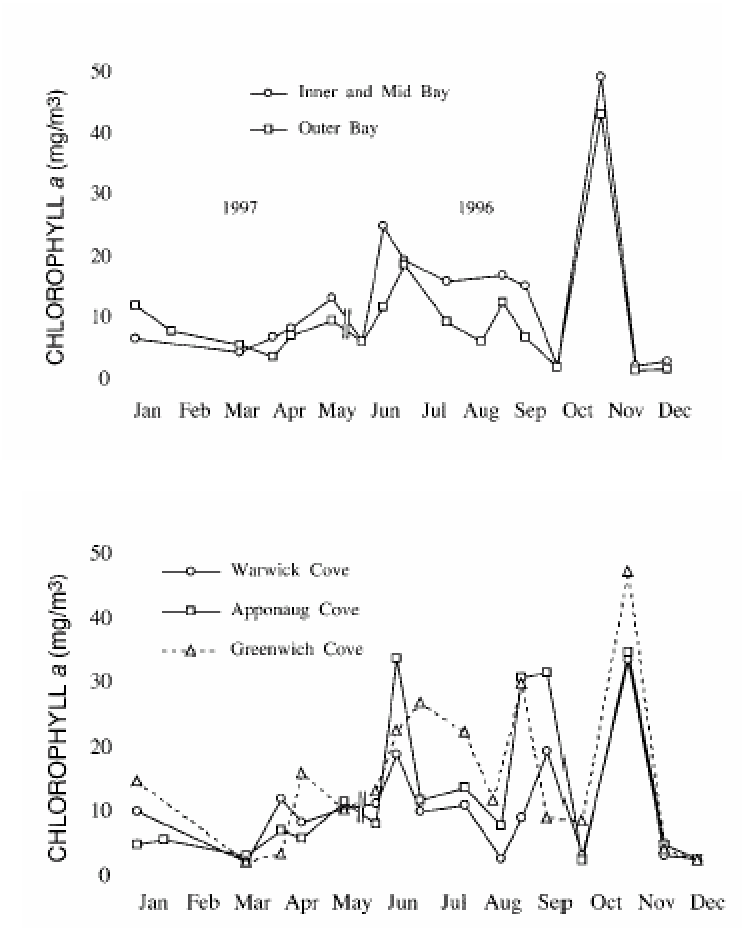
Figure 27. Dissolved inorganic nitrogen (DIN) concentrations around Greenwich Bay



Notes: Closed circles = surface layer sampling results; open circles = bottom layer sampling results. Data were collected between May 1996 and May 1997 but plotted from January to December to show annual cycle. Tic marks and labels for months are placed approximately at the beginning of each month.

Source: Brush 2002

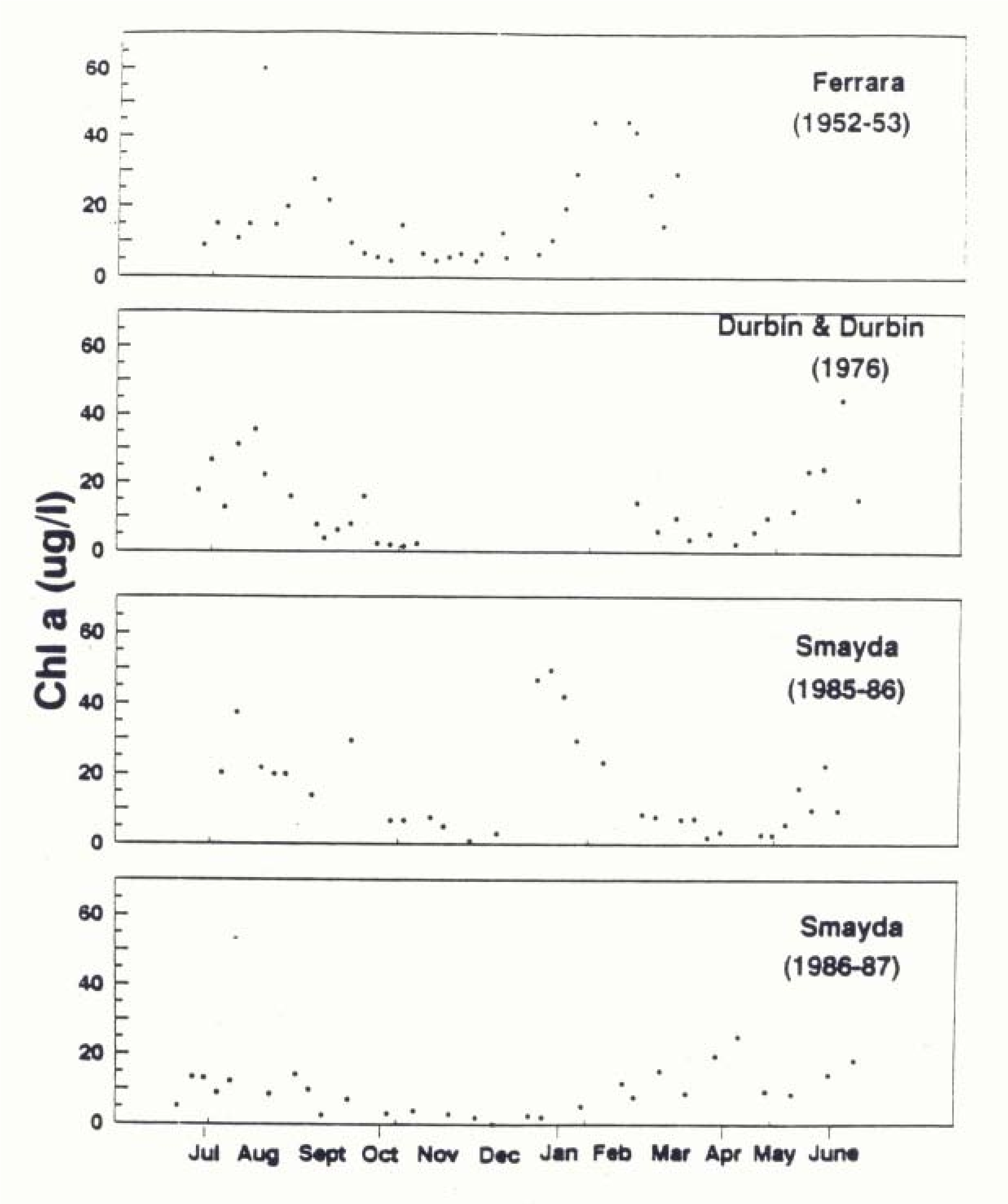
Figure 28. Chlorophyll a concentrations in Greenwich Bay from May 1996 to May 1997



Notes: Values are the mean of near surface and near bottom samples.

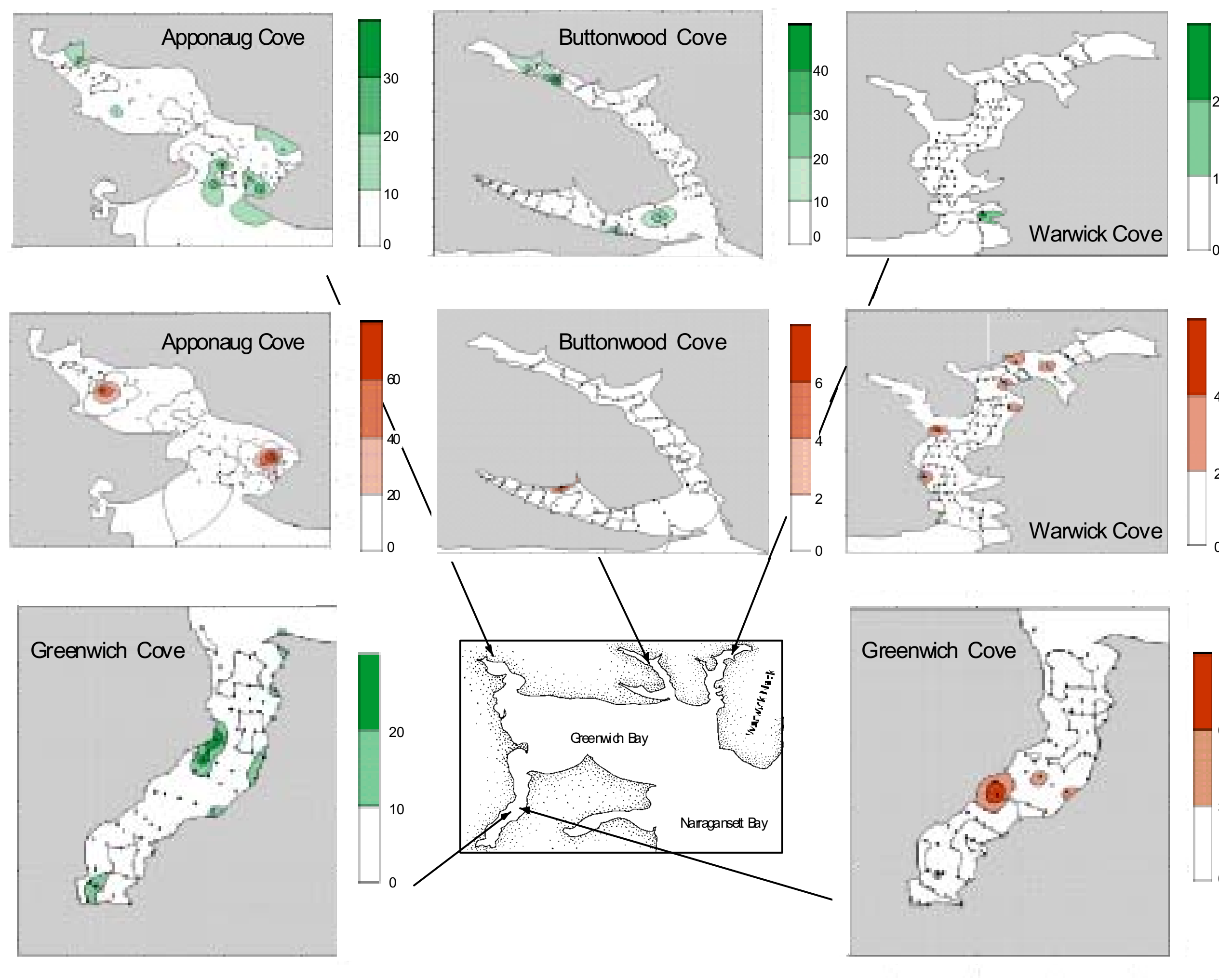
Source: Granger et al. 2000

Figure 29. Chlorophyll a concentrations in outer Greenwich Bay from four studies spanning a time period from 1952 to 1987



Source: Nowicki and McKenna 1990

Figure 30. Biomass of *Ulva* (green) and *Gracilaria* (red) in the major coves of Greenwich Bay in July 1997



Notes: Units are in grams dry weight/m^2. Dots show sampling locations.

Source: Granger et al. 2002

440.2E URI Cooperative Extension Citizen Water Quality Monitoring

1. Volunteers monitored nitrogen at 11 sites eight times between July of 1996 and October of 1997 on the Maskerchugg River with assistance from the URI Watershed Watch program (Herron et al. 1998). The Maskerchugg River is the second largest source of freshwater entering Greenwich Bay (Table 5). Nitrogen levels were low at all sites and comparable to concentrations from other studies.

440.2F URI-CVE Groundwater Discharge Study

1. URI-CVE evaluated the importance of groundwater nitrogen discharges to Greenwich Bay (Urish and Gomez, 1998; Urish and Gomez, 2004). Urish and Gomez estimated that 74% of groundwater flows to Greenwich Bay's tributaries while 26% is discharged directly to Greenwich Bay. Based on thermal infrared imagery, areas of major direct groundwater discharge are Warwick, Brush Neck, Apponaug, and Greenwich coves as well as areas southeast of Baker's Creek and near Long Point on Potowomut Neck. Groundwater DIN concentrations were measured at three sites (Table 19). DIN concentrations were higher at the sites draining developed areas, Arnold's Neck and Brush Neck. Based on a groundwater nitrate-nitrogen loading budget, Urish and Gomez estimated that 65-75% of groundwater nitrogen loadings in the Greenwich Bay watershed originate from ISDS. They also concluded that Brush Neck and Apponaug coves received the largest groundwater nitrate inputs, followed by Greenwich Cove.

Table 19. Measured nitrogen concentrations in groundwater at three shoreline sites

Shoreline Location	**Nitrogen (mg/L)**	
	Average	**High**
Arnold's Neck	8.0	12.0
Northeast Brush Neck Cove	6.75	13.5
Goddard Memorial State Park	0.9	1.95

Source: Urish and Gomez, 1998

440.2G Greenwich Bay Ecosystem Model

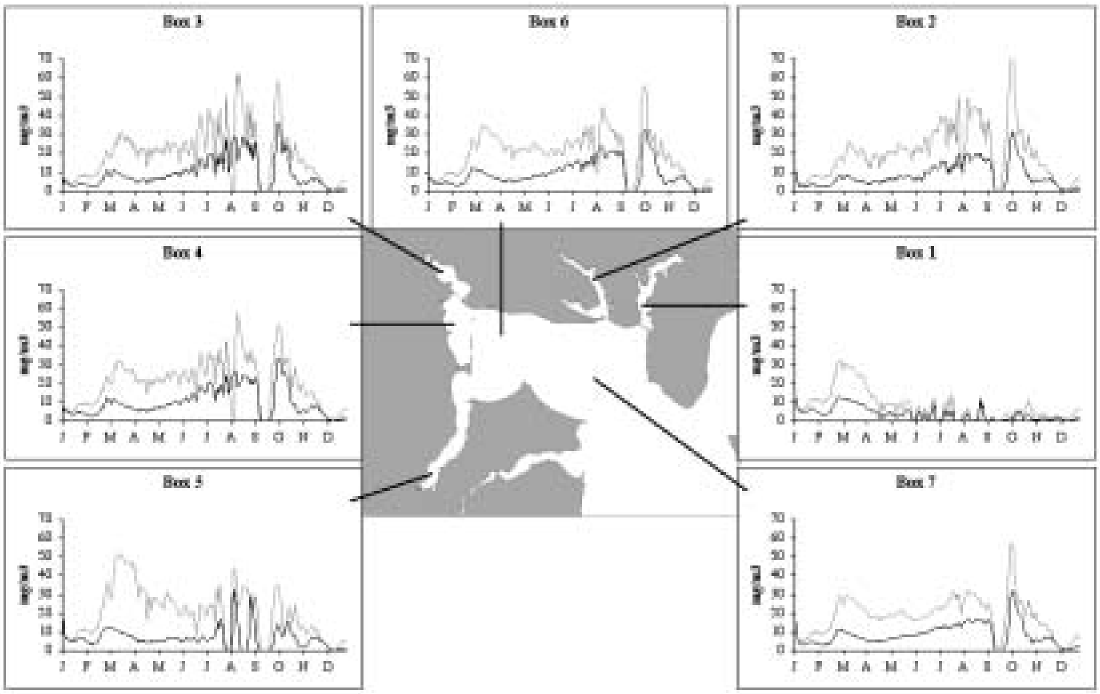
1. Brush (2002) developed an innovative numerical ecosystem box model for Greenwich Bay. The model simulates physical and biological conditions in Greenwich Bay and its coves, including chlorophyll a concentrations, net primary production, dissolved oxygen levels, and macroalgae biomass. Overall, the model does a good job of simulating current water column concentrations when compared to field data, but simulations of macroalgae distributions and abundance are problematic.

2. For the Greenwich Bay Special Area Management Plan, the ecosystem model was used to try to replicate water quality conditions in Greenwich Bay under pre-colonial conditions before eutrophication (Brush, 2004). Current nutrient inputs were based

nitrogen and phosphorus budgets prepared by Granger et al. (2000). Pre-colonial nutrient inputs were based on estimates by Nixon (1997) for Narragansett Bay. The model simulation predicts that prior to eutrophication surface chlorophyll a concentrations were lower in Greenwich Bay (Figure 31). The model simulation also predicts that dissolved oxygen concentrations in bottom waters were higher under pre-colonial conditions, except in Greenwich and Warwick coves (Figure 32). Hypoxia and anoxia may have still occurred but less frequently and over a smaller area.

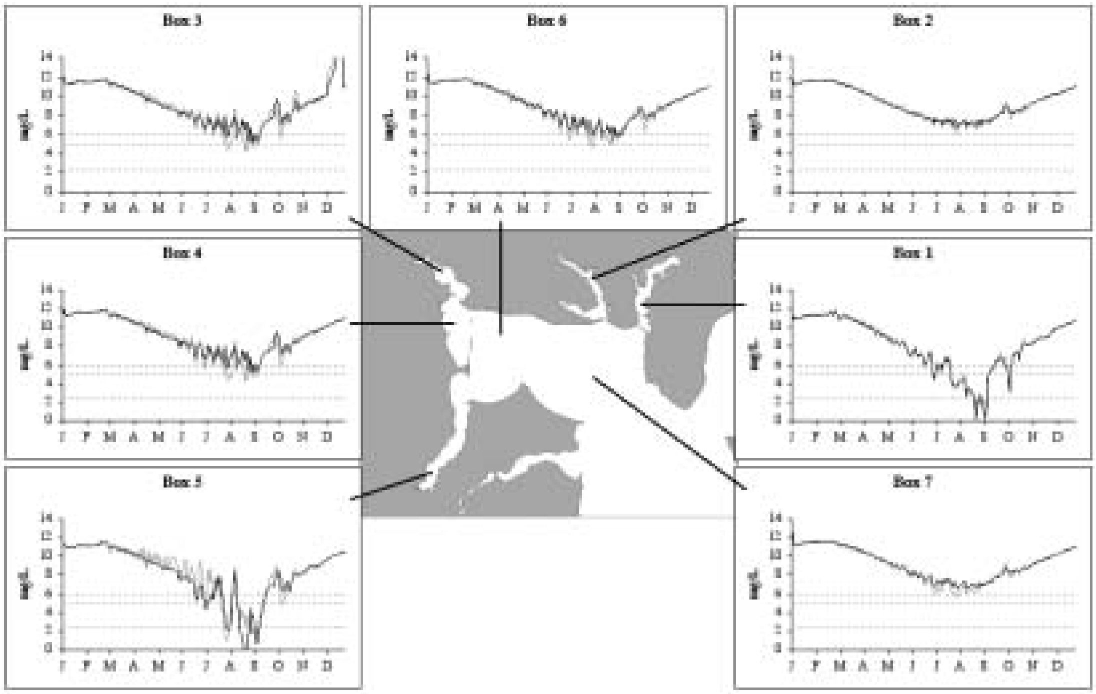
3. The model simulation results are not conclusive facts but a tool to interpret potential future ecosystem response. Ecosystem models often can replicate near past and current conditions well, but as conditions change and longer timeframes are considered, there is a greater potential for ecosystem changes outside the model's capability to predict accurately.

Figure 31. Pre-colonial simulation of surface chlorophyll a concentrations



Source: Brush, 2004

Figure 32. Pre-colonial simulation of dissolved oxygen concentrations in bottom waters



Source: Brush, 2004

440.2H Applied Science Associates/RIDEM Study

1. Applied Science Associates (ASA) and the RIDEM conducted a water quality assessment of Greenwich Bay during the summer of 2000 (Applied Science Associates, 2001). The study included measurements of nitrogen and chlorophyll a during three one-day water quality surveys. Surveys were completed on measured on August 18, August 30, and September 7, 2000 at 12 stations (Figure 33). Results showed that the highest concentrations of dissolved inorganic nitrogen are found in stations outside the mouth of Greenwich Bay and at stations within both Apponaug and Greenwich coves (Table 20). The stations with the lowest concentrations are found in Greenwich Bay proper. Chlorophyll a concentrations were highest within Apponaug and Greenwich coves. Measurements of DIN were generally comparable to concentrations reported by Granger et al. (2000) for this time of year. Bottom waters generally contained higher DIN than surface waters.

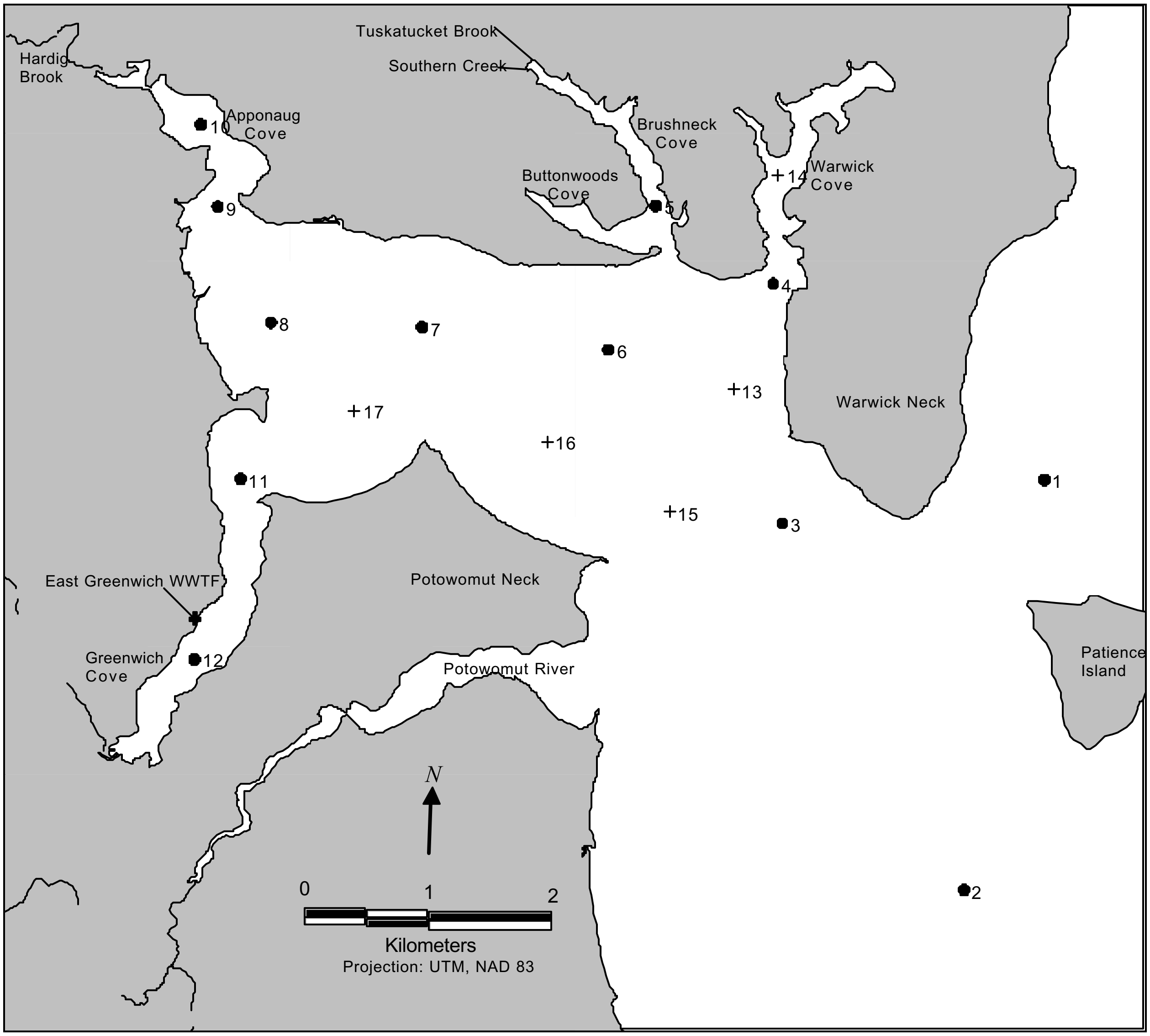
2. Three tributaries and the East Greenwich WWTF were sampled 12 times over three days preceding each water quality survey. In addition, four smaller tributaries were sampled three times, preceding the final two surveys. Tributary sampling included discharge and concentration measurements. Consistent with the URI-CVE Hardig Brook and Northern Watershed Studies (DeMelo, 1996; DeMelo et al. 1997, Wright and Viator, 1999), the ASA/RIDEM study found that DIN concentrations were high in tributary streams, such as Southern Creek (Carpenter Brook) and Tuscatucket Brook, which drained sub-watersheds containing large concentrations of ISDS (Table 17). The loads from these streams far exceeded those from tributaries, such as the Maskerchugg River, that drained much larger sub-watersheds and had much higher discharge rates. Based on this study, the RIDEM estimated that the tributary streams represented the largest nitrogen source to Greenwich Bay during the summer season because of ISDS inputs.

Table 20. ASA/RIDEM average dissolved inorganic nitrogen (DIN) and chlorophyll a concentrations in Greenwich Bay and its coves in August and September 2000

Station	DIN (µg/L)		Chlorophyll a (µg/L)	
	Surface	Deep	Surface	Deep
Greenwich Cove				
W11	56	116	18	4
W12	47	130	26	10
Apponaug Cove				
W9	88	68	15	13
W10	98	117	19	15
Brush Neck and Buttonwoods coves				
W5	22		10	
Warwick Cove				
W4	59	77	12	9
Greenwich Bay proper				
W3	86	122	8	5
W6	17	21	12	10
W7	23	52	16	5
W8	36	56	19	10
Narragansett Bay				
W1	83	127	18	8
W2	133	134	6	2

Source: Applied Science Associates, 2001

Figure 33. Sampling stations for 2000 ASA/RIDEM survey of Greenwich Bay



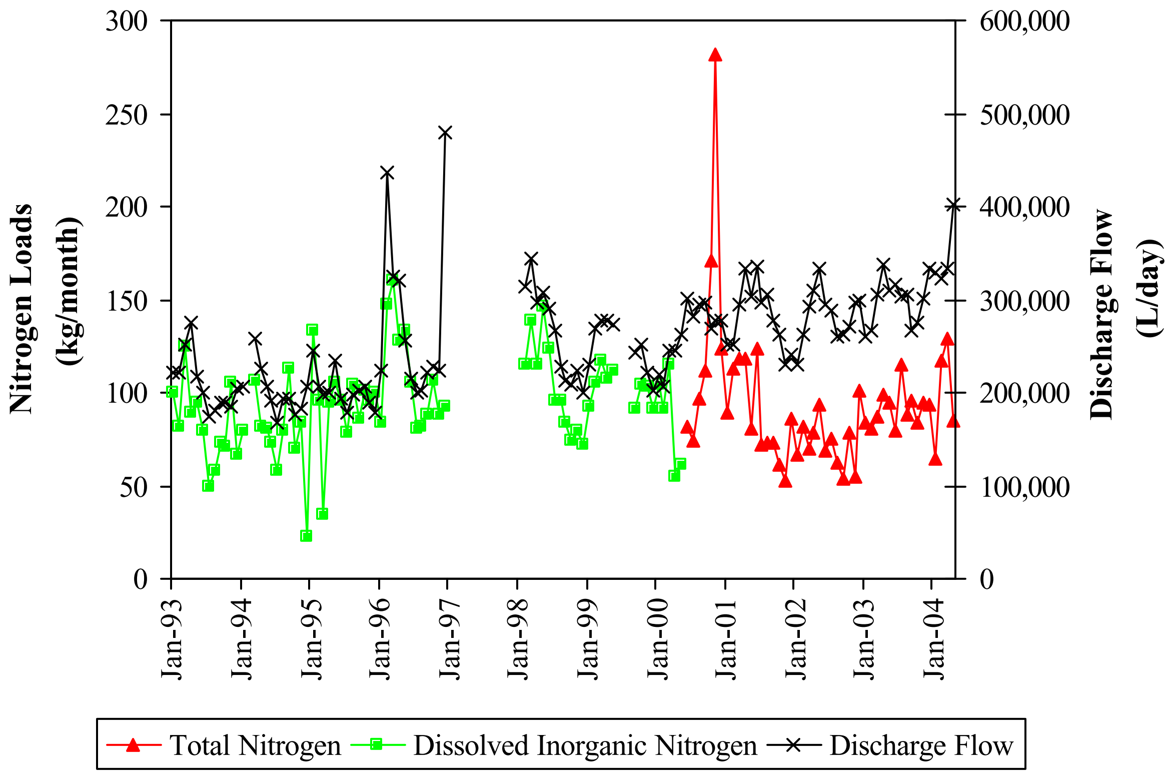
Notes: Tidal survey sampling stations for the Greenwich Bay field study are shown as solid circles. Crosses indicate additional stations for salinity, temperature and dissolved oxygen profiles.

Source: Applied Science Associates, 2001

440.2I RI Pollution Discharge Elimination System (RIPDES) Monitoring

1. The East Greenwich WWTF monitors its discharge flow for nitrogen in compliance with its Rhode Island Pollution Discharge Elimination System Permit (RIPDES). From 1993-2000, DIN concentrations in monthly discharges averaged 13.34 mg/L. Discharge flow and nitrogen loads varied over the course of a single year (Figure 34). In addition, the period of peak discharge flows and nitrogen loads vary from year to year.

Figure 34. Monthly average nitrogen loadings and discharge flow from the East Greenwich Wastewater Treatment Facility



Source: Data courtesy of the Town of East Greenwich

440.2J URI Graduate School of Oceanography and Providence College Study

1. Weekly monitoring of chlorophyll a concentrations, zooplankton abundance, and ctenophore abundance in Greenwich Cove took place during the summers of 2002 and 2003 off the outermost dock at Norton's Shipyard and Marina (Sullivan et al. unpublished data). These data were collected as part of NSF grant # OCE0115177 awarded to B.K. Sullivan (GSO), D.J. Gifford (GSO), and J. Costello (Providence College) and entitled "Initiation and Maintenance of Population Maxima of the Ctenophore *Mnemiopsis leidyi* in Northern Coastal Waters". Chlorophyll a concentrations were measured between 0-35 µg/L (Figures 20 and 21). Chlorophyll a maximum concentrations generally preceded minimum levels of dissolved oxygen, especially during August. Maximum concentrations occurred

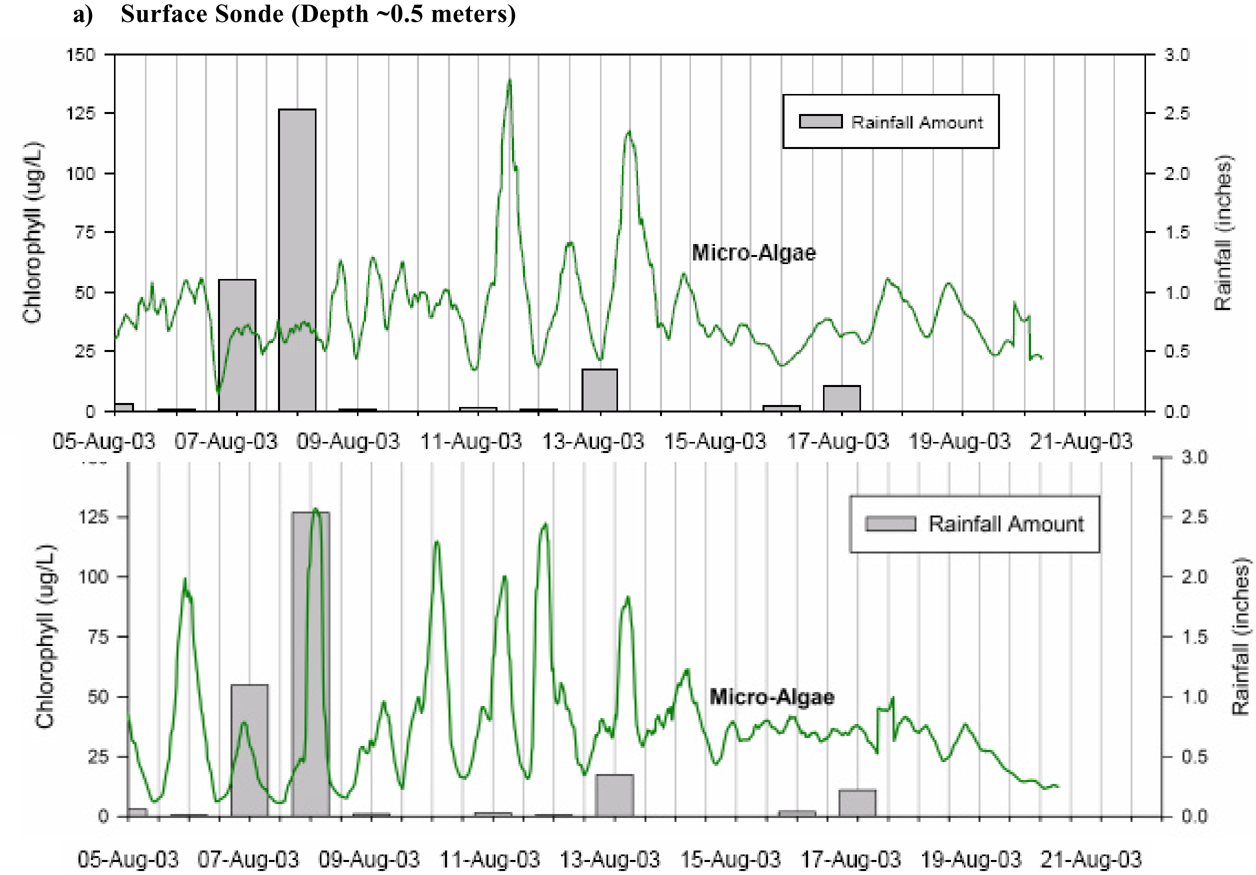
when grazing zooplankton were at their lowest abundance. Sullivan et al. hypothesized that high nitrogen loads and warm temperatures may exacerbate the size of phytoplankton blooms in Greenwich Cove by favoring ctenophores, which graze on zooplankton.

440.2K RIDEM/NBNERR Sonde Data

1. The Narragansett Bay National Estuarine Research Reserve (NBNERR) and the RIDEM have maintained in different years data sondes off a dock at Greenwich Bay Marina South near the mouth of Apponaug Cove. The majority of measured chlorophyll concentrations fell within the same range as those measured by Granger et al. (2000) during the summer of 2003 and 2004 (Figures 35 and 36). However, these finer scale measurements, compared to past data sets, did detect much higher chlorophyll concentration peaks, particularly in August 2003. Chlorophyll concentrations ranged as high as approximately 140 µg/L.

Figure 35. Chlorophyll concentrations recorded by the Greenwich Bay Marina sonde in August 2003

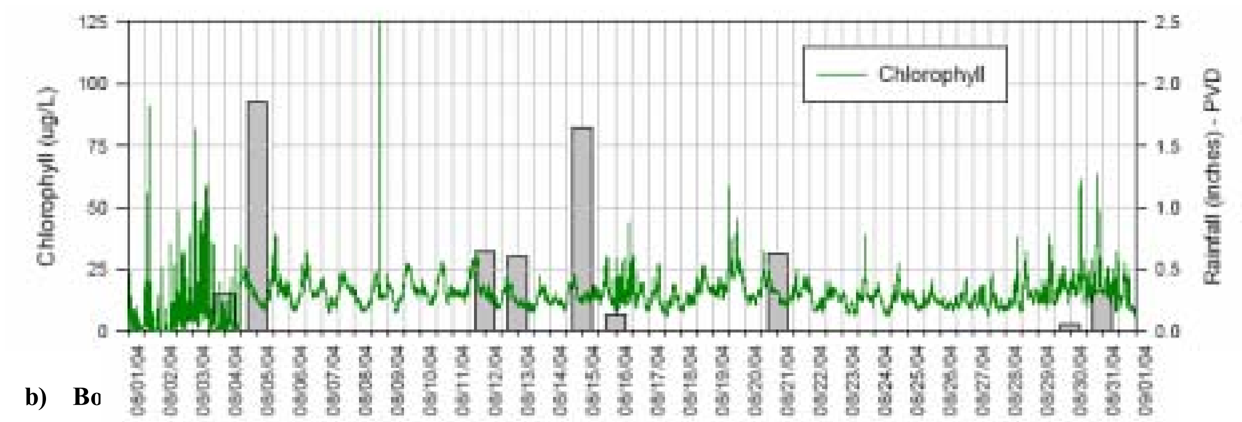
a) Surface Sonde (Depth ~0.5 meters)



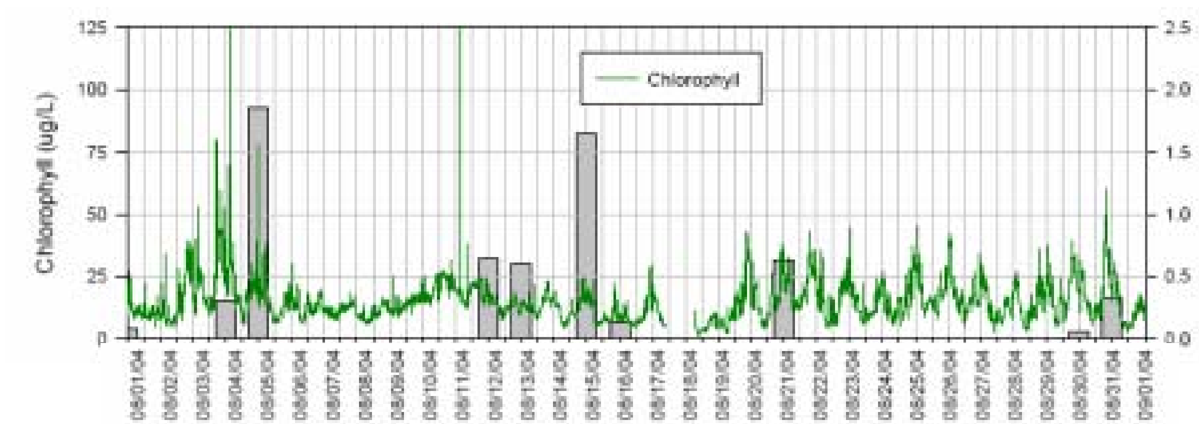
Source: RIDEM 2003e

Figure 36. Preliminary chlorophyll concentrations recorded by the Greenwich Bay Marina sonde in August 2004

a) Surface Sonde (Depth ~0.5 meters)



b) Bo



Source: Narragansett Bay National Estuarine Research Reserve, Bay Assessment and Response Team, http://www.state.ri.us/dem/bart/stations.htm

440.3 Watershed nitrogen sources to Greenwich Bay

1. Numerous nitrogen sources exist in the Greenwich Bay watershed. Sources such as the East Greenwich WWTF may directly discharge nitrogen to Greenwich Bay or its coves, or storm water, groundwater, and tributaries may transport nitrogen from its source to Greenwich Bay. Increases in population density, as occurred primarily between 1920 and 1970 in the Greenwich Bay watershed (Figure 3), heavily influence the amount of nitrogen entering Greenwich Bay (EPA, 1983). Population growth potentially increases nitrogen discharges from the East Greenwich WWTF, ISDS, and other sources.

<u>440.3A Individual sewage disposal systems (ISDS)</u>

1. A large percentage of residential areas in the Greenwich Bay watershed are still using ISDS that represent a large nitrogen source to Greenwich Bay. Sewage disposed through ISDS is a documented source of nitrogen loading for many coastal environments. This is

the case in Greenwich Bay as well as the Narrow River (Howard-Strobel et al., 198; ASA, 1995), Cape Cod (Eichner and Cambareri, 1992; Valiela and Costa, 1988; Costa et al., 1992), the Chesapeake Bay (Chesapeake Bay Program, 1995; Kemp, 1983) the Delaware Inland Bays (EPA, 1995), and Tampa Bay (Johansson and Lewis, 1992). In densely developed areas where ISDS are the primary form of sewage disposal, nitrogen may contaminate groundwater (Gold et al., 1990). A Rhode Island study found that high levels of nitrogen are transferred to groundwater from functioning septic systems, with only 10 to 20 percent of wastewater DIN removed in the septic tank (Gold et al., 1990). It has been estimated that 65-75 percent of nitrogen loading to groundwater comes from ISDS (Urish and Gomez, 2004). Failing ISDS may also contribute nitrogen to storm water if effluent rises to the surface with the water table and flows downslope with minimal infiltration (Jarrett et al., 1985).

2. An estimate of nitrogen loading to Greenwich Bay was calculated based on estimates of the unsewered population in the watershed, average annual inputs to ISDS, and treatment and attenuation factors (See Appendix F). It is estimated that ISDS contribute anywhere from 47 to 57 metric tons of nitrogen per year to Greenwich Bay. Assuming that the population using ISDS will decrease by nearly 21,000 people, current sewer construction by Warwick could eliminate more than 56 percent of these nitrogen inputs if businesses and households tie-in to available sanitary sewers. If needed, further reductions could be achieved by installation of alternative ISDS that remove larger proportions of nitrogen in areas where sewers are not planned.

440.3B East Greenwich Wastewater Treatment Facility (WWTF)

1. The East Greenwich WWTF is a direct nutrient source to Greenwich Cove. The East Greenwich WWTF was estimated to be discharging approximately 16 metric tons of nitrogen per year in the late 1990s. Assuming nitrogen concentrations in the facility's effluent are constant, the plant could discharge 23 metric tons per year at full design capacity. Current total nitrogen loads from the plant are estimated to be 19.2 metric tons per year. In 2001, the RIDEM issued a permit modification to the WWTF that specified both a maximum nitrogen concentration and an increased design flow. These new permit conditions would allow for a maximum nitrogen discharge of 11.8 metric tons per year at the new design flow rate, a 39 percent decrease from current loadings. Upgrades to the East Greenwich WWTF to remove nitrogen must be completed by March 2006.

440.3C Residential lawns and golf courses

1. Commercial and residential fertilizer applications are also nutrient sources to Greenwich Bay (EPA, 1992; EPA, 1996). High rates of microbial processes in lawns and the perennial nature of home lawns contribute to lower leaching of nitrogen to groundwater than reported for many agricultural crops (Gold et al., 1990). Gold et al. measured that 2.5 percent of applied nitrogen is transported to groundwater. However, over-watering and excess fertilizer application increase the potential for nitrogen to run off into Greenwich Bay (Morton et al., 1988). Morton et al. found that with overwatering, approximately 13.5 percent of applied nitrogen was transported to groundwater. Imprecise application or

spilling of fertilizers on impervious surfaces can also increase the amount of nitrogen in fertilizer that reaches Greenwich Bay (Gold pers. comm.). In this case, fertilizer is carried to Greenwich Bay with storm water.

2. An estimate of nitrogen inputs from fertilizer use on lawns and golf courses was calculated based on estimates for the number of households that fertilize, application rates, lawn size, watering, and nitrogen loss in the lawn and groundwater (See Appendix F). It is estimated that fertilizers contribute 4 to 11 metric tons of nitrogen annually to Greenwich Bay. The four golf courses in Greenwich Bay (Seaview Country Club, Warwick Country Club, Potowomut Golf Club, and Goddard Memorial State Park Course) contribute an estimated 6 to 21 percent of the input. Best management practices, such as controlled release fertilizer, use of bentgrass, and lower irrigation rates, can limit nutrient loss from golf courses (Johnston and Golob, 2002; Shuman, 2002).

440.3D Boats

1. Illegal discharge of boat heads is a small nitrogen source to Greenwich Bay. Discharge of boat heads in Rhode Island's marine waters is illegal. Boat owners are supposed to have their sewage holding tanks pumped out at available facilities (Figure 15) or discharge in the ocean beyond the three-mile limit. However, few authorities familiar with the current situation believe compliance is 100 percent, as evidenced by the recent boat inspection and certification law. Boats at moorings and residential docks are of particular concern.

2. A worst-case estimate of the maximum potential discharge for nitrogen from boats to Greenwich Bay was made based on the number of boats with heads in Greenwich Bay and subtracting reported pumpout use (See Appendix F). It is estimated that only 1.7 metric tons of nitrogen per year are discharged from boats in Greenwich Bay. Compliance with no-discharge requirements would eliminate nitrogen loadings from boats.

440.4 Nitrogen transport to Greenwich Bay

1. Narrangansett Bay, the atmosphere, storm water, groundwater, and streams all transport nitrogen from sources inside and outside the watershed to Greenwich Bay. Narragansett Bay waters and atmospheric deposition carry nitrogen to Greenwich Bay that was not produced in the Greenwich Bay watershed. Storm water, groundwater, and streams primarily carry nitrogen produced within the watershed as described in the previous section.

440.4A Narragansett Bay

1. Bottom water flowing into Greenwich Bay from Narragansett Bay is a significant source of nitrogen to Greenwich Bay. Mixing and circulation processes carry Narragansett Bay water into Greenwich Bay (Granger et al., 2000; Brush, 2002; Bergondo, 2004). Upper Narragansett Bay waters have high nitrogen concentrations from the many inputs into the

Providence River outside the Greenwich Bay watershed (Nixon et al., 1995), including inputs from southern Massachusetts. These include other WWTFs north of Greenwich Bay—such as Bucklin Point, Fields Point, and East Providence—that discharge nitrogen-rich effluent into the headwaters of Narragansett Bay and the Providence River. WWTFs discharging to the Pawtuxet River, such as Cranston, Warwick, and West Warwick, are also a significant nitrogen source to the Providence River. It is estimated that 66 to 73 percent of the nitrogen in upper Narragansett Bay waters originates from WWTFs (Pryor et al., 2004). These loadings enrich tidal waters that enter Greenwich Bay. Granger et al. (2000) estimated that 50 to 130 metric tons of nitrogen per year enter Greenwich Bay from Narragansett Bay. Inputs are lower in the summer and higher in the winter because DIN uptake by phytoplankton is higher in the summer than the winter. New legislation requires RIDEM to reduce nitrogen loadings by 50 percent from WWTFs, consistent with the Governor's Narragansett Bay and Watershed Planning Commission recommendations, by December 2008 (RI Gen. Laws §46-12-2). This 50-percent reduction would decrease the amount of nitrogen that enters Greenwich Bay from Narragansett Bay by approximately 35 percent.

440.4B Atmospheric deposition

1. Wet and dry deposition from the atmosphere contributes nitrogen to Greenwich Bay (Fraher, 1991). Deposition may occur on the watershed where some of the nitrogen may be removed before it reaches Greenwich Bay. Other deposition occurs directly on Greenwich Bay and its coves. Fossil fuel combustion over hundreds of miles, an area much larger than the Greenwich Bay watershed, influences and increases nitrogen levels in the atmosphere (Fraher, 1991; Granger et al., 2000).

2. The contribution of atmospheric deposition to Greenwich Bay was estimated based on deposition rates, surface area, and an estimated attenuation rate (See Appendix F). Atmospheric deposition contributes an estimated 20 to 33 metric tons of nitrogen per year to Greenwich Bay. Atmospheric deposition directly on Greenwich Bay accounts for 50 percent of that loading, or 10 to16 metric tons of nitrogen per year.

440.4C Storm water, groundwater, and stream flow

1. Storm water, groundwater, and streams transport nitrogen from ISDS, atmospheric deposition, residential lawns, and golf courses throughout the Greenwich Bay watershed to Greenwich Bay. Storm water washes effluent from failed ISDS, fertilizers spilled onto paved surfaces, nitrogen deposited from the atmosphere, and nitrogen from other minor sources into the bay. Some of this storm water also soaks into the ground, as does nitrogen from fertilizers during watering. This nitrogen continues to flow slowly in groundwater to Greenwich Bay or one of its tributaries. Based on the estimates for ISDS, residential lawns, golf courses, and atmospheric deposition on the watershed, storm water, groundwater, and streams annually deliver 62 to 85 MT of DIN to Greenwich Bay each year.

2. Increasing development changes how nutrients are transported to Greenwich Bay. Impervious surfaces and stormwater collection systems associated with this development

prevent storm water and any associated nutrients from soaking into the ground where they would be transported more slowly with groundwater. Instead, an increasing volume of storm water flows directly into Greenwich Bay or its tributaries following rain events (RIDEM, 2004a). During a 1995 storm event, flow in Southern Creek more than doubled after less than 0.5 inch of rain (Wright and Viator, 1999). Flow data from all tributaries reflect this trend. Storm water enters Greenwich Bay directly through the pathways shown in Figure 11.

3. Groundwater could potentially flow to Greenwich Bay but be recharged from outside the watershed. Surficial geology maps indicate that groundwater flow in areas immediately outside of the Greenwich Bay watershed, such as T.F. Green Airport, may lead to Greenwich Bay (See Appendix C). Unlike groundwater recharged from within the Greenwich Bay watershed, groundwater originating from outside the watershed may carry nitrogen from sources outside the watershed to Greenwich Bay. However, there is a general lack of data on how far beyond the Greenwich Bay watershed boundary the groundwater recharge area may extend, if it does at all. Therefore, the importance of this flow to Greenwich Bay is not known.

440.5 Nitrogen budgets

440.5A Total annual budget

1. Based on SAMP estimates for watershed sources of nitrogen and nitrogen transport to Greenwich Bay, it is estimated that annual dissolved inorganic nitrogen loadings to Greenwich Bay are 142 to 253 MT per year (Table 21). Based on the average annual loading estimates for each source, nitrogen transported to Greenwich Bay from outside the watershed represents 59 percent of the annual nitrogen loadings to Greenwich Bay, primarily from Narragansett Bay waters entering Greenwich Bay (Figure 37). (In cases where there is more than one loading estimate calculated in Appendix F, the average of all estimates for that source is used.) Thus, nitrogen reduction efforts outside the Greenwich Bay watershed, such as efforts in upper Narragansett Bay, can help improve Greenwich Bay water quality. ISDS and the East Greenwich WWTF are the primary watershed sources of nitrogen, representing 36 percent of the total annual inputs.

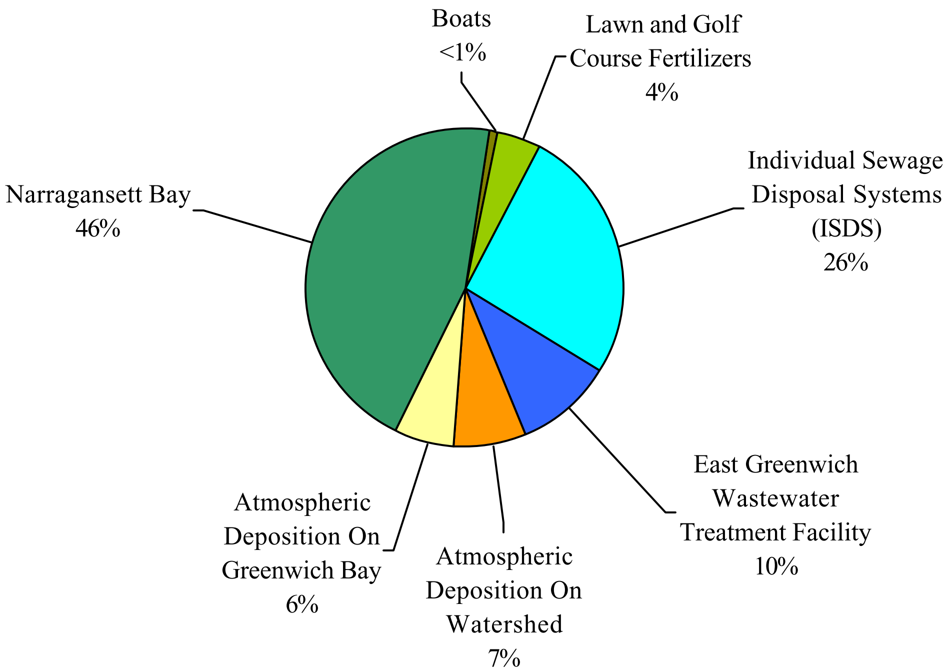
2. Watershed sources of nitrogen may have a greater impact on different areas of Greenwich Bay and during different times of year than indicated by the annual nitrogen budget. Watershed nitrogen inputs largely flow into the coves and the western end of the Greenwich Bay (Brush, 2002). Ecosystem model simulations for Greenwich Bay indicate that watershed nitrogen sources, particularly the East Greenwich WWTF, are the largest sources of nitrogen to Greenwich Cove during most of the year, particularly from March to July (Figure 38). Watershed nitrogen sources also predominate in Greenwich Bay's other coves from March until June or July.

Table 21. Total nitrogen inputs to Greenwich Bay

Nitrogen Sources	**Nitrogen Inputs [1] (Metric Tons per Year)**
Narragansett Bay [2]	50-130
Storm water, groundwater, and streams [3]	
- Unsewered human population (ISDS)	47.1-57.5
- Atmospheric deposition on watershed	10.6-17.3
- Lawn and golf course fertilizer	4.2-11
East Greenwich wastewater treatment facility	19.2
Atmospheric deposition on Greenwich Bay	9.5-15.5
Boats	1.7
Total Input	**142.3-252.2**

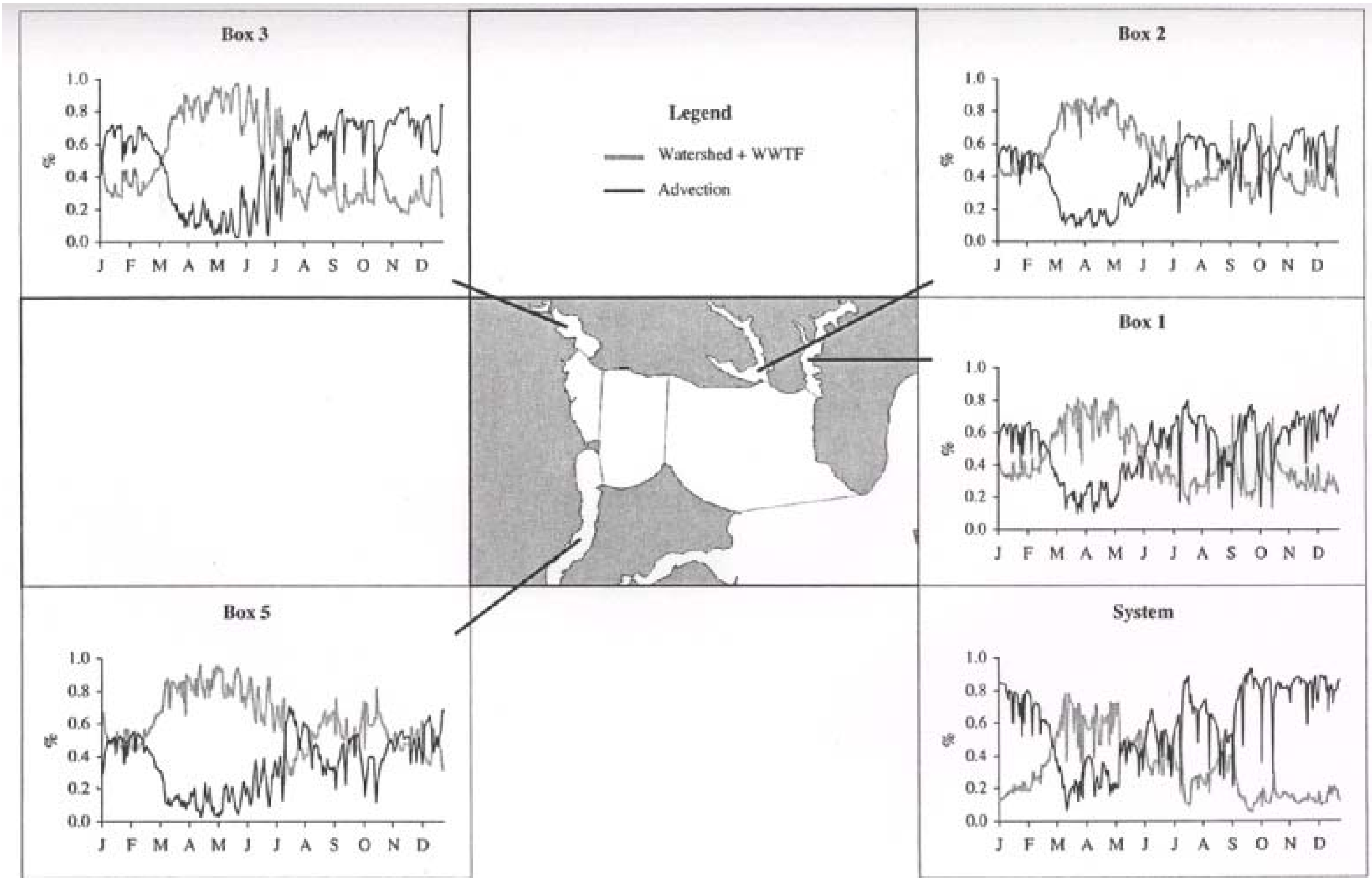
1 All nitrogen inputs were calculated for dissolved inorganic nitrogen, except for the East Greenwich Wastewater Treatment Facility (WWTF). The East Greenwich WWTF loadings were only available as total nitrogen.
2 Granger et al. (2000) estimates based on box model calculations and DIN concentrations in the upper West Passage of Narragansett Bay.
3 Estimated inputs after attenuation.

Figure 37. Estimated annual nitrogen loadings to Greenwich Bay [1]



1 Based on the average annual loading for each source (See Appendix F). In cases where there is more than one loading estimate calculated, the average of all estimates for that source is used. All nitrogen inputs were calculated for dissolved inorganic nitrogen, except for the East Greenwich Wastewater Treatment Facility (WWTF). The East Greenwich WWTF loadings were only available as total nitrogen.

Figure 38. Fraction of dissolved inorganic nitrogen from watershed sources relative to Narragansett Bay advection



Source: Brush, 2002

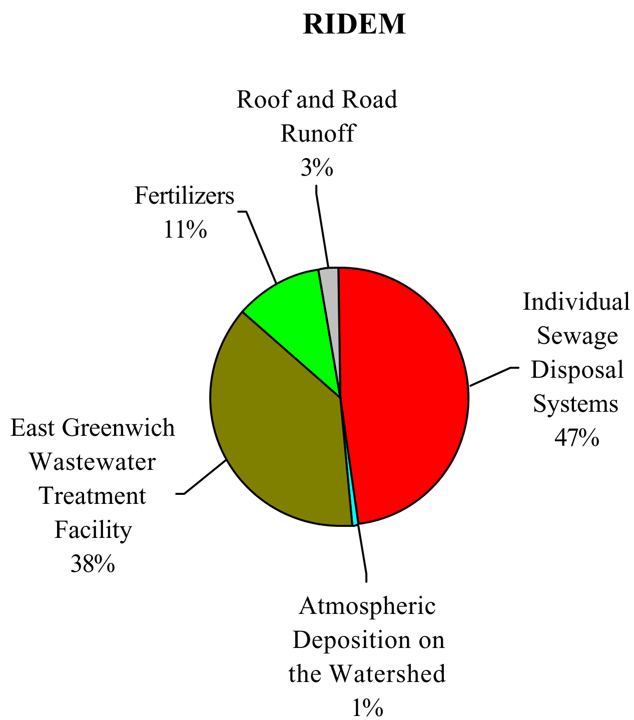
<u>*440.5B Watershed source budget*</u>

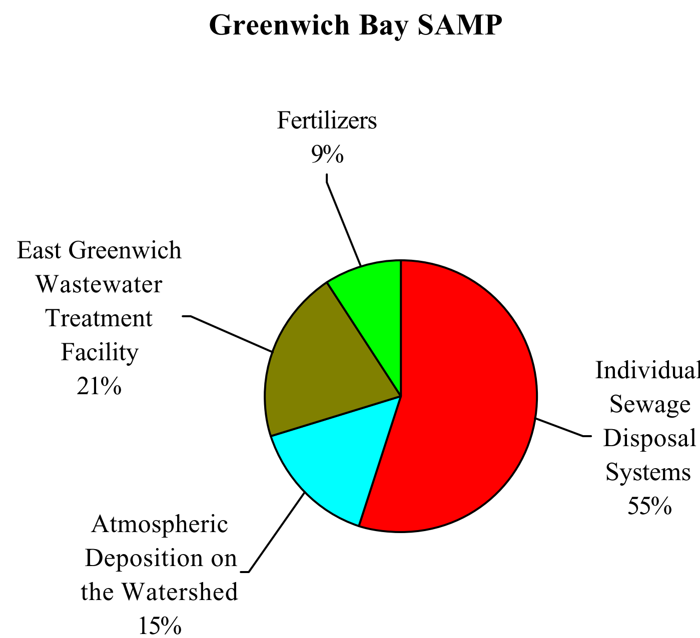
1. RIDEM developed a summer total nitrogen-loading budget to Greeenwich Bay (RIDEM, 2003e). RIDEM calculated nitrogen loads from the East Geenwich WWTF based on measured nitrogen loads during the summer of 2000 (Applied Science Associates, 2001). RIDEM placed the WWTF load in context with the groundwater sources, such as ISDS, by combining the Urish and Gomez data with ASA/RIDEM measurements of tributary total nitrogen loads. RIDEM revised its original budget published in the 2003 Greenwich Bay Fish Kill Study (RIDEM, 2003e) after Urish and Gomez (2004) revised their groundwater nitrogen loading estimates to reflect a change in per capita water use. This analysis was conducted during the critical summer season, and is considered applicable for the time of year when the waters of Greenwich Bay and its coves are most susceptible to adverse water quality impacts as a result of nitrogen loadings from watershed sources.

2. Based on this budget, RIDEM has concluded that ISDS and the East Greenwich WWTF are the principal quantifiable watershed sources to Greenwich Bay (Figure 39). The RIDEM budget estimates that ISDS in the watershed account for 47 percent of the total watershed nitrogen loading to the bay. In comparison, the East Greenwich WWTF accounts for 38 percent of the total loading. Lawn fertilizers, road and roof runoff, and atmospheric deposition were relatively minor sources to Greenwich Bay, based on proportional contributions estimated by Urish and Gomez (2004).

3. Using only the sources considered by RIDEM, the RIDEM summer budget and the SAMP annual budget estimate that ISDS and the East Greenwich WWTF are the major watershed sources of nitrogen to Greenwich Bay (Figure 39).

Figure 39. Comparison of RIDEM summer nitrogen loadings to the Greenwich Bay Special Area Management Plan annual nitrogen loadings for similar sources





440.6 Nutrient reduction scenarios

1. Regulations and recommended actions in this SAMP as well as current initiatives are aimed at reducing nitrogen loadings to Greenwich Bay to relieve eutrophication symptoms—such as hypoxia and anoxia, high macroalgae production, and loss of eelgrass habitat—that are impairing Greenwich Bay's aesthetics and habitat. Narragansett Bay waters represent the largest annual nitrogen source to Greenwich Bay, but decreases in watershed sources of nitrogen may have a relatively greater impact on conditions in Greenwich Bay's coves and western Greenwich Bay where adverse water quality impacts such as phytoplankton blooms, macroalgae blooms, and hypoxia are prevalent. The coves in Greenwich Bay receive over 80 percent of the freshwater input from the watershed and yet they constitute only 9 percent of the total volume of the bay (Brush, 2002). Greenwich and Apponaug coves each receive over 30 percent of the total freshwater input to the bay (Table 5). In addition, nitrogen-rich waters reside longer in Greenwich and Warwick coves because they have lower flushing rates than other areas in Greenwich Bay.

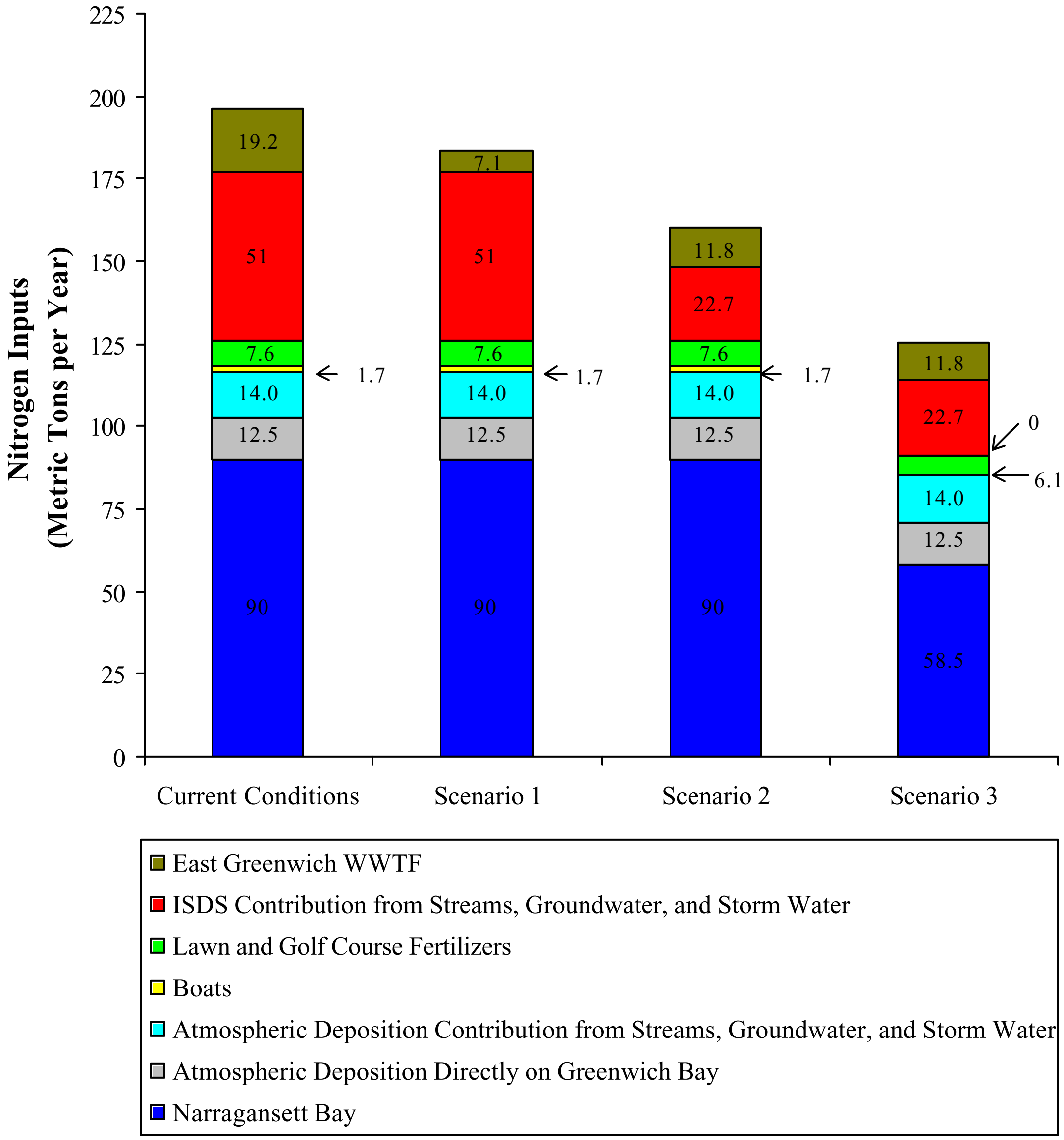
440.6A Nitrogen reduction scenarios

1. The SAMP nitrogen budget was recalculated based on three improvement scenarios where current initiatives are completed and SAMP actions implemented (Table 22; Figure 40). These scenarios show the incremental reductions in DIN loadings that can be expected with upgrades to the East Greenwich WWTF and mandatory sewer tie-ins as well as upgrades to upper Narragansett Bay WWTFs. Even greater reductions may be achieved with an increase in the area of coastal and riparian buffers in the watershed and implementation of best management practices (BMPs) for storm water that address nitrogen.

Table 22. Nitrogen reduction scenarios for Greenwich Bay

Description		Estimated Annual Nitrogen Loading Reduction	
		Watershed Sources	**Total**
Scenario 1	• Completes upgrade at the East Greenwich WWTF with no additional flow from sewer tie-ins.	15%	6%
Scenario 2	• Completes upgrade at the East Greenwich WWTF and operating at full capacity. • Complete sewering and all properties are tied in to available sewers.	45%	18%
Scenario 3	• Completes upgrade at the East Greenwich WWTF and operating at full capacity. • Complete sewering and all properties are tied in to available sewers. • Reduce nitrogen loadings from Upper Narragansett Bay WWTFs by 50%. • 100% compliance with no discharge requirements by boaters. • Implement best management practices for lawn and golf course fertilization.	49%	36%

Figure 40. Nitrogen reduction scenarios for Greenwich Bay [1]



1 See table 22 for description of nitrogen reduction scenarios

440.6B Potential impact of nitrogen reduction scenarios

1. Reductions of nitrogen inputs to Greenwich Bay are expected to improve water quality conditions. Experience from other coastal ecosystems indicates that nitrogen reductions can decrease symptoms of eutrophication. Local ecosystem model simulations indicate that improvement should be expected particularly in western Greenwich Bay. However, simulations also indicate that some hypoxia and anoxia may be natural for Greenwich Bay.

Case studies

1. Case studies from other coastal areas indicate the reductions in nitrogen inputs can improve eutrophication conditions. In both Long Island Sound and the Delaware River, there have been reductions in the severity of hypoxia and anoxia with reductions in nitrogen loads (Committee on Environment and Natural Resources, 2003). In Tampa Bay, nitrogen reductions have led to decreased frequency and duration of phytoplankton blooms, increased water clarity, and the recovery of seagrass meadows (Committee on Environment and Natural Resources, 2003).

Greenwich Bay ecosystem model

1. The Greenwich Bay ecosystem model was used to evaluate the potential impacts of nitrogen reductions on eutrophication symptoms in Greenwich Bay (Brush, 2002). Brush (2002) ran model simulations to examine the effects of changing nutrient dynamics on chlorophyll *a* concentrations, net primary production, dissolved oxygen levels, and macroalgae biomass. A simulation with 50 percent of watershed inputs roughly corresponds to nitrogen reduction scenario 2.

2. Model simulations indicate that nutrient reductions could result in varying improvements to Greenwich Bay water quality and in relief from eutrophication symptoms. Results were variable between output parameters and area of the bay, and it appears that the timing of inputs is important, especially from the watershed. If watershed inputs were 50 percent of current conditions (scenario 2), the model indicates that:

- Chlorophyll *a* concentrations and net phytoplankton primary production could be reduced by 5 to 15 percent and by 5 to 30 percent respectively depending on the area of the bay
- Peak and mean macroalgae biomass could be reduced by 0 to 50 percent and 0 to 30 percent respectively depending on the area of the bay
- Days with low dissolved oxygen conditions less than 4 mg/L could be reduced in Greenwich and Apponaug coves but with little change elsewhere in the Greenwich Bay system

Reductions in watershed inputs would have the greatest effect on Greenwich Cove and the least effect on Warwick Cove. This indicates that Warwick Cove is more influenced by nutrient inputs from Narragansett Bay whereas Greenwich Cove is more influenced by watershed inputs.

3. Model simulations did not account for reductions at the East Greenwich WWTF. However, Brush (2002) ran simulations where the discharges from the WWTF were completely eliminated. He concluded that reductions at the WWTF could have positive effects on Greenwich Cove water quality by reducing primary production, chlorophyll *a* concentrations, macroalgae biomass, and days of low dissolved oxygen levels but would have little effect on water quality in Greenwich Bay proper.

4. As a predictive tool model simulation results should be interpreted with caution. The Greenwich Bay ecosystem model was principally focused on simulating phytoplankton production; water column respiration as a function of phytoplankton biomass; delivery of phytoplankton production to the sediments; dissolved oxygen dynamics and development of hypoxia; denitrification; and layering effects on macroalgae production and respiration in Greenwich Bay, a shallow coastal embayment. Because of the research focus, other elements of the model such as transport, spatial resolution, and vertical mixing were not highly refined. The model was additionally calibrated to field data from a single year, but was not validated against an independent data set. Brush (2002) concluded that this model takes a step toward, but does not necessarily reach a level where it can be used for management decisions. The model does provide, however, a tool for providing at least a qualitative view of changes in Greenwich Bay and its coves that would occur as a result of management decisions.

<u>Conclusion</u>

1. Nitrogen loading reductions will improve water quality conditions and eutrophication symptoms in Greenwich Bay, according to the Greenwich Bay ecosystem model and experience from other areas. Improvements will be more pronounced in western Greenwich Bay where watershed nitrogen inputs appear to have the greatest influence. Decreases in phytoplankton production could lead to greater water clarity and the recovery of eelgrass beds. Macroalgae biomass may be reduced in many areas. While not completely eliminated, the frequency and extent of hypoxic and anoxic events will be reduced, particularly in western Greenwich Bay.

Section 450
Other pollutants

1. Other pollutants potentially affecting Greenwich Bay are a concern for many citizens living in the area. In particular, petroleum hydrocarbons, pesticides, and deicing fluids raise citizen interest and concern. However, relative to bacterial contamination, low dissolved oxygen levels, and eutrophication, there are little data or obvious signs of impacts to Greenwich Bay. Based on this lack of data, the SAMP cannot make definitive conclusions and recommendations. However, general knowledge about these pollutants and their potential impacts does support the use of best management practices, if not already in place, and consideration in any planning process.

Section 460
Current initiatives

460.1 Sanitary sewer construction

1. The Warwick Sewer Authority is currently extending sanitary sewers and increasing capacity at the Warwick WWTF. Sewer construction is planned for most populated areas of Warwick in the Greenwich Bay watershed (Figure 5).

2. Warwick is seeking funding to study the feasibility of constructing a community sewage collection system to serve homes on Potowomut Neck (Geagan, pers. comm.). Potowomut Neck has been identified as a potentially high risk area where sewers are not being constructed (Sinnamon, 2004).

3. East Greenwich plans to construct sewers to service areas in East Greenwich's portion of the watershed east of Route 2 (Sequino, pers. comm.).

460.2 Mandatory sewer tie-ins

1. As required by its 2000 CRMC permit, the Warwick Sewer Authority will be implementing a mandatory sewer tie-in program for existing and newly constructed sewers. The tie-in schedule is prioritized based on the study titled "Analysis of Environmental Threats and Prioritization of Mandatory Sewer Connections for the City of Warwick, Rhode Island" (Lucht,2003). Lucht (2003) used the MANAGE assessment method to determine a prioritization schedule for mandatory sewer connections. The assessment evaluates where the greatest risks from ISDS pollution to Greenwich Bay are based on housing density, percent using ISDS, soil characteristics, wetland area, and flushing rates of adjacent coves (Figure 5). The areas in order of priority are:
   - Brush Neck Cove
   - Apponaug Cove
   - West Watersheds North
   - Warwick Cove and Warwick Neck
   - Buttonwoods Cove
   - Gorton Pond
   - Lower Hardig
   - Upper Hardig
   - Lower Maskerchugg
   - Upper Maskerchugg

Completing tie-ins in the areas prioritized first should provide the greatest immediate benefit to Greenwich Bay water quality even though these areas are not necessarily the areas closest to the shore. As homes and businesses tie-in to the sewer system, fecal bacteria and nitrogen inputs to Greenwich Bay from ISDS will decrease since the Warwick WWTF discharges outside the Greenwich Bay watershed.

2 The RIDEM also enforces an informal policy that requires sewer tie-ins and prohibits issuing permits to modify or replace ISDS where sanitary sewers are available and ISDS are not operating properly.

460.3 Storm water

1. Stormwater discharges from municipal storm sewers and from facilities with industrial activities are regulated through the Rhode Island Pollution Discharge Elimination System (RIPDES) program. RIDEM amended the existing RIPDES regulations to include Phase II stormwater regulations on March 19, 2002. To streamline the permitting process, RIDEM issued a general permit in December 2003 further outlining the requirements of the Phase II regulations. Designated municipalities that own and operate municipal separate storm sewer systems (MS4s) within regulated areas must develop a stormwater management program plan (SWMPP). Since the Greenwich Bay watershed is located in a regulated area, all operators of MS4s in the watershed will need to comply with the regulations. The MS4s that discharge directly to Greenwich Bay and its tributaries are owned and operated by Warwick, East Greenwich, West Warwick, and RIDOT.

2. The Phase II program requires that at a minimum, MS4 operators must describe BMPs for each of the following six minimum control measures:

- A public education and outreach program to inform the public about the impacts of storm water on surface water bodies
- A public involvement/participation program
- An illicit discharge detection and elimination program
- A construction site stormwater runoff control program for sites disturbing more than 1 acre
- A post-construction stormwater runoff control program for new development and redevelopment sites disturbing more than 1 acre
- A municipal pollution prevention/good housekeeping operation and maintenance program

The SWMPP must include measurable narrative or numeric goals for each control measure that may be used to gauge the success of the program. It must also contain an implementation schedule that includes interim milestones, frequency of activities, and reporting of results.

3. The RIDEM director can require additional permit requirements based on the recommendations of a TMDL. Upon notification that a TMDL has been completed that contains recommendations for stormwater controls, the MS4 operator is required to amend its SWMPP to incorporate the TMDL recommendations. Based on the RIDEM bacteria TMDL for Greenwich Bay, the operators will be required to submit a scope of work (SOW) and implementation schedule to the RIDEM. The SOW must describe measures to identify catchment areas and outfalls and to perform feasibility studies to implement additional stormwater controls, as necessary. The SOW must also assess the existing implementation of the six minimum measures.

4. Warwick and East Greenwich have both invested efforts in watershed analysis for stormwater BMPs that include sewering, in-line/infiltration systems, constructed wetlands, catch

basin cleaning, detention, and wet ponds (Louis Berger Group, 2001; SRICD, 2002; Beta Group, Inc., 2003).

460.4 WWTFs

1. RIDEM requires the East Greenwich WWTF and other WWTFs impacting upper Narragansett Bay to reduce nitrogen loadings. RIDEM has developed a phased nitrogen reduction approach to achieve a 50-percent summer season reduction in the nitrogen loading from 11 facilities that impact upper Narragansett Bay by December 2008. This plan is consistent with the recommendations of the Governor's Narragansett Bay and Watershed Planning Commission. By July 2005, construction of treatment plant upgrades will be completed at the Narragansett Bay Commission Bucklin Point Facility (further modification may be necessary), Burrilllville, Woonsocket (additional modifications are needed), Cranston, West Warwick, and Warwick.

2. East Greenwich is completing upgrades to the WWTF that will increase its ability to remove nitrogen from effluent as well as increase its capacity. RIDEM has issued East Greenwich a modified discharge permit that will require nitrogen concentrations to be 5 mg/L total nitrogen or less. It is estimated that these upgrades will decrease nitrogen loading from the WWTF to Greenwich Cove by approximately 63 percent based on current WWTF capacity. The installation of denitrification technology is scheduled to be completed by March 2006.

3. RIDEM and the New England Interstate Water Pollution Control Commission invited plants to participate in training on nutrient removal in April 2000, as part of Rhode Island's nutrient removal initiative. Two recognized experts in the field conducted an initial screening analysis at five facilities to determine the feasibility of either making some minor modifications to the plants and/or making operational changes to reduce the amount of ammonia and nitrogen in the discharge. The West Warwick, Warwick, Cranston, East Greenwich and the Narragansett Bay Commission (NBC) Fields Point WWTFs participated in this program. As a result of this initial effort, with assistance from RIDEM (a $35,000 Aqua Fund Grant and additional operator training) and $7,000 in matching funds from the city, the Warwick WWTF was able to construct modifications and remove approximately 80 percent of the ammonia and 50 percent of the nitrogen in its discharge. Warwick noted that operational costs were increased due to the associated increased electrical consumption and chemical addition. The initial screening indicated that the East Greenwich, Cranston, and NBC Fields Point WWTFs may also be able to construct interim modifications that will result in significant reductions in nutrients discharged to the receiving waters prior to final improvements being completed. In August of 2004, RIDEM conducted follow-up inspections, with the use of contractor assistance at the East Greenwich, Cranston, NBC Fields Point, East Providence, and Warren WWTFs to further evaluate the feasibility, cost, and timeframes for implementing temporary nitrogen reduction measures.

460.5 Boats

1. In 2004, the R.I. General Assembly passed a law requiring a certification and inspection program to support boat no discharge requirements in Rhode Island waters (R.I. Gen. Laws §46-12-39.1). All boats operating or moored for more than seven days on Rhode Island waters other

than open boats without sleeping accommodations, must be inspected every four years by a certification agent, such as a municipal harbormaster. After a successful inspection, boats must have a RIDEM no-discharge certification decal prominently displayed. Boats with a Type III Marine Sanitation Devices (MSD) must also maintain onboard a frequency compliance record card that is stamped after every pumpout and must be pumped out prior to removal from the water for storage.

2. RIDEM, municipal harbormasters, and police officers are all authorized to enforce these requirements, including stopping and boarding vessels for periodic onboard tests (R.I. Gen. Laws §46-12-41). Violators may be subject to fines from $500–1,000 or imprisonment and denied a municipal mooring permit. If a municipality assists in the prosecution of a violation, it may keep half of any subsequent fine.

3. The new law will take effect in June 2006. Guidelines and procedures for certifying inspectors and inspecting boats will need to be developed as part of implementing the new law.

460.6 Monitoring

1. Regular monitoring of Greenwich Bay is conducted by RIDEM, HEALTH, and NBNERR. The RIDEM Shellfish Program monitors fecal bacteria levels in Greenwich Bay and its coves and conducts periodic shoreline surveys of actual and potential pollution sources. HEALTH monitors indicator bacteria levels at five licensed beaches under its Bathing Beaches Monitoring Program. NBNERR and RIDEM maintain a data sonde off a dock at Greenwich Bay Marina South near the mouth of Apponaug Cove that records dissolved oxygen levels, salinity, temperature, and chlorophyll levels. More details about these larger monitoring programs and others can be found in the descriptions of research studies in the previous sections.

2. In 2004, the R.I. General Assembly passed the Comprehensive Watershed and Marine Monitoring Act (R.I. Gen. Laws §46-23.2). The act created the R.I. Environmental Monitoring Collaborative consisting of the URI Coastal Institute, CRMC, RIDEM Office of Water Resources, RIDEM Division of Fish and Wildlife, HEALTH, URI Watershed Watch, URI Graduate School of Oceanography, NBC, Statewide Planning Program RIGIS Division, and the URI Environmental Data Center. The collaborative is charged with creating and implementing a statewide monitoring strategy.

460.7 Open Space, Recreation, Bay, and Watershed Protection Bond

1. In 2004, the R.I. General Assembly and voters approved a $70 million Open Space, Recreation, Bay, and Watershed Protection Bond with $19 million dedicated to water quality projects. The $19 million is expected to leverage an additional $47 million. Funds will be used for low-interest loans administered by the R.I. Clean Water Financing Agency for WWTF upgrades and other water quality projects, and clean water grants for implementing BMPs that address nonpoint source pollution and other pollution abatement projects.

Section 470
Regulations, recommended actions, and research needs

1. Regulations, recommended actions, and research are needed to improve Greenwich Bay water quality. In regulatory sections, plain text indicates current CRMP regulations, and underlined text indicates new regulatory language. Recommended actions and research needs may apply to federal agencies, state agencies, local governments, and nongovernment organizations (NGOs). Recommended actions are presented in plain text.

470.1 General

470.1A Recommended actions

1. CRMC recommends and encourages the formation of a Greenwich Bay watershed organization to work with federal, state, and local organizations and government agencies to advocate and implement SAMP recommended actions and research needs, to develop additional actions, to monitor action implementation and environmental conditions, and to educate citizens living in the Greenwich Bay watershed.

2. CRMC should develop and provide signs to Warwick, East Greenwich, West Warwick, and the R.I. Department of Transportation (RIDOT) to demarcate the Greenwich Bay watershed boundary along major roads.

3. RIDEM and CRMC should examine the feasibility of using mechanical devices to aerate portions of western Greenwich Bay and bay coves during summer periods when hypoxia and anoxia are likely to develop. RIDEM and CRMC should consider technologies used in Florida, Maryland, and other coastal states where hypoxia and fish kills are often a problem. In addition, they should consult with the R.I. Marine Trades Association (RIMTA) about using existing marina deicing equipment for aeration during the summer or for locating any new aeration technologies at Greenwich Bay marinas.

4. While the Open Space, Recreation, Bay, and Watershed Protection Bond was recently passed, the Rhode Island General Assembly should consider passing an additional $20 million Greenwich Bay clean water and health habitat bond to further support sewer tie-ins, cesspool elimination, buffer and wetland restoration and preservation, implementation of Phase II stormwater BMPs, and other actions to improve water quality in the Greenwich Bay watershed, as recommended by the Greenwich Bay Citizens Advisory Committee

5. Warwick and RIDEM should continue to groom beaches, removing wrack—a potential source of fecal-coliform bacteria—when beach closures occur.

470.1B Research needs

1. RIDEM, CRMC, HEALTH, and Warwick should develop bacteria source tracking study to identify and rank sources of bacteria to Greenwich Bay. The widespread and diverse sources in the Greenwich Bay watershed may limit this technique. Therefore, the

expert performing the study should be consulted in designing the sampling plan. Potential bacteria source tracking studies in Greenwich Bay could focus on identified hot spots and swimming beach areas.

2. Research should be conducted to determine if the removal of high organic sediments from Greenwich Bay improves low dissolved oxygen conditions in those areas.

3. Research should be conducted to determine if artificially created basins in Greenwich Bay are creating areas vulnerable to hypoxia and anoxia.

470.2 Monitoring

470.2A Recommended actions

1. The Rhode Island Environmental Monitoring Collaborative (RIEMC), through implementation of the RI Water Monitoring Strategy, should enhance monitoring in Greenwich Bay. Current monitoring efforts for dissolved oxygen, salinity, temperature, chlorophyll, indicator bacteria, and other parameters should be continued. In addition to the RIDEM Shellfish Growing Area Program monitoring and the HEALTH Bathing Beach Monitoring Program, the state should ensure continued deployment of fixed-stations for continuous measurements of water quality, consider expansion the number of fixed-stations, and continue synoptic surveys, as needed. Over time, monitoring data should be synthesized to provide valuable information on the effectiveness of pollution prevention and abatement actions including sewering, cesspool elimination, WWTF upgrades, Phase II storm water implementation, and TMDL and SAM Plan implementation. The Greenwich Bay Implementation Team should develop a process to ensure data is compiled and integrated to support reporting on trends in water quality and other priority indicators.

2. Fixed-station monitoring should be maintained to support the function of the state Bay Assessment and Response Team (BART) and serve as an early warning system of hypoxic and anoxic events.

3. RIDEM, RIDOT, Warwick, and East Greenwich should conduct intensive water-quality monitoring to determine hot spots for pollution discharges to Greenwich Bay, such as illicit discharges to stormwater outfalls, and to identify specific pollution sources contributing to those discharges, such as was done along Hardig Brook (DeMelo et al., 1997).

4. RIDEM, HEALTH, URI-CE, and interested stakeholders should develop a volunteer monitoring strategy for Greenwich Bay that identifies opportunities for neighborhood groups, NGOs, school groups and others to participate. The strategy would provide a framework to that coordinates volunteer efforts in the watershed, linking work in freshwater streams to coastal waters. The strategy would identify indicators appropriate for volunteers to monitor and the necessary quality assurance procedures necessary to support the intended use of the data. Training needs would be identified and new programs

developed where appropriate. Where feasible, the strategy would generate data to reduce gaps in areas such as unlicensed beaches and closed shellfishing areas.

6. Rhode Island should encourage continued federal funding from EPA in support of the beach program as well as other monitoring programs. Monitoring to support both the RIDEM Shellfish Growing Area Program and the HEALTH Bathing Beach Monitoring Program is essential to protecting public health and should be sustained.

470.3 ISDS, Sewer Construction, and Sewer Tie-ins

470.3A Regulations

Policies

1. It is CRMC policy to require sewer tie-ins to available sanitary sewer lines in the Greenwich Bay watershed. Inadequately treated wastewater from ISDS contributes to water-quality impairments in Greenwich Bay. It is important that these sources be mitigated through planned sewer extensions and mandatory tie-ins to new and existing sewers.

Prerequisites

1. Applications to construct or alter a WWTF or to construct, alter, or extend sanitary sewer lines in the Greenwich Bay watershed shall include a plan for mandatory sewer tie-ins in residential and commercial developments.

Prohibitions

1. The installation or replacement of existing ISDS is prohibited in areas where sanitary sewers are available in the Greenwich Bay watershed. Properties shall be tied in to the available sanitary sewers in these instances.

2. New expanded development shall not be allowed where sanitary sewers are available unless the property is tied in to the sewer system.

Standards

1. Mandatory sewer tie-in plans shall at least include location maps, draft ordinance language, enforcement provisions, and implementation schedules that will be used to create a mandatory sewer tie-in program.

2. Sewer tie-in plans shall include measures that make sewer tie-ins mandatory on land parcels that abut the portion of street or highway with a sewer line or within any new subdivisions that abut the sewer easement.

3. The mandatory sewer tie-in program shall be implemented and sewer tie-ins begin to be required within one year after completing WWTF improvements and sewer extensions for the areas within the Greenwich Bay watershed that currently have sewers and any new sewer extensions.

470.3B Recommended actions

1. The WSA, Warwick, and East Greenwich, with CRMC assistance, should ensure mechanisms are in place so that properties tie into available sanitary sewers. For the WSA and Warwick, mechanisms will be part of the mandatory sewer tie-in program required by their CRMC permit. Mechanisms should include, but not be limited to, ensuring that there is sufficient funding for grants and loans to assist property owners with sewer tie-in and ISDS replacement costs. If necessary, the WSA and Warwick should use their authority under the Warwick City Charter to order sewer tie-ins (Warwick City Charter, Chapter 2, Section 2.17). The WSA and East Greenwich should annually provide the Greenwich Bay Implementation Team with the numbers of new tie-ins each year and remaining properties not tied into available sanitary sewers.

2. The Rhode Island General Assembly should authorize Warwick and East Greenwich to prevent property transfers unless the property has been tied into an available sanitary sewer.

3. The WSA and East Greenwich should educate property owners in areas where sewers exist or are planned, on the benefits of decreasing ISDS use, the requirements for sewer tie-ins, the contractors available to complete tie-ins, and the availability of financial assistance programs.

4. RIDEM should formalize its policy on the application of ISDS requirements in areas where sewers are under construction or imminent. This policy requires sewer tie-ins and prohibits issuing permits to modify or replace ISDS where sanitary sewers are available and ISDS is not operating properly.

5. Warwick and East Greenwich should facilitate the marina tie-ins to sanitary sewer lines by prioritizing sewer tie-ins for all applicable marinas and boating facilities. In addition, Warwick should continue to examine the feasibility of extending sewer lines to each marina to ensure adequate disposal of boat sewage. Sewers are already available to East Greenwich marinas and most of Warwick Cove. If necessary, the municipalities should exercise its authority of eminent domain to obtain easements for these tie-ins.

6. The Rhode Island General Assembly should approve legislation that phases out cesspools in the Greenwich Bay watershed by January 1, 2015. The legislation should require sewer tie-ins where sanitary sewers are available or the installation of ISDS in compliance with any SAMP requirements where sanitary sewers are not available. Phase-out priority should be placed on failing cesspools or cesspools in the vicinity of a water body or drinking-water well. Provisions should be considered that allow property owners

with cesspools in areas that are designated to be sewered to wait for sanitary sewer construction and the required tie-in deadline for their area prior to abandonment.

7. Warwick, in conjunction with WSA, and East Greenwich should establish wastewater management districts pursuant to R.I. Gen. Laws §45-24.5 for areas where sanitary sewers are not currently planned in the Greenwich Bay watershed. In Warwick, the wastewater management district should be administered by the WSA. The wastewater management districts should:

a) Maintain records of ISDS inspections, properties not connected to the municipal sewer systems, and cesspools eliminated
b) Notify property owners when inspections are needed
c) Develop procedures for identifying sub-standard systems (such as cesspools)
d) Adopt a schedule for replacement of sub-standard systems located along the shoreline within the Greenwich Bay watershed. Priority should be placed on replacing substandard systems in high and high-medium risk areas identified by Sinnamon (2004).
e) Make determinations for appropriate action based on the information collected

The districts should administer operation, inspection, maintenance, grant, loan, and education programs for ISDS in these areas. At a minimum, if established, the districts should require and enforce that:

a) ISDS are inspected and pumped on a schedule consistent with the RIDEM "Septic System Check-Up: The Rhode Island Handbook for Inspection" (Riordan, 2000);
b) ISDS inspectors report inspection results to the district using forms available the RIDEM "Septic System Check-Up: The Rhode Island Handbook for Inspection"
c) ISDS inspectors have completed and successfully passed:
    i. URI's Conventional Septic System Inspection Short Course (INSP 100, or revised title) for conventional ISDS inspections,
    ii. URI's Innovative and Alternative Septic System Inspection Course (INSP 200, or revised title) for alternative ISDS inspections, or
    iii. Equivalent coursework
d) ISDS pumpers report to the district when ISDS are pumped or ISDS are not able to be pumped;
e) Failing ISDS be repaired or replaced; and
f) Information pertaining to failed ISDS or violations of state ISDS regulations be recorded on property deeds until such time as they are corrected, as an incentive to eliminate chronic ISDS problems and to protect future homeowners

Warwick and East Greenwich should look at ordinances adopted by other municipalities, such as Charlestown, or at the R.I. Division of Planning publication "Wastewater Management Districts: A Starting Point" to begin drafting a wastewater management district ordinance. Warwick and East Greenwich should investigate the use of municipal bonds, federal and state grants, low-interest loans (e.g., the Community Septic System Loan Program), and fee assessments to fund the wastewater management district.

1. WSA, East Greenwich, CRMC, RIDEM, and NGOs should educate homeowners with ISDS where sewers are not planned on how ISDS treat wastewater, the importance of regular inspections and maintenance, and what preventative measures can be applied to alleviate future problems. Topics could include:

a) Water conservation practices
b) Discouragement of garbage disposals
c) Avoidance of disposing grease and oil in household drains
d) Proper disposal of hazardous waste, including household hazardous waste
e) Use of environmentally sensitive cleaning products
f) Planning for alternate sites in the event of primary site failure
g) Allowing part of the leach field system to rest periodically through design or installation of alternate beds
h) Avoiding placement of pavement or other impermeable surfaces above the drainfield
i) Keeping records of system location, pumping, and maintenance
j) Preventing heavy equipment and vehicles from being placed on top system and drainfield

Agencies should consider mailing educational brochures, such as the "Septic System Information for Rhode Islanders" brochures produced by URI-CE, with regular bill and permit mailings.

3. The Rhode Island General Assembly should facilitate the development of wastewater management districts for the Greenwich Bay watershed. The General Assembly should provide funding to help cover administrative costs. In addition, the General Assembly should consider designating the WSA to administer any wastewater management district within Warwick. The RIDEM should provide technical and financial assistance to the municipalities to develop and implement onsite wastewater management districts.

4. Warwick and East Greenwich should continue to take advantage of the Community Septic System Loan Program (CSSLP). RIDEM and the RI Clean Water Finance Agency have developed the CSSLP to provide qualified citizens of communities enrolled in the program with 2 percent interest loans to repair/replace failed, failing and substandard ISDS. Communities with approved wastewater management plans can access the CSSLP.

470.3C Research needs

1. RIDEM, Warwick, and East Greenwich should identify and map all homes and businesses in the watershed currently using ISDS where sewer construction is not planned. Efforts should be made to coordinate with academic institutions, such as URI or Brown University.

470.4 WWTF

470.4A Recommended actions

1. RIDEM should continue efforts that require the East Greenwich WWTF to install advanced treatment technology that will decrease nitrogen loading to Greenwich Cove by March 2006. In addition, because Narragansett Bay waters contribute nitrogen to Greenwich Bay, RIDEM should continue efforts to require nitrogen reductions from WWTFs that impact Upper Narragansett Bay.

2. RIDEM should continue working with the NBC Fields Point facility and the Warren, East Providence, and East Greenwich WWTFs to evaluate the feasibility, cost, and timeframes for implementing temporary nitrogen controls, which should proceed concurrently with the design and construction of more reliable, permanent modifications and not used to delay them.

470.5 Storm water

470.5A Definitions

1. Stormwater BMPs include schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of and impacts to Rhode Island waters. BMPs also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, sludge or waste disposal, or drainage from raw-material storage.

470.5B Recommended actions (Consistent with EPA Phase II Storm Water Regulations)

1. RIDEM should continue working with CRMC and stakeholders to complete the on-going efforts to update the Rhode Island Stormwater Manual with improved standards for BMPs. At a minimum, BMP standards for reduction of stormwater flows and both nitrogen and fecal bacteria concentrations should be improved. CRMC and RIDEM should work to improve implementation of stormwater controls at re-development sites.

2. Warwick, East Greenwich, West Warwick, and RIDOT should place a high priority on addressing stormwater discharges that negatively impact beach areas and shellfish grounds.

3. Warwick, East Greenwich, West Warwick, and RIDOT should avoid constructing new outfalls and stormwater systems that directly discharge storm water to a water body.

4. Warwick, East Greenwich, West Warwick, and RIDOT should begin to map all the components for each storm water system while identifying stormwater outfalls. (The RIPDES Phase II Storm Water Program requires MS4 operators, including Warwick, East Greenwich, West Warwick, and RIDOT, to identify and map all their outfalls, including channelized flow.) This mapping will allow operators to begin to identify each catchment

area and its associated land use. All operators should also coordinate with the RIDEM Shellfish Program to obtain mapping information that may already exist as part of the shoreline surveys needed for all shellfish waters.

5. Warwick, East Greenwich, West Warwick, and RIDOT should work cooperatively to share existing stormwater system maps and to assist in on-going mapping, field investigations, and identification of inter-connections. The draft TMDL recommends that RIDOT, Warwick, East Greenwich, and West Warwick describe how they are cooperating with each other and what issues have arisen (RIDEM, 2004a).

6. Warwick, East Greenwich, West Warwick, and RIDOT should annually update the Greenwich Bay Implementation Team (GBIT) on the number of stormwater BMPs implemented and other efforts to limit stormwater pollution. At a minimum, they should provide the GBIT a copy of the Phase II Storm Water Annual Report by March 15th of each year. This report is required by the Phase II stormwater permit. Each operator should provide notification to the GBIT each year that the draft annual reports are available for public review and comment. They should incorporate notifying and providing reports to the GBIT as part of the public involvement and participation requirements of the Phase II permit.

7. RIDEM should continue to use its integrated priority ranking system for the project construction assistance programs. The system was developed with a grant from EPA to ensure that storm water and nonpoint source projects could be compared equally with traditional wastewater collection and treatment projects when developing a project priority list (PPL). Since 1998, ranking points are awarded based on almost seventy factors including impairment to shellfishing use and projects identified as part of a TMDL plan. On the FY 2005 PPL, Warwick storm water treatment projects with discharges to Greenwich Bay score higher than sewer projects in other communities.

8. Warwick, East Greenwich, West Warwick, WSA, and RIDOT should develop policies and procedures as safeguards to prevent and eliminate illicit connections and discharges consistent with the RIPDES Phase II storm water permit. Warwick, East Greenwich, West Warwick, and RIDOT should detect and eliminate illicit connections and discharges consistent with the permit requirements. System mapping, dry weather surveys, catch basin and manhole inspections, and responding to complaints, as required by the permit, should be given priority in areas within the Greenwich Bay watershed. The MS4 operators should also work cooperatively with the WSA to ensure sewer tie-ins are made to sanitary sewers, not storm sewers, in areas where sewers are available. All wastewater connections should be to a sanitary sewer or a functioning ISDS.

9. Warwick, East Greenwich, West Warwick, and RIDOT should include storm water BMPs for pollutant removal and runoff volume reduction in roadway reconstruction where feasible.

10. Warwick, East Greenwich, and West Warwick should adopt stormwater volume reduction requirements through local ordinances and overlay districts, or through the

development review process, for development and redevelopment of commercial and industrial properties and city-owned facilities and infrastructure in accordance with the RIPDES Phase II stormwater permit. The operators should coordinate to develop and deliver related public education and outreach to the target audience. Acceptable reduction measures include, but are not limited to, landscape and building designs and other BMPs that minimize stormwater runoff and treat storm water, such as:

a) Reducing impervious surfaces
b) Breaking up (disconnecting) large tracts or areas of impervious surfaces
c) Incorporating buffer strips, swales, buffer zones, and vegetated drainage ways
d) Installing infiltrating catch basins
e) Directing roof runoff to porous areas
f) Sloping surfaces towards vegetated areas
g) Implementing cluster zoning, low-impact development, transfer of development rights, and overlay districts for sensitive areas

Warwick, East Greenwich, West Warwick, and RIDOT with assistance from CRMC, RIDEM, and U.S. Natural Resources Conservation Service (NRCS) should always evaluate the feasibility of using BMPs throughout the drainage area of significant outfalls or inflow. Feasibility studies should include outfalls with the largest impervious drainage areas and the priority outfalls identified in the RIDEM bacteria TMDL for Greenwich Bay (Table 23; RIDEM, 2004a).

11. While the storm water Phase II minimum measures apply to the entire watershed, Warwick, East Greenwich, West Warwick, and RIDOT should phase in over time targeted retrofit activities identified in the draft RIDEM TMDL, focusing first on high-priority areas associated with recent shellfish and beach closures. Localized water-quality improvements are expected if storm water retrofit activities are concentrated at the sub-watershed level. Items 13 through 16 detail the storm water retrofit priorities for each regulated operator described in the draft TMDL.

12. RIDOT should investigate areas for storm water BMPs along Route 117. Suggestions for improvements to Hardig Brook include the mitigation of storm water from Routes 117 and I-95 using the open areas of the interstate highway. RIDOT should conduct a BMP feasibility study to identify ways to mitigate storm water entering lower Hardig Brook and Gorton Pond tributary from Routes 115, 117, and US-1. The study should address bacteria and nitrogen concentrations as well as storm water volume. RIDOT should work with Warwick to evaluate means of reducing storm water volume from Apponaug to these waters. Planning should accommodate the possibility of returning Hardig Brook to its original streambed to help restore anadromous fish runs.

13. Warwick should conduct BMP feasibility studies to identify locations for installing stormwater BMPs in the Greenwich Bay watershed that address bacteria and nitrogen concentrations as well as stormwater volume, once such BMPs are identified by CRMC and RIDEM. The draft TMDL identifies Brush Neck Cove and Apponaug Cove as priority areas for Warwick (RIDEM, 2004a). BMP feasibility studies should include outfalls with

large impervious drainage areas, the outfalls prioritized by SRICD, and the direct storm water discharges identified by URI-CVE as large bacteria loads to Greenwich Bay. While physical constraints at these locations may exist, they should be considered first for BMP construction. Warwick has received funding to construct infiltration basins at White Avenue in the Brush Neck Cove sub-watershed.

14. East Greenwich should design and construct storm water BMPs for outfalls along Greenwich Cove, where feasible, that address bacteria and nitrogen concentrations as well as stormwater volume, once such BMPs are identified by CRMC and RIDEM.

15. West Warwick should conduct a feasibility study that identifies areas within residential neighborhoods at the headwaters of Hardig Brook where stormwater BMPs would be possible to construct. Stormwater BMPs should address bacteria and nitrogen concentrations as well as stormwater volume, once such BMPs are identified by CRMC and RIDEM.

16. Warwick, East Greenwich, and West Warwick should evaluate the feasibility of creating stormwater management districts pursuant to the R.I. Gen. Laws §45-61, focusing on lands within the Greenwich Bay watershed.

17. The Rhode Island Airport Corporation should examine impacts from any expansion proposal on Greenwich Bay water quality, including the effects on stormwater runoff volume and quality and groundwater flow. Based on surficial geologic maps (See Appendix C) and potential groundwater flow, airport activities outside the watershed could affect Greenwich Bay water quality. Any expansion plans should address the use of BMPs that:

- Reduce nitrogen and bacteria concentrations
- Eliminate from reaching surface or groundwater other pollutants used at the airport, such as deicing chemicals
- Provide for a reduction in runoff volume and increase in water quality

Warwick, East Greenwich, West Warwick, and RIDOT should implement a public education program that focuses on both stormwater quality and quantity concerns within the Greenwich Bay watershed, using resources being developed by RIDEM. The municipalities are required to develop these programs as part of their implementation of state Phase II stormwater regulations. Landscape and building design and other BMPs that minimize stormwater runoff and promote infiltration should be encouraged, where possible, when developing, redeveloping, or repaving sites. The draft TMDL document contains additional suggestions for educational programs (RIDEM, 2004a).

18. Warwick, East Greenwich, West Warwick, and RIDOT should contact Save the Bay, SRICD, or the RI Rivers Council to undertake a stenciling program for storm drains to discourage dumping of pollutants into the drains. The municipalities could help by:

- Prioritizing storm drains for stenciling
- Recruiting nongovernment organizations, schools, and other volunteers to carry-out marking

- Providing supplies for stenciling
- Developing a recognition program for volunteer efforts

Warwick is already administering a storm drain stenciling program through their Department of Public Works.

Table 23. Priority direct storm water discharges identified in the RIDEM bacteria TMDL for Greenwich Bay

ID	Location	Existing or Planned BMP	Why Priority?
Greenwich Cove			
EG01	North of East Greenwich Town Dock		High bacteria loads
EG06	Division Street		High bacteria loads
EG07	Rocky Hollow Road		High bacteria loads
WK08	Norton's Shipyard		High bacteria loads
WK09	Post Road/Ocean Point Avenue West		High bacteria loads
Apponaug Cove			
WK10	Chepiwanoxet Way/Oak Grove Street		High bacteria loads
WK13	Masthead Drive/Fred Humlak Way		High bacteria loads
Brush Neck Cove			
WK29	Cottage Grove Avenue	Vortechnic Installed [1]	Large drainage area
WK30	Shand Avenue	Vortechnic Installed [1]	Large drainage area; High bacteria loads
WK35	Gordon and Hawskley	Vortechnic Installed [1]	Large impervious drainage area; High bacteria loads
WK38	Mohawk/Powhatan		High bacteria loads
WK87	West Shore Road		Large impervious drainage area
SRICD114	Burbank Drive		Impervious drainage area
SRICD116	Burgess Drive	Vortechnic Planned [1]	Impervious drainage area
SRICD121	Burbank Drive	Vortechnic Planned [1]	Impervious drainage area
SRICD123	West Shore Road		Large drainage area
SRICD127	West Shore Road		Large drainage area
SRICD128	Weslyan Avenue		Large drainage area
SRICD131	White Avenue	Infiltration Basins Planned	Large drainage area
SRICD133	Boyle Avenue	Infiltration Basins Planned	Large impervious drainage area
SRICD145	Industrial Drive		Large drainage area

1 Vortechnic units are not expected to reduce bacteria or nitrogen concentrations to storm water volu me.

Source: RIDEM, 2004a

470.6 Boats

470.6A Definitions

1. A person is considered to be living aboard their boat if they inhabit their boat while berthed or moored on Greenwich Bay for six or more months of any given 12-month period.

2. A *marina* is any dock, pier, wharf, float, floating business, or combination of such facilities that accommodates five or more recreational boats.

3. A *residential boating facility* is a dock, pier, wharf, or float, or combination of such facilities, contiguous to a private residence, condominium, cooperative or other homeowners' association property that may accommodate up to four boats.

470.6B Regulations

Prohibitions

1. The discharge of sewage, whether treated or untreated, from boats into tidal waters is prohibited.

2. Boats with people living aboard are prohibited from mooring or berthing in all tidal waters in Greenwich Bay unless they are within the boundaries of a marina that provides pumpout capability directly to boats. The boat shall be tied into the pumpout system at all times while it is moored or berthed.

Standards

1. All new or expanding marina facilities in Greenwich Bay shall provide marine pumpout capability in each slip that can accommodate a boat larger than 40 feet. All marinas should have pumpout capability in each slip that can accommodate a boat larger than 40 feet by 2014.

2. Marina pumpout facilities shall be placed in a convenient location for boaters to maximize the pumpout facility's use, such as at a fuel dock.

470.6C Recommended actions

1. CRMC, with RIMTA and RIDEM, should continue to develop a voluntary Clean Marina program that:

   a) Includes language in slip-leasing agreements to require use of marine pumpout facilities

b) Educates boaters on good waste management practices, including pet waste disposal
c) Denies access to boats without required certification decals
d) Inspects marine sanitation devices
e) Designates pet walking areas with pet waste clean-up stations

Once established, CRMC, in cooperation with RIMTA, should work with Greenwich Bay marinas to designate them as Clean Marinas. CRMC should consider providing applicants certified as Clean Marinas a priority review of Assent applications.

2. CRMC, RIDEM, RIMTA, Warwick, and East Greenwich should work together to develop on-the-water pumpout service for all boats in Greenwich Bay. CRMC should work with RIDEM and RIMTA to ensure service capacity and establish service areas at least for municipal mooring areas and residential boating facilities. A system should be developed, such as a pennant system or a designated radio channel, to request on-the-water pumpout service. The municipalities should support the pumpout service by providing information on the service and, if appropriate, a pennant with Greenwich Bay mooring permits. CRMC should provide similar information or pennants with residential boating facility permits or registrations in Greenwich Bay.

3. RIDEM, with RIMTA, municipal harbormasters, the US Coast Guard, and CRMC, should develop guidelines and procedures for certifying vessel inspectors under the no-discharge certification program (R.I. Gen. Laws §46-12-39.1). They should then develop the guidelines and procedures for inspecting boats in Greenwich Bay.

4. RIDEM, Warwick, and East Greenwich should enforce the new no-discharge certification program with periodic checks of certification decals and of pumpout frequency compliance record cards, and random onboard inspections of marine toilets, using color-dye flush tests. RIDEM and municipal harbormasters should consider coordinating random onboard inspections.

5. Warwick and East Greenwich should deny mooring permits for any boat not displaying a no-discharge certification decal and should deny a mooring permit renewal for any boat with a certification decal found to be in noncompliance with no-discharge requirements outlined in R.I. Gen. Laws §46-12-39 and §46-12-39.1. Mooring permits should include language requiring the use of marine pumpout facilities and explaining the consequences for noncompliance.

6. RIDEM should continue to oversee the operation and maintenance of the pump-out infrastructure by participating in the Clean Vessel Act (CVA) program, which provides money for the construction, repair, and replacement of pump-out facilities, and by coordinating outreach and education programs.

7. CRMC, in cooperation with RIMTA and RIDEM, should encourage the distribution of educational brochure(s) for boaters on best management practices and no-discharge requirements. Brochures should be distributed with boating registrations, marina billing

statements, mooring permits, and residential boating facility permits and registrations. In addition, CRMC, RIDEM, and RIMTA should ensure that educational materials are included in any boating safety courses. For example, the U.S. Coast Guard auxiliary discusses no discharge requirements in their classes.

8. CRMC, in cooperation with RIDEM and the Rhode Island Shellfishermen's Association, should develop an educational program aimed at commercial shellfishermen explaining no-discharge requirements, and the impact of inadequately treated or untreated human waste on water quality and the relationship to shellfish bed pollution closures.

9. RIDEM should develop and provide signs to marinas in Greenwich Bay and the municipalities that explain no-discharge requirements. Warwick and East Greenwich should post these signs at public boat ramps and municipal docks. Marinas should post these signs at their facilities.

470.6D Research needs

1. Research should be conducted to determine the fecal-coliform levels in graywater discharged from boats.

470.7 Pets and wildlife

470.7A Regulations

Policy

1. It is CRMC policy to provide technical assistance to nongovernment organizations disseminating public education and outreach materials on the contributions pet and wildlife wastes make to bacterial contamination in Greenwich Bay, including problems with bird feeding along the Greenwich Bay shoreline and tributaries.

470.7B Recommended actions

1. CRMC, RIDEM, and HEALTH should develop public outreach and education materials, including signs that can be posted throughout the Greenwich Bay watershed, explaining how pets and wildlife contribute to beach and shellfish closures, encouraging proper pet waste disposal, and discouraging bird feeding. Educational materials should emphasize that bird and pet wastes contribute to beach and shellfish bed closures as well as that feeding waterfowl is illegal and detrimental to the birds and the environment. RIDEM has already developed a brochure on the detrimental impacts of feeding waterfowl currently available on their website. In addition, education materials should encourage the establishment of native vegetated areas with tall perennial grasses and shrubs along the shoreline to discourage geese access to the water. CRMC, RIDEM, Warwick, East Greenwich, and West Warwick should work with these organizations to develop and disseminate information.

2. RIDEM and Warwick should post signs at access points to licensed beaches they operate notifying and explaining to users that pets are not allowed on the beach from April 1 to September 30. HEALTH regulations prohibit pets on beaches during this period to protect swimmers against bacterial contamination (HEALTH Rules and Regulations for Licensing of Recreational Facilities §3.0). RIDEM regulations also prohibit pets on state beaches during the bathing season and require animal owners to clean up and properly dispose of animal wastes (RIDEM Park and Management Area Rules and Regulations §2.1 and §2.5).

3. RIDEM, Warwick, East Greenwich, and West Warwick, with assistance from the CRMC and HEALTH, should post signs at public recreation areas they operate along the Greenwich Bay shoreline and tributaries notifying and explaining that wild waterfowl feeding is illegal under state law (Rhode Island Hunting Regulations §14.13) and that bird feeding contributes to Greenwich Bay's beach and shellfish closures. Eliminating this practice will decrease summer bird populations and make the area less attractive to the year-round residence of migratory birds. HEALTH should work with beach managers to discourage beach visitors from feeding birds and to undertake any other practical measures to reduce resident bird populations.

4. Nongovernment organizations, such as neighborhood associations, should disseminate public education and outreach materials explaining how pets and wildlife contribute to bacterial contamination in Greenwich Bay, including describing problems related to bird feeding at sites along the Greenwich Bay shoreline and tributaries and teaching responsible pet waste disposal methods. Nongovernment organizations could use signs, brochures, public service announcements, and other methods to educate watershed residents, particularly property owners along the shore and tributaries, and those using shoreline public access sites.

5. Warwick, East Greenwich, and West Warwick in conjunction with nongovernment organizations should consider installing and maintaining pet waste stations at popular locations for walking dogs where this waste has a chance of entering a water body or drain, and ensure that garbage cans are available and maintained nearby for proper disposal. Pet waste stations provide pet waste collection bags, scoops, and/or shovels that dog owners can use to pick up after their pets. The municipalities should post signs at these areas explaining the problems with pet waste and proper disposal.

6. RIDEM should ensure that screens or grates are placed over the end of stormwater culverts at the Goddard Memorial State Park beach in accordance with the R.I. Coastal Resources Management Program §300.6 and the State of Rhode Island Storm Water Design and Installation Standards Manual.

7. Warwick, East Greenwich, West Warwick, and RIDEM should ensure that garbage bins are covered and garbage picked up regularly at public recreation areas, especially beaches, along the Greenwich Bay shoreline and tributaries.

8. RIDEM and U.S. Fish and Wildlife Service should consider developing management plans with Warwick, East Greenwich, and West Warwick to control Canada geese and mute swan populations in the Greenwich Bay watershed.

470.8 Lawn and turf management

470.8A Regulations

Policy

1. It is CRMC policy with the assistance of the Natural Resources Conservation Service (NRCS) and URI-CE to require municipal and state programs to use integrated pest management (IPM) or less-toxic pesticides and watershed-friendly fertilizers, such as controlled-release fertilizers, in public parks, along highways, and on other public properties within 200 feet of a shoreline (coastal) feature.

2. It is CRMC policy to work cooperatively with the four golf courses in the Greenwich Bay watershed to help them achieve a Green Golf Course designation. CRMC in cooperation with URI-CE will work with golf course superintendents to help their courses meet standards and certify those courses as Green Golf Courses.

Standards

1. A Green Golf Course should:
   a) Maintain at least 0.25-inch height cut on greens
   b) Plant velvet bentgrass on greens
   c) Use IPM or other alternative practices to pesticides
   d) Use controlled-release fertilizers
   e) Install the most current irrigation technology
   f) Educate members and golfers on the benefits of green golf course practices

(Johnston and Golob 2002; Shuman, 2002; Rottenberg, 2003)

470.8B Recommended actions

1. RIDEM, Warwick, East Greenwich, and West Warwick in accordance with CRMC should evaluate establishing native vegetated buffers of tall, coarse vegetation on state-owned coastal areas and municipally owned riparian areas throughout the Greenwich Bay watershed. Vegetated buffers can help remove nutrients from storm water and groundwater. In addition, naturally vegetated buffers along coastal and riparian areas can discourage Canada geese from congregating directly on the shoreline, thus diminishing bacterial inputs from their feces (Smith et al., 1999).

2. The Natural Resources Conservation Service (NRCS), in conjunction with SRICD and URI-CE, should create a public education and outreach program on watershed-friendly fertilizer and pesticide use, and proper watering of residential lawns.

3. NRCS, in conjunction with SRICD and URI-CE, should create a training program for lawn care companies, lawn and garden center employees, and municipal employees, educating them on best management practices for turf management and available watershed-friendly fertilizers and pesticides.

4. RIDOT and Amtrak should use IPM and less-toxic pesticides along highways and railroad tracks within the Greenwich Bay watershed.

Section 480
Literature Cited

Applied Science Associates, URI Watershed Watch, SAIC Engineering, Inc., and D.W. Urish, R.M. Wright, and Runge. (1995). *Narrow River stormwater management study: problem assessment and design feasibility and appendices.*

Applied Science Associates. (2001). *Final data report for: Greenwich Bay water quality sampling, summer 2000.* Prepared for the Office of Water Resources, R.I. Department of Environmental Management, ASA Project 00-029.

Bergondo, D.L. (2004). *Examining the process controlling water column variability in Narragansett Bay: time series data and numerical modeling.* Unpublished Ph.D. dissertation, University of Rhode Island, Kingston.

Beta Group, Inc. (2003). *City of Warwick, Rhode Island: phase II storm water management program plan - DRAFT*. Prepared for the city of Warwick, Rhode Island.

Brush, M.J. (2002). *Development of a numerical model for shallow marine ecosystems with application to Greenwich Bay, R.I.* Unpublished Ph.D. dissertation, University of Rhode Island, Kingston.

Brush, M.J. (2004). *Application of the Greenwich Bay ecosystem model to the development of the Greenwich Bay Special Area Management Plan.* Prepared for the URI Coastal Resources Center.

Canter, L.W. and R.C. Knox. (1985). *Septic tank system effects on groundwater quality.* Boca Raton: Lewis Publishers, Inc.

Chesapeake Bay Program. (1995). *The state of the Chesapeake Bay*. Washington, D.C.: U.S. Government Printing Office.

Committee on Environment and Natural Resources. (2003). *An assessment of coastal hypoxia and eutrophication in U.S. waters.* National Science and Technology Council Committee on Environment and Natural Resources, Washington, D.C..

Costa, J.E., B.L. Howes, A.E. Giblin, I. Valiela. (1992). Monitoring nitrogen and indicators of nitrogen loading to support management action in Buzzards Bay. *Ecological Indicators 1,* 499-531.

Dema, M. (2004). What are the socioeconomic consequences of environmental change in Greenwich Bay? Unpublished master's thesis, Brown University, Providence.

DeMelo, A.C.V. (1996). Hardig Brook Water Quality Assessment: Identification of Point and Nonpoint Source Pollution. Unpublished master's thesis, University of Rhode Island, Kingston.

DeMelo, A.C.M., O.J. Viator, and R.M. Wright. (1997). *Greenwich Bay initiative – water quality evaluation of Hardig Brook*. Final report submitted to the R.I. Department of Environmental Management and the Narragansett Bay Project by the Department of Civil and Environmental Engineering, University of Rhode Island, Kingston.

Doering, P.H., M.E.Q. Pilson, and C.A. Oviatt. (1988). *SPRAY cruise dissolved oxygen and chlorophyll*. Data report to the Narragansett Bay Project.

Durbin, A.G. and E.G. Durbin. (1981). Standing stock and estimated production rates of phytoplankton and zooplankton in Narragansett Bay, R.I. *Estuaries 4*, 24-41.

Eichner, E.M. and T.C. Cambareri. (1992). *Nitrogen loading*. Water Resources Office, Cape Cod Commission, Barnstable.

Erikson, L. H. (1998). *Flushing Times of Greenwich Bay, Rhode Island: Estimates Based on Freshwater Inputs.* Unpublished master's thesis, University of Rhode Island, Kingston.

Ferrara, R.N. (1953). *Phytoplankton studies in upper Narragansett Bay.* Unpublished master's thesis, University of Rhode Island, Kingston.

Fraher, J. (1991). *Atmospheric wet and dry deposition of fixed nitrogen to Narragansett Bay*. Unpublished master's thesis, University of Rhode Island, Kingston.

Gage, S.D. and P.C. McGouldrick. (1924). *Report on investigations of the pollution of certain Rhode Island public waters during 1923 and 1924*. Board of Purification of Waters, State of Rhode Island and Providence Plantations.

Gold, A.J., W.R. DeRagon, W.M. Sullivan, and J.L. LeMunyon. (1990). Nitrate-nitrogen losses to groundwater from rural and suburban land uses. *Journal of Soil and Water Conservation 45,* 305-310.

Goldberg, E.D. (1995). Emerging problems in the coastal zone for the twenty-first century. *Marine Pollution Bulletin 31,* 152-158.

Granger, S., M. Brush, B. Buckley, M. Traber, M. Richardson, and S.W. Nixon. (2000). An assessment of eutrophication in Greenwich Bay. Paper No. 1. In: Schwartz, M. (ed.), *Restoring Water Quality in Greenwich Bay: A Whitepaper Series.* Rhode Island Sea Grant, Narragansett.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. (1990). *State of the marine environment*. United Nations Environment Programme.

Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection**.** (1990). *State of the marine environment*. United Nations Environment Programme.

Herron, E., L. Green, A. Gold, and G. Boisclair. (1998). *Maskerchugg River watershed – Warwick, West Warwick, and East Greenwich, R.I.* Prepared for the R.I. Department of Environmental Management.

Howard-Strobel, M.M., T.G. Simpson, and T. Dillingham. (1986). *The Narrow River Special Area Management Plan*. Prepared for the R.I. Coastal Resources Management Council, Wakefield.

Hunt, C.D., P.A. Sampou, M.F. Fox, S.R. Jackson, W.M. Warren, J.D. Cullen, J. Coyne, M.E.Q. Pilson. (1987). *Narragansett Bay water quality monitoring and source strength measurements.* Final report to the R.I. Department of Environmental Management, Providence.

Jarrett, A.R., D.D. Fritton, and W.E. Sharpe. (1985). *Renovation of failing absorption fields by water conservation and resting*. American Association of Agricultural Engineers.

Johansson, R.O.R. and R.R. Lewis. (1992). Recent improvements of water quality and biological indicators in Hillsboro Bay, a highly impacted subdivision of Tampa Bay, Florida, USA. *Science of the Total Environment Supplement* 1199-1215.

Johnston, W.J. and C.T. Golob. (2002). Nitrogen leaching through a sand-based golf green. *USGA Turfgrass and Environmental Research Online 1*(19): 1-7.

Kemp, W.M., R.R. Twilley, J.C. Stevenson, W.R. Boynton, and J.C. Means. (1983). The decline of submerged vascular plants in Chesapeake Bay: summary of results concerning possible causes. *Marine Technical Mar. Tech. Soc. Journal 17,* 78-89.

Kopp, B., A.M. Doherty, and S.W. Nixon. (1995). *A guide to site-selection for eelgrass restoration projects in Narragansett Bay, Rhode Island.* Final report submitted to the Rhode Island Aquafund Program, R.I. Department of Environmental Management, Division of Water Resources, Providence.

Louis Berger Group, Inc. (2001). Hill and harbor district stormwater abatement project – East Greenwich, Rhode Island. Prepared for the East Greenwich planning department.

Lucht, J. (2003). Analysis of environmental threats and prioritization of mandatory sewer connections for the city of Warwick, Rhode Island. Draft Report prepared for the Warwick Sewer Authority.

Mallin, M., K. Williams, E. Esham, and R. Lowe. (2000). Effect of human development on bacteriological water quality in coastal watersheds. *Ecological Applications 10,* 1047-1056.

Morton, T.G., A.J. Gold, and W.M. Sullivan. (1988). Influence of overwatering and fertilization on nitrogen losses from home lawns. *Journal of Environmental Quality 17*, 124-130.

Nixon, S.W. (1989). An extraordinary red tide and fish kill in Narragansett Bay, p. 429-447. In: E.M. Cosper, V.M. Bricelj, and E.J. Carpenter (eds.), *Coastal and Estuarine Studies*. New York: Springer-Verlag.

Nixon, S.W. (1993). Nutrients and coastal waters—too much of a good thing? *Oceanus 36,* 38-47.

Nixon, S.W. (1995b). Coastal marine eutrophication: a definition, social causes, and future concern. *Ophelia 41*, 199-219.

Nixon, S.W. (1997). Prehistoric nutrient inputs and productivity in Narragansett Bay. *Estuaries 20*(2): 253-261.

Nixon, S.W., S.L. Granger, and B.L. Nowicki. (1995). An assessment of the annual mass balance of carbon, nitrogen, and phosphorus in Narragansett Bay. *Biogeochemistry 31,* 15-61.

Nixon, S.W. and M.E.Q. Pilson. (1983). Nitrogen in estuarine and coastal marine ecosystems, p. 565-648. In: E.J.C. a. D.G. Capone (eds.), *Nitrogen in the Marine Environment*. New York: Academic Press.

Nixon, S.W., C. Oviatt, and S. Granger. (2004). *Anatomy of a fish kill*. Graduate School of Oceanography, University of Rhode Island. Public presentation, September 23, 2004.

Noble, R.T., D.F. Moore, M.K. Leecaster, C.D. McGee, and S.B.Weisberg. (2003). Comparison of total coliform, fecal coliform, and *enterococcus* bacterial indicator response for ocean recreational water quality testing. *Water Res 37*, 1637-1643.

Nowicki, B.L. and J.H. McKenna. (1990). A preliminary assessment of environmental quality in Greenwich Bay, Rhode Island. Final Report to the Narragansett Bay Project.

National Research Council. (2000). Clean coastal waters: understanding and reducing the effects of nutrient pollution. Washington, D.C.: National Academy Press.

National Shellfish Sanitation Program. (1997). *National shellfish sanitation program guide for the control of molluscan shellfish, Interstate Shellfish Sanitation Conference.* Department of Health and Human Services, Public Health Service, U.S. Food and Drug Administration.

O'Rourke, P. (1995). *Reducing the pollution potential in the Greenwich Bay and Green Hill Pond through septic system compliance activity*. R.I. Department of Environmental Management, Office of Water Resources, Providence.

Oviatt, C.A., P. Doering, B. Nowicki, L. Reed, J. Cole, and J. Frithsen. (1995). An ecosystem level experiment on nutrient limitation in temperate coastal marine environments. *Marine Ecology Progress Series 116,* 171-179.

Pilson, M.E.Q. (1985). On the residence time of water in Narragansett Bay. *Estuaries 8*, 2-14.

Postma, F.B., A.J. Gold, G.W. Loomis. (1992). Nutrient and microbial movement from seasonally used septic systems. *Journal of Environmental Health 55*, 5-10.

Pratt, S.D. and G.L. Seavey. (1981). *The environment of Apponaug Inner Cove and the impact of development on the cove*. Prepared for Robinson Green Beretta Corp., Providence.

Prell, W., E. Saarman, D. Murray, and C. Deacutis. (2004). Summer season: nighttime surveys of dissolved oxygen in upper Narragansett Bay (1999–2003). <http://www.geo.brown.edu/georesearch/insomniacs>.

Pryor, D., T. Brueckner, R. Chateneuf, B. Costa-Pierce, C. Deacutis, T. Getz, C. Giles, A. Gold, S. Hamburg, E. Julian, K. Kubic, V. Lee, A. Liberti, R. Pastore, and C. Wigand. (2004). *Nutrient and bacteria pollution panel: initial report.* Report to the Governor's Narragansett Bay and Watershed Planning Commission, Providence.

Rhode Island Statewide Planning Program. (2004a). *Rhode Island population projections: state, county, and municipal 2000–2030*. Statewide Planning Program, Rhode Island Department of Administration, Providence.

Rhode Island Statewide Planning Program. (2004b). *Rhode Island population by city and town, 1790–2000*. Statewide Planning Program, Rhode Island Department of Administration, Providence.

R.I. Department of Environmental Management. (1993). Emergency Closure of Shellfish Grounds Notice. *Providence Journal-Bulletin*, Legal Notice, January 5.

R.I. Department of Environmental Management. (1994). Opening of Shellfish Grounds – Greenwich Bay. *Providence Journal-Bulletin*, Legal Notice, June 25.

R.I. Department of Environmental Management. (1998). *Greenwich Bay growing area 8 shoreline survey–1998 Report.* R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2001). *Greenwich Bay growing area 8 shoreline survey–2001 Report.* R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2002). Notice of polluted shellfishing grounds May 2002. *Providence Journal*. Legal Notice, May 28.

R.I. Department of Environmental Management. (2003a). *State of Rhode Island 2002 303(d) list: list of impaired waters*. Office of Water Resources, R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2003b). Notice of polluted shellfishing grounds May 2003. *Providence Journal*. Legal Notice, May 22.

R.I. Department of Environmental Management. (2003c). *Greenwich Bay growing area 8 shoreline survey – 2003 Annual Update*. R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2003d). Identification of bacteria sources in Green Hill Pond using polymerase chain reaction (PCR). Office of Water Resources, R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2003e). The Greenwich Bay fish kill–August 2003: causes, impacts and response. Office of Water Resources, R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2004a). *Total Maximum Daily Load Analysis for Greenwich Bay Waters, DRAFT for public comment.* Office of Water Resources, R.I. Department of Environmental Management, Providence.

R.I. Department of Environmental Management. (2004b). *DEM announces annual seasonal shellfish closures and conditional re-opening of 240 acres in Greenwich Bay to shellfishing.* R.I. Department of Environmental Management, Providence.

R.I. Department of Health. (2004a). *Beach monitoring program – 2003 season report*. Office of Food Protection, R.I. Department of Health, Providence.

Rose, J.B., R.M. Atlas, C.P. Gerba, M.J.R. Gilchrist, M.W. LeChevallier, M.D. Sobsey, M.V. Yates, G.H. Cassell, and J.M. Tiedje. (1998). Microbial pollutants in our nation's water: environmental and public health issues. American Society of Microbiology, Washington, D.C.

Rottenberg, R. (2003). *Green golf courses: a study of maintenance practices in Rhode Island.* Unpublished bachelor's thesis, Brown University, Providence.

Saarman, E.T. (2003). *Hypoxic conditions in Narragansett Bay during the summer of 2001*. Unpublished master's thesis, Brown University, Providence.

Schwartz, M. (2004). URI scientists report Greenwich Bay fish kill not unexpected. *41°N 2*(2): 18-19.

Seitzinger, S.P., R.W. Sanders, and R. Styles. (2002). Bioavailability of DON from natural and anthropogenic sources to estuarine plankton. *Limnology and Oceanography 47*(2): 353-366.

Shuman, L.M. (2002). Nutrient leaching and runoff from golf courses. *USGA Turfgrass and Environmental Research Online 1*(17): 1-9.

Sinnamon, M. (2004). Protecting Greenwich Bay from cesspools and septic systems: risk management strategies. Unpublished master's thesis, Brown University, Providence.

Smayda, T.J. (1989). *Survey of environmental conditions and plankton dynamics along a eutrophication gradient in Narragansett Bay during an annual cycle*. Final report to the Narragansett Bay Project, Narragansett.

Smith, S.V. (1984). Phosphorus versus nitrogen limitation in the marine environment. *Limnology and Oceanography 29,* 1149-1160.

Smith, A.E., S.R. Craven, and P.D. Curtis. (1999). *Managing Canada geese in urban environments: a technical guide*. Ithaca: Cornell University Cooperative Extension.

Speaker, J.C. (2003). *2001 review shellfish growing area monitoring program statistical evaluation and comments.* Office of Water Resources, R.I. Department of Environmental Management, Providence.

Southern Rhode Island Conservation District. (1999). *Greenwich Bay storm water management program: evaluation of storm water systems for maintenance and retrofit potential (An Aqua Fund Project)*. Final Report submitted to the city of Warwick.

Southern Rhode Island Conservation District. (2002). Storm Water Evaluation in Warwick Cove.

Southern Rhode Island Conservation District. (2003). *Warwick Cove direct storm water discharges*. Data given to the R.I. Department of Environmental Management.

Sullivan, B.K., D.J. Gifford, and J. Costello. In Preparation. *Initiation and maintenance of population maxima of the ctenophore* Mnemiopsis leidyi *in northern coastal waters.* Graduate School of Oceanography - University of Rhode Island and Providence College.

Taylor, D.I., S.W. Nixon, S.L. Granger, and B.A. Buckley. (1995). Impacts of different forms of nutrients on the roles of coastal lagoons as nutrient sources or sinks - a mesocosm study. *Ophelia 42,* 353-370.

Thursby, G., D. Miller, S. Poucher, L. Coiro, W. Munns, and T. Gleason. (2000). *Ambient aquatic life water quality criteria for dissolved oxygen (saltwater): Cape Cod to Cape Hatteras.* National Health and Environmental Effects Research Laboratory, Atlantic Ecology Divison, U. S. Environmental Protection Agency, Narragansett.

Urish, D.W. and A.L. Gomez. (1998). *Determination of the quantity, quality, and location of coastal groundwater discharge to a marine embayment: Greenwich Bay, Rhode Island.* Final Report prepared for the city of Warwick.

Urish, D.W. and A.L. Gomez. (2004). Groundwater discharge to Greenwich Bay. Paper No. 3. In: Schwartz, M. (ed.), *Restoring Water Quality in Greenwich Bay: A Whitepaper Series.* Rhode Island Sea Grant, Narragansett.

U.S. Environmental Protection Agency. (1983). *Results of the nationwide urban runoff program: executive summary.* U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (1995). *A comprehensive conservation and management plan for Delaware's inland bays.* National Estuary Program, U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (1999). *Decentralized systems technology fact sheet: septic tank soil absorption systems.* Office of Water, U.S. Environmental Protection Agency.

U. S. Food and Drug Administration. (1993). *Greenwich Bay, R.I. shellfish growing area survey and classification considerations.* U.S. Public Health Service, Food and Drug Administration, Davisville.

Valente, R.M., D.C. Rhoads, J.D. Germano, and V.J. Cabelli. (1992). Mapping of benthic enrichment patterns in Narragansett Bay, Rhode Island. *Estuaries 15*(1): 1-17.

Valiela, I. and J. Costa. (1988). Eutrophication of Buttermilk Bay, a Cape Cod coastal embayment: concentrations of nutrients and watershed nutrient budgets. *Environmental Management 12,* 539-553.

Weiskel, P.K., B.L. Howes, and G.R. Heufelder. (1996). Coliform contamination of a coastal embayment: sources and transport pathways. *Environmental Science and Technology 30,* 1872-1881.

Wright, R.M., M. Fanning, and O. Viator. (1998). *Characterization of nonpoint source pollutant sources to an estuary under wet weather conditions–direct storm water discharges*. Final report submitted to the city of Warwick.

Wright, R.M. and O.J. Viator. (1999). *Greenwich Bay Initiative—northern watersheds loading estimates to Greenwich Bay*. Final report submitted to the city of Warwick.

Chapter 5

Cultural and Historical Assets

Table of Contents

Table

Figure

Section 500
Introduction

1. Greenwich Bay's protected shoreline has attracted human use for thousands of years. Its archaeological sites, historic districts and buildings, and its waterfront and open space areas define the unique character of life in Warwick and East Greenwich.

2. Native Americans established fairly permanent year-round settlements at Greenwich Bay by approximately 3,000 years ago. These settlements focused on the coastal edge but also spread inland along the waterways. The people prospered from the variety and abundance of wild plants and animals: Oyster, soft-shelled clam and quahog, white-tailed deer, squirrel, rabbit, bear, weakfish, tautog, turkey, and hickory nuts and acorns were easily found in the Greenwich Bay area.

3. When Roger Williams established a trading post at Wickford in the 1630s, the Narragansetts were the dominant political force in the area, with strong social and political ties to some tribes and colonists.

4. Samuel Gorton, an English clothier with fervent beliefs about freedom from religious and political systems, was banished from Plymouth, MA, and Portsmouth, Providence, and Pawtuxet after fighting with town leaders. He bought nearly 100 square miles of land—a transaction known as the Shawomet Purchase—from a branch of the Narragansetts. Gorton convinced English royalty to approve his purchase, and he named his settlement "Warwick" in deference to the earl who granted the official charter in 1647. Yet Gorton and his followers encountered trouble after they built Old Warwick Village at the head of Warwick Cove.

5. In 1675, a bloody battle for land began that pitted colonists against Native American tribes. The battle, King Philip's War, ended in 1676 with the murder of Wampanoag leader Metacom, known to the English colonists as King Philip. Many Native Americans were subsequently forced into exile or slavery.

6. After the war, colonial villages started a recovery, with Apponaug Village becoming Warwick's hub and thriving as a government and military center, shipping port, and mill location.

7. In 1677, the Rhode Island General Assembly gave land to 48 soldiers who had fought King Philip's War, forming the town of East Greenwich. Most of the men chose not to settle in East Greenwich, but rather in Newport, Portsmouth, and Jamestown, deeding their grants to younger members of their families.

8. Eventually, East Greenwich's natural attributes attracted shipbuilding, fishing, and textile operations, which fostered the town's development as a political and military center. In 1750, East Greenwich served as one of five seats of Rhode Island's colonial government. The town provided elite soldiers, the Kentish Guards, who fought in the Revolutionary War and built a key stronghold—Fort Daniel—at the entrance to Greenwich Bay at the end of Williams Street (now in Warwick).

9. From the 1770s to the early 1900s, tanneries, cloth-makers, fulling mills, fabric printers, cotton mills, and ship builders were among the manufacturing firms that grew in East Greenwich and Warwick and provided jobs for residents, including European immigrants.

10. In the early 20th century, manufacturing grew to drive the economy in East Greenwich and Warwick, increasing land use. Large-scale consumption of land for commercial and residential expansion escalated significantly after World War II. This slow but steady conversion of commercial and subsistence farms to post-war suburban neighborhoods yielded patchwork development that prompted local governments to create zoning laws. While fledgling ordinances addressed development in new residential and business areas, they did little to protect older villages, shorelines, and farmland.

11. The Post World War II GI Bill, which made home ownership available to returning soldiers, fostered the rapid development of suburbs in Rhode Island. These suburbs make up many of the residences in the Greenwich Bay area, shaping the way people live in Warwick and East Greenwich today.

12. Two features that have traditionally defined life in Greenwich Bay are shellfishing and shoreline recreation.

13. In the early 20th century, oysters dominated commercial shellfishing in Narragansett Bay, but the oyster population gradually declined after the 1920s, and at the same time, the quahog fishery expanded. East Greenwich emerged in the late 1870s as Rhode Island's leader in scallop production. Shellfishing boomed between 1890 and the 1913. Greenwich Cove's legendary "Scalloptown" came into being as fishing shacks were built along the waterfront. These were havens for fights, prostitution, and even murders, according to legend. Overfishing, pollution, and public concern about the safety of crime-ridden wharf areas brought about the decline of Scalloptown in the 1930s. Greenwich Bay quahogs continue to be distributed wholesale nationwide.

14. Recreation has always beckoned people to the bay. Excursion steamboats from other parts of Warwick and Providence brought people to Greenwich Bay for beachfront stays and shore dinners. Commercial clambakes were born in Greenwich Bay in the 1830s. Recreational shellfishing has always been important to Greenwich Bay residents. The state's first recreational boating facility built as a true marina was in Greenwich Bay in the 1950s. Greenwich Bay now hosts more marinas per area than the rest of Narragansett Bay, with boaters from Rhode Island, Massachusetts, Connecticut, New York, and New Jersey. Recreational fishing is growing, and takes place both from shore and on boats.

15. Today, decisions over use of space and resources for these activities will determine how these traditions continue in Greenwich Bay.

Section 510
Cultural and historical assets

1. Cultural and historical assets in the Greenwich Bay watershed include archeological sites and artifacts and historic districts, buildings and cemeteries (Figure 1).

2. Archeological sites in East Greenwich and Warwick are often more than 3,000 years old and confirm the presence of Native American communities both along the shoreline of the bay and deeper within the watershed. Native American camps, burial grounds, tools, weapons, and other artifacts have been found at many Warwick locations including Drum Rock and Lambert Farm in Cowesett, the Sweet Meadow Brook site near Apponaug, a Potowomut site near the head of Greenwich Cove, Mary's Creek, Cedar Tree Point, and Nausauket.

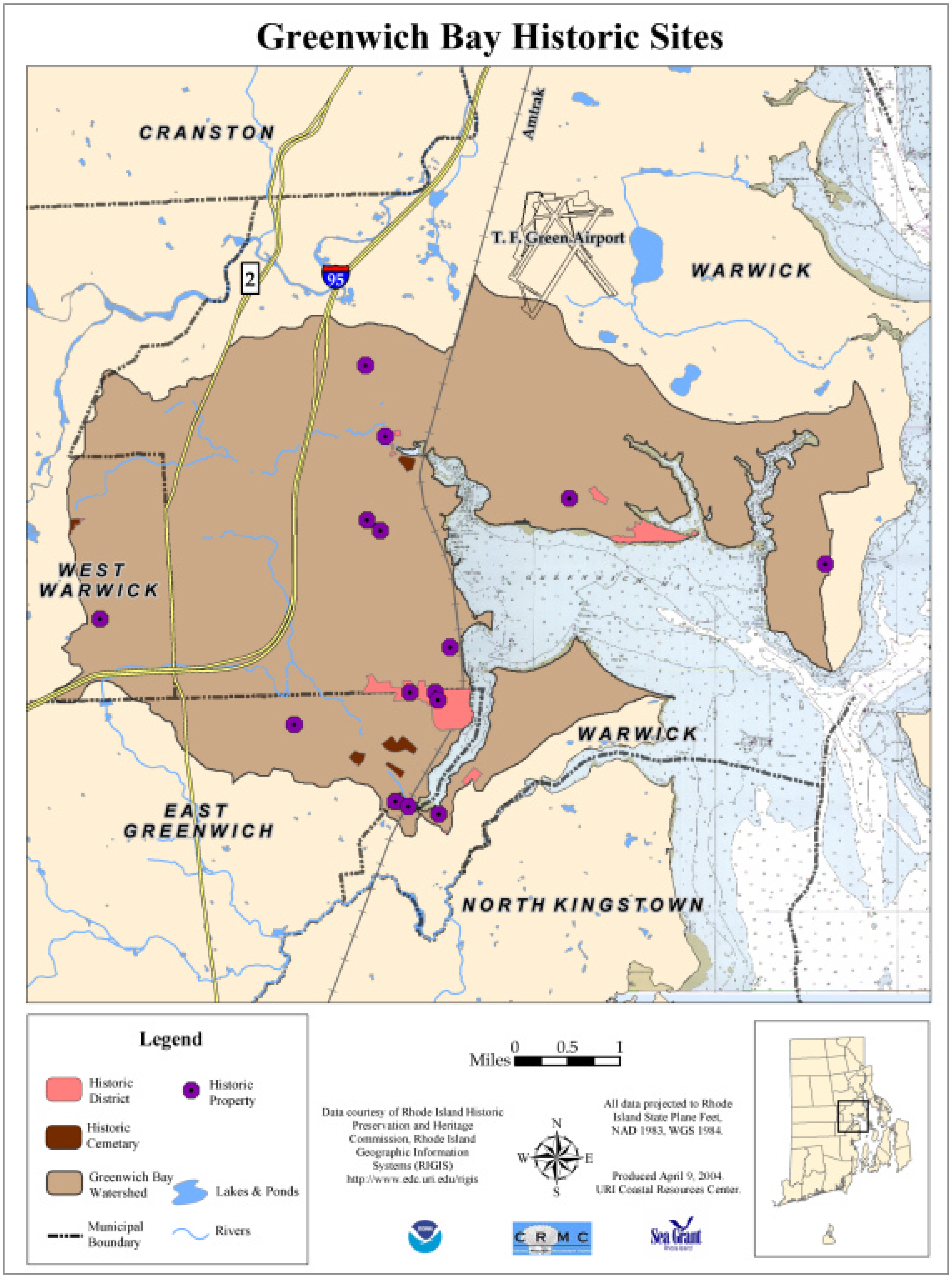
3. At least two archeological findings in the watershed have generated significant public interest. Shell pits at Apponaug Cove show that Native Americans both harvested and traded large amounts of shellfish, and a fort belonging to a legendary Native American warrior, Shawomet Chief Pomham, is located off Payne Street on the east side of Warwick Cove (Insana, pers. comm.).

4. Historic buildings in the Greenwich Bay watershed provide valuable housing, commercial space, visual interest, and opportunities for cultural appreciation and education. The state's historic properties are major attractions for Rhode Island's billion-dollar tourism industry, and historic properties in Warwick and East Greenwich help generate that revenue. For an area its size, the Greenwich Bay watershed has a significant number of historic districts. The chief historic district in the East Greenwich portion of the watershed is the East Greenwich Historic District (the Hill and Harbor District), although the town has created two other districts—the Tillinghast Road Historic District, and the Fry's Hamlet Historic District. Within Warwick, the watershed is impacted by the Apponaug Historic District.

5. Historic cemeteries are increasingly regarded as important cultural resources. Cemeteries contain information about local individuals and families, landscape and architectural design, grave marker artisanry and technology, religious beliefs, and community history. Of the 273 historic cemeteries in Warwick and East Greenwich, more than half are within the Greenwich Bay watershed and range in size from small family burial grounds to landscaped garden cemeteries.

6. Municipalities manage cemeteries through ordinances and commissions and provide permissions for cemetery maintenance and cleanup projects undertaken by public, private and community organizations. Maintenance and cleanup efforts are often supported by combinations of public, private, and community organization funds and manpower. Yet, many cemeteries and burial grounds continue to be threatened by neglect, vandalism, and encroaching development. In terms of resources, The Rhode Island Historical Preservation & Heritage Commission (RIHPHC) provides guidance on cemetery protection measures and programs, the Rhode Island Cemeteries Database is a statewide project that relies on volunteer input to document gravemarkers and burials in cemeteries around the state, and the Rhode Island General Assembly makes cemetery legislation available on its web site.

Figure 1. Greenwich Bay historic sites



Section 520
Asset protection

1. While the state administers its own historical preservation program, the RIHPHC, municipalities have created historic district commissions to regulate proposed changes to building in specified districts designated by local ordinance. The commissions work closely with local planning departments and serve as conduits to community efforts to preserve historical resources. Both East Greenwich and Warwick, through their historic preservation/district commissions, have zoned historic districts in the Greenwich Bay watershed. These districts regulate proposed changes to buildings or sites through the mechanism of the building permit. Proposed changes are reviewed by a local commission.

2. East Greenwich and Warwick have taken steps to protect archeological resources by accessing state (CRMC, RIHPHC) technical assistance and federal (U.S. Department of Housing and Urban Development) and private funding sources to support protection efforts. Financial assistance is available to properties that are eligible for inclusion in the National Register of Historical Places, whether they are in a local historic district or not.

3. Still, both municipalities recognize that further steps must be taken to work with state and federal agencies to maximize the efficiency and breadth of government identification, review, regulation, and protection mechanisms. For example, the discovery of a historically significant site at Lambert Farm, Cowesett, brought to light the threat development may pose to city archeological sites. The site owner and members of Warwick's Historical District Commission worked out an agreement to delay development to allow removal of data from the site. The city recognized that it should have a more formal mechanism to identify and protect historical sites.

4. National Register historic districts are proposed by the state and designated by the National Park Service, and may include buildings and archeological sites. No regulation of action by private property owners occurs in National Register districts unless a property owner applies to a state or federal program such as CRMC or the U.S. Army Corps of Engineers for financial assistance or a permit. Activities of federal and state government, however, are reviewed. Grant funds are administered by RIHPHC to Warwick as part of the Certified Local Governments grants program, which originates with the National Park Service. Warwick secured a $5,000 state grant to initiate underwater exploration for artifacts in waters off of Cedar Tree Point. RIHPHC maintains a list of historical resources for both communities.

5. East Greenwich and Warwick planning department staff and historical preservation/district commission members indicate that compared to many other places, the Greenwich Bay region is rich in historic districts and buildings and stands to benefit both economically and aesthetically from continued or expanded government policies and programs that protect these assets. Both the East Greenwich and Warwick comprehensive plans indicate that economically, protected historical and cultural assets increase the value of surrounding properties and raise tourism revenues. Community and neighborhood groups indicate that residents take pride in historic districts, buildings, and assets, and identify them as part of the neighborhood culture and quality of life.

6. Neighborhood efforts often play key roles in the identification, protection, and maintenance of historical and cultural assets. Neighborhood organizations provide volunteer manpower for the physical upkeep of historical buildings and places and have worked with municipal and state offices to secure funding for preservation projects. Neighborhood organizations are also valuable sources of local historical information that is often passed down by word of mouth.

7. Neighborhood efforts have enhanced the Greenwich Bay environment and preserved its heritage. For example, the Chepiwanoxet Neighbors Association worked with government and community partners for more than a decade to ensure that Chepiwanoxet Island was preserved as open space in 1994. Also, the Oakland Beach Association/Oakland Beach Carousel Foundation is honoring the beach's heritage as a 20th century seaside park with the construction of a traditional carousel, and the Apponaug Area Improvement Association has assisted government efforts to rehabilitate and preserve historic sites and buildings in the village. Neighborhood organizations in Buttonwoods, Cedar Tree Point, Cowesett, and Potowomut have cleaned up portions of beach, helped find archeological sites and artifacts, and provided educational opportunities to the public through forums such as historical and wildlife tours and talks. Other organizations, such as the Buckeye Brook Coalition, have provided similar benefits, even though the groups are not primarily active in the Greenwich Bay watershed.

8. Rhode Island mandates the protection of historical assets through the CRMC and RIHPHC. See Table 1.

Table 1. Historical asset protection offices and duties

Agency	Duties
State Authorities	
CRMC	CRMC regulates development in Rhode Island's coastal zone, an area extending from the territorial sea limit, 3 miles offshore, to 200 feet inland from any coastal feature. In addition, an extended contiguous area of 200 feet from the inland borders of natural features such as coastal beaches, dunes, barriers, coastal wetlands, cliffs, bluffs, banks, rocky shores, and manmade shorelines is under CRMC authority. Cultural features of historical or archaeological significance are also within CRMC jurisdiction. The Greenwich Bay watershed falls within CRMC jurisdiction. As part of the permitting process, CRMC consults with the RIHPHC to ascertain whether proposed projects pose risks to historical resources. http://www.crmc.state.ri.us/
RIHPHC	**RIHPHC operates a statewide historical preservation program that identifies and protects historic buildings, districts, structures, and archaeological sites. RIHPHC:** • **Is charged with developing historical property surveys for each Rhode Island municipality** • Reviews projects that may impact historical resources • Provides technical assistance to government and community members • Regulates archeological exploration on state land and in state waters http://www.rihphc.state.ri.us/
Local Authorities	
Municipal planning departments	Municipal planning departments work with councils, planning and zoning boards, administrators, historical district commissions, and citizen groups to ensure that community comprehensive plans offer policies and recommendations compatible with historical preservation goals.
Historical preservation/district commissions	**Historical preservation/district commissions review and permit development proposals and serve as conduits to community efforts to preserve historical resources.**
Warwick Historical Cemetery Commission	**The commission offers an adopt-a-cemetery programs that enables individuals or groups to adopt and maintain cemeteries.**
Neighborhood Organizations	
Citizen organizations	Citizen organizations provide volunteer manpower for physical upkeep of historical and cultural assets, work with municipal and state offices to secure public and private funding for preservation projects, and serve as sources of local historical information and lore.

Section 530
Regulations, recommended actions, and research needs

1. The historical and cultural resources of the Greenwich Bay watershed are a valuable asset to local communities and to the state. CRMC considers preservation of these resources as a high priority for the SAMP and utilizes the CRMC application process to ensure that the RIHPHC has the opportunity to encourage the study and protection of various locations in the Greenwich Bay region.

2. Regulations, recommended actions, and research needs to protect Greenwich Bay's cultural and historical assets follow. In the following sections, the Rhode Island Coastal Resources Management Council is referred to as CRMC. Regulations apply to CRMC and amend the R.I. Coastal Resources Management Program (RICRMP) administered by CRMC. In regulatory sections, plain text indicates current RICRMP regulations whereas underlined text indicates new regulatory language and strikethrough text indicates deleted regulatory language. Recommended actions and research needs may apply to a variety of federal agencies, state agencies, local governments, and nongovernment organizations and are not necessarily binding. All recommended actions are presented in plain text.

530.1 Regulations

530.1A Policies

1. Preserve cultural, historical and archeological resources of the Greenwich Bay watershed.

2. Educate the public about the value of cultural, historical, and archeological resources of the Greenwich Bay watershed.

3. Conduct research to assist with the identification and preservation of cultural, historical and archeological resources of the Greenwich Bay watershed.

530.1B Standards

1. Applications for major activities within the Greenwich Bay watershed shall be forwarded to RIHPHC for review and comment as part of the standard CRMC regulatory process.

2. Applicants for activities proposed along the Greenwich Bay shoreline will have to perform archeological investigations when required by RIHPHC. Though other areas may exist and RIHPHC reserves the right to require additional information and potential studies, these areas are identified to give applicants a sound idea of areas of concern.

3. CRMC will await the response of RIHPHC prior to completion of its own staff review and subsequent council decision. Unless a variance is granted, CRMC will incorporate the RIHPHC guidance into its regulatory decision-making and permit

stipulations. Applicants are encouraged to contact RIHPHC prior to filing with CRMC in order to expedite permitting.

4. Where possible, those sites identified by RIHPHC as having potential historical or archeological significance will be incorporated into the buffer zone by extending the boundary of the buffer where appropriate.

5. The state and municipalities will ensure that cultural, historical, and archeological assets are not compromised by runoff.

530.2 Recommended actions

1. Municipalities should prioritize for acquisition or preservation sites identified by RIHPHC as having historical or archeological significance. (See RIHPHC for further guidance on targeted areas).

2. RIHPHC should conduct a detailed survey of areas pre-identified as likely to contain archeological or historical resources.

3. CRMC and RIHPHC should investigate the potential of signing a memorandum of understanding with Native American tribes to facilitate communication between the tribe and the state during the CRMC permit review process regarding the discovery, identification, and potential excavation and/or preservation of archeological resources.

4. Municipalities should work with RIHPHC to develop an education process to engage the public in activities to broaden community interest in, and understanding of, Native American archeological sites, and other historical and cultural assets in the Greenwich Bay watershed. Potential activities that citizen groups, government and businesses could engage in together include:

a) Placement of information kiosks at public parks in the Greenwich Bay watershed
b) Implementation of "Adopt-a-Spot" maintenance programs at parks beaches, marshes, historic cemeteries and Native American burial grounds
c) Creation of a process that encourages and enables citizens to alert the RIHPHC of potential archeological finds through neighborhood groups
d) Development of printed materials with public schools to build student awareness of the need to preserve historical, cultural and archeological assets for future generations

5. CRMC should amend policy to prohibit or restrict dredging and underwater surface modifications in potentially archeologically significant areas and/or permits should include provisions where applicants are required to provide evidence that suspected areas are free of historical artifacts before continuing.

530.3 Research needs

1. CRMC encourages the development of a funded research program to designate archeologically sensitive zones on the floor of Greenwich Bay. Research is needed to identify archeological and historical assets both on land and underwater.

Chapter 6
Economic Assets

Table of Contents

Tables

Section 600
Introduction

1. For centuries, the environmental resources of Greenwich Bay were the foundation of the area's economy. Native Americans traded seafood and clamshells—wampum—for tool metals. Greenwich Bay provided a naturally protected haven for fishing and marine enterprise, and colonists transformed Apponaug and Greenwich coves into international shipping ports and textile centers. Industrial-era entrepreneurs created a lucrative tourism industry based on beach resorts, commercial clambakes, and pleasure boating.

2. The Greenwich Bay area's growing connections to the larger urban regions of Providence and Boston are prompting residential development. Since 1950 the area has been a bedroom community for Providence and Boston, driving up the cost of housing—especially waterfront property. However, the area has for several decades seen an industrial/manufacturing decline, often due to high utility costs and taxes.

3. Over the past 10 years, local and state economic initiatives and public-private partnerships have been created to assist area businesses, and are supporting traditional marine industries such as shellfishing and boating.

4. Working together, the public and private sectors have developed Greenwich Bay marine industry projects, including a boatbuilding high-school curriculum, a shellfish aquaculture collaboration, a clean marinas program, and waterfront and maritime heritage festivals.

5. Traditional marine-related businesses face several challenges. Some industries, such as shellfishing and boat repair, need infusions of trained workers. Marinas identify dredging as a priority and consider it increasingly difficult to secure permits, funds, and public support. Although some residents are customers of local marine-based businesses, some desire the government to restrain development to preserve public access and traditional pastimes such as clamming and swimming.

6. Because all these activities are dependent on a healthy marine environment, the policies and recommendations in this chapter are aimed at balancing economic vitality, community development, and natural resources protection for Greenwich Bay. The goal of this chapter is to help East Greenwich and Warwick enhance Greenwich Bay marine business to create jobs and revenues while supporting opportunities to protect natural resources.

Section 610

Economic assets, issues, and opportunities

1. The following represent the results of an April 15, 2004 public workshop and subsequent Greenwich Bay Citizens Advisory Committee chapter review meetings.

610.1 Greenwich Bay economic assets

1. An appealing natural landscape
2. Native American and Colonial history and artifacts
3. Waterfront restaurants that serve local seafood
4. Naturally protected bay and coves for commercial and residential needs
5. Beaches and parks that provide escape from the urban environment
6. Exceptional fin- and shellfishing
7. Numerous boat docks and mooring spaces
8. Proximity to T.F. Green Airport, Providence, and Amtrak commuter rail line

610.2 Challenges for marine-related tourism and boating-related businesses

1. Pollution
2. Lack of public gathering areas that attract potential customers and tourists
3. Lack of road signage and promotional materials to attract visitors
4. Lack of residential appreciation for the bay and its assets
5. Increased need for public access to shoreline areas
6. Lack of parking at public access points
7. Increasing costs for road and infrastructure repairs
8. Beach erosion in some places and sand buildup at others
9. Loss of marinas and public access to residential development
10. Increasing residential and commercial tax burdens

610.3 Opportunities for marine-related tourism and boating-related businesses

1. Promoting recreational fishing to spring and fall visitors
2. Developing a Chepiwanoxet Point walk-bike tour that would encourage wildlife preservation at the site
3. Developing a Scalloptown historical walking tour that incorporates the East Greenwich town dock
4. Improving the Apponaug Village waterfront to enable development of historic waterfront tours and other educational attractions
5. Examining the potential of implementing ferry services that could decrease customer dependence on shoreline parking lots
6. Building a network of marinas, marine businesses, and fishermen to explore pooling resources
7. Working with local and state tourism offices to market the region
8. Continuing to improve water quality
9. Working with government to expedite permit processes for water-dependent business projects

610.4 Challenges for fisheries and aquaculture

1. Securing affordable dock space
2. Ensuring funds and manpower are available for continued public-private shellfish transplant programs
3. Finding new locations and partnerships for aquaculture projects
4. Securing funds for studies to explore hatchery potential and disease mitigation
5. Identifying staff and funds to participate in debate about whether public or private aquaculture businesses should profit from marine resources
6. Finding and training a new generation of fishermen and shellfishermen
7. Avoiding loss of harvest area to marina expansion

610.5 Opportunities for fisheries and aquaculture

1. Launching a marketing campaign to promote the Greenwich Bay shellfish "brand"
2. Working with CRMC to ensure preservation of traditional Scalloptown fishing docks via a restrictive permit process
3. Developing ties to the tourism market to supplement fishermen's incomes
4. Continuing educational aquaculture programs with local schools
5. Examining the potential for oyster and scallop "gardens" that would enable private docks within certified waters to yield seed and ecological benefits
6. Participating in forums to explore aquaculture and shellfishing partnerships
7. Engaging with Roger Williams University as it considers taking a lead role in industrializing upweller systems for clams and oysters
8. Working with marinas to develop upweller programs

Section 620
Integrating policies and marine-related industries

1. Marine industries that share the same resource can mutually benefit from partnerships that share space and take advantage of clean marine waters, and provide residential benefits, such as increased tax revenue, recreation services, social gathering places, and bay access (Table 1). Governments can use SAMP actions to build the Greenwich Bay marine economy (Table 2) and help develop an integrated marine industry by supporting connections that encourage:

- Marinas to partner with shellfishermen in aquaculture production
- Marinas to provide shellfishermen with less-desirable dock space at low rental cost
- Tourists to visit historical and working waterfronts
- Service industry to provide recreational amenities (kayaking, boat taxi, maritime museums, food, etc.) at targeted public waterfront places

Table 1. Estimated value of Greenwich Bay marine-related business in 2003[2]

Values	Boating-related	Marine recreation and tourism	Commercial fishing
Indicators of economic value	▪ Approximately $100 million in Greenwich Bay boating-related business ▪ $58,500 in municipal mooring fees	▪ $44,000 in beach/park fees ▪ $71 million statewide in recreational fishing-related business	▪ $5.2 million total sales value of Greenwich Bay quahog fishery ▪ Approximately $19 million potential value if all SA[3] waters were open
Social values	▪ Skilled jobs ▪ Public access (fee) ▪ Working waterfront	▪ Public access (fee) ▪ Fishing lengthens the tourism season ▪ Quality of place	▪ Cultural tradition ▪ Working waterfront ▪ Tourism attraction

---

[1] These are estimated values from the data gathered in this chapter. These values are meant to only be indicative of the general value each industry adds to the Greenwich Bay region and is not a substitute for comprehensive economic studies of these industries. There is likely overlap in the above values between these industries.

[3] According to Rhode Island's water quality regulations, class SA waters are designated for shellfish harvesting for direct human consumption, primary and secondary contact recreational activities, and fish and wildlife habitat. They shall be suitable for aquacultural uses, navigation and industrial cooling. These waters hall have good aesthetic value.

Table 2. Intersection of certain SAMP actions and local and state economic policies

SAMP actions	Marine cluster	Growth centers	Regional economy	Warwick economic development	East Greenwich downtown revitalization
Extend sanitary sewers in the watershed	x	x	x	x	x
Require tertiary treatment in all wastewater treatment facilities (WWTFs)		x			x
Improve Greenwich Bay pumpout facilities	x		x		
Require sewer connections	x	x		x	x
Reduce stormwater discharge, N, and P			x		
Restore anadromous fish runs in Greenwich Bay tributaries	x				
Establish vegetated buffers around wetlands	x	x			
Create land-acquisition program to protect vegetated buffers bordering critical areas		x			
Create programs to encourage planting vegetated buffers in developed areas		x	x		
Trim tree limbs to reduce storm damage		x			
Place signs at all public rights -of-way	x		x		x
Clean storm drains periodically to reduce sediment inputs	x		x		
Create mooring-fee fund to support harbormasters			x		x
Increase budget for rights -of-way designation and resolution of legal disputes	x		x		
Explore potential of Federal Emergency Management Agency as public access program funding source	x		x		
Support maintenance dredge/beach renourishment for Warwick Cove and Oakland Beach	x			x	

Section 630
Population and employment trends in Greenwich Bay

1. The Greenwich Bay region has become increasingly populated over time. Modern-day Warwick experienced its greatest growth after World War II, when many soldiers took advantage of the G.I. Bill to buy homes in newly platted neighborhoods. Over the past 35 years, however, city population has leveled off. East Greenwich, on the other hand, remained rural much longer than Warwick, with limited population growth until the 1970s. In 2000, East Greenwich's population was about 13,000, and Warwick's population was about 86,000.

2. Both municipalities have depended on traditional industries such as farming, fishing, shipping, and manufacturing, but those have been replaced largely by the service, financial and communications sectors. Still, the area's connection to the bay is highly visible in its recreational assets—its marinas, beaches, and sportfishing—and its commercial shellfish industry. While Table 3 shows a spike in recent fishing employment, the increase may be due to part-time fishing licenses. Overall, the industry has suffered losses in fish and jobs.

Table 3. Employment trends in East Greenwich and Warwick

	1975	1981	1991	2001	Change	% Change
Agriculture, forestry, and fisheries	23	15	27	132	109	473.91%
Construction	102	144	91	385	283	277.45%
Manufacturing	1,210	1,880	1,830	1,767	557	46.03%
Transportation, communications, and utilities	17	214	154	72	55	323.53%
Wholesale trade	87	196	152	349	262	301.15%
Retail trade	941	841	1,038	1,349	408	43.36%
Finance, insurance, and real estate	120	111	268	643	523	435.83%
Service industries	328	575	900	1,393	1,065	324.70%
Total	**2,827**	**3,977**	**4,475**	**6,090**	**3,262**	**115.39%**

	1975	1981	1991	2001	Change	% Change
Agriculture forestry, and fisheries	123	109	237	423	300	243.90%
Construction	739	939	922	1,721	982	132.88%
Manufacturing	6,568	9,608	6,180	6,062	-506	-7.70%
Transportation, communications, and utilities	463	603	1,136	2,864	2,401	518.57%
Wholesale trade	897	1,239	1,446	1,926	1,029	114.72%
Retail trade	6,418	9,172	11,633	13,007	6,589	102.66%
Finance, insurance, and real estate	479	2,423	3,145	4,844	4,365	911.27%
Service industries	4,639	7,252	12,183	15,693	11,054	238.28%
Total	**20,342**	**31,412**	**36,899**	**46,567**	**26,225**	**128.92%**

Source: R.I. Economic Development Corporation

Section 640
Boating-related businesses

640.1 Marinas and yacht clubs

1. Marinas are the largest commercial maritime economic income generator in Greenwich Bay. The number of marinas, yacht clubs, and boat slips in Greenwich Bay has grown steadily over the past 35 years. Today, there are an estimated 3,419 slips at 33 marinas, yacht clubs, and commercial docks, and more than 4,000 recreational boats in the bay. Greenwich Bay has the largest number of marinas and boats compared to any other part of Narragansett Bay.

2. In addition to their own contributions to the economy, marinas bring money into the Greenwich Bay area as their clients require services such as boat repair, painting, and electronics outfitting, while making few demands on local government (Ross, 2004).

640.2 Marine retail

1. It is estimated that the annual economic value for motorboating in Rhode Island is $328 million (Colt et al., 2000). Since 30 percent of the state's slips and moorings are located in Greenwich Bay, Greenwich Bay boating-related businesses may contribute over $100 million annually in revenues, with additional revenues from boat ramps. The majority of jobs and revenue generated by marinas can be attributed to their boat repair and maintenance services, restaurants, and slip fees.

2. Gasoline tax estimates are another economic indicator. The state gasoline tax is 30 cents per gallon, and one Greenwich Bay marina owner reports paying more than $35,000 in 2002-03 state gas taxes in a slow season (John Williams, Warwick Cove Marina). Gasoline sales are private records, but it can be conservatively estimated that in Greenwich Bay at least six marinas and marine-related businesses paid a total of approximately $210,000 in state gas taxes in 2002-03. The municipalities get about 4 to 7 percent of this revenue.

640.3 Moorings

1. In 1988, East Greenwich developed a plan to annually distribute 35 municipal moorings to commercial operators and allot the rest in a 4:1 ratio to residents and non-residents. The East Greenwich Harbor Management Commission allocates the moorings, and the town council sets the fees, which fund the town's harbormaster. There are no plans to increase moorings in Greenwich Cove. In 2003, East Greenwich generated $25,580 in revenue from 110 moorings, averaging $232 per mooring (Table 4).

2. In 1989, Warwick developed a plan to allocate mooring permits on a first-come, first-served basis. The Warwick Harbor Management Commission allocates the moorings and the Department of Parks and Recreation sets the fees: $25 for residents, $50 for nonresidents, and $100 for commercial use. The city maintains a 3:2 ratio of private to commercial moorings. Of these private moorings, an approximate 3:1 ratio of resident to nonresident moorings is maintained. Warwick is currently developing a new fee schedule that will likely be consistent to

rates in neighboring municipalities. All revenues generated by boat-launch ramp fees, mooring permits, and fines levied under the provisions of the harbor management ordinance are deposited into the Harbor Management Fund to pay for harbor ordinance enforcement. In 2003, Warwick generated $33,000 in revenue from 515 moorings, averaging $64 per mooring (Table 4).

3. By contrast, commercial mooring operators (usually marinas) typically charge in the $20 to $30 range per foot of boat length. Thus, a 30-foot boat may bring a $900 charge, generally covering costs connected to buying, installing, and maintaining the mooring and its anchor, chain, pennant, and float, and supporting the cost of off-street parking, shuttle-boat service, and dinghy docks. Also, riparian property owners may install moorings within “reasonable proximity” to their property. These moorings must be registered with the city and comply with the Warwick Harbor Ordinance. They produce some revenue, but are not maintained by the city and are not reflected in above data.

Table 4. Estimated 2003 Greenwich Bay mooring revenue

	Type	Fee	Moorings	Revenue
East Greenwich	Resident	$160	53	$8,480
	Nonresident	$300	22	$6,600
	Commercial	$300	35	$10,500
	Total	-	**110**	**$25,580**
Warwick	Resident	$25	~200	$5,000
	Nonresident	$50	~70	$3,500
	Commercial	$100	245	$24,500
	Total	**-**	**515**	**$33,000**

Source: Barris personal communication, Bradley personal communication

Section 650
Marine recreation and tourism

650.1 Recreational fishing

1. Statewide, resident and nonresident saltwater anglers spent about $71.1 million in Rhode Island on equipment, food, lodging, transportation, and other trip costs in 2001 (U.S. Department of the Interior & U.S. Department of Commerce, 2003; National Marine Fisheries Service, 1998). According to these surveys, nonresidents conduct 55 to 66 percent of Rhode Island's recreational fishing.

2. People fish year-round from the shore, and from small boats in warm weather. Rhode Island Saltwater Anglers Association (RISAA) indicates that 25 percent of its members are from other states. Recreational fishing in Greenwich Bay is enhanced by fair weather, fish migration, and public fishing programs, and has a strong connection to pleasure boating, with an estimated 80 percent of boaters participating in fishing.

650.2 Waterfront food and lodging

1. Waterfront restaurants and lodgings are critical to the Greenwich Bay marine economy, both generating and accessing a boating and fishing customer base supported by locals and visitors.

650.3 Waterfront parks and beaches

1. Parks and beaches are considered vital to the Greenwich Bay marine economy and a cornerstone for potential community development and tourism initiatives. The state, East Greenwich, and Warwick maintain public recreational facilities on the waterfront that provide jobs and revenues. Small parks, such as the Barbara M. Tufts playground in East Greenwich, charge no fees and attract town residents. Other facilities, such as Goddard Memorial State Park, Oakland Beach, and Warwick City Park, collect lower fees than those charged at larger state beaches. Greenwich Bay beaches have generated fewer revenues in recent years due to fecal coliform contamination and subsequent beach closures ordered by the state.

650.3A Goddard Memorial State Park

1. Goddard Park is located in Warwick on the southern shore of Greenwich Bay and is the only state park in the watershed. Goddard Park generates revenues by renting ball fields, gazebos, and picnic shelters, and charging golf course fees. From 2000 to 2003, annual attendance averaged 846,751, and revenues averaged $275,784.

650.3B Oakland Beach and Warwick City Park

1. Warwick's Oakland Beach and City Park generate revenue chiefly through parking fees. From 2000 to 2003 City Park and Oakland Beach have averaged $5,645 and $10,038

per year in revenue, respectively. Due to fecal coliform bacteria levels, City Park is closed on average 14 days and Oakland Beach is closed 22 days each summer, reducing revenue.

Section 660
Commercial Fisheries

1. Greenwich Bay is one of southern New England's most productive winter shellfishing grounds, and provides product to regional and worldwide markets. Naturally protected from the weather, the bay offers safety to the winter quahog fleet. Greenwich Bay is a nursery for quahogs, and transplant programs replenish quahogs elsewhere in Narragansett Bay, since the coves of Greenwich Bay itself are closed to shellfishing. (Art Ganz pers.comm., 2003).

2. The industry faces several challenges, including water pollution, dock expansion into fishable waters, overharvesting, restricted fishing periods, low wholesale shellfish prices, and an aging workforce.

3. To remain viable, the shellfishing industry is working with local and state government, colleges and private partners to explore aquaculture and other opportunities. The Rhode Island Shellfishermen's Association is experimenting with aquaculture upwellers under marina docks. These box-like devices are placed under docks and grow shellfish at an accelerated rate by supplying a constant, nourishing flow of oxygenated water to the crop. Currently, there are limited opportunities for privatized aquaculture on leased Greenwich Bay bottomlands because of pollution closures and Greenwich Bay's status as a shellfish management area.

4. Greenwich Bay is a state shellfish management area, and is only open to harvesting between December and April on Monday, Wednesday, and Friday mornings. Fishing time is also shortened by pollution closures that often follow heavy rainfall. So, even though there are an average of 108 potential fishing days in any harvest season, a shellfisherman might only get to work about 31 days.

660.1 Value of the Greenwich Bay quahog fishery

1. The Greenwich Bay quahog industry is worth about $5.13 to $6.42 million annually, when wholesale and retail values are included (Ganz, 1994; Ganz, pers.comm., 2003). Closures have decreased the economic yield of quahogs by over 45 percent (Ganz, 1994). The combined value (primary and secondary) of the quahog industry in Greenwich Bay could total $19.24 million if the conditional areas and areas designated for restoration were opened. This estimate is based on a value of $1,488 per acre of fishing ground ($2.526 million per 1,700 acres in Greenwich Bay) multiplied by the 650 potential acres for reopening. The assumption is that the areas of the bay targeted for reopening have the same capacity for quahog production as the present grounds.

Section 670
Municipal economic plans and public investments

670.1 Warwick

670.1A Warwick City Comprehensive Plan (1992)

1. To encourage economic revitalization, the city of Warwick updated its comprehensive plan, created zoning ordinances, and developed special master plans for Apponaug Village and Oakland Beach. Warwick's economic development plan recommends that the city consider enhancing coastal economic resources.

2. Building on a recommendation in its economic development plan, the city should support to provide networking, education, and resource sharing opportunities to new marine businesses, professionals, and students. Partners could include the city, other municipalities, the R.I. Economic Development Corporation (RIEDC), chambers of commerce, industry groups, and local schools and colleges.

3. The city is a leading hospitality center for Rhode Island and should continue its efforts to enhance tourism and business interest in its hotels, coastline, skilled work force, and rail, highway, and air transportation.

670.1B Warwick Harbor Ordinance

1. Warwick's Harbor Ordinance states that pleasure boating and commercial fishing are valuable to the city, and require:

- A balance between the demands of the two industries
- Continued protection and enhancement
- Maintained or upgraded water quality designations

Where possible, the city will coordinate efforts with the town of East Greenwich.

2. According to the Warwick Harbor Ordinance, a harbor management fund has been "created to receive and expend monies for harbor management purposes determined by the city. All revenues generated by boat launch ramp fees, mooring permits, and fines levied under the provisions of the harbor management ordinance shall be deposited into this fund. Funds shall be disbursed for purposes directly associated with the management and implementation of the harbor management plan. Monies from this fund may be allocated to the chief harbormaster or his/her designee for the purpose of enforcing the provisions of the harbor management plan and/or the harbor management ordinance. The harbor management fund shall be established, budgeted and administered in a manner consistent with the procedure contained within the city Charter and funded through the department's annual budget as a line item."

670.1C Warwick public investments

Wastewater

1. In 1996, Warwick voters approved a $130 million bond to build sewer extensions in priority areas, including large parts of the Greenwich Bay watershed. The bond is also paying for treatment plant upgrades to enhance nitrogen removal, and assistance programs to help low- to moderate-income families pay for sewer connections and septic systems. For a period, the city also funded free sewer connections for the Oakland Beach neighborhood.

Open space purchases

1. Warwick has invested about $5 million in open space purchases since 1994, acquiring more than 240 acres, including land within the Greenwich Bay watershed. Funding sources include the R.I. Department of Environmental Management (RIDEM), The Champlin Foundations, and The Nature Conservancy. Acquisitions include Chepiwanoxet (10 waterfront acres), Barton Farm (59 acres), and Dawley Farm (63 acres).

Stormwater treatment and water quality

1. A comprehensive city effort to improve stormwater treatment within the drainage system is expected to enhance Greenwich Bay water quality. Projects include:

- Updating the city's stormwater management plan to conform with Environmental Protection Agency (EPA)/RIDEM Phase II regulation.
- Installing $400,000 worth of vortex stormwater treatment systems to improve stormwater quality by removing sediments and pollutants prior to discharge into Greenwich Bay.
- Partnering with RIDEM on a $500,000 project to treat stormwater in Brush Neck Cove to infiltrate runoff and remove pollutants.

Related water quality projects

1. Implementing a $140,000 program for marina pumpout station maintenance to ensure more consistent pumping service for boaters.

2. Participating in research projects with government and community partners, including the EPA, R.I. Coastal Resources Management Council (CRMC), RIDEM, Roger Williams University, the University of Rhode Island (URI), the URI Coastal Resources Center, Rhode Island Sea Grant, and the Southern Rhode Island Conservation District.

3. Working with developers to ensure that residential and commercial building projects in the Greenwich Bay watershed (30 to 50 percent of an estimated $120 million in citywide development projects) include plans to address storm water, waste disposal, and water pollution issues.

4. Examining opportunities to increase the number of clean and accessible entry points to the bay, including rehabilitating public boat ramps.

Apponaug Master Plan

1. The city is developing an Apponaug Village Master Plan to guide development in this federally recognized historic district and improve public access to Apponaug Cove by implementing a safe and attractive sidewalk system.

Oakland Beach Master Plan

1. The city has implemented an Oakland Beach Master Plan to guide community development and neighborhood enhancement projects, including a $750,000 partnership with the state to build a wheelchair-accessible public boat ramp.

670.2 East Greenwich

670.2A East Greenwich Comprehensive Plan (1991)

1. The 1991 East Greenwich Comprehensive Plan identifies the waterfront as the main area appropriate for linking marine-related and tourist activities.

2. East Greenwich identifies its coastal community image as a key economic benefit that could be strengthened by continued efforts to link the shellfishing, tourism, and marina sectors.

3. The local marine cluster (sailmakers, marine equipment suppliers, outfitters, outfitting distributors, machine suppliers, and machine repairers) is identified as a network that should be supported and linked to shellfishing and marina industries.

4. A detailed waterfront development plan (WDP) is recommended in the comprehensive plan to revitalize and enhance a mixture of compatible waterfront uses. The WDP could further address building the marine cluster and establishing policies for public access, priority water uses, parking, and project funding for Greenwich Cove. The town has taken the position that the Harbor Management Plan should be adopted as the WDP.

5. The East Greenwich Comprehensive Plan outlines specific issues that the WDP should consider, such as:

- Linking streets and public facilities to enable the public to travel along the waterfront.
- Examining the feasibility of parking options.
- Making use of zoning and planning tools to establish riparian ownership and limit the construction of docks and piers in Greenwich Cove.

- o Developing policies and programs with government, business, and community interests to ensure the shellfishing industry can afford Scalloptown dock space and increase its presence as an economic asset and historic and cultural attraction.
- o Continuing to study the feasibility of relocating the town transfer station to increase public access to the cove.
- o Introducing water-related businesses in safe and appropriate mixed-use commercial areas.

670.2B East Greenwich Harbor Management Plan

1. The plan identifies four key waterfront issues: revitalizing the shellfishing industry by securing dock and equipment space, preserving Scalloptown, providing more public access, and developing town property, such as the abandoned landfill and the transfer station for recreational purposes. The estimated $3.2-million landfill project is under government study to ascertain appropriate closure methods and post-closure uses as either a sporting field or trail site.

670.2C East Greenwich public investments

1. The WWTF is receiving a $7.2-million denitrification upgrade to further remove nitrogen from effluent before it enters the bay.

2. A $1.2-million downtown revitalization plan is expected to improve pedestrian traffic between Main Street and the waterfront by enhancing sidewalks and landscaping and installing signs and period-style lighting.

3. A boat ramp improvement project has lengthened the ramp by 50 percent and widened it by 40 percent.

4. A bike path plan to link the waterfront with Goddard Park and Potowomut is being developed and would enable bikers to traverse the shoreline and bridge the Maskerchugg River.

5. A commuter rail station plan is being considered to connect residential areas, including potential affordable housing, with commercial and work areas. The plan would connect East Greenwich residents to Main Street, provide more access to the waterfront, and may link East Greenwich to larger state transportation centers, including T.F. Green Airport in Warwick

6. The town has developed a plan to install vortex systems and design and implement swill separators to remove more pollutants from Greenwich Cove's seven storm drain outfalls.

7. The East Greenwich sewer system is connected to a boat pump out located at the East Greenwich Yacht Club in Greenwich Cove to meet the state no-discharge law.

Section 680
Regulations, recommended actions and research needs

1. Regulations, recommended actions, and research needs to enhance Greenwich Bay's economic assets follow. In the following sections, the Rhode Island Coastal Resources Management Council is referred to as CRMC. Regulations apply to CRMC and amend the R.I. Coastal Resources Management Program (RICRMP) administered by CRMC. In regulatory sections, plain text indicates current RICRMP regulations whereas underlined text indicates new regulatory language and strikethrough text indicates deleted regulatory language. Recommended actions and research needs may apply to a variety of federal agencies, state agencies, local governments, and nongovernment organizations and are not necessarily binding. All recommended actions are presented in plain text.

680.1 Regulations

680.1A Policy

1. The CRMC will identify and grandfather existing quahog facilities in Greenwich Bay that have been in existence since 2000. Grandfather permits will be issued to those facilities as long as 75% of the facility is used by commercial fishermen. Once the facility falls below the 75% commercial fishing occupancy level, this permit will be null and void.

680.2 Recommended actions

680.2A Initiatives for increasing shellfishing and fisheries resources

1. East Greenwich and Warwick should work with RIEDC to explore opportunities to develop policies and programs with government, business, and community interests to ensure affordable dock space for the shellfishing industry. Partnership opportunities could include an effort between East Greenwich, Warwick, the RIEDC and the Rhode Island Shellfishermen's Association to investigate potential federal grants for establishing a shellfishing services cooperative.

2. An effort should be made by the Rhode Island Shellfishermen's Association and the RIEDC to improve the marketing of Rhode Island shellfish.

3. Marina and shellfishing industry groups should explore opportunities to expand the aquaculture upweller program to more marinas, residential docks, and waterfront businesses.

4. Rhode Island should support further efforts to investigate aquaculture as an economic opportunity for Greenwich Bay, acknowledging the current limitations on aquaculture opportunities because of pollution closures and shellfish management.

5. The Rhode Island Shellfishermen's Association and the Rhode Island Marine Trades Association (RIMTA) should continue to work with local and state government and

colleges to explore opportunities to secure public and private funds (municipal funds, commercial shellfishing license fee revenues, Rhode Island Clean Water Financing Authority, Rhode Island State Omnibus Bond, venture capital, etc.) for upweller projects.

680.2B Greenwich Bay tourism strategy

1. East Greenwich and Warwick in conjunction with the RIEDC should consider developing a comprehensive tourism strategy for Greenwich Bay that connects to state efforts and links special places, cultural and historic resources, educational facilities, commercial development, open space, and recreational facilities through trails, signs, water taxis, marketing, and education.

2. East Greenwich and Warwick should work with the tourism industry to explore increasing revenue in Greenwich Bay by promoting attractions such as kayaking, boat rides, shoulder-season incentives for recreational boaters and fishermen, fishing tournaments, seafood festivals, boat parades, and charity events.

3. East Greenwich and Warwick should consider creating a Greenwich Bay shorewalking and boating guide to encourage interest in the bay's historical and natural assets.

4. To increase the Apponaug waterfront's tourism potential, Warwick should work with CRMC to include ~~on~~ a comprehensive redevelopment plan for the waterfront in the Apponaug Village Master Plan.

5. East Greenwich and Warwick should continue to expand their cultural, historical, and archeological tourism opportunities by working with community groups to identify additional sites and activities.

6. East Greenwich and Warwick should consider enhancing waterfront appeal by identifying priority areas within commercial development zones for ecological or historical revitalization.

680.2C Marina viability

1. East Greenwich and Warwick should consider working with RIMTA to expand their support and staffing of high school programs for technical training in boat building and repair and marina management to train a local workforce.

2. Marinas should advertise their compliance with the clean marina program to attract clients and educate the community of marinas' role in marine resources stewardship.

680.2D General

1. CRMC should build on the findings of fact and recommendations of the Greenwich Bay SAMP to assist in developing a state marine resources development plan to guide future government economic investments in Greenwich Bay.

2. CRMC should prepare a Greenwich Bay marine resources development plan in conjunction with the state's plan.

3. East Greenwich and Warwick should consider requesting growth center designations, which carry priority funding and technical assistance status, from the Governor's Growth Planning Council. Specific areas for applying sustainable growth principles include Apponaug Village, Oakland Beach, East Greenwich's waterfront, and Main Street.

680.3 Research needs

1. Research should be conducted to demonstrate the link between a clean environment and improved economic performance.

2. The Rhode Island Economic Policy Council should be done to quantify the economic importance and environmental impacts associated with recreational boating and marinas in Greenwich Bay.

3. Research should be conducted to ascertain the benefits and drawbacks of aquaculture.

Section 690
Literature Cited

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. Holling, B. Jansson, S. Levin, K. Maler, C. Perrings, and D. Pimental. (1995). Economic growth, carrying capacity, and the environment. *Ecological Economics* 15:91–95.

Callaghan, D., R. Comerford, and H. Schwarzbach. (1979). *Marine and Boatyard Financial Structure and Performance: A Manual of Average Financial and Operating Ratios for Southern New England Coastal Marinas and Boatyards 1976-77 AND 1977-1978*. Sea Grant/University of Rhode Island Marine Technical Report. Narragansett, R.I.

Colt, A., T. Tyrell, and V. Lee. (2000). Marine recreation and tourism in Narragansett Bay: critical values and concerns. *Narragansett Bay Summit 2000 White Paper*. Narragansett, R.I.

City of Warwick, Rhode Island. (1996). Harbor Management Plan.

Colgan, C., and H. Kite-Powell. (2001). The ocean economy of Rhode Island. Prepared for the Rhode Island House Policy Office. Providence, R.I.

Collins, C., and S. Sedgwick. Recreational boating in Rhode Island's coastal waters: a look forward. University of Rhode Island Coastal Resources Center Marine Technical Report 75. Narragansett, R.I.

Dema, M. (2004). *What are the socioeconomic consequences of environmental change in Greenwich Bay?* Unpublished master's thesis, Brown University, Providence.

Ely, E. (1988). An Overview of Narragansett Bay. Rhode Island Sea Grant. Narragansett, R.I.

Ganz, A., N. Lazar, and A. Valliere. (1994). Quahaug Management Project, Phase I–Greenwich Bay. The Narragansett Bay Project. Providence, R.I.

Governor's Growth Planning Council. (2002). Recommendations for Encouraging Growth and Investment in Economically and Environmentally Sound Locations in Rhode Island. Providence, R.I.

National Marine Fisheries Service. (1998). Marine Recreational Fisheries Statistics Survey Facts and Figures Rhode Island. National Oceanic and Atmospheric Administration. http://www.st.nmfs.gov/st1/recreational/fact_sheets/index.html

R.I. Department of Environmental Management. (2004). Total Maximum Daily Load Analysis for Greenwich Bay Waters (draft). Providence, R.I.

R.I. Department of Health. (2004). Beach Monitoring Program: 2003 Season Report. Office of Food Protection/Environmental Health. Providence, R.I.

R.I. Economic Development Corporation. (2004). Research on Employment Trends for Warwick and East Greenwich. Providence, R.I.

R.I. Economic Policy Council. (2001). A Rhode Island Economic Strategy: 10 Ways to Succeed Without Losing Our Soul. Providence, R.I.

Rhode Island House of Representatives. (2004). Rhode Island House of Representatives Bay Trust Study Commission: Findings and Recommendations. Providence, R.I.

Rhode Island Senate. (2004). Habitat-based management for Rhode Island's marine environment. Providence, R.I.

Rhode Island Senate Policy Office. (2002). The Marine Cluster: An Investment Agenda for Rhode Island's Marine Related Economy. Providence, R.I.

Ross, N. (2004). Marinas, Their Environment and Importance to Water Recreation. University of Wisconsin-Madison, National Docks and Marina Conference, October 11, 2004.

Town of East Greenwich. (1998). Harbor management plan.

U.S. Department of the Interior and the U.S. Department of Commerce. (2003). 2001 National Survey of Fishing, Hunting, and Wildlife-associated Recreation–Rhode Island. United States Fish and Wildlife Service, Department of the Interior. Washington, D.C.

Chapter 7
Recreational Use

Table of Contents

Tables

Figures

Section 700
Introduction

1. Greenwich Bay provides numerous recreational opportunities. Recreational uses, such as boating, swimming, fishing, and shorewalking, enhance both the economy and quality of life in the Greenwich Bay watershed. Marinas, yacht clubs, mooring fields, residential docks, parks, beaches, boat ramps, and public rights-of-way (ROWs) facilitate public use and enjoyment of Greenwich Bay. The highly used bay and its developed shoreline limit the open water and shoreline space available for competing recreational uses. The Greenwich Bay Special Area Management Plan (SAMP) can help achieve a balance among these uses.

2. Natural attributes attract recreational users. Some recreational uses depend on high-quality natural resources —swimming requires good water quality, for instance, and recreational fishing requires healthy fish habitats—and others may enhance natural resources—for instance, parks and recreation areas may preserve valuable habitats. However, some uses, though they provide public access, can negatively impact habitat and water quality and compete with each other for space.

3. Recreational use of watershed resources is important to the local and state economy, with water-related businesses and restaurants providing jobs and revenues.

4. The R.I. Coastal Resources Management Council (CRMC) creates water-use classifications for coastal waters primarily based on current shoreline features and land use (Figure 1). These classifications direct future shoreline development and coastal water-use decisions that impact recreational opportunities (Table 2). For example, in Type 3 (High Intensity Boating) waters, CRMC's goal is to preserve, protect, and enhance boating opportunities, boating facilities, and public access. Based on negotiations with the Rhode Island Marine Trades Association (RIMTA) and Warwick, CRMC recently updated its water-use classifications in Greenwich Bay. Approximately five shoreline miles of primarily residential and open space areas along Apponaug and Warwick coves were changed from Type 3 waters to Type 2 (Low Intensity Use) waters to protect the shoreline from intense development. Mary's Creek, a significant natural resource, was changed from Type 3 waters to Type 1 (Conservation Area) waters, the most protective classification. Inner Apponaug Cove was changed from Type 3 waters to Type 5 (Commercial and Recreational Harbor) waters to support Warwick's land-use plans.

Table 1. Important federal and state agencies for recreational issues

Agency	**Duties**
Federal agencies	
USACE	The USACE regulates dredge and fill activities in U.S. waters, including wetlands, and regulates the construction of structures that affect navigable waters. It is involved in environmental restoration, wetlands conservation, fish and wildlife mitigation, and environmental protection. http://www.nae.usace.army.mil/
U.S. Coast Guard	The Coast Guard's protects the public, the environment, and U.S. economic interests in the nation's ports and waterways, along the coast, on international waters, or in any maritime region as required to support national security. The Coast Guard conducts regular patrols to enforce boating safety laws; carries out searches and rescues; and teaches boating safety classes through the U.S. Coast Guard Auxiliary. http://www.uscg.mil/USCG.shtm
NMFS	NMFS conserves, protects, and manages living marine resources and promotes healthy ecosystems. NMFS collects data on recreational fishing in its Marine Recreational Fisheries Statistics Survey. http://www.nmfs.noaa.gov/
FWS	FWS biologists protect and restore important wildlife habitat, safeguard endangered species, minimize environmental contamination, and restore fish populations. FWS also supports state fish and wildlife programs and enforces federal laws protecting wildlife. http://www.fws.gov/
State agencies	
CRMC	CRMC is the lead state agency for coastal zone management in Rhode Island. Its primary responsibilities are to preserve, protect, develop, and where possible, restore coastal areas of the state via coastal planning and the issuance of permits for work within the state's coastal zone. CRMC's core jurisdiction is defined by the area extending from the territorial sea limit (3 miles offshore) to 200 feet inland from any coastal feature, such as a beach, but its jurisdiction may be larger for certain activities. CRMC regulates the construction and maintenance of marinas and residential docks on submerged lands, creation of mooring areas, dredging, and maintenance of public access through public rights-of-way designation and permitting. http://www.crmc.state.ri.us/

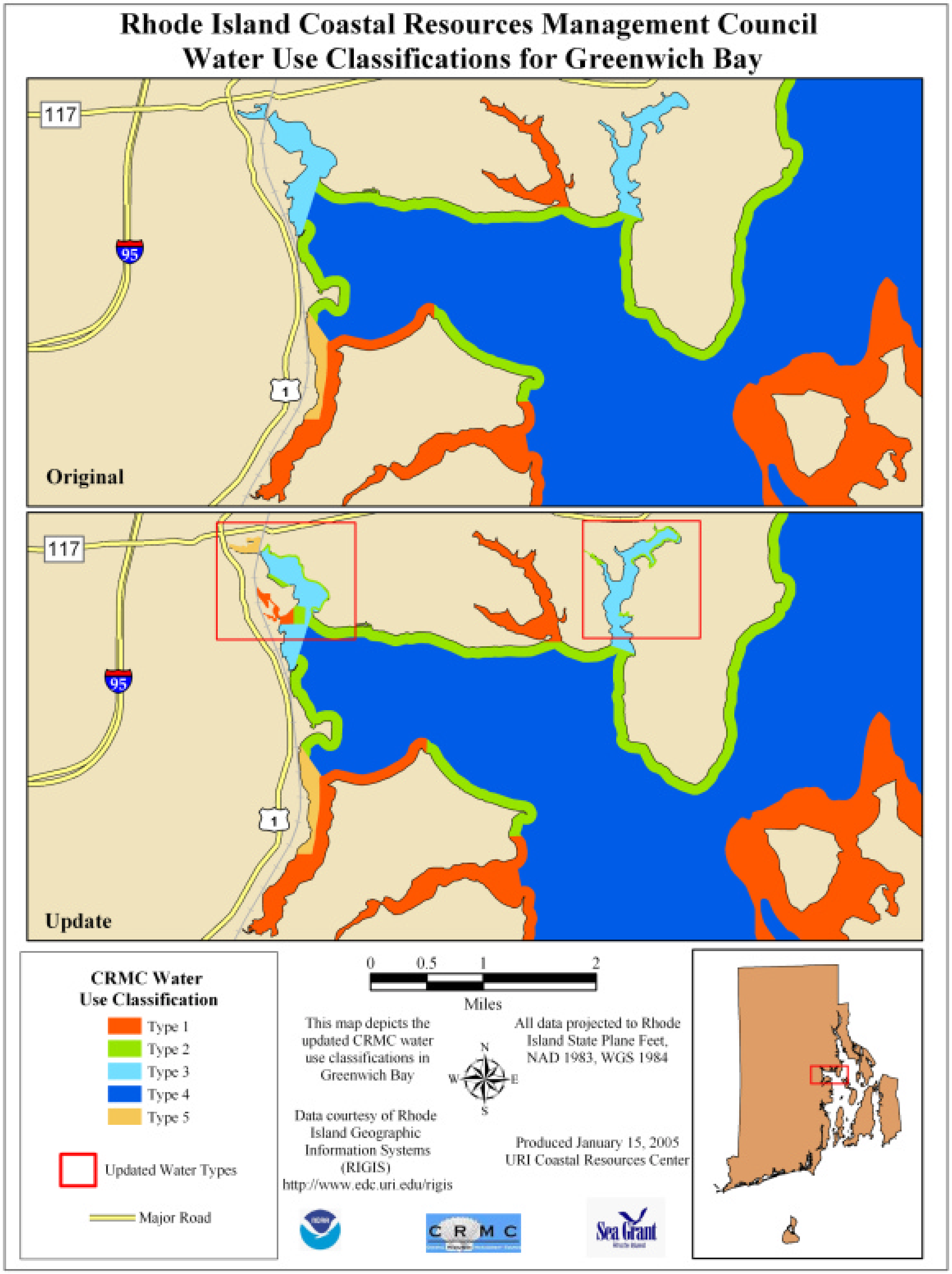
Agency	Duties
RIDEM	RIDEM is the lead state agency for environmental protection statewide. RIDEM offers assistance to individuals, business and municipalities; conducts research; and enforces laws created to protect the environment. RIDEM manages recreational fishing and hunting activity; promulgates and enforces boating safety regulations; manages state parks; and sets standards for dredge material use. http://www.state.ri.us/dem/
HEALTH	HEALTH is the lead state agency for bathing beach monitoring statewide. HEALTH is responsible for the protection of public health by minimizing the public's exposure to disease causing bacteria in bathing waters. HEALTH licenses and regulates 119 beaches statewide. Through an EPA grant, HEALTH collects water quality samples at all coastal beaches and, when appropriate, closes these facilities when standards are violated. http://www.health.state.ri.us/environment/beaches/index.html

Table 2. CRMC water-use classifications for Greenwich Bay

Classification	Title	Activities
Type 1	Conservation areas	• Protect for scenic, habitat, water quality, and wildlife values • Allow shoreline and bottom alterations to enhance or preserve habitat or beaches • Prohibit new marinas, shoreline protection structures, new recreational boating facilities, filling, houseboat or floating business moorings, non-fishery commercial and industrial structures, shoreline and bottom alterations unless to enhance or preserve habitat value, and point source discharges other than properly treated runoff
Type 2	Low intensity uses	• Maintain and restore scenic, water quality, and habitat value while providing for low-intensity recreational and residential uses • Allow the following as long as activities do not significantly impact the public use and enjoyment, water dependent uses, or coastal resources: (1) Maintenance dredging in existing marinas, (2) Shoreline protection structures, (3) Limited expansion of existing marinas, (4) public boat ramps, and (5) residential boating facilities • Prohibit new marinas, new or deepened dredge channels, filling, houseboat or floating business moorings, and non-fishery commercial and industrial structures
Type 3	High intensity boating	• Preserve, protect, and enhance boating opportunities, boating facilities, and public access • Priority to marinas, mooring areas, public boat ramps, and other recreational boating facilities and businesses that support recreational boating
Type 4	Multipurpose waters	• Maintain balance of uses • Protect fishery habitats and fishing grounds from alterations and activities that threaten Rhode Island fisheries • Maintain good water quality
Type 5	Commercial and recreational harbors	• Maintain a balance among tourism-related activities, such as commercial fishing, restaurants, and water-related businesses • Use space efficiently • Protect scenic areas valuable to tourism • Priority given to commercial and recreational water-related and water-enhanced facilities and activities, maintenance of navigation channels, and activities that maintain or enhance water quality and scenic qualities

Source: Rhode Island Coastal Resources Management Program

Figure 1. Rhode Island Coastal Resources Management Council (CRMC) water use classifications for Greenwich Bay



Section 710
Boating

1. Boating is one of Greenwich Bay's primary recreational activities on the water.

2. Greenwich Bay is an ideal location for boating, with its protected harbor and affordable slips and mooring rates. Consequently, Greenwich Bay is the second most popular harbor in Narragansett Bay, trailing only the Newport area, and is the most popular location for in-state users (Brown, 1990). While the exact number of boats that use Greenwich Bay is not known, Greenwich Bay's marinas, yacht clubs, mooring areas, anchorages, and commercial, municipal, and residential docks can accommodate at least 4,000 boats, not counting trailered boats launched from boat ramps (Table 3). Greenwich Bay is not generally visited by boaters whose home port is outside the bay (Brown, 1990).

Table 3. Count of boating facilities and associated boat slips and moorings in Greenwich Bay and its coves, July 2003

Location	Number of marinas [1]	Number of docks [2]	Number of moorings		Number of slips [3]	
			Boats with heads [4]	Total	Boats with heads [4]	Total
Greenwich Cove	10	41	320	368	337	612
Apponaug Cove	3	19	90	112	423	559
Greenwich Bay proper	2	28	25	36	610	664
Brush Neck and Buttonwoods Cove	1	1	10	19	4	4
Warwick Cove	17	66	9	45	761	1603
TOTALS	**33**	**155**	**454**	**580**	**2,135**	**3,442**

1 Includes marinas, yacht clubs, commercial docks, and municipal docks with five or more boats
2 Includes all commercial, municipal, and residential docks as well as docks associated with marinas and yacht clubs
3 Includes all boat slips available at residential docks or docks associated with marinas, yacht clubs, and commercial and municipal docks
4 Since mooring and slip counts were counted whether they were occupied or not and boats were determined to have a head by visual inspection, number of boats with a head may be underestimated

Source: 2003 Survey of Greenwich Bay Boating Facilities. The Rhode Island Sea Grant and RIDEM conducted a survey of boating facilities in Greenwich Bay during the summer of 2003. On July 21,23, and 28, 2003, boat slips at marinas, mooring buoys, and all docks were counted from the water, and the number of boats with heads was determined by visual inspection. Cruising-type boats with cabins, generally over 25 feet, were assumed to have a head (Ganz pers. comm.).

3. Greenwich Bay and its coves support a diverse boating community, ranging from larger pleasure boats and commercial fishing boats to personal watercraft and kayaks. Powerboats represent the majority of boats using Greenwich Bay, though out-of-state boats tend to be larger

sailing vessels (Brown, 1990). A survey of Warwick marinas[4] with the majority of Greenwich Bay's boat slips indicates that approximately 20 percent of boats at Greenwich Bay marinas are from out-of-state (Robinson pers. comm.). Boats originating from East Greenwich are predominantly sailboats, whereas boats from Warwick are primarily powerboats. Consequently, boaters from East Greenwich primarily use their boats for day-sailing, while Warwick boaters are generally fishing (Brown, 1990).

4. Boaters cruise, day-sail, fish, kayak, water ski, or jet-ski. Many sailboats participate in local yacht club regattas held each week in Greenwich Bay during the boating season. Larger cabin power and sailboats from Greenwich Bay anchor overnight in sheltered anchorages around Narragansett Bay, particularly between Prudence and Patience islands and in Potter's Cove of Prudence Island. Small outboard boats, kayaks and canoes head to Prudence and Patience islands. In addition, kayaking is popular in upper Greenwich and Brush Neck coves as well as western areas of Greenwich Bay and Apponaug Cove, with water skiing near Potowomut Neck north of Chepiwanoxet Point. Youth sailing occurs in the mouth of Greenwich Cove and in Greenwich Bay off Goddard Memorial State Park and Potowomut Neck. Boaters swim at the transient anchorage off Goddard Memorial State Park. However, the predominant boater activity is fishing (Brown, 1990). Boaters support businesses directly related to boating, such as marinas, boat repair, and boat hauling, as well as local restaurants and retail shops.

5. Shoaling concerns boaters and boating facility managers because shoaling at boating facilities makes water too shallow to accommodate the draft of many boats and can make slips and buoys inaccessible. Channel shoaling prevents deeper draft boats from navigating Apponaug Cove. Shoaling at boat ramps means that certain boats can be launched from these ramps only when tides permit.

6. Boats in Greenwich Bay are increasing in numbers. Recent marina expansions in Apponaug Cove and along western Greenwich Bay, municipal and marina waiting lists for moorings, and residential dock construction indicate an unmet demand for places to keep boats in Greenwich Bay. Many people trailer their boats, but many boat ramps are in poor condition or have insufficient parking for practical use. If not addressed, these issues could limit boating opportunities in Greenwich Bay. Mooring areas, residential docks, and marinas can impede small non-powerboat navigation in the nearshore areas as well as block walking access along the shoreline. The loud unmuffled exhaust from the large racing-style powerboats can be a nuisance to other boaters and residents around Greenwich Bay. As boating activity increases, safe navigation around Greenwich Bay becomes more of a concern. Larger and faster powerboats, as well as personal watercraft, can affect swimming safety and small non-powerboats, such as kayaks and small sailboats. At least at the moment, different boaters appear to self-segregate into different areas of the bay to minimize safety issues. However, personal watercraft and powerful cigarette boats have been reported as exceptions. The demand for additional boating facilities and potential solutions to meet demand for additional facilities should take into account impacts on public access and navigation along the shoreline as well as natural resources and water quality.

[4] Apponaug Harbor Marina, Ponaug Marina, Greenwich Bay Marina South, Greenwich Bay Marina North A, Brewers Yacht Yard at Cowesett, Nick's Dock, Warwick Cove Marina, Wharf Marina, Bay Marina, and Narragansett Bay Marina.

7. Poorly regulated or unregulated boating activity can have negative impacts on Greenwich Bay's natural resources. In shallower areas, boats resuspend bottom sediments, disturbing benthic habitats and increasing water turbidity (EPA, 2001), although impacts may be limited to the boating season, and minor compared to quahogging and storms. The wake from boats moving too quickly close to shore can contribute to shoreline erosion (EPA, 2001). Boat heads can be a source of bacterial contamination and organic matter. However, Greenwich Bay is a no-discharge area, and nationally 99 percent of boats over 26 feet with a toilet are equipped with a holding tank in no-discharge areas (Battelle, 2004). Nearly 2,600 boats, or 64 percent of the boats at Greenwich Bay's slips and moorings have heads that could potentially discharge (Table 3). Oil and fuel from boats can also contribute hydrocarbons to coastal waters. These pollutants can concentrate in bottom sediments and harm benthic fish and other animal species (Fields, 2003). Antifoulants used on boat hulls may also contribute toxic pollutants to coastal waters (Milliken and Lee, 1990). These impacts are being minimized by best management practices (BMPs) used by boaters and the facilities that serve them.

710.1 Boating facilities

1. CRMC designates Greenwich Bay and its coves as suitable areas for boating facilities with the exception of Buttonwoods and Brush Neck coves, Mary's Creek, areas of Greenwich Cove, and along the shore of Goddard Memorial State Park (Figure 1). Greenwich Bay and its coves are home to 33 marinas, yacht clubs, and commercial fishing and municipal docks; 18 mooring areas and anchorages; 67 residential docks; and 12 boat ramps that are accessible to the public.

710.1A Marinas, yacht clubs, and commercial and municipal docks

1. Marinas, yacht clubs, and commercial and municipal docks with five or more boats, collectively referred to here as marinas, can be found in every cove, except Buttonwoods Cove, and in Greenwich Bay itself to accommodate boating in the bay. As of 2003, there were 33 marinas in Greenwich Bay (including the Warwick City Dock on Apponaug Cove), covering 93 acres of water surface, with the ability to accommodate 3,417 boats at slips (Table 4; Figure 2). The majority of these facilities are located in Warwick and Greenwich coves with three in Apponaug Cove, two along the western shore of Greenwich Bay, and one in Brush Neck Cove. However, the facilities in Apponuag Cove and on the western shore of Greenwich Bay (Cowesett) are generally larger, with an average of 243 slips per facility compared to an average of only 79 slips per facility in the rest of the bay. Greenwich Bay has the largest number of marinas and boat slips in Narragansett Bay.

2. The number and size of marinas in Greenwich Bay has grown over the past 35 years (Figure 3), along with boating opportunities. In 1978, the bay held 19 marinas and yacht clubs with a total of 2,391 slips (Collins and Sedgwick, 1978). Today, there are 3,417 slips at 33 marinas. The majority of this growth has occurred in Warwick and Greenwich coves, where boat slips have increased by 63 percent since 1978. However, almost all the growth in Warwick Cove occurred prior to 1988. Since that time, boat slips in Warwick Cove have only increased by 1 percent whereas boat slips in Apponaug and Greenwich coves and Greenwich Bay have increased by 32 percent on average.

3. Besides boat slips, many marinas provide fueling areas, launching ramps, hauling, winter storage, pump-out and trash facilities, restrooms, showers, food, and lodging (Johnson and Wales University 2002). It is not uncommon for typical boats to take out 15 to 45 different people per boat one or more times each summer season (Ross, pers. comm.). Assuming a typical boat takes out an average of 25 people, then the 3,417 boats at Greenwich Bay's marinas provide access to the water to 85,425 citizens and at no cost to the taxpayer. Marinas also provide public access to the shoreline through paths to the shore, parking spots, and boat ramp access. However, marinas can also restrict public access and navigation along the shore, particularly for small boats, kayaks, and canoes.

4. Marinas are in a continual state of being rebuilt because their infrastructure requires regular maintenance as well as periodic modernization. Ice and large storms can damage and destroy marina infrastructure necessitating rebuilding. Increases in boat length, depth, height, and width and boat market changes may require slip reconfigurations and enlargement. Increased boating activity and demand for boat slips can lead to pressure for dock expansions. Finally, maintenance dredging in marinas is a regular need due to shoaling.

5. Marinas can potentially impact the surrounding environment both positively and negatively, although only limited research has been directed at marina ecology. Marinas often compete for space with other valuable coastal services, such as tidal wetlands and shellfish beds. By concentrating many boats together in one area, marinas may concentrate many of the problems related to boating, such as releasing sewage, petroleum hydrocarbons, and antifoulants to the water. While many studies have looked at the toxicological impact of marinas, few studies have looked at the actual ecological impact (Turner et al., 1997). In one of the few studies, Nixon et al. (1973) found the ecological systems in a cove with marinas and a cove without marinas to be similar. Marinas were better sportfish habitat than natural areas with fouling organisms providing a food source, but sediments did show higher concentrations of copper, a toxic antifoulant. Iannuzzi et al. (1996) also estimated that primary production pre- and post-marina construction were similar. In Greenwich Bay, marinas sit on top of some of the most productive shellfish beds that are essentially protected from harvesting pressures and serve as brood stock for the rest of Greenwich Bay. More thorough research into the ecological impacts of marinas is needed to build on these initial efforts.

6. Marinas mitigate many adverse impacts by following BMPs. The concentration of boats in a managed facility can allow marinas to handle boating-related impacts better than residential docks, anchorages, or mooring areas. For example, 10 marinas provide pump-out facilities, and Greenwich Bay Marinas operates two pump-out boats. CRMC is developing a clean marina program to encourage marinas to adopt BMPs.

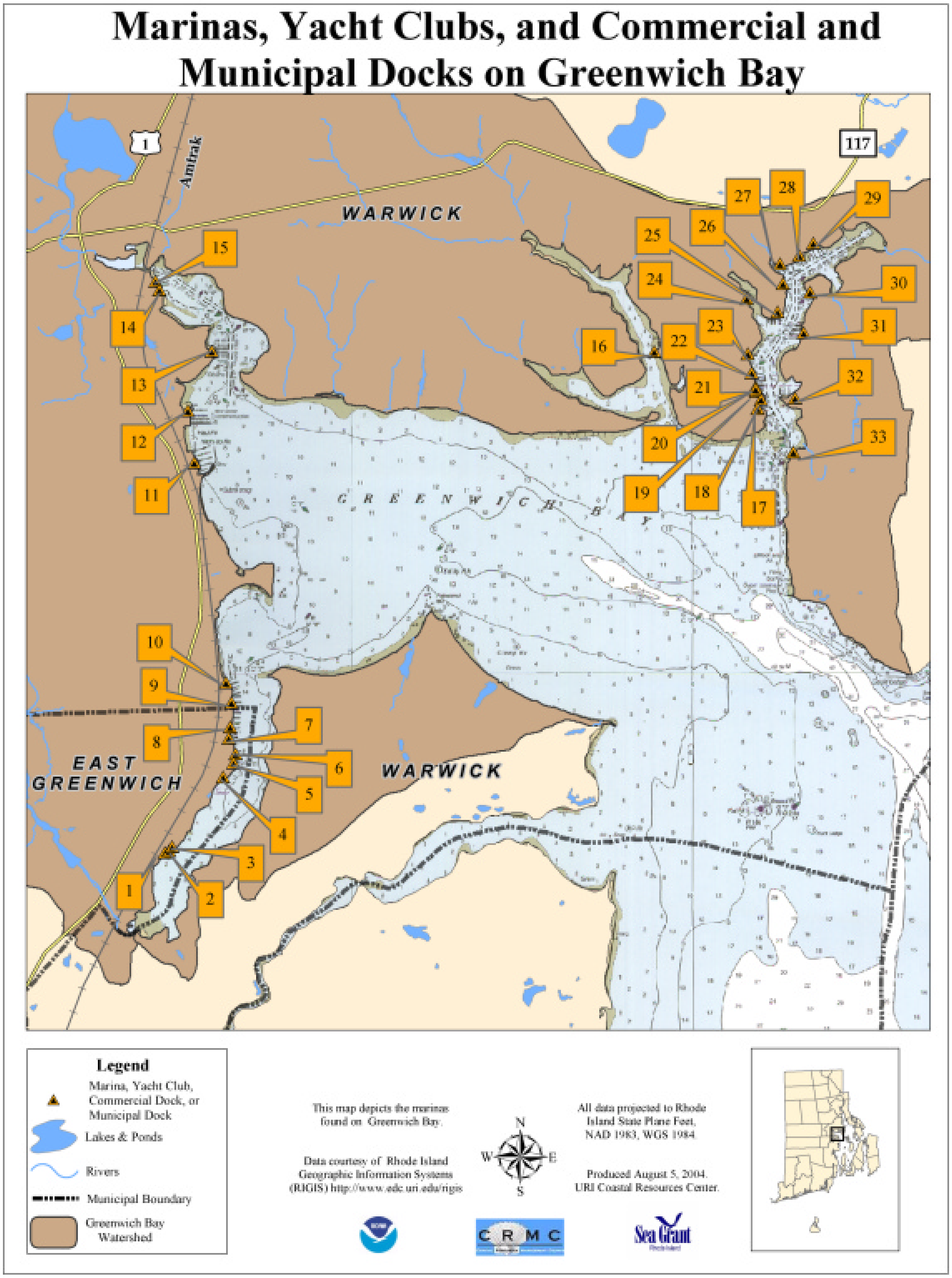
Table 4. Greenwich Bay marinas, yacht clubs, and commercial and municipal docks

Name	Map Locator Number [1]	Municipality	Location	Approximate Slip Count
Anderson Marina	1	East Greenwich	Greenwich Cove	14
Angel's Marina (Oakland Beach Yacht Club)	17	Warwick	Warwick Cove	85
Apponaug Harbor Marina (Dickerson's Marina)	13	Warwick	Apponaug Cove	347
Aqua Vista Marina & Boat Sales	19	Warwick	Warwick Cove	28
Bay Marina	29	Warwick	Warwick Cove	187
Breezy Point Marina	30	Warwick	Warwick Cove	42
Brewer Yacht Yard at Cowesett	11	Warwick	Greenwich Bay	246
Commercial Shellfish Docks	24	Warwick	Warwick Cove	27
East Greenwich Marina	7	East Greenwich	Greenwich Cove	41
East Greenwich Yacht Club	9	East Greenwich	Greenwich Cove	120
Greenwich Bay Marina North A (Carlson's Marina)	27	Warwick	Warwick Cove	142
Greenwich Bay Marina North B (C Lark Marina)	25	Warwick	Warwick Cove	330
Greenwich Bay Marina South	12	Warwick	Greenwich Bay	418
Greenwich Cove Marina	5	East Greenwich	Greenwich Cove	44
Harbor Light Marina	32	Warwick	Warwick Cove	159
Harbourside Lobstermania	6	East Greenwich	Greenwich Cove	8
Harris Marina	2	East Greenwich	Greenwich Cove	52
J. Andrew Craig	3	East Greenwich	Greenwich Cove	15
Little Rhody Boat Club (Private Club)	16	Warwick	Brush Neck/ Buttonwoods	4
Milt's Marina	8	East Greenwich	Greenwich Cove	23
Narragansett Bay Marina (Aqua Vista Marina South)	20	Warwick	Warwick Cove	N/A
Nick's Dock	21	Warwick	Warwick Cove	12
Norton Shipyard & Marina (Norton's Shipyard and Marina Sales Division)	10	East Greenwich	Greenwich Cove	188
One Bay Avenue Restaurant (Pleasant-Sea View Certified Sales)	18	Warwick	Warwick Cove	8
Pleasure Marina	23	Warwick	Warwick Cove	72
Ponaug Marina, Inc./RI Boat Movers, Inc.	15	Warwick	Apponaug Cove	166
Scalloptown	4	East Greenwich	Greenwich Cove	100
T&N Realty (Dorr's Dock)	33	Warwick	Warwick Cove	10
Warwick City Dock (Arnold's Neck Shellfishermen Association)	14	Warwick	Apponaug Cove	40
Warwick Cove Marina	22	Warwick	Warwick Cove	119
Warwick Light Shellfish	26	Warwick	Warwick Cove	18
Wharf Marina	28	Warwick	Warwick Cove	85
Winstead's Marina	31	Warwick	Warwick Cove	267
Total	-	-	-	**3,417**

1 Match locator number with numbers in Figure 2 to determine marina location.

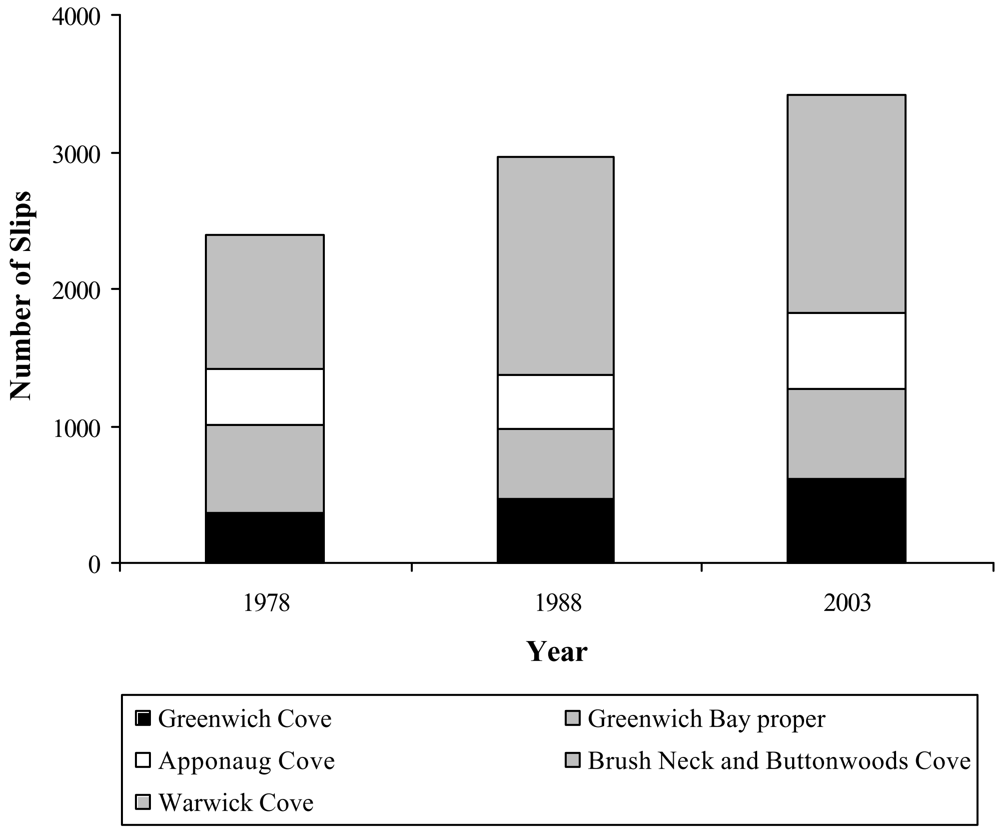
Source: 2003 Survey of Greenwich Bay Boating Facilities

Figure 2. Marinas, yacht clubs, and commercial and municipal docks on Greenwich Bay [1]



1 See table 4 for description of marina locations.

Figure 3. Boat slips at marinas, yacht clubs, and commercial and municipal docks on Greenwich Bay



710.1B Mooring areas and anchorages

1. Greenwich Bay and its coves offer ample areas to moor boats. Sixteen mooring areas and two transient anchorages cover approximately 268 acres of water surface in the bay and coves (Figure 4). Greenwich Cove contains the majority of mooring and anchorage areas whereas Brush Neck and Buttonwoods coves contain none (Table 3). In addition to the designated mooring areas and transient anchorages, riparian owners may be permitted to establish a mooring in the water adjacent to their properties. A 2003 Greenwich Bay boating facilities survey shows approximately 454 moorings in Greenwich Bay and its coves (Table 3). However, Warwick and East Greenwich report 625 permitted moorings (Barris, pers. comm.; Bradley pers. comm.). In either case, the number of moorings has decreased since 1988, when 912 moorings were reported in Greenwich Bay and its coves (Colt et al., 2000).

2. Mooring areas, transient anchorages, and individual moorings are regulated at the federal, state, and local levels. Recreational mooring areas and transient anchorages must have permits from CRMC and the U.S. Army Corps of Engineers (USACE). Additionally, East Greenwich and Warwick have harbor ordinances that require a permit and fee to install a mooring. These ordinances regulate the size, type, location, and use of moorings within Greenwich Bay and its coves. Changes to the harbor ordinances may require approval from CRMC. The municipalities generally are responsible for maintaining depth and managing the mooring areas and anchorages in Greenwich Bay and its coves though the transient anchorage area in Warwick Cove and three mooring areas, covering about 22 acres, are maintained by USACE (Warwick Harbor Management Plan, 1996).

3. There is high demand for municipal moorings, and it can take years to get a mooring. As of October 2004, East Greenwich had 63 people on its mooring waiting list, and Warwick had approximately 80 people citywide on its list (Barris pers. comm., Bradley pers. comm.). In Warwick, it can take anywhere from 1 to 5 years to get off the waiting list and get a permit, depending on the requested mooring area and boat size (Barris pers. comm.).

4. Increased mooring fees could reduce some demand for moorings. Boaters instead might shift towards using other boating facilities, such as launch ramps, marinas, or residential docks. Increased fees could also encourage use of smaller boats. However, mooring fees could also potentially lock out lower income boaters if they have been using moorings and if other boating facilities are beyond their means. Through more efficient and effective mooring area management, including use of helix anchors, shorter mooring scopes, and closer siting, many more boats could be safely moored in existing areas (Ross pers. comm.). The municipalities could also expand existing mooring areas or designate new ones. Options for mooring area expansions or new mooring areas may be limited within the more protected coves. A geographic information system (GIS) was used to estimate (1) the acreage of each cove, (2) marina boundaries determined from permits or aerial photography, and (3) mooring area boundaries determined from the municipal harbor management plans. With current mooring areas, marinas, and channels, there are only 304 acres of unallocated surface water area in Greenwich Bay's coves (Table 5), and more than

40% are in Brush Neck and Buttonwoods coves (Type 1 water bodies), or in extremely shallow areas.

5. Shoaling in municipal mooring areas limits the size and depth of boats that can use them. Dredging can alleviate shoaling in mooring areas. While neither municipality reports any significant dredging needs for mooring areas (Barris pers. comm., Cullen pers. comm.), past harbor management plans have documented dredging needs (Warwick Harbor Management Plan, 1996), and future needs could arise. If any dredging needs arise in federally maintained areas, the current discrepancies between mooring fees charged to residents and nonresidents could be an issue. USACE will not provide federal assistance to maintain mooring areas that are not accessible to all on equal terms (Warwick Harbor Management Plan, 1996). Furthermore, USACE does not allow municipalities to raise fee revenue in federally maintained mooring areas greater than the municipalities' costs for managing those areas.

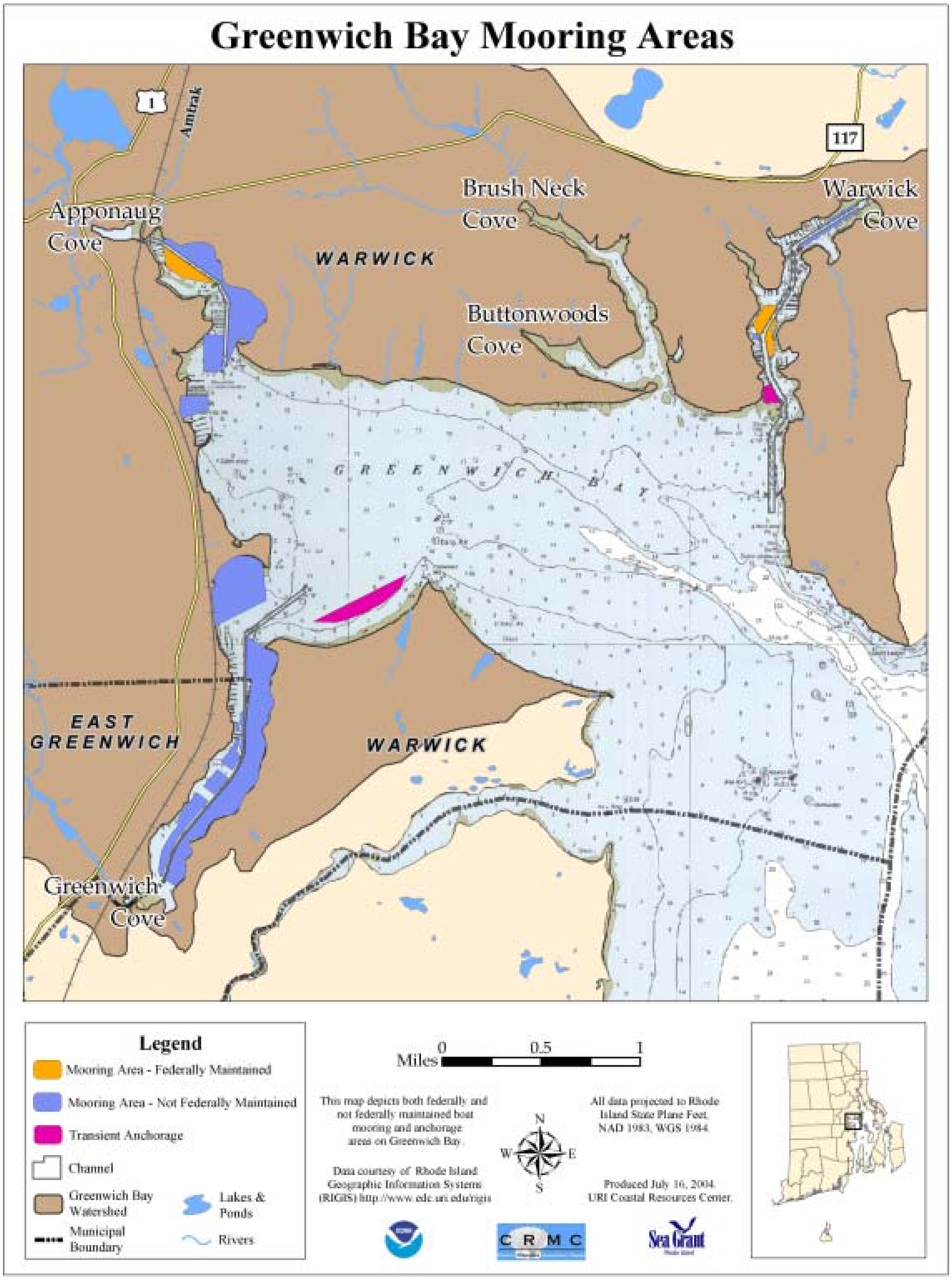
6. Citizens using Greenwich Bay are also concerned about the infringement of moorings into navigational channels. Mooring area boundaries do not technically infringe on current navigation channels (Figure 4), and Warwick and East Greenwich require that moorings be set back 25 feet from navigation channels or fairways. However, citizen concerns could indicate a need for increased harbormaster activity to ensure moored boats do not infringe on navigation channels or fairways.

7. As with other recreational uses, sufficient parking is needed to make moorings accessible.

Table 5. Approximate surface water area of moorings, marinas, and channels in Greenwich Bay

	Acres			Total	
	Moorings	**Marinas**	**Channels**	**Acres**	**Percentage of Water Body**
Greenwich Cove	155	18	13	186	68%
Apponaug Cove	52	12	10	74	70%
Brush Neck and Buttonwoods Coves	0	<1	0	<1	<1%
Warwick Cove	17	39	21	77	55%
Greenwich Bay proper	44	24	9	77	3%
Total	**268**	**94**	**53**	**415**	**13%**

Figure 4. Greenwich Bay mooring areas


Greenwich Bay Mooring Areas
1
Amtrak
117
Apponaug
Cove
Brush Neck
Cove
Warwick
Cove
WARWICK
Buttonwoods
Cove
G R E E N W I C H B A Y
EAST
GREENWICH
WARWICK
Greenwich
Cove
Legend
Mooring Area - Federally Maintained
Mooring Area - Not Federally Maintained
Transient Anchorage
Channel
Greenwich Bay Watershed
Lakes & Ponds
Municipal Boundary
Rivers
Miles 0 0.5 1
This map depicts both federally and not federally maintained boat mooring and anchorage areas on Greenwich Bay.
Data courtesy of Rhode Island Geographic Information Systems (RIGIS) http://www.edc.uri.edu/rigis
N
W E
S
All data projected to Rhode Island State Plane Feet, NAD 1983, WGS 1984.
Produced July 16, 2004. URI Coastal Resources Center.
C R M C
Sea Grant

710.1C Residential docks

1. A residential dock is a dock "contiguous to a private residence, condominium, cooperative or other home owners association properties that may accommodate up to four boats" (R.I. Coastal Resources Management Program §300.4). Using 2003 aerial photographs, it is estimated that there are 67 residential docks along Greenwich Bay and its coves. The majority of these docks are located in Warwick and Apponaug coves (Figure 5; Table 6).

2. Residential docks are increasing along the Greenwich Bay shoreline. Comparing 1997 aerial photographs to current dock estimates, it is estimated that there are 27 more residential docks along the shoreline of Greenwich Bay and its coves, a 65 percent increase over six years (Table 6). The largest increases have been along Potowomut and Warwick necks where there are now estimated to be 14 residential docks compared to only two docks in 1997. A lack of new moorings, rising property values, and new shorefront residential development are contributing to residential dock construction.

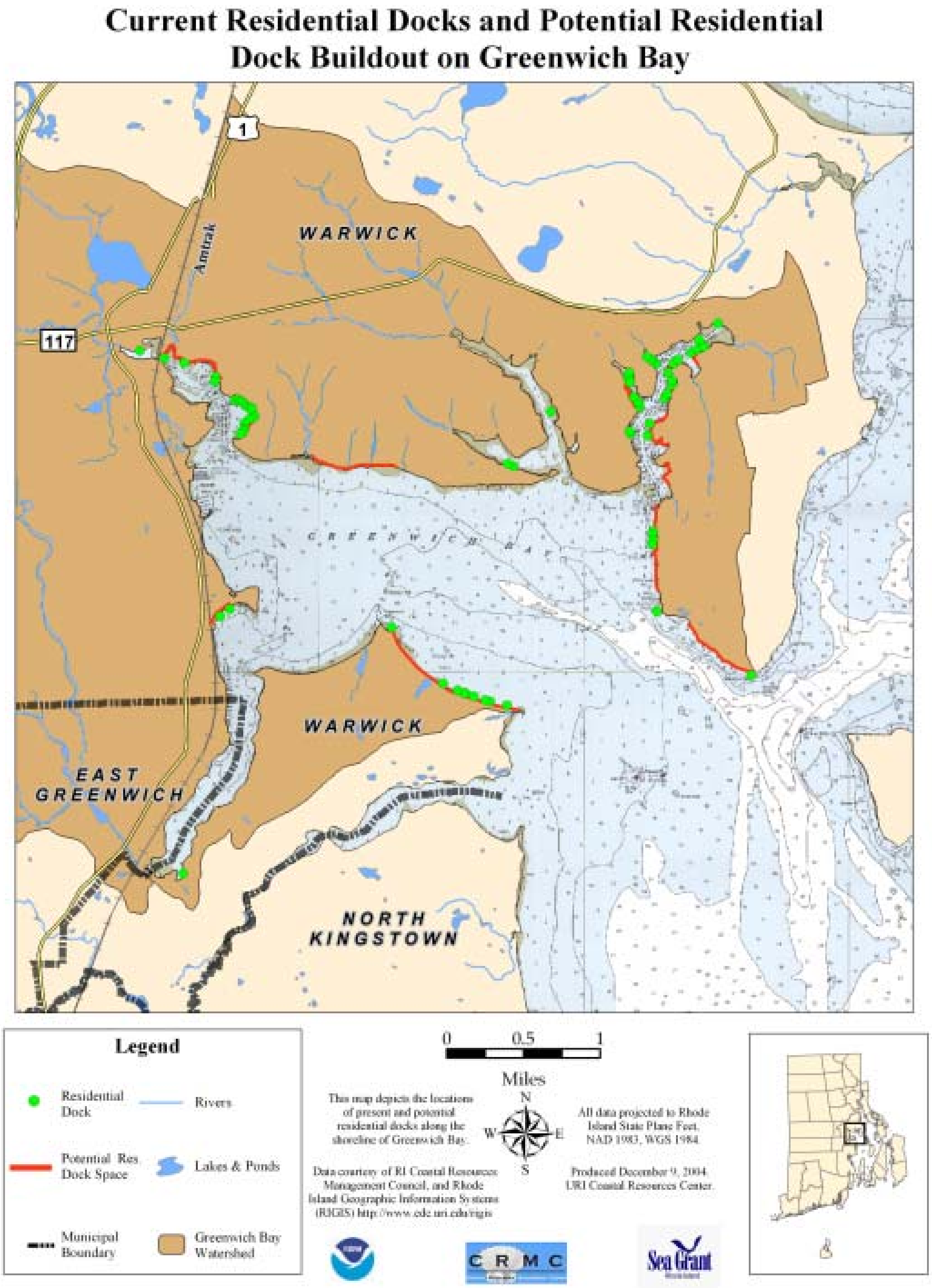
3. Residential docks can impede shoreline access, a protected constitutional right in Rhode Island. However, residential docks can be constructed to provide access. Environmental impacts may also be a concern. Residential docks under 10 feet tall can shade submerged aquatic vegetation, reducing the bottom area covered (Burdick and Short, 1999; Kelty and Bliven, 2003). However, CRMC regulations require that dock height be sufficient to limit impact on submerged aquatic vegetation based on the Burdick and Short (1999) model, and there is currently little such desired vegetation, such as eelgrass, in Greenwich Bay (See Section 320.3 of this SAMP). Also, preservatives, such as chromated copper arsenate, can leach from pilings, although around 99 percent of leaching occurs within the first 90 days and generally only affects areas within 10 feet of pilings (Kelty and Bliven, 2003; Massachusetts Office of Coastal Zone Management, 2003). Finally, general environmental impacts associated with boating are concentrated around docks where activity is frequent. Good management practices by boat owners can mitigate many of these impacts.

Table 6. Estimated number of residential docks along the Greenwich Bay shoreline in 1997 and 2003 and potential residential dock buildout

Location	Number of Residential Docks		
	1997	**2003**	**Buildout**
Potowomut Neck	1	9	65
Greenwich Cove	3	3	9
Western Shore	0	0	3
Apponaug Cove	15	22	51
Northern Shore	0	0	23
Buttonwoods and Brush Neck coves	1	3	3
Warwick Cove	19	25	94
Warwick Neck	1	5	33
Total	**40**	**67**	**281**

Source: 1997 and 2003 dock numbers from interpretation of aerial photography

Figure 5. Current residential docks and potential residential dock buildout on Greenwich Bay



710.1D Buildout analysis

1. The potential buildout of residential docks based on current municipal zoning and CRMC water use classifications was conducted. All shoreline properties zoned residential were assumed to have the potential to build a residential dock, except for residential properties on Type 1 (Conservation Area) waters, separated from the water by an existing or platted city street, or undeveloped lots in known wetland areas. The analysis did not account for conformance with municipal codes, other resource constraints, or site or construction constraints, such as if site conditions are appropriate for a dock. Based on this analysis, residential docks could be constructed on over five miles of Greenwich Bay's shoreline, or 214 additional residential docks (Figure 5, Table 6). Only Greenwich Cove, Brush Neck Cove, Buttonwoods Cove, and the western shore of Greenwich Bay did not have any significant buildout potential. This scenario represents a maximum potential buildout.

2. A marina buildout analysis was conducted for Greenwich Bay based on existing limits to marina expansion, such as CRMC water use classifications, municipal zoning, navigation channels, mooring areas, adjacent marinas, and parking availability. For this analysis, Geographic Information System (GIS) coverages were created of the following features:

- In-water boundary of marinas was created based on CRMC permits. If there was no permit for a marina, the boundary was delineated based on current extent of docks in 2003 orthophotography.
- Federal navigation channel boundaries of federal navigation channels were created based on data from the U.S. Army Corps of Engineers – New England Division.
- Boundaries of the Greenwich Cove fairway was created based on Volume 3 of 3, Rivers and Harbor, Project Maps, September 1988.
- Boundaries of mooring areas was created based on the Warwick and East Greenwich Harbor Management Plans.
- Municipal zoning for Apponaug and Warwick Cove were created based on paper zoning maps provided by the Warwick Planning Department.
- Boat ramps based on data in the Warwick and East Greenwich Harbor Management Plans and provided by the Rhode Island Saltwater Anglers Association.

In addition, a new GIS coverage of recently updated CRMC water use classifications was created based on coverages of the old CRMC water use classifications and updates for Apponaug and Warwick Cove. A potential expansion area for each marina was calculated assuming:

- No expansion in waters classified as Type 1,
- No expansion into navigation channels or mooring areas,
- No expansion off of areas zoned residential or open space,
- No expansions that block in-water access to existing public boat ramps, and
- Limited 25% expansion in Type 2 waters.

Expansion areas were further limited based on known parking restrictions and known shoreline natural resource constraints, based on CRMC permit files and an interview with CRMC permit staff.

3. The marina buildout analysis indicates that there is limited remaining opportunities for marina expansion in Greenwich Bay. The only remaining expansion opportunities identified are in Warwick Cove and Greenwich Bay proper outside of Apponaug Cove (See Figures 6 and 7). Greenwich Cove has limited opportunities for marina expansion because of current slip configurations, parking restrictions, mooring areas, the navigation fairway, public access, boat ramps, and the presence of Type 1 waters. Apponaug Cove has limited opportunities for marina expansion because of municipal zoning, the navigation channel, mooring areas, and known parking restrictions. There is no expansion potential for marinas in Brush Neck and Buttonwoods coves because they are Type 1 waters.

Figure 6. Greenwich Bay marina buildout scenario: Warwick Cove

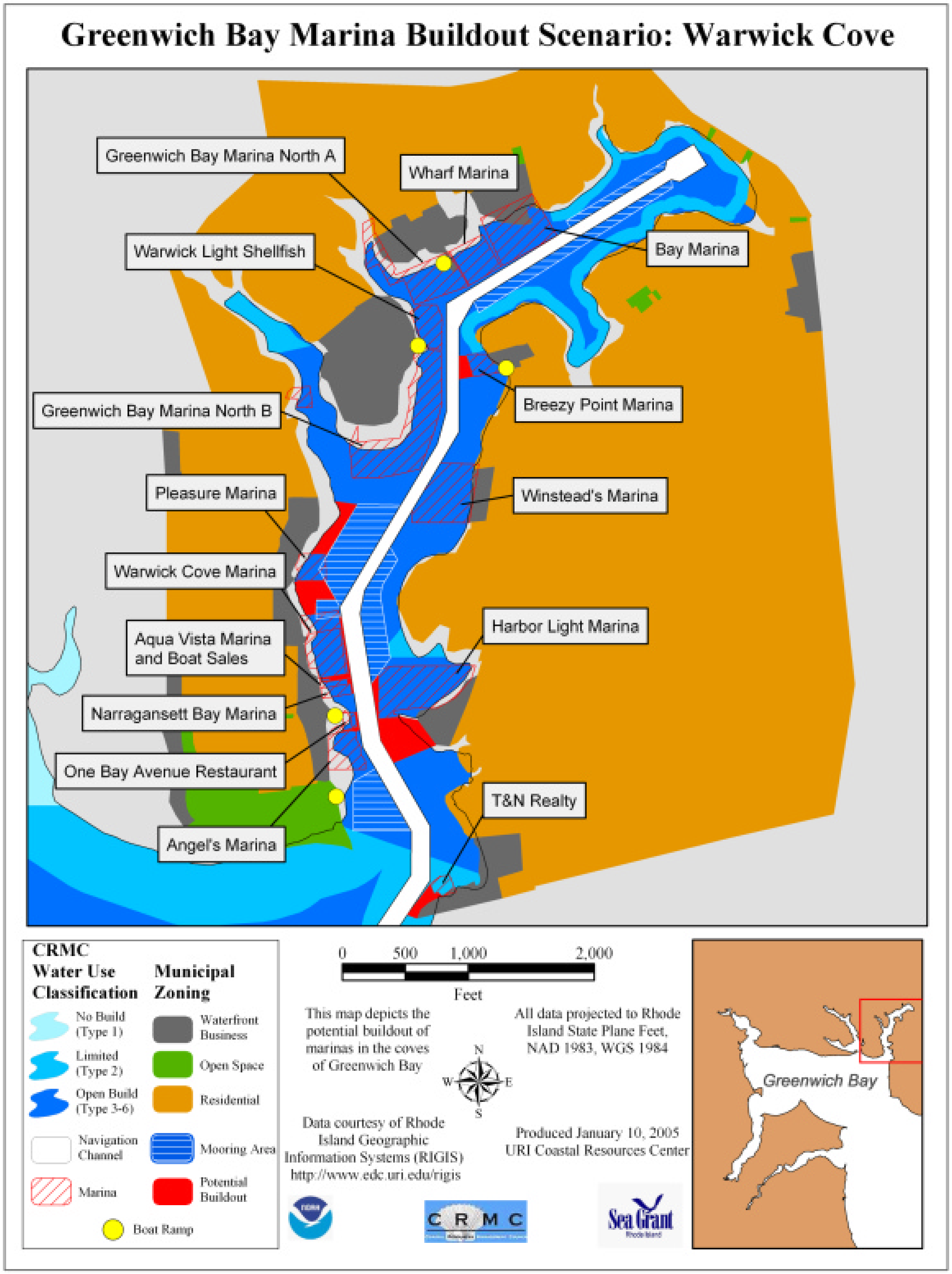
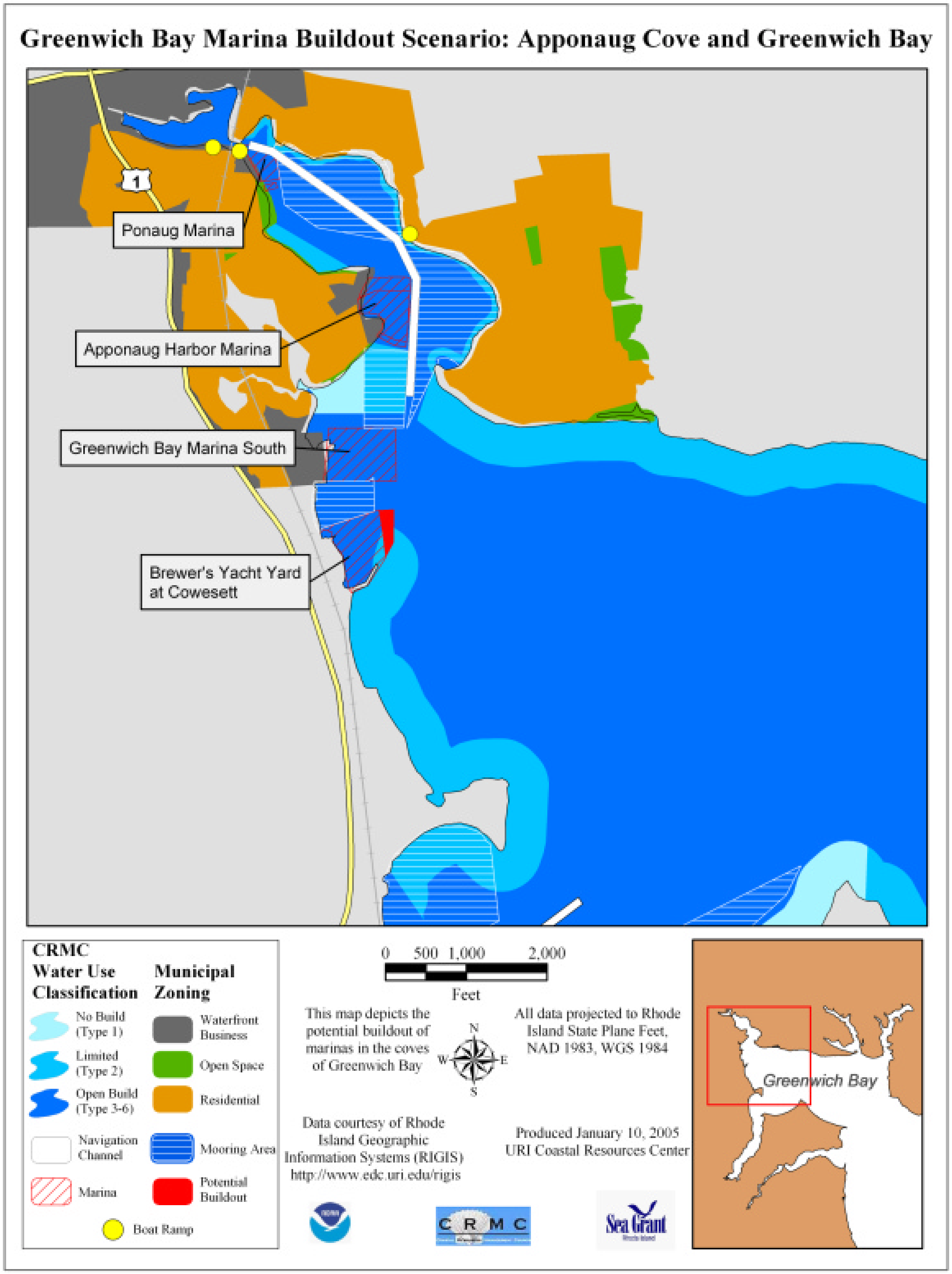


Figure 7. Greenwich Bay marina buildout scenario: Apponaug Cove and Greenwich Bay



710.2 Safety and enforcement

1. Boating safety and enforcement are concerns in Greenwich Bay. While it is not known how many boats are operating on Greenwich Bay at any one time, with over 4,000 boats at slips or moorings, not accounting for boats using ramps, there could be a boat every 200 feet if spread evenly across Greenwich Bay. Almost all of these boats are kept in Greenwich, Apponaug, and Warwick coves as well as the area just outside of Apponaug Cove on Greenwich Bay proper. Boats moving out of these areas, particularly within the coves, are restricted to relatively narrow channels, creating the potential for even more congested movement on the water during peak departure and arrival times. Boat congestion occurs most commonly at three channels of traffic—off of Goddard Memorial State Park into Greenwich Cove, at the Warwick Cove entrance channel along Warwick Neck, and more recently from mid-bay to Cowesett and Apponaug Cove—particularly during peak afternoon hours when boats are returning to slips. These boatways act like funnels that focus the traffic into narrow navigation corridors. The Warwick Cove entrance is a particularly problematic area (Barris pers.comm.).

710.2A Boating regulations

1. The primary means to ensure boating safety are federal, state, and local safety regulations. Federal law requires that boats be registered, carry certain equipment, such as personal flotation devices and visual distress signals, and not be operated in a negligent manner or while the operator is intoxicated (U.S. Coast Guard, 2003), and Rhode Island has similar safety requirements. Rhode Island also has boater education requirements and specific boat speed limits. At the local level, Warwick and East Greenwich limit boat speed to 5 miles per hour within Greenwich Bay's coves. Warwick also prohibits reckless operation and boating while under the influence of alcohol or drugs.

710.2B Enforcement

1. Municipal harbormasters are the primary boating enforcement authorities, though federal and state authorities may also get involved with enforcement on Greenwich Bay.

Harbormasters

1. Both Warwick and East Greenwich employ a part-time harbormaster to patrol local waters and to administer municipal moorings. Municipal harbormasters enforce municipal harbor management ordinances as well as other federal, state, and local laws. The Warwick and East Greenwich harbormasters are funded through municipal general fund appropriations. Both harbormasters report that their current salaries and operating budgets are more than offset by the mooring fee revenue that they collect (Barris pers. comm., Cullen pers. comm.).

2. Warwick employs a part-time harbormaster and assistants in its parks and recreation department. The Warwick harbormaster's jurisdiction covers all of Greenwich Bay (excluding the East Greenwich portion of Greenwich Cove), as well

as areas outside of Greenwich Bay as far north as Pawtuxet Cove. The Warwick harbormaster spends the majority of his time managing moorings, including permit system management and visual inspections, as well as conducting boating safety patrols, monitoring shoreline activities, and dealing with wrecks. In the past, the Warwick harbormaster worked approximately 20 hours per week and employed five or so assistants from Memorial Day to Columbus Day. However, Warwick currently only funds the harbormaster for 2 hours per week on average. The Warwick harbormaster does not have the authority to take people into custody but can detain them and contact other enforcement authorities, such as the Coast Guard or RIDEM, which do have that authority.

3. East Greenwich employs a part-time harbormaster in its police department. The East Greenwich harbormaster's core jurisdiction is the western shore of Greenwich Cove within East Greenwich. In addition, he may assist other authorities at their request, such as the Coast Guard. The East Greenwich harbormaster's core responsibility is to manage moorings; enforce federal, state, and local laws; assist boaters with seamanship and storm preparation; and search and rescue. He is a full-time police officer who averages about 20 hours per week from April to October working as the harbormaster. The East Greenwich harbormaster currently works alone although assistant harbormasters have been employed in the past. As a police officer, the East Greenwich harbormaster has the power to detain and take into custody individuals violating federal, state, or local regulations.

4. The East Greenwich harbormaster generally patrols the bay on weekends, holidays, and weekend and Thursday evenings from late April to early October. The Warwick harbormaster operates two patrol boats on the water during summer weekends, mostly during late mornings and early evenings when boat traffic is most heavy. During the week, only one boat usually goes out in the morning, but primarily to inventory moorings. In total, the Warwick harbormaster reports that he and his assistants spend approximately 40 hours per week total on the water during the summer, primarily in Greenwich Bay. While the two harbormasters do not coordinate their patrols on the water, they do have a good working relationship. Through an informal agreement, the East Greenwich harbormaster patrols and enforces regulations on all of Greenwich Cove as far out as Chepiwanoxet Point and Sally Rock, and the Warwick harbormaster can enforce regulations in East Greenwich's jurisdiction.

<u>Other enforcement authorities</u>

1. RIDEM and the U.S. Coast Guard may also patrol areas within Greenwich Bay. With so many boats on the water, Greenwich Bay is one of the focus areas for the RIDEM Division of Law Enforcement. RIDEM enforces safety regulations, such as equipment requirements, registration, speed limits, and no-wake zones, as well as shellfish and no-discharge regulations. When the shellfish management area is open, starting in December, RIDEM is on the water from 7 a.m. to noon, approximately 3 days per week. During the summer, RIDEM patrols Greenwich Bay almost every day

of the week although it may only be for a short period of time. The Coast Guard does not conduct regular patrols on Greenwich Bay but will respond to a safety emergency. The Coast Guard Auxiliary may also maintain a presence on the water (Connors pers. comm.).

710.2C Safety and enforcement issues

1. RIDEM finds that the major safety problems on Greenwich Bay are boaters operating under the influence of alcohol (BUI) and excessive speed and wakes (Connors pers. comm.). The East Greenwich harbormaster has occasional BUI problems near Greenwich Cove's waterside restaurants but considers the situation under control (Cullen pers. comm.). The Warwick harbormaster reports some problems with boat speeds and excessive wakes (Barris pers. comm.). Warwick Cove is a particularly problematic spot with issues such as groundings, wakes at fuel docks, and boaters not staying in lanes. In his opinion, inexperienced boaters unaware of the rules on the water are at the heart of the problem. Rhode Island requires, with certain exceptions, completion of a boating safety course by boat operators born after January 1, 1986, who operate a boat with more than a 10-horsepower engine. In addition, all personal watercraft operators must complete a boating safety course.

2. Both harbormasters believe that, while the situation is generally under control, a full-time presence on the water during the summer could improve boating safety on Greenwich Bay. The depositing of all mooring fee revenues in a harbor management fund for the harbormaster could facilitate this enhancement. Currently, Warwick does have a provision in its harbor management ordinance to place all mooring fee revenue into a harbor management fund for harbor management purposes, but apparently does not use this provision (Barris pers. comm.).

710.2D Personal watercraft

1. Often referred to as jet skis, personal watercraft are popular in Greenwich Bay because they are fast, highly maneuverable, and operational in shallow waters. In addition, personal watercraft can often be rented from local businesses, increasing access to them. The nature of personal watercraft and the inexperience of some users leads to acknowledged safety concerns.

2. In addition to boating safety course regulations that include personal watercraft, the Personal Watercraft Safety Act restricts personal watercraft use, including limiting use to people 16 years or older, to daylight hours, and to headway speed (the slowest possible speed at which it is still possible to maintain steering) within 200 feet of swimmers, divers, shore, or moored vessels. Reckless operation, such as weaving through congested vessel traffic, unreasonable circling of a larger vessel or wake jumping is prohibited. Violations are a misdemeanor with penalties up to a $500 fine or imprisonment up to 6 months. RIDEM, local police, and harbormasters are authorized to enforce the statute.

3. All local governments can establish speed limits for personal watercraft under state law. Warwick restricts personal watercraft to headway speed in Apponaug, Brush Neck, Buttonwoods, and Warwick coves as well as within mooring areas, or within 200 feet of swimmers, divers, shore, or moored vessels (Barris pers. comm.). East Greenwich restricts all boats, including personal watercraft, to headway speed in Greenwich Cove. In addition, the Personal Watercraft Safety Act authorizes certain local governments to pass local ordinances with more stringent regulations, such as bans. Warwick and East Greenwich have not received this explicit authorization in statute.

4. Harbormasters from East Greenwich and Warwick have not experienced personal watercraft use to be a major problem in Greenwich Bay (Barris pers. comm., Cullen pers. comm.). However, anecdotal reports from the Greenwich Bay Citizens Advisory Committee indicate that reckless personal watercraft use in areas of Greenwich Bay and its coves is a safety concern. The Warwick Parks and Recreation Department placed buoys to prevent personal watercraft from cutting across the swimming area at Oakland Beach to protect swimmers (Rooney pers. comm.), indicating an area-specific safety issue.

Section 720
Swimming

1. Swimming occurs off both licensed and unlicensed beaches along the shoreline, including saltwater beaches at Potowomut Neck, Goddard Memorial State Park, Chepiwanoxet, Cedar Tree Point, Nausauket, Buttonwoods, Warwick City Park, Seaview Beach, and Oakland Beach as well as small freshwater beaches along Gorton Pond and at the Kent County YMCA (Figure 8). Swimming also occurs off residential docks, boats, and along other shoreline areas. The bathing season generally runs from Memorial Day to Labor Day, with the majority of use after July 1.

2. While much of Greenwich Bay's shoreline is considered swimmable, the Rhode Island Department of Health (HEALTH) only monitors water quality and regulates licensed bathing beaches to protect the public from bathing-related illnesses. In the Greenwich Bay watershed, licensed beaches are Goddard Memorial State Park, Warwick City Park, Oakland Beach, Gorton Pond, and the Kent County YMCA.

3. Violations of the state's bacteria water quality standards force the frequent closure of licensed beaches in the Greenwich Bay watershed during the summer bathing season. Beaches were closed to swimming for 397 days from 1998-2004, with 143 days in 2003 (Figure 9). In 2003, Greenwich Bay's licensed beaches were only five of the 27 beaches closed statewide but represented nearly 30 percent of actual beach closure days (HEALTH, 2004). The Warwick Parks and Recreation Department attributes a drop in 2003 attendance and revenue at Warwick City Park and Oakland Beach to beach closures. Most beach closures occur after periods of heavy rainfall. HEALTH is investigating the transience of indicator bacteria, especially during wet weather events, to better identify periods that present a public health risk, and if possible, develop a rainfall closure model based on indicator bacteria concentrations and their persistence over time.

4. Safety may also be an issue for swimmers in Greenwich Bay. Boats and personal watercraft may place swimmers outside of designated swimming areas or in unmarked swimming areas at risk. State law prohibits the operation of motorboats or vessels in marked swimming areas. In addition, Warwick prohibits water-skiing, surfboarding, sailboarding, personal watercraft, or similar activities within 200 feet of swimmers, except at headway speed. Warwick has placed buoys around the Oakland Beach swimming area to alert personal watercraft users to avoid these areas during the bathing season (Rooney pers. comm.). Buoys are also present at the Gorton Pond beach. However, the Warwick City Park beach and unlicensed beaches do not necessarily have marker buoys alerting boaters and protecting swimmers.

Figure 8. Greenwich Bay recreational beaches

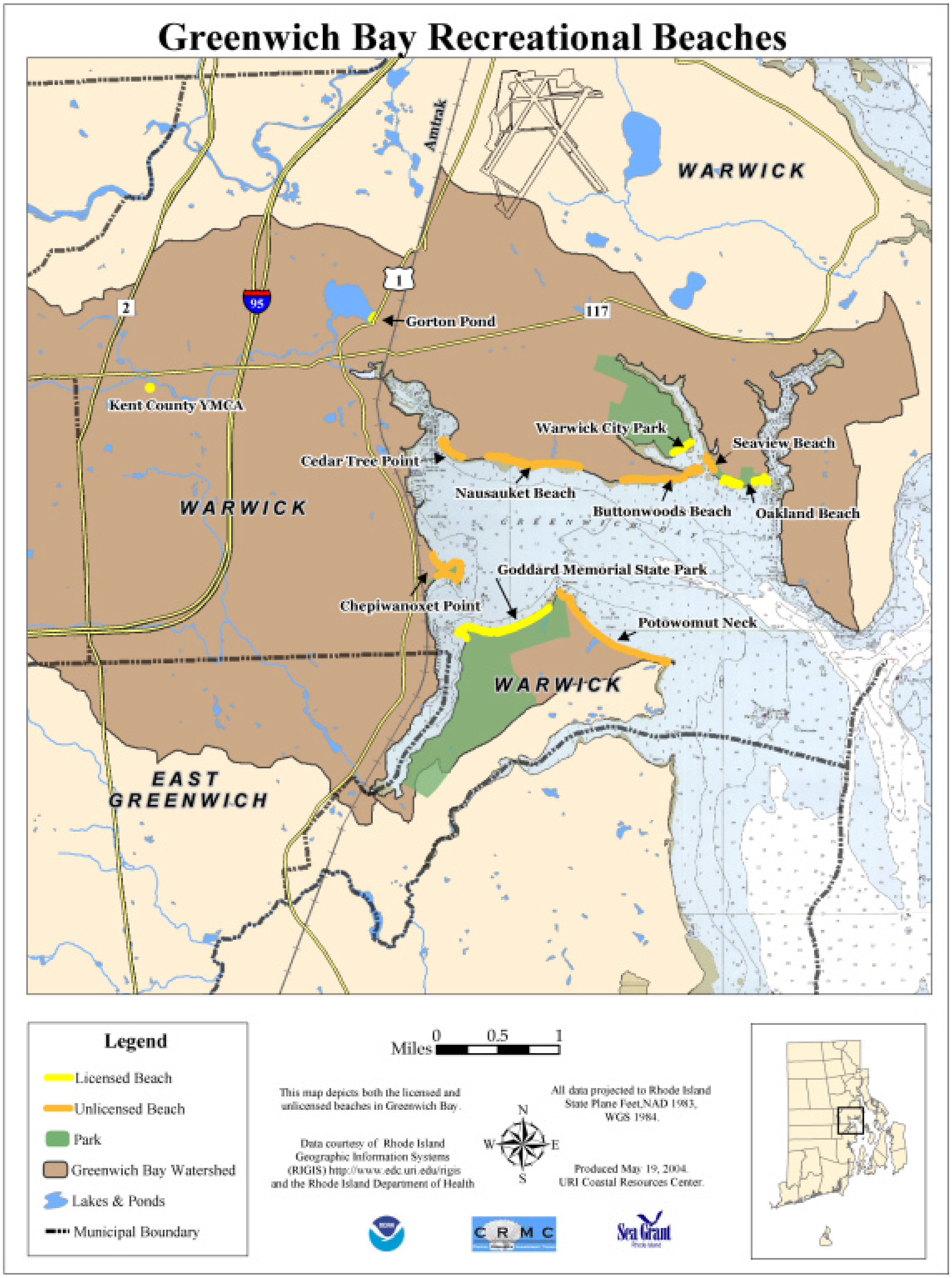
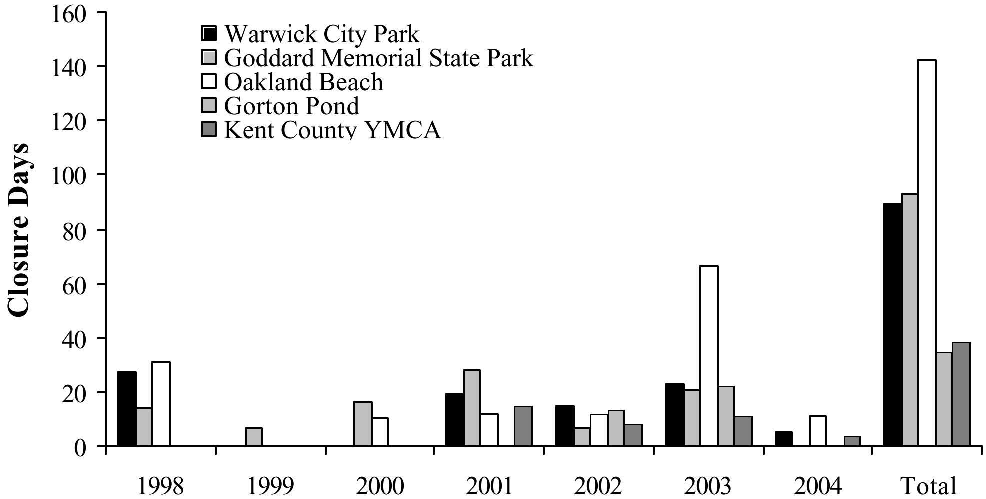


Figure 9. Closures at Greenwich Bay beaches, 1998-2004 [1]



1 The freshwater beaches at the Kent County YMCA and Gorton Pond were only monitored sporadically prior to 2001 and 2002, respectively.

Source: Rhode Island Department of Health Beach Monitoring Program

Section 730
Fishing

730.1 Finfish

1. Narragansett Bay provides abundant opportunities for recreational finfishing. The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation estimated that 149,000 U.S. adult residents (>16 years old) fished recreationally in Rhode Island's saltwaters (U.S. Department of the Interior and the U.S. Department of Commerce, 2003). Approximately, 67,000 of these anglers were Rhode Island residents. The Rhode Island Saltwater Anglers Association (RISAA) indicates that 25 percent of its members are from other states (Medeiros pers. comm.). Resident and nonresident saltwater anglers spent about $71.1 million in Rhode Island on equipment, food, lodging, transportation, and other trip costs in 2001 (U.S. Department of the Interior and the U.S. Department of Commerce, 2003). There is no statistically accurate data for recreational fishing participation and economic impact specific to Greenwich Bay.

2. The Rhode Island recreational fishery includes numerous species. Striped bass and bluefish were the most popular target for saltwater anglers in 2001 (U.S. Department of the Interior and the U.S. Department of Commerce, 2003), particularly during August and September, although tautog, scup, and summer flounder are also commonly caught in Rhode Island's inland waters (National Marine Fisheries Service (NMFS) pers. comm.). Historically, winter flounder also supported a popular recreational fishery, but catch has declined sharply since the early 1980s (Figure 10). Recreational landings have declined dramatically since 1981, from 21.1 million pounds to 4.4 million pounds in 2001 (RIDEM 2002a). There is no accurate catch data specific to Greenwich Bay.

3. Recreational fishing in Greenwich Bay is enhanced by fair weather, fish migration, and public fishing programs, and has a strong connection to pleasure boating, with an estimated 80 percent of boaters participating in fishing. Summer is the most popular season for recreational fishing in Greenwich Bay, although late spring and early fall are also very active (Medeiros pers. comm.). Since most commercial methods of fish harvest are banned in Greenwich Bay, it is a sport-only fishery. In the past, Greenwich Bay provided a multitude of winter flounder, squeteague (weakfish), scup, smelt, and silver hake ("frost fish") that supported the local recreational fishery. Most of these species have declined in Greenwich Bay, particularly winter flounder. However, seasonal migrations of bluefish and striped bass continue to make Greenwich Bay a valued area. These carnivorous species feed on the juvenile fish and baitfish that use coves and tributaries as nurseries. The season for these species generally runs from May through October, with the striped bass catch peaking earlier in the season and the bluefish catch peaking later (NMFS pers. comm.).

4. Recreational fishing in Greenwich Bay occurs from boats in warm weather and along the shore throughout the year (Medeiros pers. comm.). Fishing from boats dominates the Greenwich Bay recreational fishery. Chepiwanoxet Point and Sally Rock Point are particularly popular areas for shore fishing. NMFS lists 21 access sites in Greenwich Bay where it surveys recreational anglers (Table 7). During the summer months, 60 to 135 people on average use sites in Greenwich Bay on weekdays and 105 to 185 people do so on weekends (NMFS pers. comm.).

Ponaug Marina/Ray's Bait and Docks, Harbor Light Marina, Greenwich Bay North B Marina (C-Lark Marina), and the East Greenwich Town Ramp are the most popular surveyed launching points for recreational anglers using boats; Goddard Memorial State Park, Oakland Beach, and Chepiwanoxet Point are the most popular surveyed locations for shorefishing (Figure 11).

5. RIDEM is the primary state agency regulating recreational fishing in Greenwich Bay. With advice from the Marine Fisheries Council, RIDEM uses a combination of minimum size requirements, seasonal closures, and possession limits to regulate the state's marine recreational fishery. The 2004 requirements for a few marine recreational species are provided in Table 8. RIDEM prohibits harvesting or possessing winter flounder in Greenwich Bay. For the freshwater fishery, RIDEM also issues licenses and restricts gear that can be used for recreational fishing. To promote the restoration of anadromous fish runs, RIDEM has prohibited the harvest of river herring (alewife and blueback herring) from Gorton Pond and the Hardig Brook outlet on Sundays, Mondays, and Tuesdays and limits the harvest to 12 fish per day.

6. Recreational anglers want to maintain their freedom to access and move along the shore for fishing. Parking at many access sites is not available. Residential docks that block access along the shore, such as along Potowomut Neck, are a concern. Boat ramps with insufficient depth to launch boats during lower tides, such as at Goddard Memorial State Park, are also a concern.

Table 7. Recreational fishing patterns at access sites in Greenwich Bay

Access site	Spring		Summer		Fall	
	Boat	Shore	Boat	Shore	Boat	Shore
Apponaug Cove						
Apponaug Harbor Marina	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 5-8 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Edgewater Drive	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4
Ponaug Marina/Ray's Bait and Docks	Weekends 5-8 Weekdays 1-4	-	Weekends 13-19 Weekdays 9-12	Weekends 1-4	Weekends 9-12 Weekdays 5-8	Weekends 5-8 Weekdays 1-4
Warwick City Dock	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 9-12 Weekdays 5-8	Weekends 1-4 Weekdays 1-4	Weekends 5-8 Weekdays 1-4	Weekends 1-4 Weekdays 1-4
Warwick Cove						
Bay Marina	-	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Breezy Point Marina	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4	-
Greenwich Bay Marina North A	Weekends 5-8 Weekdays 1-4	-	Weekends 5-8 Weekdays 5-8	-	Weekends 1-4 Weekdays 1-4	-
Greenwich Bay Marina North B	Weekends 5-8 Weekdays 5-8	-	Weekends 9-12 Weekdays 5-8	-	Weekends 5-8 Weekdays 5-8	-
Harbor Light Marina	Weekends 1-4 Weekdays 1-4	Weekends 1-4	Weekends 9-12 Weekdays 5-8	Weekends 1-4	Weekends 9-12 Weekdays 5-8	Weekends 1-4
Winstead's Marina	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 5-8	-	Weekends 5-8 Weekdays 5-8	-
Greenwich Bay						
Brewer Yacht Club at Cowesett	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Chepiwanoxet Point	-	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4
Greenwich Bay Marina South	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Oakland Beach	-	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4
Oakland Beach Point	-	-	-	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4

Access site	Spring		Summer		Fall	
	Boat	Shore	Boat	Shore	Boat	Shore
Greenwich Cove						
East Greenwich Marina	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
East Greenwich Town Ramp	Weekends 5-8 Weekdays 5-8	Weekends 1-4 Weekdays 1-4	Weekends 9-12 Weekdays 5-8	Weekends 1-4 Weekdays 1-4	Weekends 5-8 Weekdays 1-4	Weekends 1-4 Weekdays 1-4
Goddard Memorial State Park	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4	Weekends 5-8 Weekdays 5-8	Weekends 1-4 Weekdays 1-4	Weekends 1-4 Weekdays 1-4
Greenwich Cove Marina	-	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Norton's Shipyard & Marina	Weekends 1-4 Weekdays 1-4	-	Weekends 5-8 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-
Brush Neck Cove						
Little Rhody Boat Club	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-	Weekends 1-4 Weekdays 1-4	-

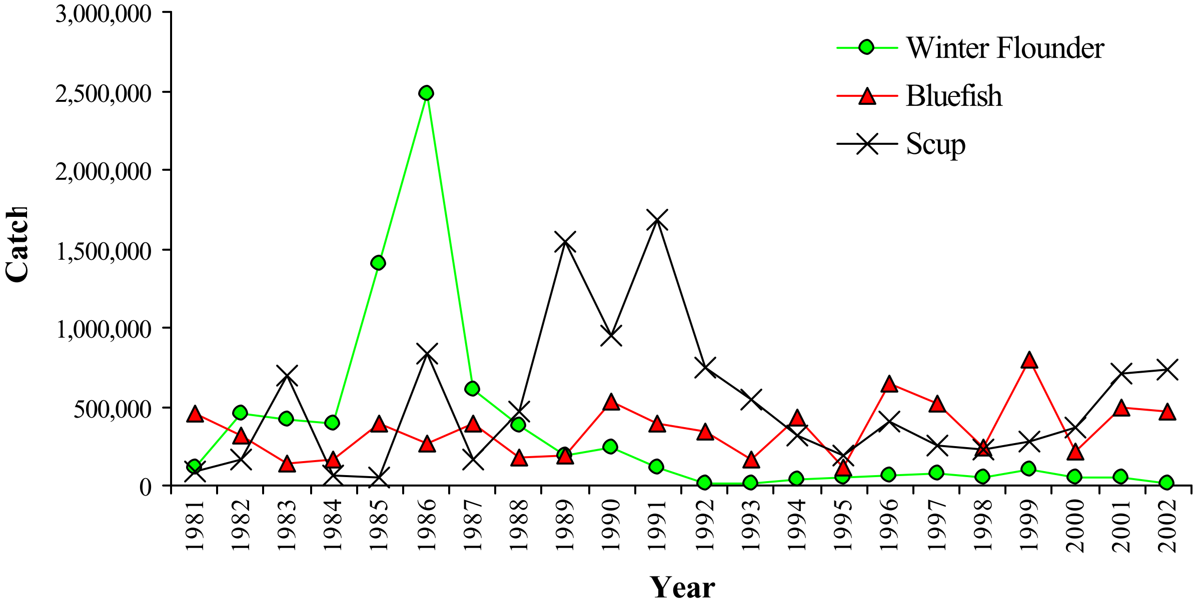
Source: Marine Recreational Fisheries Statistics Survey, Fisheries Statistics and Economics Division, National Marine Fisheries Service

Table 8. 2004 Marine recreational fisheries regulatory limitations

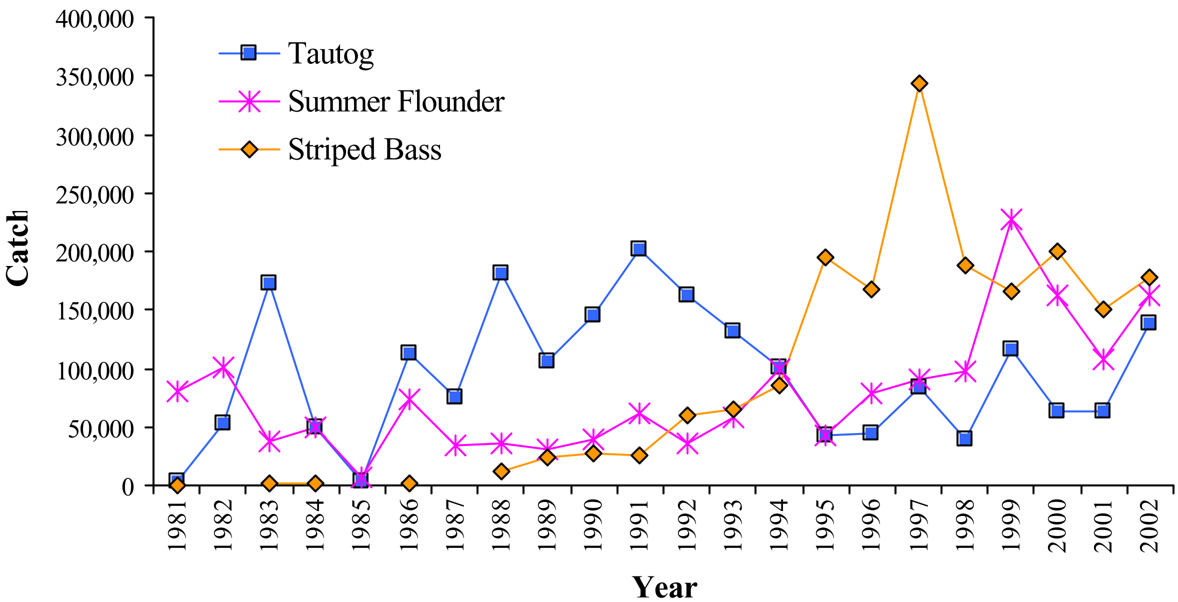
Species	Minimum Size	Season	Possession Limit
Bluefish	None	No closed season	10 fish/person/day
Scup	10 ½”	January 1 – July 25 August 4 – December 31	50 fish/person/day
Striped Bass	28”	No closed season	2 fish/person/day
Squeteague (Weakfish)	16”	No closed season	10 fish/person/day
Winter Flounder	The harvesting or possession of winter flounder is prohibited in northern Narragansett Bay, including Greenwich Bay.		

Source: Rhode Island Marine Fisheries Statutes and Regulations, Rhode Island Department of Environmental Management

Figure 10. Recreational fishing catch in Rhode Island's inland waters

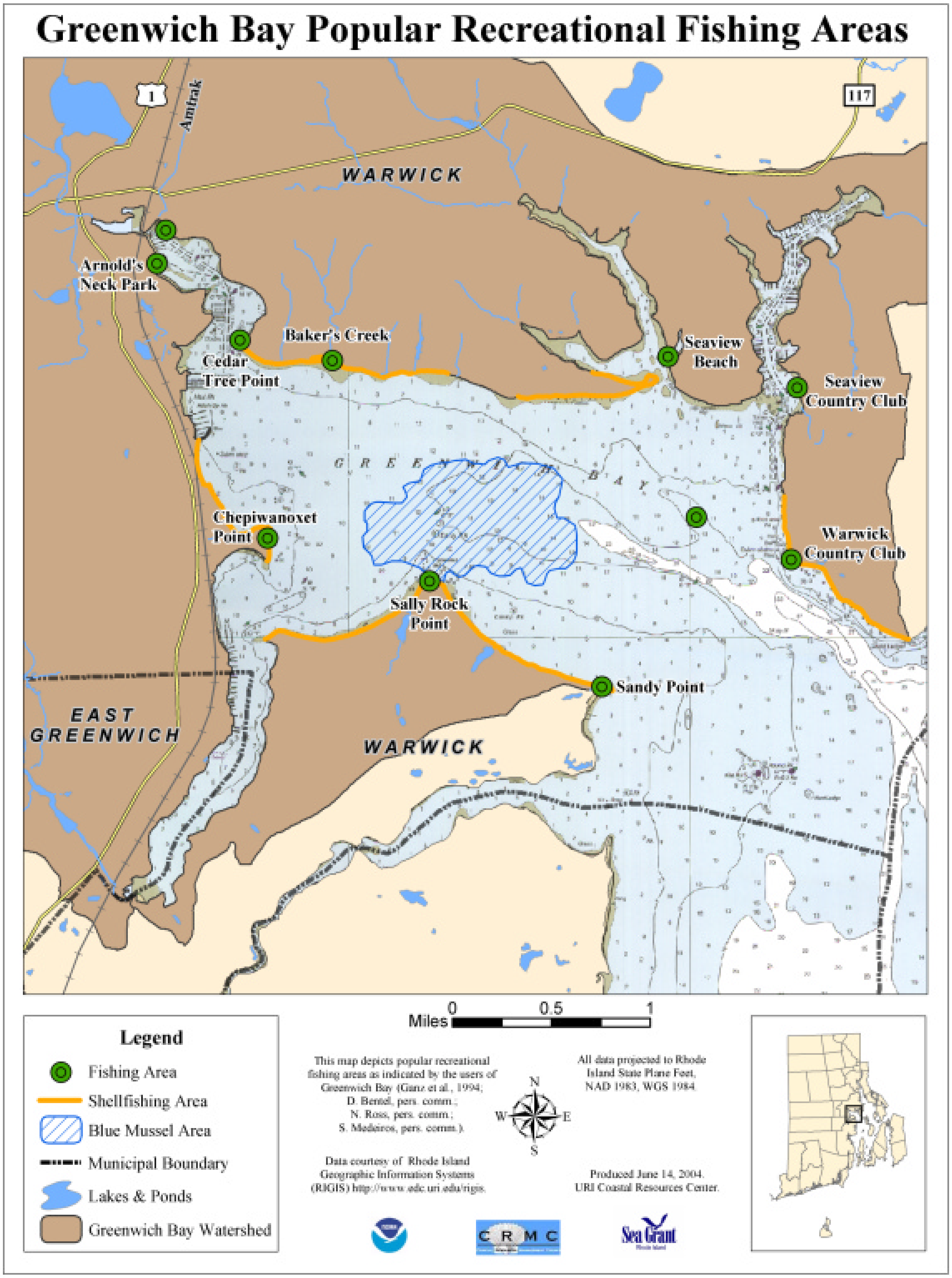


Source: Marine Recreational Fisheries Statistics Survey, Fisheries Statistics and Economics, Division National



Marine Fisheries Service

Figure 11. Greenwich Bay popular recreational fishing areas



730.2 Shellfish

1. Bay quahogs and soft-shelled clams can be found along the entire perimeter of Greenwich Bay. The gentle slope of the shoreline provides substantial quahog and clam habitat accessible to the public for gathering seafood. In particular, the sandy areas along Potowomut Neck, Chepiwanoxet, Cedar Tree Point, Nausauket, Buttonwoods, and Warwick Neck have been identified as traditional recreational shellfishing areas (Figure 11). In addition, the waters off of Sally Rock provide a substantial blue mussel resource (Ganz et al., 1994).

2. Provisions for shellfishing date back to colonial times and the Rhode Island Constitution, which provides for free and common fishing. Reflecting this right, Rhode Island residents do not need to be licensed to harvest shellfish for personal use, and nonresidents pay only a token amount licensing fee, ranging from $11 for a 14-day limited license to $200 for an annual license. However, some regulations are needed to prevent overexploitation and protect public health.

3. RIDEM regulates the recreational shellfish fishery. All recreational shellfishing is prohibited between sundown and sunrise, and shellfish must be larger than a certain size to be harvested: 1-inch shell thickness for quahogs and 1.5-inch shell diameter for soft-shelled clams and mussels. Since the 1970s, RIDEM has managed all of Greenwich Bay as a shellfish management area. To control overexploitation, RIDEM limits daily shellfish catch to 1 peck for residents and 0.5 peck for licensed nonresidents. Finally, each cove and large portions of western Greenwich Bay are currently closed to all shellfishing because of high fecal coliform levels, a public health risk. Other areas of Greenwich Bay are routinely closed to shellfishing after storms.

4. Heavy fishing pressure from recreational harvesters occurs in specific areas. In the past, both Mary's Creek and Nausauket shorelines have been temporarily closed to allow for natural recruitment to occur. Chepiwanoxet and Oakland Beach are routinely inundated with recreational shellfishermen on nice summer days. Overfishing by recreational shore diggers is directly proportional to public access. Neighborhoods like Buttonwoods, Cedar Tree Point, and Bay Ridge have access for their residents but limited access to the general public, and thus, are not as heavily exploited. Pollution closures in Greenwich Bay prohibit shellfishing in many areas, so fishing pressure is intensified in the remaining accessible open areas (Ganz pers. comm.). For example, Mary's Creek is currently permanently closed to shellfishing because of high fecal coliform levels.

5. Conflicting development and pollution closures can prevent the public from accessing shellfish beds. For example, marinas can cover recreational shoreline shellfish beds, residential docks can limit movement along the shore, and land development can limit access to the shore. Pollution closure lines along western Greenwich Bay, Cedar Tree Point, the Nausauket shoreline, and Brush Neck and Buttonwoods coves may shift from year to year based on RIDEM monitoring. In 2003, 34% of these Class SA waters were permanently closed to shellfishing. In 2004, some areas were reopened, although 25% of these waters remained closed. RIDEM posts signs in local neighborhoods to make shoreline users aware of pollution closures. However, citizens report that in some cases these signs may not be repositioned on a timely basis when pollution closure lines shift (Langseth pers. comm.). According to RIDEM, they remove signs that they have posted as soon as changes are announced. However, RIDEM makes additional signs available to local municipalities and will work with them to ensure all signs are relocated in a timely manner.

Section 740
Hunting

1. In 2001, the U.S. Fish and Wildlife Service (FWS) reported that Rhode Island had 11,484 paid hunting license holders. The 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation estimated that 9,000 U.S. adult residents (>16 years old) hunted in Rhode Island (U.S. Department of the Interior and the U.S. Department of Commerce, 2003), representing about 1 percent of Rhode Island's adult population. Nationally, about 6 percent of the adult population hunts. While a relatively small number of people hunt in Rhode Island, they were still estimated to have spent more than $5 million on hunting in 2001 (U.S. Department of the Interior and the U.S. Department of Commerce, 2003).

2. Available space for hunting is limited in the Greenwich Bay watershed, as it is primarily an urban environment. State law forbids hunting within 500 feet of an occupied dwelling without the owner's permission (R.I. Gen. Laws §20-13-7). In addition, state law effectively bans wild bird hunting in Brush Neck and Buttonwoods coves (R.I. Gen. Laws §20-14-8.1). Locally, Warwick forbids hunting using a firearm within city limits with the exception of waterfowl hunting on or near the shoreline (Warwick City Ordinance §40-2 and §40-3). In this case, firearms must be discharged toward open water (seaward). Finally, Warwick forbids the discharge of firearms or projectile-type firing devices in any public beach, playground, ballfield, park or recreation area (Warwick City Ordinance §58-13). East Greenwich prohibits hunting east of route 2 (East Greenwich Code of Ordinances §14-2) as well as specifically on the landfill site on Greenwich Cove (East Greenwich Code of Ordinances §15-45). All hunting must be conducted within the appropriate open seasons.

3. While data is not available specifically for the Greenwich Bay watershed, waterfowl hunting is considered the primary hunting activity in the watershed (Tefft pers. comm.). Waterfowl hunting seasons vary based on the species but generally begin in early October and are over by late January. These seasons generally do not interfere with warm-weather-based recreational activities, such as swimming and recreational boating. State and local laws in combination with the urban environment in the Greenwich Bay watershed restrict land-based hunting. In recent years, East Greenwich was the only watershed municipality where deer and turkey were reported harvested, with 18 deer taken in the 2002-2003 and 2003-2004 seasons (RIDEM 2003; RIDEM 2004b) and 7 wild turkeys taken since 1986 (Tefft, 2003).

Section 750
Other recreational activities

750.1 Recreational vehicles

1. Recreational vehicles, such as all-terrain vehicles (ATVs), may be used in certain areas of the Greenwich Bay watershed. As defined under state law, a recreational vehicle is a motor vehicle, such as a minibike, that is designed to travel over natural terrain and which has been determined by the R.I. Division of Motor Vehicles as unsuitable for operation on the public way and not eligible for registration. While there are no designated areas for recreational vehicle use in the watershed, use often occurs along power line rights-of-way, particularly around Cowesett (Rooney pers. comm.). In addition, recreational vehicle use has been reported from Baker's Creek to Budlong Farm Road during the winter months (Langseth pers. comm.). Recreational vehicles must be registered every year with RIDEM and are currently prohibited on publicly owned beaches and other specific areas in the Greenwich Bay watershed. More details on current restrictions on recreational vehicle use can be found in Section 360.2 of this SAMP.

750.2 Golfing

1. Two private golf clubs and two public courses cover 329 acres in the Greenwich Bay watershed near its shoreline. Built in the 1920s, the Warwick Country Club on Warwick Neck and the Potowomut Golf Club on Potowomut Neck are private clubs with 18-hole courses. The Seaview Country Club on Warwick Neck and the Goddard Memorial State Park course are public nine-hole courses. The golfing season generally runs from March through October with the exception of the Potowomut Golf Club, which is open year round. While golf courses provide recreational opportunities, maintaining them with fertilizer and pesticide applications can impact nearby water quality.

750.3 Wildlife watching

1. In 2001, an estimated 298,000 adults (>16 years old) participated in a wildlife watching activity in Rhode Island, spending an estimated $169.6 million. Non-Rhode Island residents account for a disproportionate share of this spending (86 percent) even though they only comprise about 20 percent of the participants (Caudill, 2003). It is not known how much of this activity occurred in the Greenwich Bay watershed, but statewide, wildlife watching participation and expenditures are larger than those estimated for recreational fishing, and much larger than statewide hunting participation and expenditures (U.S. Department of the Interior and the U.S. Department of Commerce, 2003). Parks, recreation areas, and natural areas in the Greenwich Bay watershed help support this recreational activity and generate economic activity within the watershed.

750.4 Walking paths

1. Goddard Memorial State Park, Warwick City Park, and Chepiwanoxet Point all provide walking trails. The beaches at Goddard Memorial State Park, Warwick City Park, and Oakland Beach provide shoreline and paved or wooden boardwalks (Figure 8). In addition, a path for

walking and biking is proposed for the site of the former East Greenwich landfill. Users are concerned that constitutionally protected access along the shoreline is being blocked by marinas, residential docks, and other shoreline structures.

Section 760
Recreational access to Greenwich Bay

1. The 450-mile Rhode Island coastline is one of the most densely populated in the country, with approximately 1,000 people per square mile (Pogue and Lee, 1993). As more people purchase highly desirable coastal property, the demand for protected public access to the shore increases. Public access generally consists of CRMC-designated rights-of-way (ROWs) or public parks, and freedom to move along the shore. Historically, Rhode Islanders have relied on shoreline access for food, shelter, transportation, maritime commerce, and military defense (Pogue and Lee, 1993). Today, Rhode Islanders continue to rely on shoreline access for boating, fishing, swimming, and other water-dependent recreational activities. In addition, commercial fishermen around Greenwich Bay continue to depend on access to the water for their livelihoods.

2. The Rhode Island Constitution states that the citizens of Rhode Island “shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore … including but not limited to fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea and passage along the shore.” However, state waters of public domain only extend from the mean high water mark out to sea. Areas above mean high water can be privately owned. Therefore, Rhode Island citizens must have public access to the shoreline to exercise their rights along the shoreline.

3. Rhode Islanders achieve access to Greenwich Bay at nearly 100 locations along the 25.8-mile shoreline (Table 9). Access locations are available to every cove and length of shoreline on Greenwich Bay. State- and municipally designated ROWs provide paths to the shoreline and scenic views. Public boat ramps allow people to launch boats and also fish or view the water. Marina boat ramps may also be accessible to the general public for a fee. State- and municipally owned lands, such as parks, beaches, and recreation areas, provide physical access to Greenwich Bay for multiple recreational uses. Finally, marinas and private association ROWs may provide public access to the shoreline. Table 8 and Figures 12 –15 summarize most access points available to the public long Greenwich Bay.

4. CRMC is the lead agency in protecting, maintaining, and enhancing public access to tidal waters. CRMC defines public access as “a general term used to describe the ways and means by which the public may legally reach and enjoy the coastal areas and resources of the state.” CRMC protects and maintains public access by requiring that certain shoreline projects have no net impact on public access. When reviewing these activities, CRMC requires that impacts to public access be avoided and minimized. If they cannot be avoided, applicants must compensate for lost public access by creating public access of a similar type or level on-site or, if not feasible, off-site. Commercial and industrial redevelopment projects, new and significant marina expansions, filling of tidal waters, and beach nourishment projects are assumed to impact public access and a public access plan or component is required unless a variance is granted. CRMC enhances public access to tidal waters through its ROW designation process. To educate ROW users, CRMC has produced a code of conduct in several languages.

5. The municipalities and RIDEM also play a role in protecting, maintaining, and enhancing public access, particularly on municipally or state-owned land. Both the Warwick and East Greenwich harbor management plans emphasize improving public access to the shoreline. RIDEM receives federal money to improve public access for recreational sportfishing, such as boat ramps.

6. While numerous public access points to the shore exist, they are not necessarily distributed evenly around Greenwich Bay, they can be difficult to find, and some of them lack parking and adequate maintenance. In addition, public access is impacted by development such as marinas, residential docks, and shoreline protection structures.

Table 9. Public access sites along Greenwich Bay (as of June 2004)

		Type of public access			Description			
Locator number[1]	**Location**	**CRMC designated right-of-way (ROW)**	**Harbor management plan right of way (ROW) (Plat/Lot)**	**Other coastal access**	**Primary use**	**Sign posted**	**Parking available**	**Notes**
				CITY OF WARWICK				
1	Charlotte Drive		201/164-187			No Data		
2	Charlotte Drive 1	J-3	201/135-149		Path to the shore		Roadside	A 10-foot-wide grassy path at the intersection of Sydney Avenue
3	Charlotte Drive 2	J-4	201/114-132		Path to the shore		Roadside	A grassy path at the intersection with Hale Avenue
4	Robert Avenue		201/87-109	Municipal boat ramp	Boat ramp	X	Roadside	A CRMC ROW sign is posted at this municipal ROW. It is probable that the municipal sign was intended to be placed here but instead was placed at CRMC designated ROW at Charlotte Drive 4 (J-6).
5	Charlotte Drive 3	J-5	201/57-85		Path to the shore		Roadside	This grassy ROW at the intersection with Collins Avenue seems to be part of a private lawn and is barely noticeable.
6	Charlotte Drive 4	J-6	201/24-54		Path to the shore	X	Roadside	This ROW at the intersection of Hopkins Avenue provides a grassy path to the water. A municipal ROW sign is posted at this CRMC designated site. It is probable that CRMC sign was intended to be placed here but instead was placed at the municipal ROW at Robert Avenue.

		Type of public access			Description			
Locator number [1]	**Location**	**CRMC designated right-of-way (ROW)**	**Harbor management plan right of way (ROW) (Plat/Lot)**	**Other coastal access**	**Primary use**	**Sign posted**	**Parking available**	**Notes**
7	Sawyer Avenue		201/-1-19		No Data			
8	Beachwood Drive 1	J-7	203/21-22		Path to the shore			ROW at pole 30/31 offers two flights of stairs down to a nice shaded beach.
9	Beachwood Drive 2	J-8	203/6-7		Path to the shore			ROW at pole 23/24 offers a set of wooden stairs down to a sandy beach.
10	Overlook Drive		203/128-1		No Data			
11	Goddard Memorial State Park			State park; boat ramp	Public park	X	X	
TOWN OF EAST GREENWICH								
12	East Greenwich Landfill			Municipal vacant land	Scenic view		X	Not currently accessible while improvements are made.
13	Rocky Hollow Road access at Crompton Ave.	H-2	X		Scenic view	X	X	Not accessible to shoreline. Overgrown with vegetation. Bordering property is collecting trash and junk.
14	Bridge Street access at Crompton Ave.	H-5	X		Path to the shore	X		A wide, grassy strip just north of the Harbor Heights condominiums.
15	East Greenwich Town Overlook and Boat Ramp			Municipal boat ramp	Boat ramp	X	Lot	Situated off Water Street, next to the municipal transfer station, the municipal overlook and renovated boat ramp offers both visual and boating access to Greenwich Bay. The boat ramp is in good condition.
16	Barbara M. Tufts			Municipal	Public park	X	X	

Locator number [1]	Location	Type of public access: CRMC designated right-of-way (ROW)	Type of public access: Harbor management plan right of way (ROW) (Plat/Lot)	Type of public access: Other coastal access	Description: Primary use	Description: Sign posted	Description: Parking available	Description: Notes
	Playground			Park				
17	London Street	H-1	X		Scenic View	X		Overgrown with vegetation and steep slope.
18	Long Street access at Water Street	H-3	X	Municipal boat ramp	Boat ramp	X		This right-of-way is a boat ramp located on Water Street, among several marinas
	Queen Street	Under review		Not applicable				
19	King Street access at Water Street	H-4	X		Scenic view	X		A seafood restaurant is located here.
20	Division Street access at Water Street	H-6	X		Path to the shore		X	A 5-minute walk from downtown East Greenwich and an ideal location for watching harbor activities
CITY OF WARWICK								
21	Oakgrove Street		221/51-RR	No data				
	Chepiwanoxet Point			Municipal park	Public park	X	X	
22	Louise Street		222/107-108		No data			
23	Harbor Lane		222/96-98					
24	Neptune Street		222/34-86					
25	Masthead Drive – Off Courtland Lane	J-37	366/1		Scenic view			Dense vegetation blocks any reasonable passage to the water on this ROW directly south of Greenwich Bay Marina South.
26	Greenwich Bay Marina South			RICRMP Section 335				Parking spaces set-aside for public use in marina lot.

		Type of public access			Description			
Locator number [1]	**Location**	**CRMC designated right-of-way (ROW)**	**Harbor management plan right of way (ROW) (Plat/Lot)**	**Other coastal access**	**Primary use**	**Sign posted**	**Parking available**	**Notes**
27	Apponaug Harbor Marina			RICRMP Section 335	Path to the shore			Footpath to Long Point as well as access to parking lot, pumpout facility, and porta-potty dump
28	Arnold's Neck Drive #1		365/200-201					
29	Arnold's Neck Drive #2		365/209-204-210-208					
30	Arnold's Neck Park			Municipal park	Public park	X	X	
31	Ray's Bait			Private boat ramp	Boat ramp	No data		Fee charged
32	Harrop Avenue/Warwick City Ramp		244/165-147	Municipal boat ramp	Boat ramp			Asphalt boat ramp in fair condition, shallow water depth with cove bottom exposed at low tides
33	Colonial Avenue		245/7-6	No data				
34	Edgewater Drive			Boat ramp	Boat ramp		Roadside at low tide	Cement, sand, and gravel ramp appropriate for small to medium craft launching, road in poor condition and inundated during high tide
35	Midget Avenue (Intersection with Grandview Drive)		367/27-275			No data		CRMC has reviewed this site for designation but found insufficient evidence.
36	Grandview Drive at Melbourn Road			Private association ROW	Path to the shore	X	Small lot with two spaces	

		Type of public access			Description			
Locator number [1]	Location	CRMC designated right-of-way (ROW)	Harbor management plan right of way (ROW) (Plat/Lot)	Other coastal access	Primary use	Sign posted	Parking available	Notes
37	Preston Drive			Private association ROW	Road to the shore			
38	Melbourn Road			Private Association ROW	Path to the Shore			
39	Nausauket Road	J-24	367/1-201		Path to the shore	X	X	Roadside parking is prohibited during the summer months.
40	Sylvia Drive	J-9	369/26-42		Path to the shore	X	X	
	Warwick City Park			Municipal park	Public park		X	
41	Sunny Cove Drive		363/588-611					No data
42	Cove Avenue		362/544-545					No data
43	Spring Grove Avenue		362/116-74					No data
44	Cottage Grove Avenue		362/264-171					No data
45	Pine Grove Avenue		362/316-269					No data
46	Shand Avenue		362/434-316					No data
47	Reynolds Ave. Off Reynolds Ave.	J-11 J-35	361/35-819		Path to the shore			Two CRMC-designated ROWs appear to be in same location. J-11/35 is a path between two oak trees, east of the residence at 229 Reynolds Ave.
48	Haswill Street		361/129-302					No data

Locator number [1]	Location	Type of public access			Description			
		CRMC designated right-of-way (ROW)	Harbor management plan right of way (ROW) (Plat/Lot)	Other coastal access	Primary use	Sign posted	Parking available	Notes
49	Canfield Avenue		361/328-362					
50	Langley Street		360/436					
51	Northup Street		360/174-268					
52	Wilcox Street		375/106-94					
53	Wilson Avenue		375/202-108					
54	Ottawa Avenue 2		375/303-205					
55	Seaview Beach			Community beach	Path to the shore		X	
56	Oakland Beach			Municipal beach Boat ramp	Swimming beach Boat ramp		X	
57	Burr Avenue		376/375-439	No data				
58	One Bay Ave Restaurant			Private boat ramp	Boat ramp	No data		Fee charged
59	Suburban Parkway – Formerly Delaware Avenue	J-31	376/253-374				Roadside	Road end and floating dock are part of ROW.
60	Mohawk Avenue		376/162-244	No data				
61	Off Logan Street		376/154-155-157	No data				CRMC has reviewed this site for designation but found insufficient evidence.
62	Ottawa Avenue 1		376/87-152	No data				
63	Quonset Avenue		376/539-540					
64	Sheffield Street/ Coburn Street	J-10	376/8-9				Three spots in	Landowner to the south has posted several "No Parking" and "No

Locator number [1]	Location	Type of public access			Description			
		CRMC designated right-of-way (ROW)	Harbor management plan right of way (ROW) (Plat/Lot)	Other coastal access	Primary use	Sign posted	Parking available	Notes
							ROW	Trespassing" signs just at the property line that may be misleading to the public.
65	Wadsworth Street		359/44	No data				
66	North Shore Street	J-12	359/57-58				Roadside	East of the road-end of Crown Street. This is an obvious attempt to block a ROW with a truck and tent. Beyond the resident's truck, vegetation is too dense to even pass.
67	Ray Street		359/84-85		No data			
68	Bennett Street		359/88-98		No data			
69	Off Ship Street (Ship Court)	J-30	359/124-125				Roadside	ROW is completely overgrown with vegetation making passage impossible. However, a small foot path has been cleared in an adjacent vacant lot.
70	Briggs Street		359/179-227		No data			
71	Waterfront Street		359/250-258		No data			
72	Waterfront Drive/ Second Point Ave. Boat Ramp	J-13	359/271-272	State boat ramp	Boat ramp	X		This boat ramp consists of a gravel path leading into the water between two docks of a private marina.
73	Henzie Street		359/290-285		No data			
74	Wharf Marina			Private boat ramp	Boat ramp	No data		Fee charged
75	Marblehead Street		359/435-407		No Data			

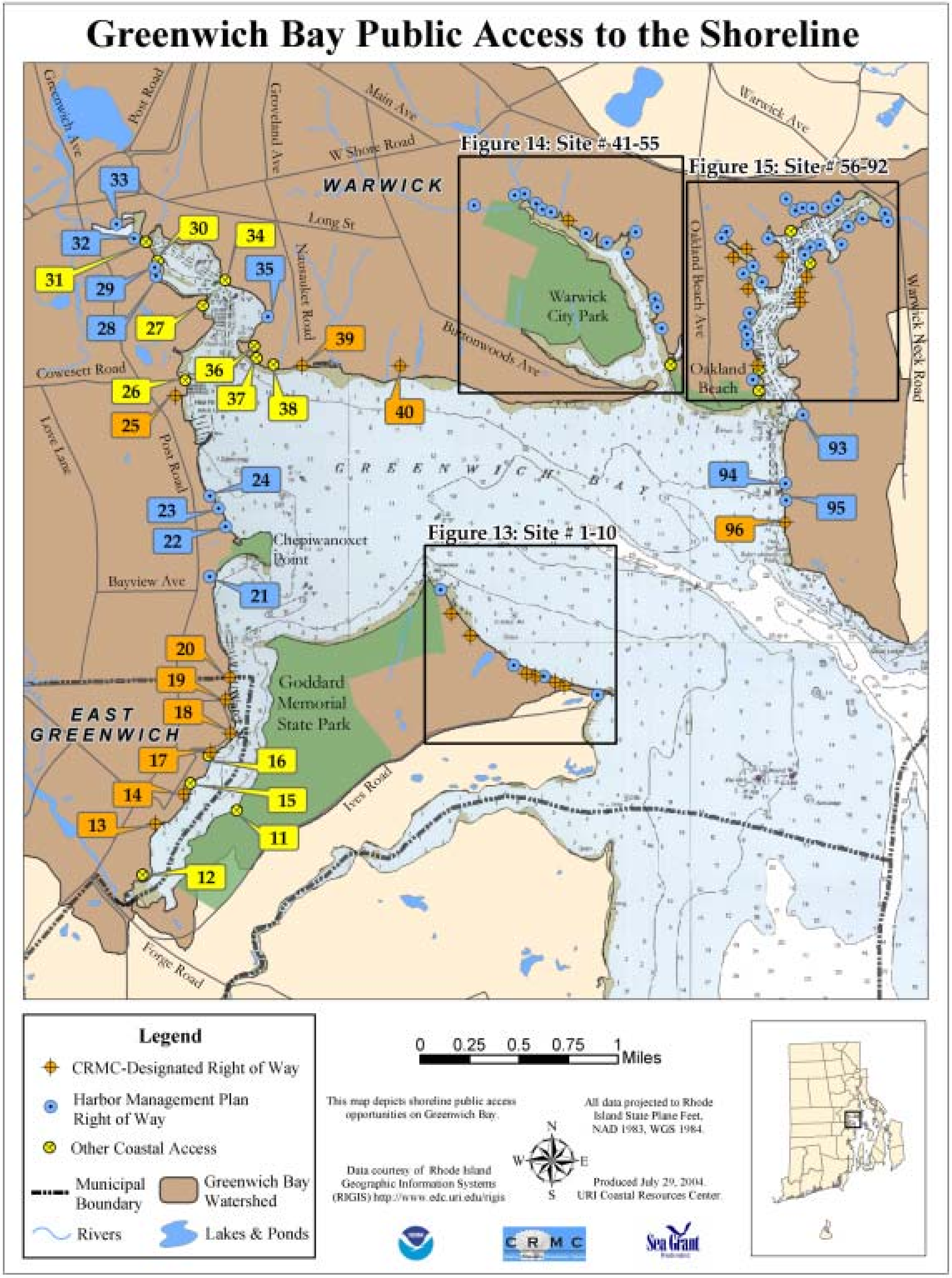
		Type of public access			Description			
Locator number [1]	Location	CRMC designated right-of-way (ROW)	Harbor management plan right of way (ROW) (Plat/Lot)	Other coastal access	Primary use	Sign posted	Parking available	Notes
76	Rita Street		359/436-427					
77	Searle Street		359/461-450					
78	Holden Street		359/512-461					
79	Vanstone Avenue		358/327-370					
80	Garden Road		358/377-373					
81	Capen Street		358/260-271					
82	Off Capen Street		358/257-261					
83	Charlestown Avenue		358/214-244					
84	Harris Avenue		358/187-188					
85	Ernest Avenue		358/125-126					
86	Mitchell Court		358/33-29					
87	Sayles Avenue		358/409-30					
88	Mars Avenue		358/11-7					
89	Breezy Point Marina			Private boat ramp	Boat ramp	No data		Fee charged
90	Off Cooney Street/ Extension of Lilac Street Cooney Street	J-33 J-14	377/2-3		Path to the shore		Roadside	Two CRMC-designated ROWs appear to be in same location. ROW appears to be a resident's driveway at the end of Lilac Street. It is completely overgrown making even visual access to the water impossible.
91	Tiffany Avenue/Progress	J-26	377/17-371				Roadside	A partially overgrown road-end with a private dock that appears to be in the ROW. Includes Lot 371

		Type of public access			Description			
Locator number [1]	Location	CRMC designated right-of-way (ROW)	Harbor management plan right of way (ROW) (Plat/Lot)	Other coastal access	Primary use	Sign posted	Parking available	Notes
	Street							that extends south and runs along the shoreline, but is blocked by a truck and machinery
92	Progress Street	J-15	377/..-37				Three spots in ROW as well as parking in adjacent marina	ROW runs straight through the parking lot of a marina to a riprap shoreline. Provides little, if any, functional access.
93	Randall Avenue		378/16-90-91		No data			
94	Blackstone Avenue		382/50-94		No data			
95	Kirby Avenue		382/113-314		No data			
96	Narragansett Bay Avenue	J-28	383/45					Rough rock path leads 10 feet through vegetation onto a cobble beach. "No Parking" signs are posted all over road-end.

1 Match locator number with numbers in Figures 12-15 to determine public access location.

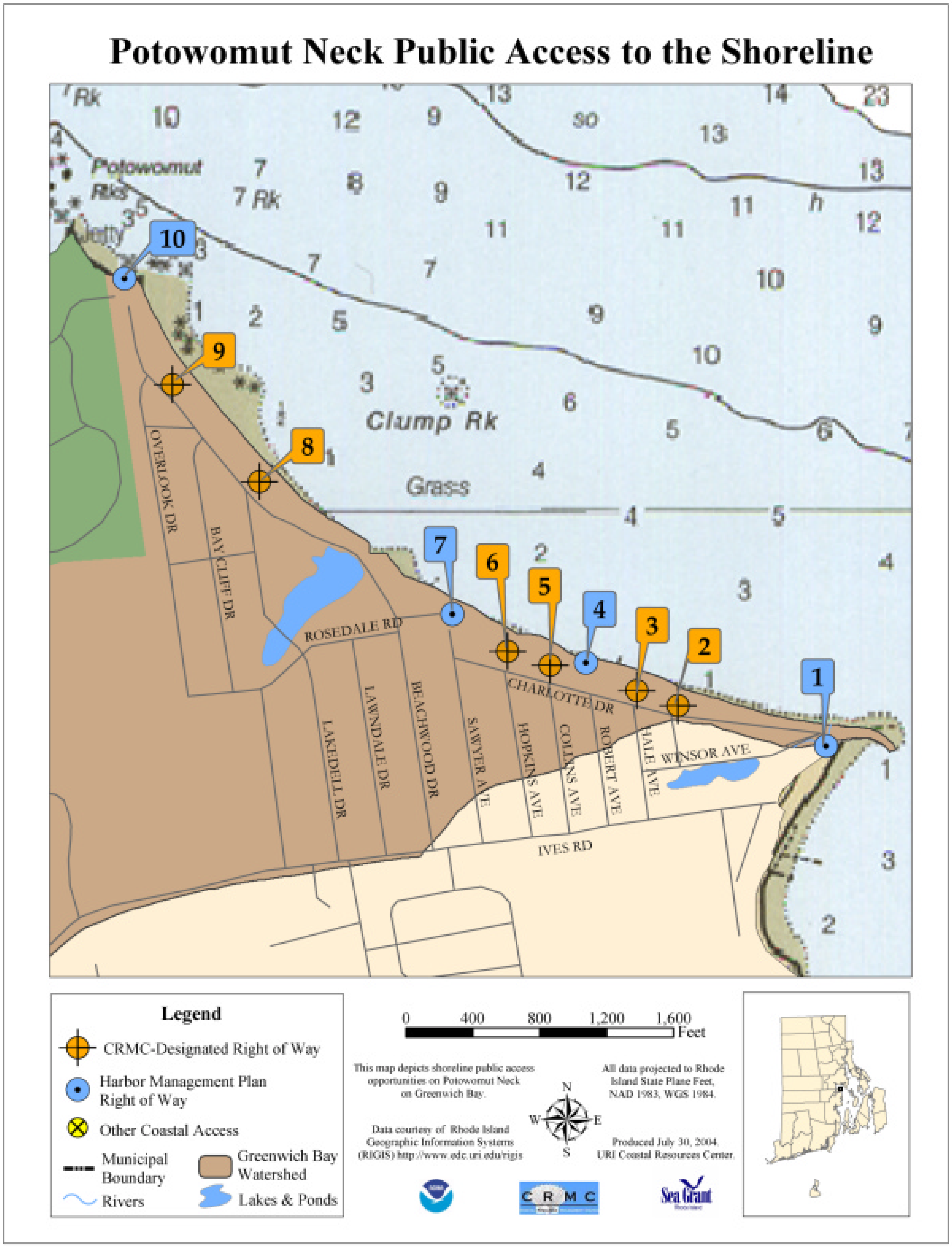
Source: Pogue and Lee 1993; CRMC 2004; RISAA 2003; Warwick Harbor Management Plan, 1996; Littell et al. 1988

Figure 12. Greenwich Bay public access to the shoreline [1]



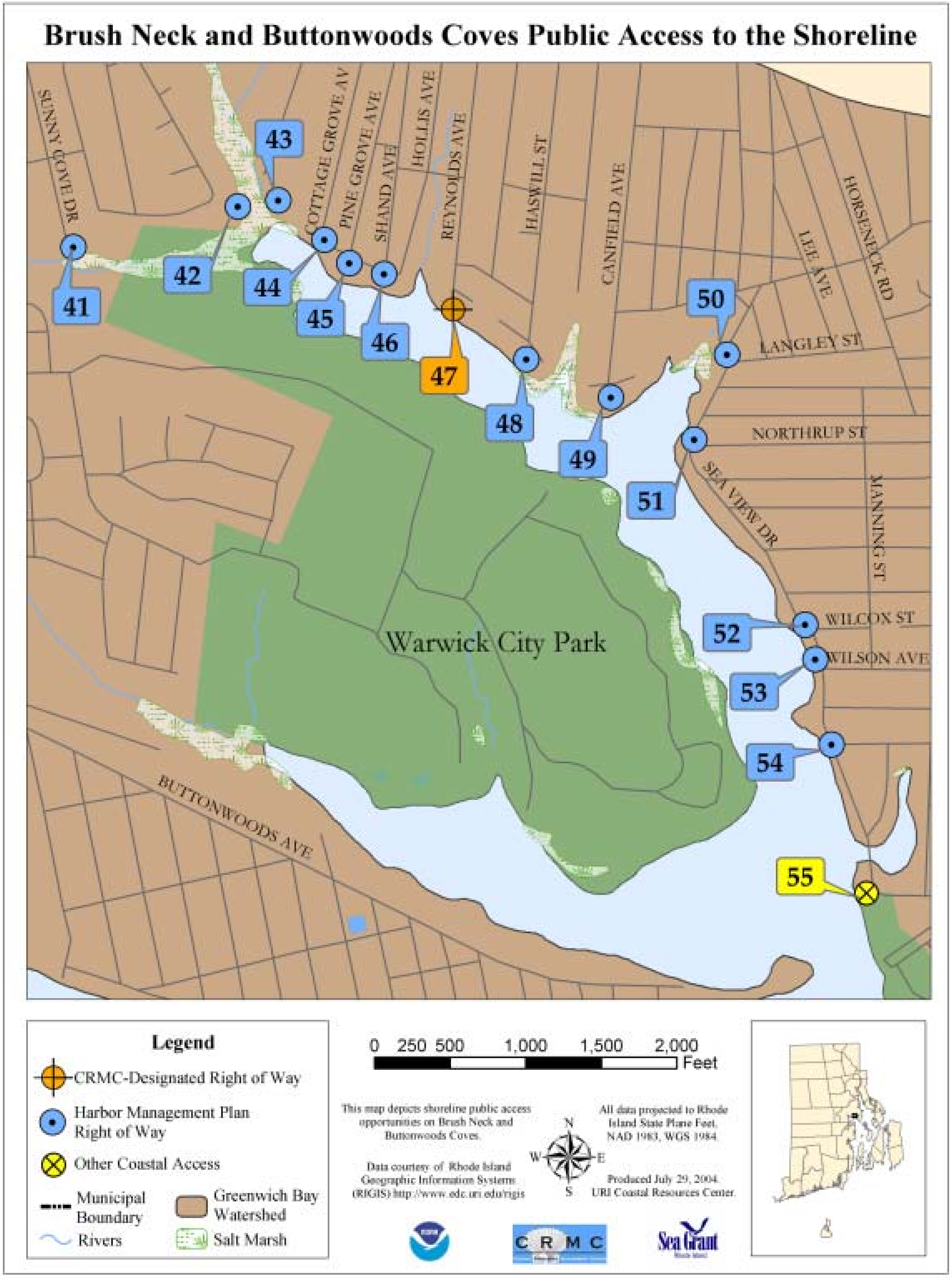
1 See table 9 for description of public access sites.

Figure 13. Potowomut Neck public access to the shoreline [1]



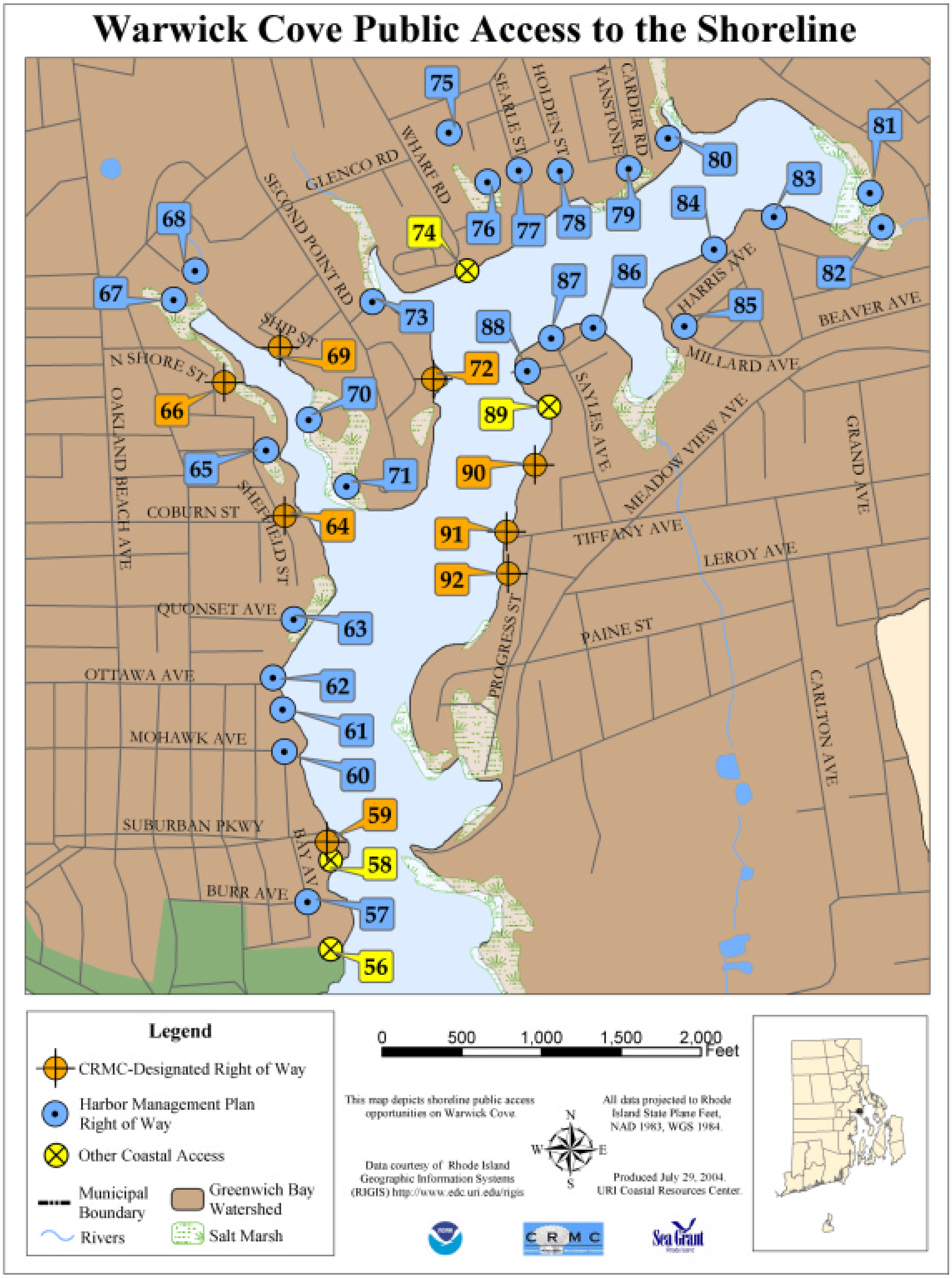
1 See table 9 for description of public access sites.

Figure 14. Brush Neck and Buttonwoods Coves public access to the shoreline [1]



1 See table 9 for description of public access sites.

Figure 15. Warwick Cove public access to the shoreline [1]



1 See table 9 for description of public access sites.

760.1 Public rights-of-way to the shoreline

1. Public ROWs are strips of land that the public has a right to pass over on foot and, in some cases, by a vehicle. ROWs may provide a path to the shore, a ramp to launch a boat, a point from which to fish, or a scenic view. They are not necessarily publicly owned lands; a public ROW may be recorded as an easement that allows the public to pass over a private property. CRMC recognizes six types of legally established public ROWs in Rhode Island:

- Roadways that have been laid out, recorded, opened, and maintained by a city or town council
- Highways by grant or use
- Ways that have been approved by recordation of a subdivision plat
- Ways that have been offered to the public by dedication and accepted by public use or by official city or town action (implied dedication)
- Highways that have been used by the public since time immemorial
- Ways that have been obtained by the public's adverse use

In addition to CRMC-designated ROWs, established public ROWs to the shoreline have been recognized in East Greenwich and Warwick harbor management plans, and are primarily highways and roadways platted to the water.

2. CRMC is responsible under state law for designating public ROWs to tidal waters. CRMC designation process does not create public ROWs or determine site ownership, but does formally recognize public ROWs and helps resolve any disputes over the existence of a public ROW. In addition, private landowners receive limited liability protection when CRMC designates a public ROW. Finally, a municipality cannot abandon a CRMC-designated ROW without prior CRMC approval.

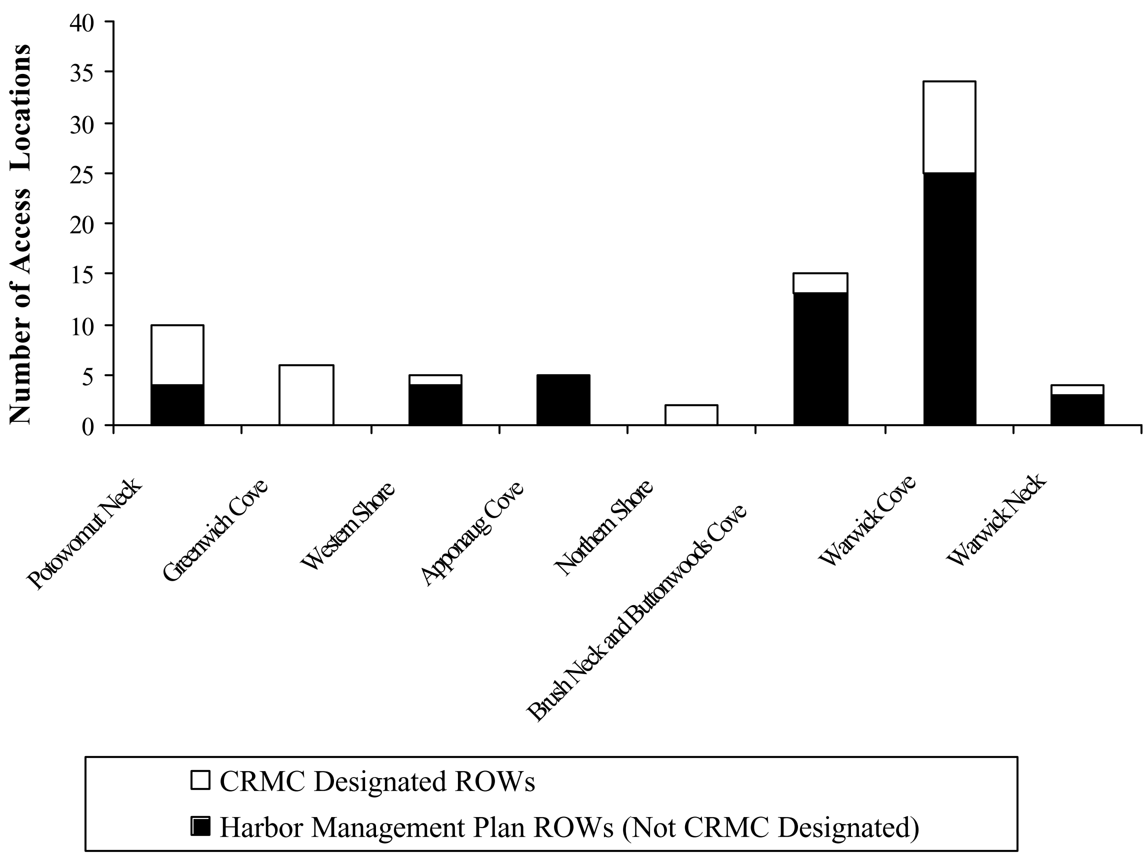
3. Over the last seven years, CRMC has received only $5,000 annually in federal funding for ROW designation and no state monies, limiting the number of public ROW designations that can be made.

4. Public ROWs make up the majority of public access sites on Greenwich Bay. There are 79 total public ROWs that are recognized in municipal harbor management plans, and 27 of these are also CRMC-designated ROWs along the Greenwich Bay shoreline.

5. Numerous public ROWs are located along Greenwich Bay (Figure 16). Potowomut Neck, Greenwich Cove, and Warwick Cove contain the most CRMC-designated ROWs in Greenwich Bay. Numerous harbor management plan ROWs are located along Warwick, Brush Neck, and Buttonwoods coves. However, the western and northern shore of Greenwich Bay, Apponaug Cove, and Warwick Neck have a limited number of public ROWs, although public access to the western shore is enhanced by access to Chepiwanoxet Point and to Apponaug Cove by other types of coastal access, such as boat ramps and private association paths to the shore (Figure 12). Greenwich Cove has few public ROWs, but its entire eastern coast is part of Goddard Memorial State Park. The longest distance along the shore between access locations is about 2 miles

between CRMC-designated ROW at Sylvia Drive (J-9) and the edge of Warwick City Park through the private Buttonwoods neighborhood.

Figure 16. Number of public rights-of-way (ROWs) to Greenwich Bay by region



6. CRMC has funded Rhode Island Sea Grant to do additional legal research into designating public ROWs as part of SAMP development. With assistance in identifying sites from Warwick, research has been completed on eight sites along Greenwich Bay: Alger Avenue near Chepiwanoxet Point; Midgley Avenue and Arnolds Neck Drive on Apponaug Cove; Powhatan Street and Sea View Drive on Brush Neck Cove; and Burr Avenue, Capen Street, and Millard Avenue on Warwick Cove. These sites are now ready to be considered by CRMC for ROW designation.

7. Most of the public ROWs along Greenwich Bay and its coves are poorly marked, making them difficult to find. Rhode Island Sea Grant public access surveys showed that CRMC signs are only posted at nine ROWs (Table 9). In general, compared with Warwick, CRMC-designated ROWs in East Greenwich were easier to find and had signs posted. No survey data is available for the majority of the 54 public ROWs that are only designated in the municipal harbor management plans.

8. Parking was available at a little over half of the 27 CRMC-designated ROWs (Table 9). Many public ROWs are situated between privately owned homes, where there is little or no parking available. In some cases, "No Parking" signs are posted, such as at Nausauket Road (J-24) and Narragansett Bay Avenue (J-28). Municipalities may post these signs to ensure that emergency vehicles can traverse roads quickly and safely. Limited on-street parking is available in some locations, such as at the six public ROWs along Charlotte Drive. Under a recent Rhode Island Superior Court ruling, parking may be developed in public ROWs if space is available (CRMC, 2004).

9. Many public ROWs are not well maintained. Paths are overgrown or cluttered with garbage and debris. The Rhode Island Sea Grant surveys identified at least eight CRMC-designated ROWs where access was essentially unavailable due to poor maintenance (Table 9). In most of these cases, the ROW is overgrown with vegetation, such as at Rocky Hollow Road (H-2), Masthead Drive (J-37), Off Ship Street (J-30), Cooney Street-Off Cooney Street/Extension of Lilac Street (J-14 and J-33), and Tiffany Avenue/Progress St. (J-26). In a few cases, debris and other objects may block access, such as at North Shore Street (J-12).

10. CRMC and RISAA have partnered to develop an Adopt-A-ROW program for maintenance, improvements, and posting signs. (Cute pers. comm.).

760.2 Other coastal access sites

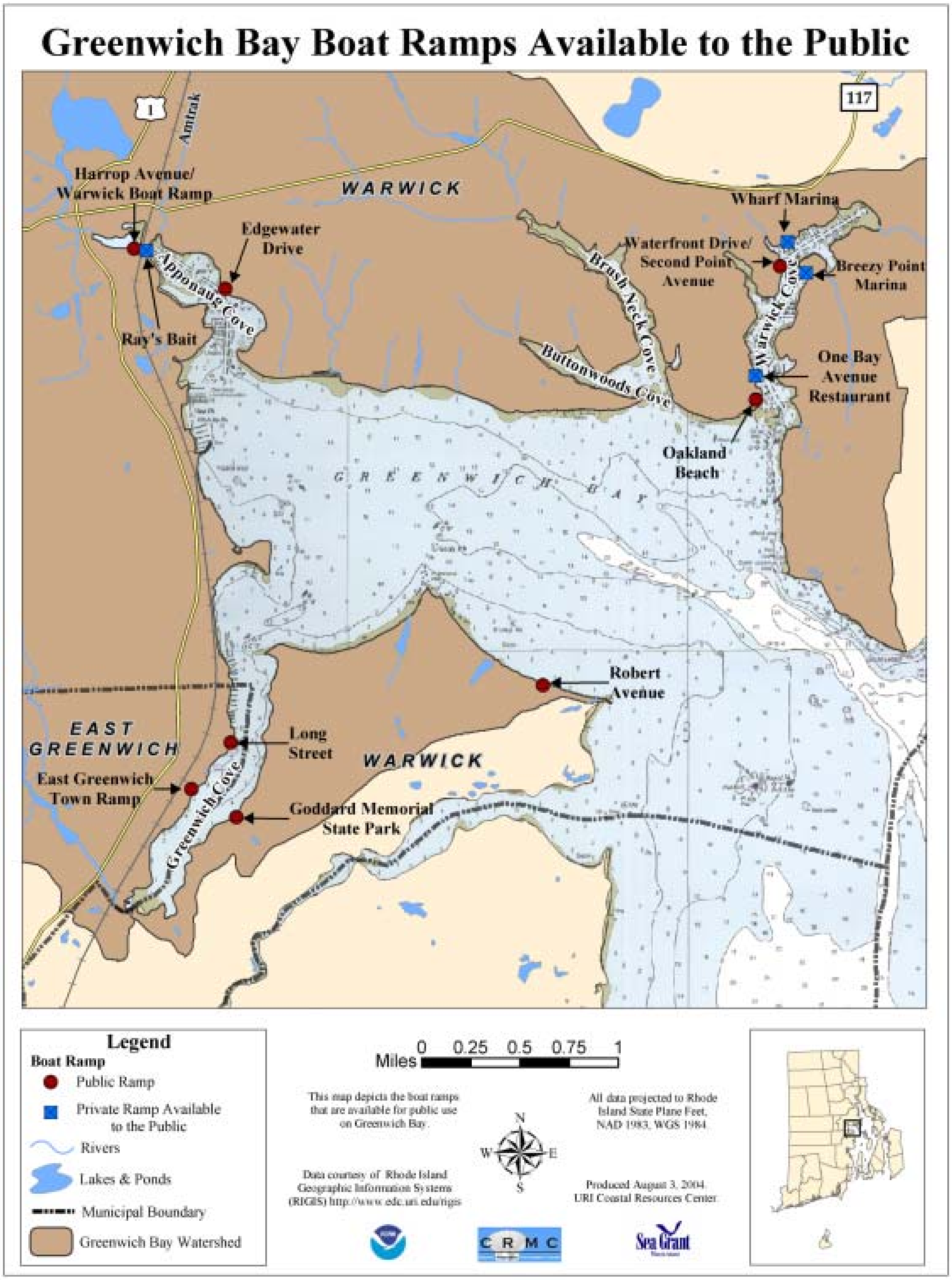
760.2A Boat ramps

1. Greenwich Bay has eight public boat ramps and four private boat ramps as available to the public for a fee found (Table 9). Some Greenwich Bay coves offer boat ramps that are accessible to the public (Figure 17).

2. Lack of parking and poor maintenance make many ramps around Greenwich Bay difficult to use. Boat ramps at Long Street on Greenwich Cove and Waterfront Drive/Second Point Avenue on Warwick Cove do not have parking. Some sites with good parking, such as the boat ramp at Goddard Memorial State Park, do not have sufficient depth to launch most boats except at higher tides. The ramps at Robert Avenue on Potowomut Neck, Harrop Avenue/Warwick city ramp on Apponaug Cove, and Waterfront Drive/Second Point Avenue can also only be used during high tides. Deteriorating ramp conditions are also a problem. The asphalt ramps at the Harrop Avenue/Warwick city ramp and the Robert Avenue ramp are crumbling. The ramp off Edgewater Drive on Apponaug Cove is gravel and sand, and is only appropriate for launching small boats. Edgewater Drive is a dirt road that is underwater during high tides. Residents are also concerned about the road conditions along Edgewater Drive (Fritz pers. comm.) although Warwick does grade and level the road annually (Geagan pers. comm.). Finally, the historic gravel boat ramp at the foot of Ocean Point Road (formerly Arch Road) at Chepiwanoxet has been blocked and lost to public use (Ross pers. comm.).

3. Public access to boat ramps has been enhanced significantly in recent years at two locations on Greenwich Bay. Warwick, FWS, and RIDEM cooperated to construct the two-bay handicap-accessible ramp at Oakland Beach (Warwick Harbor Management Plan, 1996). The ramp has parking along with sufficient depth to launch at low tides. East Greenwich recently lengthened and widened the town ramp and dock on Greenwich Cove. The improvements were made as part of a state-funded project to establish a high-speed ferry leaving from Greenwich Cove although there are no current plans to begin ferry service.

Figure 17. Greenwich Bay boat ramps available to the public



760.2B Marinas

1. Except for yacht clubs, where membership is required, marinas along Greenwich Bay provide public access to the water, generally for a fee. In some cases, marinas provide public access and parking free of charge or for a minimal charge. RISAA indicates that Breezy Point Marina, One Bay Avenue Restaurant, and Wharf Marina in Warwick Cove, and Ray's Bait and Tackle in Apponaug Cove allow the public to use their boat ramps for a fee. In addition, CRMC requires any new marinas or marinas with significant expansions to develop a public access plan unless a variance is granted. In this case, the public access requirement is stipulated in the permit.

2. Greenwich Bay Marina South and Apponaug Harbor Marina both have public access requirements stipulated in their CRMC permits. Greenwich Bay Marina South is required to set aside parking spaces for the public. However, these spaces are not currently marked as available to the public. Apponaug Harbor Marina maintains a footpath to Long Point, a popular bass fishing spot, for public use as part of its permit. In addition, a porta-potty dump and pump-out facility can be used by the public from May 15 to October 31, and the parking lot is open to the public.

3. Greenwich Bay's marina owners have expressed concerns over potentia1 vandalism and liability associated with public access. However, state law does provide limited liability protection to marina owners if CRMC requires the public access as a condition of granting a permit. Under this protection, the marina owner generally does not "assume responsibility for or incur liability for any injury to any person or property caused by an act of omission of that person" if the owner does not charge for access to the property (R.I. Gen. Laws §32-6-3).

760.2C Parks, beaches, and recreation areas

1. Public parks, beaches, and recreation areas provide access to about 6 miles or nearly 25 percent of the Greenwich Bay shoreline, covering more than 727 acres.

Goddard Memorial State Park

1. Goddard Memorial State Park covers 482 acres along approximately 2.6 miles of shoreline bordering southern Greenwich Bay and eastern Greenwich Cove. Recreational activities and areas include a handicap-accessible beach, a boat ramp, a pavilion and bathhouse, saltwater fishing, a nine hole golf course, an equestrian show area, 18 miles of bridle/walking trails, recreation paths, fire pits, and portable stove areas with picnic tables, 11 game fields, and a performing arts center for special events (Gibbs et al., 1995; RIDEM, 2001). The park is the state's third most-visited park (Table 10) and generates revenue from facility rentals and golf course fees..

2. Since 1998, there have been more than 93 beach closures at Goddard Park because of bacterial contamination. In addition, concerns have been raised that beach

nourishment will be needed. Finally, the boat ramp, while providing ample parking, does not have sufficient depth to launch most boats at low tides.

Table 10. Annual attendance at five most-visited Rhode Island state parks

State park	Attendance		
	2000	2001	2002
Colt	1,285,389	1,436,777	1,413,579
Lincoln Woods	1,204,093	1,108,917	1,393,122
Goddard	749,300	784,563	1,006,391
Scarborough North & South	572,033	762,002	796,145
Fort Adams	754,299	773,812	684,416

Source: RIDEM, Parks and Recreation Dept.

Warwick City Park

1. Warwick City Park is a 196-acre municipally owned park with an approximately 1.9-mile shoreline along Brush Neck and Buttonwoods coves (Figures 12 and 14). City Park features 3 baseball fields, a 2.7-mile paved bike/walking path, basketball and tennis courts, picnic areas, playgrounds, a beach with boardwalk, benches, and bathrooms. The beach is 350 feet long with a gradual slope that is protected from waves by the Buttonwoods peninsula. Shore birds and other coastal wildlife can be seen at the wetland areas at the ends of the beach.

2. Swimming at Warwick City Park is primarily limited by beach closures and erosion. Since 1998, the City Park beach has been closed 84 days due to bacterial contamination, and in 2002, approximately 3,000 cubic yards were lost to beach erosion during winter storms (Rooney pers. comm.). Beach nourishment is the primary option to mitigate erosion at the beach since Brush Neck and Buttonwoods Coves are classified as Type 1 waters, prohibiting shoreline protection structures.

Oakland Beach

1. Oakland Beach is a 27-acre municipally owned waterfront park with a two-third mile shoreline on Greenwich Bay bridging the mouths of Warwick, Brush Neck, and Buttonwoods coves (Figure 12). In the early part of the 20^{th} century Oakland Beach featured amusement rides, and a trolley line brought visitors from Providence.

2. Oakland Beach is 1,000 feet long, with views of Greenwich and Narragansett bays. The shoreline is engineered, as evidenced by the rock groins, and designed to contain sand and prevent erosion. The beach has lifeguards in the summer, and there is also a grassy commons area, a ballfield, parking, and nearby concessions. The two-bay handicap-accessible boat ramp at Oakland Beach has sufficient depth to launch at

low tides and parking available for trailers (Warwick Harbor Management Plan, 1996).

3. Oakland Beach was closed to swimming for more than two-thirds of the three-month 2003 bathing season. As at Warwick City Park, the Warwick Parks and Recreation Department suspects beach closures are largely responsible for a 51 percent decline in revenue and attendance at Oakland Beach in 2003. Beach closures may also lead to a decline in revenue for surrounding businesses. A Warwick Beacon editorial noted that patron numbers were down at Oakland Beach restaurants in 2003, whereas waterfront restaurants in other areas were experiencing normal summer business.

4. Beach erosion is a chronic problem at Oakland Beach. Oakland Beach and its associated structures were almost completely destroyed by the 1938 hurricane. Warwick purchased the land and, attempting to control further erosion, constructed a seawall abutting the parking lot, installed seven wooden groins along the western beach, and installed one terminal groin at the eastern most portion of the beach. These structures deteriorated and the beach receded by approximately 1 to 2 feet per year due to the combined effects of wave activity and minimal sediment input (LeBlanc and Bottin, 1992). In the mid-1970s, the eastern beach was eroded, leaving no dry sand above the mean high water line. Warwick requested the help of USACE to solve the problem (LeBlanc and Bottin, 1992).

5. The USACE erosion study examined the effects of tides, winds, waves, littoral (the region or zone between the limits of high and low tides) drift, and currents, along with beach profiles and sand samples. Based on the study, USACE concluded that the beach erosion is primarily a result of more frequent winter storms, although hurricane winds do affect Oakland Beach. Due to the configuration of the beach and surrounding land, only waves approaching from the southeast through the southwest seem to have a significant impact on beach erosion (LeBlanc and Bottin, 1992). The water depth has a greater effect on the size of waves hitting Oakland Beach rather than the fetch or wind duration. Littoral drift and current studies indicated minimal drift in a westward direction but did show increased sediment transport during flood tide and storm waves. Further studies indicate the sediment type as fine-grained sand and silt, which is easily moved by tidal or wave activity.

6. USACE designed a beach erosion control project based on the results of the erosion study. The beach erosion control project, pursuant to the authority of section 103 of the 1962 Rivers and Harbors Act, as amended, was authorized in April of 1980 (LeBlanc and Bottin 1992). The project involved widening the beach on either side of the existing seawall to a backshore elevation of 8.0 feet above mean low water. A medium-grained coarse sand was chosen and imported from Coventry in the hopes that it would be less likely to be carried away (S. Onysko, Project Engineer, personal communication to N. Ross). Four high groins, one low-profile groin, and a rock revetment in front of the sea wall were added. This project resulted in a 100-foot wide recreational beach area and plans for periodic nourishment over the 50-year economic

cycle of the project (LeBlanc and Bottin, 1992). This project was completed in August of 1981. However, the center cell in front of the revetment never received any nourishment even though it was part of the project plan. Thus, no beach area currently exists in this area.

7. Erosion and accretion was monitored at Oakland Beach from April 1982 to April 1985 as part of the Monitoring Completed Coastal Projects (MCCP) Program. An analysis of the littoral transport at Oakland beach was conducted and the erosion and accretion rates were determined (Table 11). These data constitute the most recent erosion/accretion data for Oakland Beach. Overall, this study determined that Oakland Beach was reaching stabilization but, over time, due to littoral transport and collection on the western side of the groins, the beach would need to be reshaped and graded to minimize sand loss.

Table 11. Erosion and accretion rates for Oakland Beach [1]

Survey dates	Net sediment transport (cubic yards)			
	Reach 1	Reach 2	Reach 3	Total
Sept. 1982 & Sept. 1983	-18,920	-950	+8,530	-11,340
Sept. 1983 & Sept. 1984	+670	-1,560	+8,990	+8,100
April 1983 & May 1984	-6,770	-7,750	-4,760	-19,280
May 1984 & March 1985	+290	+4,210	+11,230	+15,730

1 For the survey, the beach was divided into 3 reaches. Reach 1 included the east beach area. Reach 2 was the revetment area. Reach 3 was the west beach area.

Source: LeBlanc and Bottin 1992

8. Since the USACE beach erosion control project in 1981, Oakland Beach has not been the focus of a major nourishment project despite the continued transport of sediments around the eastern tip of Oakland Beach and the shoaling within the mouth of Warwick Cove.

Chepiwanoxet Park

1. Chepiwanoxet Park is a 10-acre recreation area with a two-third mile shoreline on the western shore of Greenwich Bay (Figure 12). Historically, Chepiwanoxet Point (formerly an island) has been used as a commercial and industrial area. It was home to the Gallaudet Aircraft Company from 1915 to 1922, a seaplane manufacturer, and home to a marina and industrial area until the 1960s (Stevens et al.,1996). AMTROL Corporation and Dyer Boats began at Chepiwanoxet (Ross pers. comm.). In 1994, Warwick purchased Chepiwanoxet Point to protect it from proposed condominium and marina development (Warwick Harbor Management Plan, 1996).

2. Chepiwanoxet Park currently exists as an undeveloped public recreation area. Visitors can walk along dirt trails around the point and enjoy panoramic views of Greenwich Bay and its coves. Traditionally, the area has been a popular location for recreational fishing and shellfishing (Warwick Harbor Management Plan, 1996). The eastern face of Chepiwanoxet Point was once a sandy beach, but industrial dumping of rock and metal wastes make the shore unsafe for swimming (Ross pers. comm.). There is limited parking on-site at a dirt lot at the entrance.

3. The major recreational issue at Chepiwanoxet Point is enhancing its use as a recreational area without compromising its natural condition. The recreation area can be hard to find from main roads. Nuisance plants, such as *Phragmites* and poison ivy, may need to be controlled as well. There are few amenities that promote its current uses as a walking and fishing area.

East Greenwich landfill

1. The old site of the East Greenwich landfill is currently vacant land at the southern end of Greenwich Cove (#12 on Figure 12). The landfill site covers 12 acres with one-third mile of shoreline on Greenwich Cove. The landfill is closed to the public while the town works with RIDEM to officially close the site as a landfill and remove it from the federal list of potentially contaminated sites. The town is working with RIDEM and a consultant to develop a closure plan (Walusiak pers. comm.). East Greenwich will likely cap the site with clean fill and then use it as a passive or active recreational facility (Sequino pers. comm.). A bike path through the site has been proposed as part of the Warwick-East Greenwich Bicycle Network (Marshall pers. comm.). It is estimated the landfill closure and subsequent development will cost $3.2 million.

Arnold's Neck Park

1. Arnold's Neck Park in Warwick is a public park on the western shore of Apponaug Cove (#30 on Figure 12), created in 1963 by USACE with fill dredged from Apponaug Cove's federal channel and anchorage (Ross pers. comm.). Hawks, geese, and ducks in the fringing marsh across the cove may be observed from the park. Parking is available for approximately 60 cars and trailers. There are picnic tables, a municipal dock, and a restaurant nearby. Offshore is a public mooring area.

Barbara M. Tufts Playground

1. Barbara M. Tufts Playground in East Greenwich is a municipally owned play area off Water Street (#16 on Figure 12) that offers playground equipment, picnic tables, and views of Greenwich Cove and Goddard Memorial State Park.

Community beaches

1. Unlicensed community beaches have traditionally been used by residents around Greenwich Bay. Seaview Beach in Warwick is an unlicensed beach at the west end of Suburban Parkway across Brush Neck Cove from Warwick City Park and adjacent to the tidal channel (#55 on Figure 14). Although this site is not well maintained, it is traditionally a popular local spot for soft-shell clam digging, although currently areas of the site are closed to shellfishing due to pollution. Swimming is not advised because there are no lifeguards on duty and there are strong currents in this area. On-site parking is available behind the beach. Beaches along Potowomut Neck, Chepiwanoxet, Cedar Tree Point, Nausauket, and Buttonwoods traditionally provide recreational opportunities where public access is available. All these beaches, with the exception of Buttonwoods, have public access to the shoreline (Figure 12). Because these beaches are not licensed, they are not monitored for bacterial contamination and do not necessarily have buoys alerting boaters to swimming activity. Therefore, these sites are a higher risk for swimming than the public licensed beaches around Greenwich Bay. Another issue at these beaches is erosion. Residents report beach erosion, such as at Cedar Tree Point (Fritz pers. comm.) and Chepiwanoxet (Ross pers. comm.).

760.2D Private association access

1. Neighborhoods around Greenwich Bay, such as at Cedar Tree Point and Buttonwoods, may provide shoreline access to member residents, who may extend this access to visitors. At Cedar Tree Point, three public ROWs to the shoreline are available, although only one site is clearly marked with parking available (Figure 12, Table 9).

760.3 Shoreline access

1. Marinas, residential docks, and other structures perpendicular to the shore can restrict public access and navigation along shores that have historically been open for boating, swimming, fishing, and walking. RISAA and citizen groups have expressed concerns over the loss of access along the shore, particularly along Potowomut Neck, and loss of canoe and kayak navigation near the shore. Currently, marinas cover approximately 2.6 shoreline miles of Greenwich Bay and its coves, and residential docks 3/4 of a mile of shoreline. Together, marinas and residential docks affect 13% of the shoreline, especially along Warwick Cove, Apponaug Cove, and Potowomut Neck. Looking forward, potential marina expansions and new residential dock construction could increase the miles of shoreline affected (Figures 5-7).

760.4 Warwick-East Greenwich Bicycle Network

1. The Warwick-East Greenwich Bicycle Network, established by Warwick, East Greenwich, and the R.I. Department of Transportation (RIDOT) provides a nearly complete bike route around Greenwich Bay (Figure 18). The majority of the bike network is on existing roads with signs directing bikers and alerting motorists.

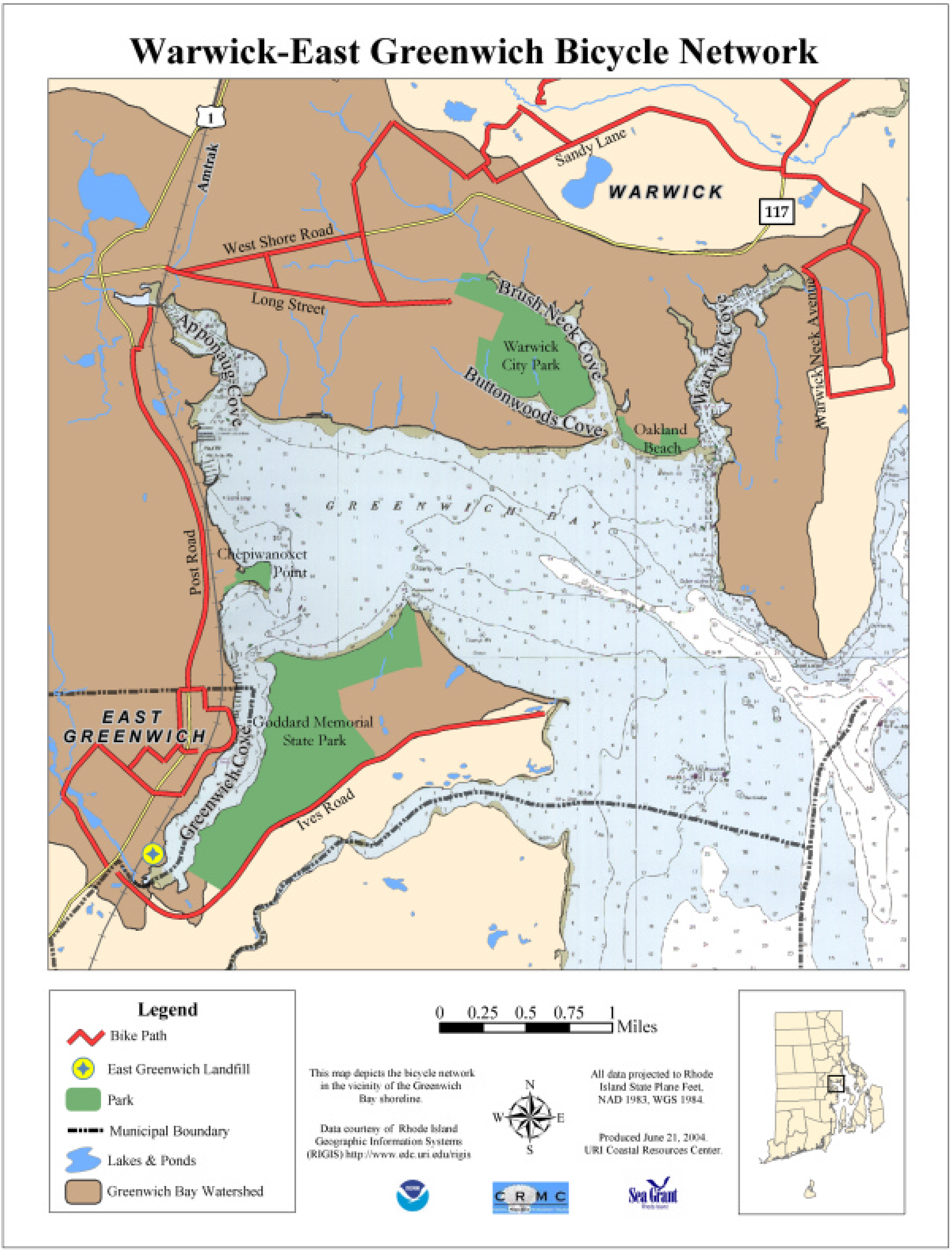
2. There are two major sections of the bicycle network around Greenwich Bay. The first section runs from Sandy Point on Potowomut Neck down Ives Road, with a connection to Goddard Memorial State Park, through East Greenwich, and ends at Arnold's Neck Drive on Apponaug Cove. Along Greenwich Cove, the bicycle network provides a waterfront route down Crompton Avenue and Water Street and a historic route along Peirce Street to First Avenue (Barbara Sokoloff Associates, Inc. et al., 1999). In addition, a multi-use path specifically for pedestrians and bicyclists has been proposed for construction along Greenwich Cove through the former East Greenwich landfill. This path could be completed as soon as 2006 (Marshall pers. comm.).

3. The bicycle network's second section begins at the intersection of Post Road and Colonial Avenue in Warwick's Apponaug district and runs down West Shore Road/Route 117, continues along Sandy Lane, and towards Warwick Cove. There are connections to Warwick City Park down Long Street and Buttonwoods Avenue from West Shore Road/Route117. An extension to Oakland Beach is also planned and is expected to be completed by 2006 (Marshall pers. comm.).

4. Bike paths connect recreational and other cultural opportunities around Greenwich Bay. While not a substitute for parking, the Warwick-East Greenwich Bicycle Network provides an alternative means to visit public ROWs, coastal parks, and other coastal access points on the Greenwich Bay shoreline, particularly on Potowomut Neck. Bikers may also continue along bike paths within the larger parks, such as Goddard Memorial State Park and Warwick City Park.
In addition, an extension to Chepiwanoxet Park from the current network could promote the park's use with relatively low impact or cost. The bicycle network could provide a seamless route between Greenwich Bay neighborhoods and major recreational areas.

5. Bike paths along the Greenwich Bay shoreline are limited by safety concerns, including high traffic and narrow lanes (City of Warwick, 2003). In addition, citizens may have concerns with noise and privacy when bike paths, particularly constructed multi-use paths, are proposed in their neighborhoods. A proposed multi-use path that would have been part of the Oakland Beach extension was eliminated based on citizen concerns (Marshall pers. comm.).

Figure 18. Warwick-East Greenwich bicycle network



Section 770
Dredging

1. Dredging in Greenwich Bay and its coves is needed periodically to maintain recreational uses and potentially improve habitat. Dredging is "in the interest of the state in order to protect public health and safety, to enhance environmental quality, and to preserve the recreational opportunities and promote the economic well being of the people of the state" (R.I. Gen. Laws §46-6.1-2). Currently, maintenance dredging at Greenwich Bay's boating facilities as well as the federal channel in Apponaug Cove is needed, particularly as boats grow larger with deeper drafts. Potentially, dredge material from these projects could be used to nourish eroding beaches along the Greenwich Bay shoreline.

2. Some believe that current regulatory measures impede dredging projects. While some measures may need to be reevaluated, such as RIDEM criteria for levels of metals and arsenic in dredge material suitable for beach nourishment, most regulatory measures, such as dredging timetables and physical barriers, are important safeguards that minimize potential dredging impacts on fish, wildlife, and people.

770.1 Current water depths in Greenwich Bay, its coves, and channels

1. There are three federal navigation dredging projects within the SAMP area. These channel projects are Apponaug Cove, Warwick Cove, and Greenwich Cove. There are no state channels within the SAMP area.

2. Apponaug Cove's channels, mooring areas, anchorages, and private facilities are all experiencing shoaling. The federal channel was last maintained in 1963 and currently is significantly shoaled with approximately 4 feet of depth in the channel, 2 feet less than the authorized depth. This project has a low priority due to its limited commercial use—USACE considers marinas are recreational facilities, not commercial ones—compared to the costs of dredging and disposing of the material.

3. Warwick Cove's channel is at authorized depth, but marinas are experiencing significant shoaling. The federal channel was last maintained in 1966. The sandy delta at the entrance of the cove, which forces the channel to the east, existed when the channel was authorized by Congress in 1965. The easterly turn follows naturally deeper water that tends to shoal slowly. USACE performed a condition survey of the entire channel during the winter of 2003–2004. The survey indicates minor channel shoaling. The channel is essentially at the authorized depth (6 feet below mean low water) for its authorized 150-foot width and is in the location authorized by Congress. Therefore, the channel does not warrant any federal action. However, the current channel configuration is difficult and dangerous to navigate, according to users. Straightening the channel could improve navigation. In addition to the channel, Warwick Cove has one of the highest densities of marinas in Rhode Island. Many of these marinas are experiencing significant shoaling resulting in slip loss or slips that can only be used during higher tides. The type of

material that will need to be dredged as well as the rate at which it accretes varies significantly within the cove.

4. The mouth of Brush Neck and Buttonwoods coves is also experiencing shoaling. The mouth is primarily the remains of a flooded tidal delta. The continued shallowing of this area is due, in part, to sediment overwash from the1938 and 1954 hurricanes in addition to erosion from the shoreline and upper shore face. While Buttonwoods Cove is almost inaccessible and too shallow for boat traffic, Brush Neck Cove is still accessible for now.

5. The Greenwich Cove project area was last dredged in the late 1800's and is not considered a priority by the State or USACE.

770.2 Dredging needs

1. The biggest dredging needs facing Greenwich Bay and its coves are the federal channel dredging in Apponaug Cove and maintenance dredging at marinas. Boats have been getting bigger, requiring deeper drafts, a trend in conflict with past perceptions and state policies that limited dredging in recreational marinas, as well as most other facilities. The increasing draft of recreational boats, controversy over dredging, and past state dredging policies have created a significant backlog for dredging at boating facilities.

2. Shoaling and deeper draft boats create a regular need for maintenance dredging at Greenwich Bay's marinas. Marinas will continue to shoal and boats are likely to get bigger with deeper draft. This combination will pressure marinas to dredge. The dredge material from the marinas in Greenwich Bay and its coves ranges from sand suitable for beach nourishment (only a select few marinas) to silt that takes a long time to dry and is suitable only for select reuse projects, if at all. A comprehensive dredge material management plan, not only for Greenwich Bay but for the state, with a full spectrum of predictable disposal options, could be an environmentally and economical solution to this long-term problem.

3. The federal navigation project in the Providence River (2003–2004) enabled all Rhode Island water-dependent owners to "piggy-back" onto the project and dispose of dredge material in confined aquatic disposal (CAD) cells. The state provided an expedited permit process and waived permit fees to help these small businesses. The CAD cells allowed cost-effective dredge material disposal ($11.65 per cubic yard) regardless of the contamination level. Seven marinas from within the SAMP area have either dredged or are in the permit process to dredge. As of January 2005, the proposal is to keep the CAD cell open to receive dredge material for at least five more years and take advantage of additional capacity as materials settle in the cell. Clean dredge material would eventually be used to cap the cell (Walker pers. comm.).

770.3 Dredging methods and limitations

1. There are two main types of dredging that are suitable within Greenwich Bay and its coves: mechanical dredging, which is typically accomplished with a clam-shell bucket mounted to a crane on a barge (or sometimes an excavator), or a hydraulic cutter-head dredge. The equipment used for a project depends on most importantly on the reuse or disposal type and location for the dredge material, and also on the physical properties of the dredge material. In general, hydraulic dredging is used only for sandy material for beach nourishment, while mechanical dredging is used for all other projects.

770.4 Potential impacts at dredge project locations

770.4A Turbidity

1. Dredging has the potential to create turbidity with negative impacts on aquatic species. The re-suspension of sediment during dredging increases turbidity that can degrade water quality and primary productivity (Ingle 1952, Kaplan et al. 1974). Resuspended sediment can settle and smother sea grass beds and shellfish beds, clog the gills of fish, and alter the character of the bottom substrate (Saila et al. 1972, Carriker 1967). Turbidity may be produced during digging and from overflow while loading material on a barge. The most important considerations in determining potential turbidity impacts is proximity to sensitive areas and grain size of material. A sandy material has very low potential to generate turbidity while a silty material has a higher potential.

2. The effects of turbidity are managed in two ways. First, dredging is limited to times of the year when the biological activity of sensitive non-mobile aquatic species is low. Second, physical barriers, such as a turbidity curtain or an enclosed bucket, are used to limit turbidity. The typical dredge project is required to dredge during November and December of each year without turbidity controls. When dredging occurs outside of that window, the material type and the estimated life-stage of animals in the area are evaluated on a case-by-case basis to determine further turbidity controls.

770.4B Shellfish

1. The largest impact dredging has on shellfish is impacts at the dredge site. Since most shellfish are in the sediment during the normal dredge windows, the impact is removal from the area. For marinas, which are not open for shellfishing, maintenance dredging's impact to the resource is the potential loss of breeding stock. Greenwich Bay plays a significant role in protecting the brood stock of quahogs and supplies incredible numbers of quahogs for transplantation to areas where commercial shellfishing is allowed (Ganz et al. 1994). However, the potential impact of maintenance dredging is difficult to quantify because the quantity of spat from shellfish immediately outside of the impacted area may also be large and the ability to quantify the loss to the overall system is based on best professional judgment rather than measurable indicators. Discussions on mitigating any impacts from maintenance dredging on shellfish are currently occurring

between CRMC and RIDEM. Mitigation has been to remove and transplant them prior to dredging.

770.4C Finfish

1. Dredging's effect on finfish are typically limited to early in their life-cycle when finfish are sensitive and non-mobile. The most important and managed species of concern is the winter flounder. It is challenging to find eggs and early life-stage fish, so habitat substrate and location are used to indicate the potential presence of winter flounder. Turbidity and removal are the biggest potential impacts on finfish. Turbidity controls have been discussed previously. The only other method used in avoiding impacts is implementing dredge windows outside of typical breeding times. Determining dredge windows is difficult with many variables impacting the time and conditions for breeding. Consequently, a conservative dredge window is currently used to protect finfish populations. This conservative window has led to complaints from dredge project proponents, although there is a system in place for extension of the window. However, proponents feel the extension process is an additional, and sometimes burdensome, process.

770.5 Dredge disposal options

1. Disposal options are limited within Greenwich Bay. In order of preference, options are beneficial reuse, upland disposal, or possibly open-water disposal in the bay or offshore. Beneficial reuse consists of beach nourishment, habitat creation, habitat restoration, cover material for landfill closures, and fill for marine structure repair, in that order. The chemical and physical properties of the material and site constraints limit its potential uses. Other limiting factors are the levels of natural and manmade elements in the material. For example, dredge materials need to be of a certain grain size, sufficiently clean, and compatible with the naturally occurring beach material to be appropriate for beach nourishment. Open-water disposal for boating facilities within Greenwich Bay is not a realistic choice given the costs of testing (approximately $100,000), and because the type of dump scows necessary to bring the material offshore cannot navigate the shallow coves. In-bay disposal is an option, but any such proposal is likely to meet strong resistance.

770.6 Regulatory limitations to dredge material management

1. While Rhode Island regulations are protective of the environment, dredging is possible. The regulatory process in Rhode Island is streamlined so that only one application to both CRMC and RIDEM is required. CRMC serves as the lead agency.

2. There are some areas where state regulation is conservative, and some scientific review is needed. The most significant of these areas are those that limit the beneficial reuse of dredge material. The levels of metals in material suitable for beach nourishment and the arsenic levels for all types of reuse are currently set at low levels that may need to

be reevaluated. Since arsenic is a naturally occurring element, it is typically found in all samples of sediment, particularly in low areas that act as sediment sinks, such as under marinas. In addition, local citizens would like to be able to use dredge material from local marinas to renourish their beaches as long as the material's particle size is similar to that currently on the beach (Fritz pers. comm.).

Section 780
Regulations, recommended actions, and research needs

1. Regulations, recommended actions, and research needs to protect, restore, and enhance Greenwich Bay's recreational assets follow. In the following sections, the Rhode Island Coastal Resources Management Council is referred to as CRMC. Regulations apply to CRMC and amend the R.I. Coastal Resources Management Program (RICRMP) administered by CRMC. In regulatory sections, plain text indicates current RICRMP regulations whereas underlined text indicates new regulatory language and strikethrough text indicates deleted regulatory language. Recommended actions and research needs may apply to a variety of federal agencies, state agencies, local governments, and nongovernment organizations and are not necessarily binding. All recommended actions are presented in plain text.

780.1 Boating

See additional regulations and recommended actions related to potential boating pollution in section 470.6 (Water Quality Chapter) of this SAMP.

780.1A Recommended actions

1. Warwick should employ a full-time harbormaster to administer a more intensive harbor patrol program, especially in light of increasing recreational use in Greenwich Bay. The harbormaster's fulltime presence can reduce the city's liability and provide greater enforcement of municipal mooring ordinances, safety laws, and the no-discharge law. Given Warwick's large number of marinas and significant miles of shoreline, the city should investigate possible funding based on homeland security concerns. Consistent with these concerns, Warwick should consider placing the harbormaster under the police department and employing a harbormaster or assistant harbormasters that are police officers to facilitate on-the-water enforcement.

2. Warwick and East Greenwich should enter into a formal agreement authorizing reciprocal enforcement authority by the harbormasters and law enforcement personnel in Greenwich Cove. The municipalities are authorized to enter into these agreements under R.I. Gen. Law §46-23-15.1.

3. Warwick should implement a mooring fee schedule comparable to those of other Rhode Island municipalities to fund increased harbor management activities.

4. Warwick should update its authorization by the Rhode Island General Assembly to regulate activities in tidal waters.

5. Warwick and East Greenwich should increase the awareness of personal watercraft users of state and local safety laws. The municipalities should consider posting signs, at popular launching points for personal watercraft and in waterways,

describing restrictions, such as speed limits. In addition, the municipalities should consider providing educational information to businesses that rent out personal watercraft.

6. Warwick and East Greenwich should revisit and revise as appropriate mooring standards for mushroom anchors to allow for a wider range of options. Revised standards could allow for more dense moorings by using helix anchors, shorter mooring scopes, and closer siting. Caution should be exercised when using mushroom anchors in sandy bottoms as they do not always sink sufficiently to be effective storm anchors. The CRMC sediment maps can be used to identify areas of concern.

780.2 Swimming

See regulations and recommended actions for improved water quality in section 470 (Water Quality Chapter) and for protecting beaches in section 390.6 (Habitat and Environmental Assets Chapter) of this SAMP.

780.2A Recommended actions

1. Warwick should consider designating known swimming areas off limits to personal watercraft use.

2. Warwick, in conjunction with HEALTH, should evaluate the value of placing signs at unlicensed beaches that either indicate that water quality at the beach is not monitored or that a storm water outfall is present that could cause bacterial pollution after storms. HEALTH should work with the city to develop proper wording for these signs.

780.3 Fishing

See additional regulations and recommended action for improved recreational access to the shoreline in section 780.5 and improved water quality in section 470 (Water Quality Chapter) of this SAMP.

780.4 Hunting

780.4A Recommended action

1. The U.S. Fish and Wildlife Service should consider allocating federal duck stamp revenue from the Rhode Island to purchase open space in the Greenwich Bay watershed.

780.5 Recreational access

780.5A Definitions

1. "Public access to the shore" is a general term used to describe the ways and means by which the public may legally reach and enjoy the coastal areas and resources of the state.

780.5B Regulations

Policy

1. It is CRMC policy to fully utilize RICRMP Section 335 to continue to protect and provide for new public access sites as part of the ongoing permit process. CRMC shall ensure that all permitted activities maintain public access at CRMC-designated ROWs to Greenwich Bay and its coves. Where appropriate, CRMC shall require applicants to provide access of a similar type and level to that which is being impacted as the result of a proposed activity or development project.

2. It is CRMC policy that marinas, prior to seeking expansions, exhaust all options for making full use of existing in-water footprints.

3. It is CRMC policy to work cooperatively with RISAA, Warwick, East Greenwich, and nongovernment organizations to identify and adopt CRMC-designated ROWs on Greenwich Bay and its coves as part of the Adopt-A-ROW Program. The Adopt-A-ROW Program encourages citizen involvement with the cleanup and maintenance of public ROWs.

4. It is CRMC policy to work with the municipalities to identify and designate additional public ROWs listed in their harbor management plans. The municipalities and CRMC shall prioritize ROWs in areas with more limited access, such as Apponaug Cove, Warwick Neck, and the western and northern shore of Greenwich Bay. CRMC designation provides added enforcement, protection against encroachment, and limited liability protection for private landowners.

5. It is CRMC policy to encourage marinas along Greenwich Bay and its coves to voluntarily include provisions for public access in their permits. Marinas receive limited liability protection under state law if public access is stipulated in their CRMC permits (R.I. Gen. Laws §32-6-5).

6. CRMC recognizes that, due to public safety, security, or environmental considerations, certain sites may not be appropriate for development of facilities that encourage physical access to the shoreline. It is CRMC's policy to consider these issues during its ROW designation process. In the Greenwich Bay watershed, areas not appropriate for facilities that encourage physical access include, but are not limited to, salt and brackish marshes, such as Mary's and Baker's creeks and upper Brush Neck Cove; barrier beaches; and shallow silty waters.

7. It is CRMC policy to provide Warwick and East Greenwich with signs for posting at CRMC-designated ROWs. CRMC shall provide signs as needed at the request of the municipalities.

8. It is CRMC policy, in cooperation with Warwick and East Greenwich, to educate residents about their rights in respect to accessing the shore. Education shall include posting and maintaining a list of CRMC-designated ROWs at East Greenwich Town Hall and Warwick City Hall. In addition, CRMC recommends that citizens who wish to be involved in preserving public access:
- Clean up public access sites and beaches
- Participate in Adopt-A-Spot programs
- Participate in local harbor management processes
- Gather information necessary to designate public ROWs
- Report the unlawful blockage of any public ROW to CRMC and/or to local officials

Prohibitions

1. CRMC prohibits Warwick and East Greenwich from abandoning CRMC-designated ROWs along Greenwich Bay and its coves by unless new equivalent access is provided.

Standards

1. In cases where a CRMC-designated ROW exists on or adjacent to a land parcel where new structures are being proposed, applicants will survey their property line adjacent to the ROW. Any infringement on the ROW by the proposed activity will be eliminated.

2. Residential docks along Greenwich Bay and its coves should maintain reasonable access along the shoreline by providing access over the dock or at least a 5-foot clearance (above mean high water) under some portion of the dock.

780.5C Recommended actions

1. Warwick and East Greenwich should implement measures that prevent the loss of public access sites to new or expanded development. As part of this effort, Warwick and East Greenwich should review the list of public ROWs prior to approving any building permit. If a ROW exists on or adjacent to the land parcel, applicants should be required to survey the ROW. This information could be used to build Geographic Information System (GIS) coverages of public access for the permitting process. Any infringement on the ROW by the proposed construction should be eliminated or compensated for. In addition, the municipalities should explore means to make public ROWs more evident during planning and permit review, such as by updating any land parcel coverages contained in GIS or other parcel databases.

2. CRMC and Warwick should consider forming a working group to monitor beach erosion at Greenwich Bay beaches, disseminate erosion information to agencies and the public, prioritize sites in need of beach nourishment, and assess options for addressing erosion at priority sites. This information should be incorporated into a sediment management plan.

3. The Rhode Island General Assembly should increase the administrative penalties that CRMC can levy for encroachment on a public ROW. Currently, CRMC can only initially apply an administrative fine of $2,500.

4. CRMC should work with Warwick to investigate designating appropriate sections of water around Chepiwanoxet Point as Type 1 (Conservation Areas).

5. Warwick and East Greenwich should develop and implement a plan to maintain public ROWs and municipal boat ramps. The municipalities should consider developing a volunteer program with community groups to ensure maintenance of ROWs.

6. Warwick and East Greenwich should consider public safety, security, and environmental considerations prior to development of facilities that encourage physical access to the shoreline. In the Greenwich Bay watershed, areas including but not limited to salt and brackish marshes, such as Mary's and Baker's creeks and upper Brush Neck Cove, barrier beaches, and shallow silty waters, are not appropriate for facilities that encourage physical access.

7. Warwick and East Greenwich should continue to dedicate funds, including block grants, to increase and support public access, for purchasing waterfront properties for public access and other efforts.

8. Warwick and East Greenwich should explore the potential of the Federal Emergency Management Agency (FEMA) as a funding source for the creation of new public access and maintenance, protection, and restoration of current public access.

9. RIDEM and Warwick should continue to explore opportunities to secure public and private funds to build or improve boat ramps in Greenwich Bay. Specifically, RIDEM should explore repairing and dredging the existing Goddard Memorial State Park boat launch facility. RIDEM and Warwick should make every effort to ensure, where feasible, that any new or improved boat ramps are handicapped accessible.

10. The Rhode Island General Assembly should increase funding to CRMC so it can develop a legal inventory of Greenwich Bay public access sites, designate additional ROWs, and provide signage.

11. Warwick and East Greenwich should work to improve the visibility of public ROWs. The municipalities should post signs provided by CRMC at all CRMC-designated ROWs. In addition, Warwick should consider posting signs at all other municipal public ROWs identified in the SAMP, and remove "no trespassing" signs from public property where appropriate. Both municipalities should consider creating a fine for unauthorized removal of official signs that identify public ROWs or placing unauthorized signs that falsely characterize a public ROW as private.

12. Warwick and East Greenwich should consider developing joint educational materials and road signs to encourage access to Greenwich Bay. The municipalities could post and maintain a list of public ROWs at East Greenwich Town Hall and Warwick City Hall.

13. RIMTA, in cooperation with CRMC, should develop signs and maps for marinas to post that clearly state public access is available under limited conditions. Consideration should be given to making public access part of any Clean Marina Program.

14. Warwick and East Greenwich should implement means to improve parking availability at public ROWs and boat ramps. The municipalities should consider removing any "no parking" signs where emergency vehicle access will not be affected, and explore the use of RIDOT enhancement grants to improve parking at shoreline access points. The Warwick City Council and the East Greenwich Town Council should consider amending their respective code of ordinances to remove unnecessary "no parking" signs. The municipalities should also explore the purchase of tax sale parcels within close proximity of public ROWs for parking.

15. Warwick should develop a plan to enhance access and recreational opportunities at Chepiwanoxet Park, consistent with the area's designation as protected open space. As part of the plan, the city should consider additional road signs directing visitors to the park. In addition, the city and RIDOT should evaluate creating a spur off the Warwick-East Greenwich Bicycle Network.

780.6 Dredging

780.6A Regulations

Policy

1. It is CRMC policy to facilitate public and private dredging needs while providing appropriate protection to shellfish, finfish, and other natural resources in Greenwich Bay and its coves.

780.6B Recommended actions

1. CRMC, in conjunction with RIDEM, Warwick, East Greenwich, RIMTA, the state geologist, University of Rhode Island, and USACE, should develop a sediment management plan that links erosion, deposition, and management measures for Greenwich Bay and its coves. The plan could facilitate ongoing partnerships between public and private entities that link dredging and beneficial reuse projects, such as beach nourishment and wetland restoration. For example, currents carry sediment from Oakland Beach onto the western shore and waters of Warwick Cove. The sediment is impeded by the Warwick City Dock and is causing shoaling in several of the nearby marinas. This material, if suitable, should be part of an on-going maintenance dredging and beach nourishment project.

2. CRMC should acquire funding and dredge an alternative entrance to Warwick Cove. Material that is dredged should be used for beach nourishment of Oakland Beach. Once done, the Warwick Department of Public Works will maintain the groin field cells consistent with the beach management plan for this area.

3. Marina operators should work together to consider opportunities for coordinating dredging projects to save equipment costs and potentially assist beach nourishment programs. The CRMC dredge coordinator can facilitate this process by providing lists of current dredge permits or applicants to operators.

4. RIDEM, in conjunction with CRMC and HEALTH, should review and make recommendations for modifications of the rules regarding the allowable physical and chemical contamination levels that determine the suitability of dredge material for reuse. Requirements for beach nourishment regarding levels of arsenic, total petroleum hydrocarbons (TPH), and zinc, as well as particle size are of particular interest.

5. CRMC, in conjunction with RIDEM, should explore expanding dredge windows, taking into consideration the unique needs of the large number of boating facilities within Greenwich Bay and its coves and the significant role Greenwich Bay plays as a spawning area and nursery for many marine species.

780.6C Research needs

1. USACE, in conjunction with CRMC, should study the effects of dredging the delta at the mouth of Brush Neck and Buttonwoods coves as well as portions of the coves. This study should look at various levels of dredging impacts on navigation, flushing, habitat, water quality, and shellfish populations.

2. CRMC should study channel realignment at the entrance channel of Warwick Cove. Any dredging could be conducted as a state project.

Section 790
Literature Cited

Barbara Sokoloff Associates, Inc., Bicycle Federation of America, Applied Bio-Systems, Inc., Bryant Associates, Inc., and Diane C. Soule & Associates, ASLA. (1999). *Warwick-East Greenwich bicycle network: feasibility/design study report—executive summary.* Prepared for the Division of Intermodal Planning, Rhode Island Department of Transportation.

Battelle. (2004). No discharge zone evaluation. Prepared for the U.S. Environmental Protection Agency.

Brown, J.W. (1990). An analysis of recreational boating on Narragansett Bay. Unpublished master's thesis, University of Rhode Island, Kingston.

Burdick, D.M. and F.T. Short. (1999). The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. *Environmental Management 23*(2): 231-240.

Carriker, M.R. (1967). Ecology of estuarine benthic invertebrates: a perspective. In: Lauff, G.H. (ed.), *Estuaries.* Washington, D.C.: American Association for the Advancement of Science.

Caudill, J. (2003). 2001 National and state economic impacts of wildlife watching: addendum to the 2001 national survey of fishing, hunting and wildlife-associated recreation. Alexandria: United States Fish and Wildlife Service, Department of the Interior.

City of Warwick. (2003). Comprehensive plan.

Collins, C. and S. Sedgwick. (1978). *Recreational boating in Rhode Island's coastal waters: a look forward.* Marine Technical Report 75. Narragansett: Coastal Resources Center, University of Rhode Island.

Colt, A.B., T. Tyrrell, and V. Lee. (2000). *Marine recreation and tourism in Narragansett Bay: critical values and concerns.* Working Draft of Narragansett Bay Summit 2000 White Paper.

CRMC. 2003. Public right of ways: CRMC's designation process. Coastal Briefing produced by the Rhode Island Coastal Resources Management Council, 2 p.

CRMC. 2004. Designation of public right of ways to the tidal areas of the state: progress report for July 2003 through June 2004. Report submitted by the Coastal Resources Management Council Subcommittee on Right-of-Ways, 26 pp.

Environmental Protection Agency. (2001). *National management measures guidance to control nonpoint source pollution from marinas and recreational boating.*

Fields, S. (2003). The environmental pain of pleasure boating. *Environmental Health Perspectives 111(4)*: A216-A223.

Ganz, A., N. Lazar, and A. Valliere. (1994). *Quahaug management project, phase I—Greenwich Bay*. Wakefield: R.I. Department of Environmental Management, Division of Fish, Wildlife, and Estuarine Resources.

Gibbs, E., T. Corey, M. Schwartz, D. Grossman-Garber, C. Jaworski, and M. Bucheit. (1995). *A guide to Rhode Island's natural places.* Narragansett: Rhode Island Sea Grant.

Iannuzzi, T.J., M.P. Weinstein, K.G. Sellner, and J.C. Barrett. (1996). Habitat disturbance and marina development: an assessment of ecological effects. I. Changes in primary production due to dredging and marina construction. *Estuaries 19(2A)*: 257-271.

Ingle, R.M. (1952). Studies on the effect of dredging operations upon fish and shellfish. Technical Survey No. 5. St. Petersburg: Florida State Board of Conservation.

Marinas of Greenwich Bay. (2002). *Class Report for Dynamics of Recreation-Leisure Management and Travel Tourism*. Johnson and Wales University, Providence.

Kaplan, E.H., J.R. Welker, and M.G. Kraus. (1974). Some effects of dredging on population of macrobenthic organisms. U.S. National Marine Fisheries Service. *Fishery Bulletin 72(2)*: 445-480.

Kelty, R. and S. Bliven. (2003). *Environmental and aesthetic impacts of small docks and piers—workshop report: developing a science-based decision support tool for small dock management, phase 1: status of the science.* Coastal Ocean Program, National Oceanic and Atmospheric Administration.

LeBlanc, C.L. and R.R. Bottin Jr. (1992). *Monitoring of the beach erosion control project at Oakland Beach, Rhode Island.* Washington, D.C.: Department of the Army, Army Corps of Engineers,

East Greenwich. (1988). Harbor management plan.

Massachusetts Coastal Zone Management Program. (2003). The science & management of docks/piers workshop summary. http://www.state.ma.us/czm/dockpiersummary.htm.

Milliken, A.S. and V. Lee. (1990). Pollution impacts from recreational boating: a bibliography and summary review. Narragansett: Rhode Island Sea Grant.

Nixon, S.W., C.A. Oviatt, and S.L. Northby. (1973). *Ecology of small boat marinas*. Kingston: University of Rhode Island.

Pogue, P. and V. Lee. (1993). *Public Access to the Rhode Island Coast*. Narragansett: Rhode Island Sea Grant.

R.I. Department of Environmental Management. (2001). *The Rhode Island parks and beach system study and asset management plan.*

R.I. Department of Environmental Management. (2002a). *Stock status of marine resources and summary of fisheries management in Rhode Island: a report to the Rhode Island General Assembly.*

R.I. Department of Environmental Management. (2004a). *Marine fisheries minimum sizes and possession limits.* www.state.ri.us/dem/programs/bnatres/fishwild/MFSIZES.htm.

Ross, N. (2004). Marinas, their environment, and importance to water recreation. National Docks and Marina Conference, University of Wisconsin, Madison.

Saila, S.B., S.D. Pratt, and T.T. Polger. (1972). *Dredge spoil disposal in Rhode Island Sound.* Kingston: University of Rhode Island.

Turner, S.J., S.F. Thrush, V.J. Cummings, J.E. Hewitt, M.R. Wilkinson, R.B. Williamson, and D.J. Lee. (1997). Changes in epifaunal assemblages in response to marina operations and boating activities. *Marine Environmental Research 43(3)*: 181-199.

U.S. Department of the Interior and the U.S. Department of Commerce. (2003). 2001 National survey of fishing, hunting, and wildlife-associated recreation—Rhode Island. Washington, D.C.: United States Fish and Wildlife Service.

U.S. Fish and Wildlife Service. (2001). Numbers of anglers and hunters remains steady. Washington, D.C.: U.S. Fish and Wildlife Service News Release, August 15, 2001.

U.S. Coast Guard. (2003). Federal requirements and safety tips for recreational boats. http://www.uscgboating.org/safety/fed_reqs/intro.htm.

Warwick Harbor Management Plan. (1996). Warwick harbor management plan.

Chapter 8
Natural Hazards

Table of Contents

Figures

Tables

Section 800
Introduction

1. A natural hazard is "an event or physical condition [caused by nature] that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss" (Federal Emergency Management Agency (FEMA), 1997). Natural phenomena such as floods or hurricanes are considered hazards only when people and property are affected.

2. The most significant hazards for Greenwich Bay are tropical storms (hurricanes) and extra-tropical storms (nor'easters). Hurricanes and tidal fooding have killed hundreds of people and caused millions of dollars in property damage in Rhode Island coastal communities. While no major hurricanes have swept across the state in the 40 years since Hurricane Carol in 1954, smaller hurricanes occurred in 1976, 1985, and 1991. The U.S. Army Corps of Engineers (USACE) 1995 Rhode Island Hurricane Study counted 29 hurricanes and 67 tropical storms since 1886 (USACE, 1995). The study calculates the recurrence interval at close to one hurricane every 5.4 years and a tropical storm every 1.7 years. Thunderstorms embedded within the hurricane rain bands can spawn tornados and trigger microbursts and downbursts. Wind-borne debris can also cause serious damage during an extreme wind event.

3. Nor'easters—winter storms that move up the East Coast bringing heavy wind and precipitation—strike from October through May, and can cause severe flooding and erosion. The degree of damage is dependent on five storm characteristics: 1) size and intensity, 2) forward speed, 3) tidal phase, 4) path with respect to the shoreline, and 5) time interval between storms (Hayes and Boothroyd, 1969).

4. Greenwich Bay is susceptible to storm-surge flooding that damages homes, buildings, utilities, roads, and shoreline protection structures. Rhode Island has significant areas of shoreline that are exposed to storm winds and waves (USACE, 1995). As hurricanes move north of Cape Hatteras, N.C., they tend to weaken but gain speed.

5. Hurricane destruction is measured using the Saffir-Simpson Scale, which categorizes hurricane wind speed on a scale of 1 to 5, with a Category 1 hurricane being the least severe and Category 5 the most severe. However, these categories can be deceiving. A Category 4 storm may have stronger winds, but a Category 2 storm that is moving more quickly along its path (forward motion) may cause more damage if it generates a storm surge (USACE, 1995). The rapid forward speed of these quickly moving storms decreases the amount of time available for evacuation. This is compounded by the fact that storm-surge flooding can occur hours before the hurricane landfall.

6. Potential natural hazard impacts to the Greenwich Bay watershed depend on a variety of factors, including geology and sea level rise. The land surrounding Greenwich Bay is predominately glacial delta plain, consisting of unconsolidated sand and gravel, with some till mantle and ice marginal deposits (Boothroyd and McCandless, 2003). The tide range in

Greenwich Bay is about four feet. Long-term sea level trends show an average rise between 0.07 inches and 0.10 inches per year.

7. FEMA provides technical assistance and funding to states and municipalities for hazard mitigation and has jurisdiction for land above mean high water (MHW). Rhode Island municipalities, including East Greenwich and Warwick, have drafted hazard mitigation plans to reduce the impacts of natural hazards on residents, properties, and natural resources. The plans address municipal areas from MHW and above in accordance with FEMA guidelines.

Section 810
Hazard identification

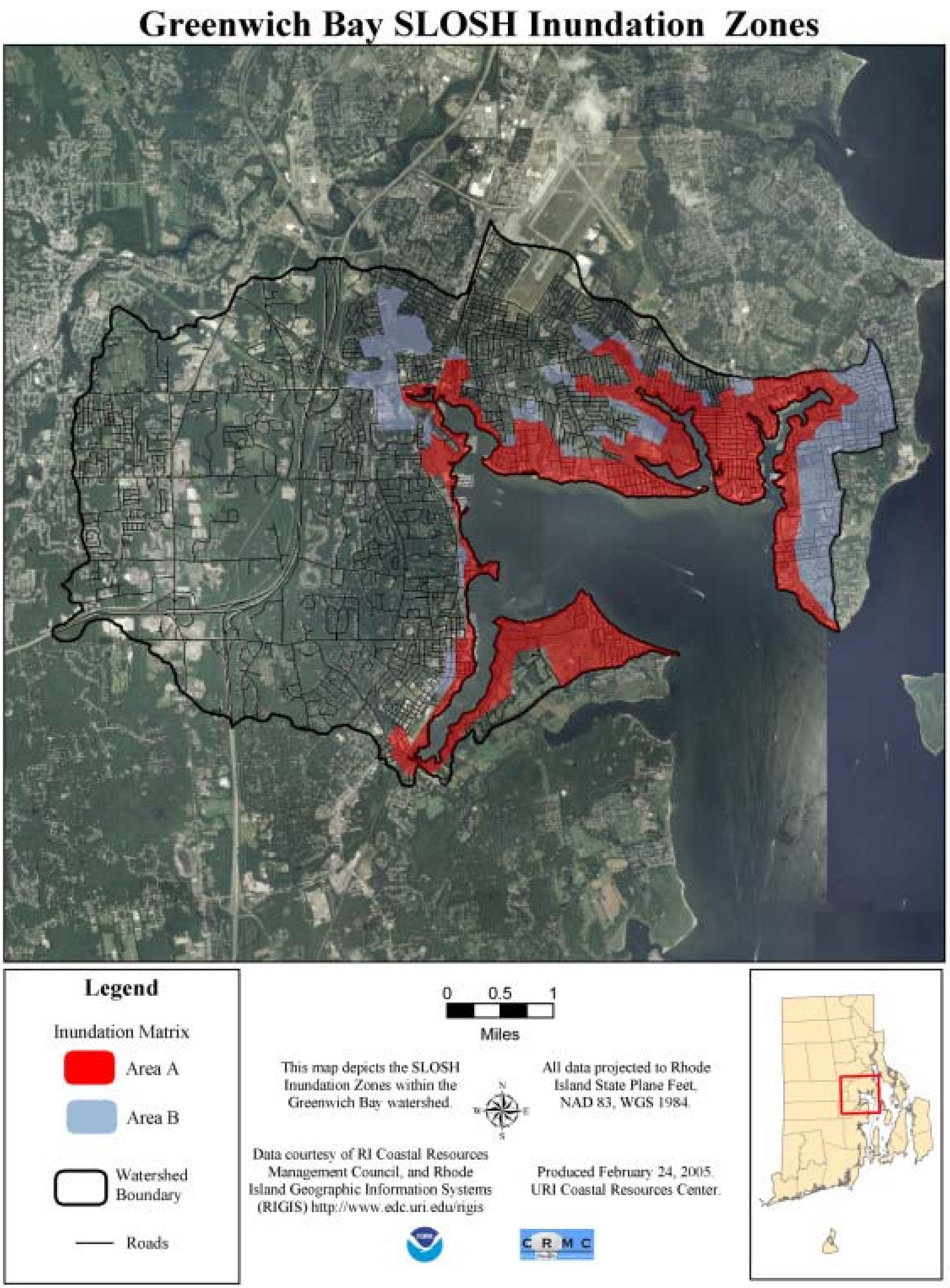
810.1 Storm surge

1. Storm surge is the elevation of the ocean surface above a given astronomical tide elevation resulting from a storm. It is measured as the difference between actual sea-surface elevation during a storm and the sea-surface elevation associated with the astronomical tide at the time. Storm surges result from several factors but are primarily a function of the high winds blowing across the ocean surface and reduced atmospheric pressure associated with extratropical and tropical storms. The onshore-directed winds of a severe storm or hurricane interact with the ocean surface and push the ocean water mass toward the shoreline. This onshore flow of water piles up (or sets up) against the coast, while reduced atmospheric pressure (called the inverse barometer effect) causes an additional rise by reducing the pressure on the ocean surface. While set up and the inverse barometer effect are the primary forces causing elevated water levels during storms, probably the most important factor in the peak elevation attained during any individual surge event is the phase of the tide relative to the time of storm passage. Surges, combined with waves on top of the surge, can completely inundate low-lying areas and can cause death and severe property damage (Boothroyd, 1999; Gordon, 1980).

2. During severe storm surge, water moves rapidly over the low barrier spits and headlands in a process called overwash. Driven by the wind, waves, and swash of the storm, overwash water delivers sediment eroded from the front of the barrier onto the back barrier flat and into the lagoon or onto low-lying headland areas. The overwash process results in deposition of washover fans on the back of the barrier and low-lying headlands.

3. Federal agencies assess the potential for storm surge by using the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model. The National Hurricane Center developed a SLOSH model for Narragansett Bay using the bathymetry of the Bay and the topography of coastal Rhode Island to predict coastal flooding effects from potential hurricanes in the region. The SLOSH model for Greenwich Bay predicts storm surges of 18 to 23 feet (USACE, 1993) and identifies Oakland Beach, Buttonwoods, and Potowomut as areas at highest risk for coastal flooding from storm surge (Figure 1). The resulting SLOSH zones—A (Category 1 and 2 hurricanes with wind speeds up to 40 miles per hour (mph) and Category 3 hurricanes with wind speeds up to 20 mph) and B (all other categories and wind speeds), are used to mark hurricane evacuation areas.

Figure 1. Greenwich Bay SLOSH inundation zones



810.2 Wind

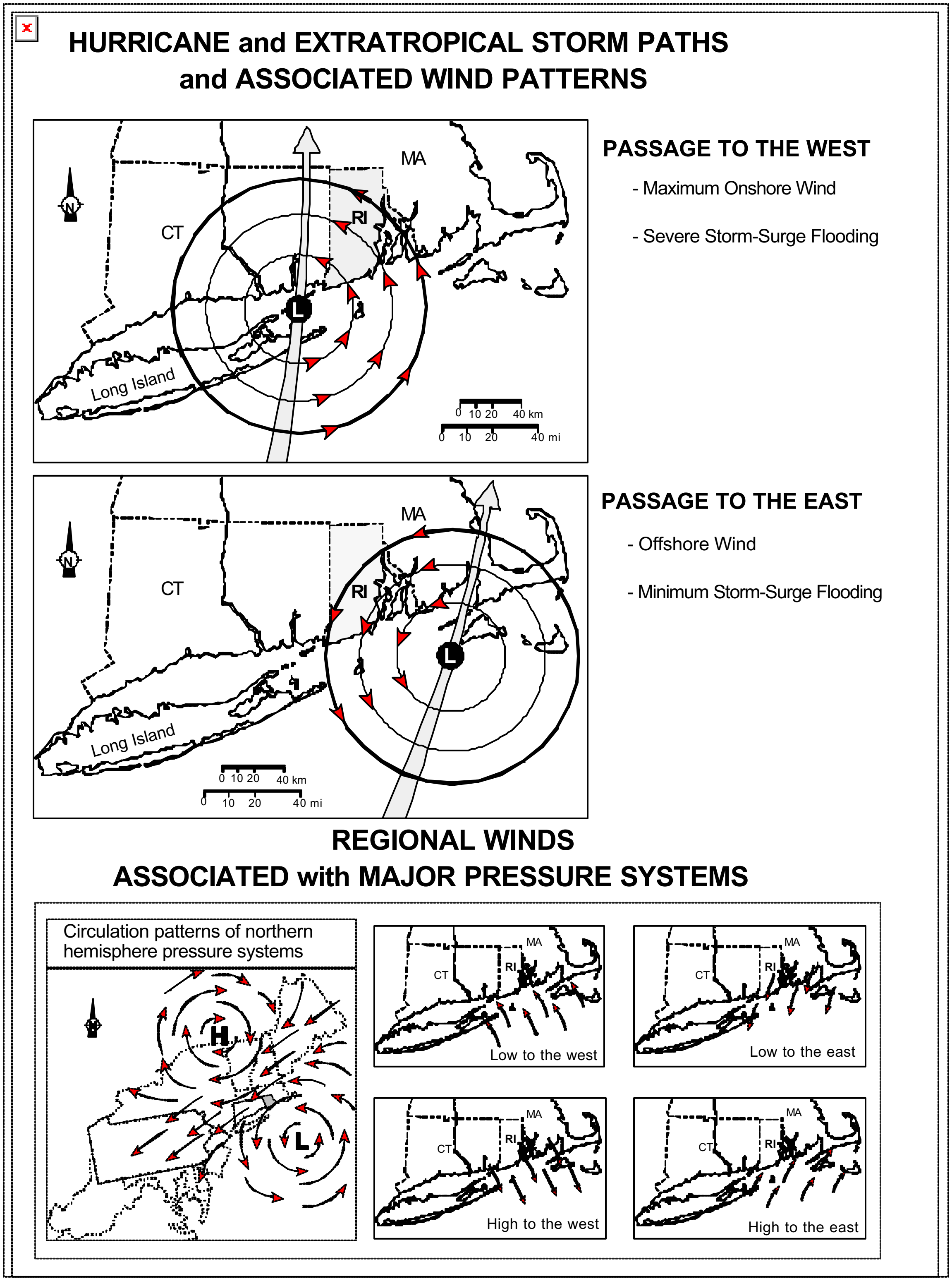
810.2A Hurricanes

1. Tropical storms become hurricanes once wind speeds exceed 74 mph, with major infrastructure damage occurring once winds exceed 100 mph. New England's southern coast is susceptible to meteorological factors that produce severe hurricanes and coastal storms. Hurricanes generally approach Rhode Island from the south and the southwest between June and November (Figure 2). The substantial damages associated with these storms are the result of high wind speeds, torrential rain, large waves and swells, and storm surges (Nichols and Marston, 1939; Keller, 1975). Aside from storm size and speed of advance, the severity of a hurricane's impact depends on the tide and storm direction (Boothroyd, 1999; Boothroyd, Klinger and Galagan, 1998; Olsen et al., 1980). In Greenwich Bay, waves generated by wind from the southeast make the bay's northern shore, including Oakland Beach and Buttonwoods Cove, especially vulnerable to erosion.

810.2B Extra-tropical cyclones

1. Extra-tropical cyclones are large coastal winter storms that generally pose the same hazards as hurricanes. Rain from such storms often leads to flooding. Furthermore, winter cyclones often coincide with extreme temperature drops that bring snow and ice. Wind speeds are usually 40 mph or greater and can generate waves comparable to those of hurricanes. Although less forceful than hurricanes, these storms can cause more cumulative damage because they tend to remain in a fixed location (Gordon, 1980).

Figure 2. Storm tracks and wind patterns for Rhode Island



Source: Adapted by J. Boothroyd, University of Rhode Island, from Wright and Sullivan, 1982

810.3 Floods

1. Flooding is the accumulation of water within a water body and the overflow of water into adjacent floodplains. Flooding may be brought on by heavy rains associated with hurricanes and other storms, or by storm surge. Nine out of 10 hurricane fatalities are due to flooding. (FEMA, 1997).

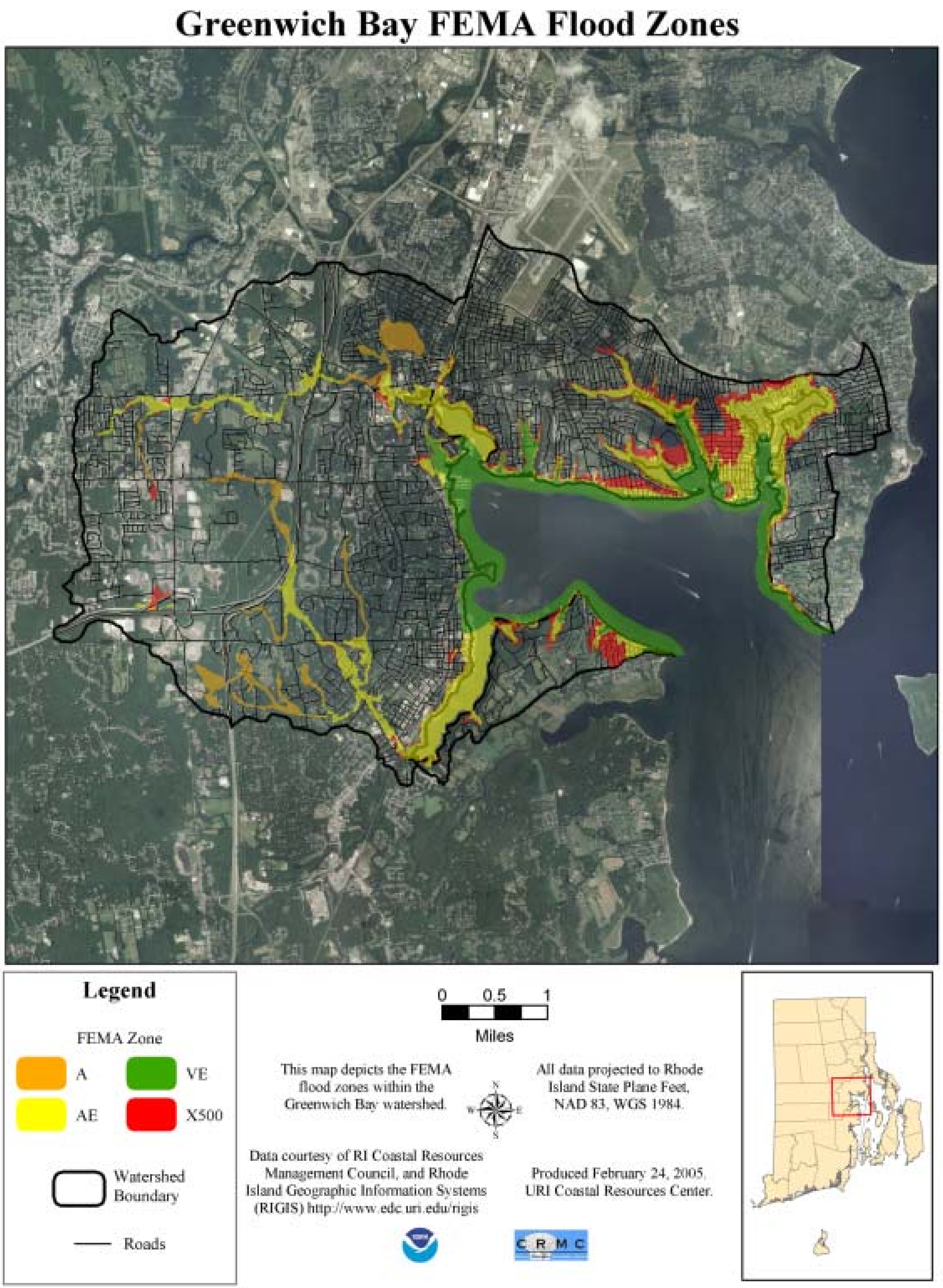
2. Low-lying coastal areas with poor drainage and substantial urbanization are especially susceptible to flooding. Flood zone designations in the Greenwich Bay area include VE, A, and AE (Table 1; Figure 3). Zone VE (breaking waves higher than 3 feet) is at the greatest risk for flooding and is more likely than other areas to be inundated by flood waters once every 100 years. To a lesser degree, zones A (standing water) and AE are also subject to 100-year flood inundation. All these zones require mandatory flood insurance for development.

Table 1. FEMA flood insurance rate zones

Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.
Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.
Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in FIS by detailed methods. In most instances, whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.
Zone AH is the flood insurance rate zone that corresponds to the areas of the 100-year shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.
Zone AO is the flood insurance rate zone that corresponds to the areas of 100-year shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-depths derived from the detailed hydraulic analyses are shown within this zone.
Zone X, or the 500-year flood zone, is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year flood plain, and to areas of 100-year flooding where average depths are less than 1 foot, areas of flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No base flood elevation or depths are shown within this zone.

Source: www.fema.org*, 2003.*

Figure 3. Greenwich Bay FEMA flood zones



810.3A Stream and flash floods

1. Since the 1970s, inland flooding has caused more than half of all deaths associated with tropical cyclones in the United States. Floods generally develop over a couple of days but can rise rapidly. Flash floods, which can occur due to high inland precipitation or from dam failure, are increasingly dangerous in urban areas that have impermeable surfaces such as roads and parking lots and limited vegetated buffers.

810.4 Sea level rise

1. Based on worldwide tide gauge records dating back to the 1800s, the level of the global ocean has been rising at a rate of approximately 3 to 5 inches per century (Gornitz and Lebedeff, 1987). The global sea-level rise estimates for the year 2100, derived from the Environmental Protection Agency (EPA) climate model (Hoffman et al., 1983; Hoffman, 1984), range from 1.8 feet to 11.3 feet above the 1980 level.

2. In Rhode Island, the land is subsiding at a rate of approximately 5.9 inches per century (Douglas, 1991). When this rate is added to a global sea-level rise rate of 3.9 inches per century, the rate of relative sea-level rise in Rhode Island is 9.8 inches per century. If this historic trend continues to the year 2100, sea level in Rhode Island will rise approximately 17.7 inches above zero elevation—a measurement known as National Geodetic Vertical Datum (NGVD)—on government topographical maps. Accelerated sea-level rise estimates for Rhode Island based on the latest data (CRMC, 1999) indicate a rise of 17.7 to 39.4 inches by the year 2100.

3. Rise in relative sea level along Rhode Island's coast will increase the extent of flood damage over time. The mean trend for sea-level rise at the Newport tide gauge is 0.1 inches per year (0.84 feet per century) with a standard error of 0.004 inches per year (National Oceanic and Atmospheric Administration, 2004b). The lower elevation areas are more susceptible to flooding, with high erosion areas having the greatest risk. Areas likely to be first affected include the north shore of Greenwich Bay from Apponaug Cove to Warwick Neck and the south shore of Potowomut. Based on current projections, these areas, which are about 4.3 feet above mean high tide, will likely be above mean sea level for at least 100 to 200 years (Titus and Richman, 2001). Other risks associated with sea level rise include salt intrusion into aquifers and higher water tables (Nicholls and Leatherman, 1994).

4. Any future sea-level rise will increase coastal erosion, which will reduce the protection provided to development by coastal engineering structures such as seawalls and riprap. Low-lying areas adjacent to the shorefront will be subject to increased flooding, known as in-place drowning, during storms. Rising water tables will cause failure of individual sewage disposal systems.

810.5 Erosion

1. The north and south shores of Greenwich Bay and Buttonwoods, Brush Neck, and Warwick coves are characterized by coastal bluffs that are fairly low (10 to 20 feet NGVD).

However, the west shore of the bay and Greenwich and Apponaug coves are steeply sloping (greater than 50 feet NGVD). The north and south shores of Greenwich Bay are unconsolidated glacial deposits that are easily eroded. During natural coastal processes, coastal bluffs erode, supplying sand to beaches and spits. A survey of shoreline changes between 1939 and 1975 shows erosion along most of the Greenwich Bay shoreline (Dein, 1981). The highest erosion rates occurred at Oakland Beach, where the shoreline migrated northward about 6 inches per year. The study measured long-term changes that were averaged for an annual rate of change. In reality, much larger losses occur within a few hours during storms, followed by little net loss or accretion during non-stormy years.

2. Although Dein's research showed that more than half of the Greenwich Bay shoreline was eroding, less than 20% measured erosion rates that averaged more than a foot per year. She characterized approximately 25 percent of the shoreline as manmade, a protection measure that may have been prompted by the damage from the Hurricane of 1938 and 1952. The structures likely slowed the rate of erosion by offering protection in moderate storms. The west shore from Greenwich Cove to the mouth of Apponaug Cove shifted less than 0.1 foot per year, partially because the shoreline is somewhat protected from the direct attack of storm waves. Also, shoreline protection structures have long been in place to protect infrastructure. The Buttonwoods shoreline showed a very small net gain over the study period. This may be because more than half the shoreline was already armored with both shore parallel and shore perpendicular structures. The structures that run perpendicular to the shoreline are designed to capture sand as it is transported along the shoreline. Hurricanes in 1991 severely damaged an unarmored section, prompting construction of a revetment.

3. Shoreline property owners have installed protection structures. Much potential beach sediment is trapped behind these structures. The loss of sediment supply coupled with erosion and sea-level rise is leading to the narrowing or disappearance of Greenwich Bay beaches. These beaches, in addition to being important recreational resources, are the first line of defense against storm waves. Shoreline protection structures may give property owners a false sense of security. Most of the structures that line the Greenwich Bay shore are not built to withstand the storm surge and waves that accompany a severe hurricane or winter storm. Remnants of structures that did not survive earlier storms can be seen protruding through the sand at low tide.

4. The R.I. Coastal Resources Management Plan regulates the construction of shoreline protection throughout the state. New structures are prohibited on shorelines where adjacent waters are classified as Type 1 (conservation areas). Structures are allowed on shorelines adjacent to waters classified as Type 2 (low-intensity boating) through Type 6 (industrial waterfronts). Pre-existing structures can be maintained regardless of water type. Urban shorelines, such as Greenwich Bay's, that are prone to erosion, are armored with structures that pre-date the plan. Most of these structures are eligible for maintenance permits.

5. A 2003 Box, Freedman, and Boothroyd survey indicates that the overwhelming majority of Greenwich Bay shoreline protection structures are functioning (Box et al., 2004). Groins, for the most part, trapped sediment as it moved along the shore. Seawalls and revetments reflected wave energy even when in a state of disrepair. Many structures will

likely fail in a severe storm. Several will probably fail due to gravity. There was often a large gap between the base of the structure and the beach surface. Many structures are not as high as the anticipated storm surge for low-frequency, high-energy storms.

6. Approximately 27 percent of the shoreline of Greenwich Bay and adjacent coves was armored with revetments, seawalls, and bulkheads (Box et al., 2004). In addition, 37 groins, four breakwaters, five old bulkheads, and six boulders were recorded. Generally, if there was a residential or commercial structure close to the shore, there was a shoreline protection structure. The high density of structures disrupts and moves sediment supply, erodes beaches, and provides a false sense of security in the effectiveness of the structures to control erosion during severe storms.

810.6 Snow and ice

1. While the Greenwich Bay area generally receives less snow than the rest of the New England region, snow and ice storms still pose threats. Two major threats are downed power lines and rooftop loading (Pogue, 2002). From 2003 to 2004, there were numerous reports of marina pilings and private docks in Greenwich Bay coves being moved, crushed, or damaged due to ice cover that moved up and down with tides.

Section 820
Past hazard events and future exposure

820.1 Hurricanes

1. In the 20th century, the most devastating hurricanes to hit Rhode Island took place between 1938 and 1954 and generated floods and winds that caused significant death and property destruction (Figure 4 and Table 2). The damages associated with Hurricane Bob in 1991 were mainly due to winds rather than floods.

Table 2. Hurricane losses for Rhode Island from 1935 to 1999

Date	Name	Storm category	Magnitude (mph)	Forward motion (mph)	Property damage (millions)	Deaths
September 21, 1938	-	3	121	82	$100	262
August 31, 1954	Carol	3	110	56	$90	19
August 19, 1955	Diane	Tropical Storm	45	24	$170	0
September 12, 1960	Donna	2	58	39	$2.4	0
August 27, 1985	Gloria	2	81	72	$19.8	1
August 19, 1991	Bob	2	100	51	$115	0

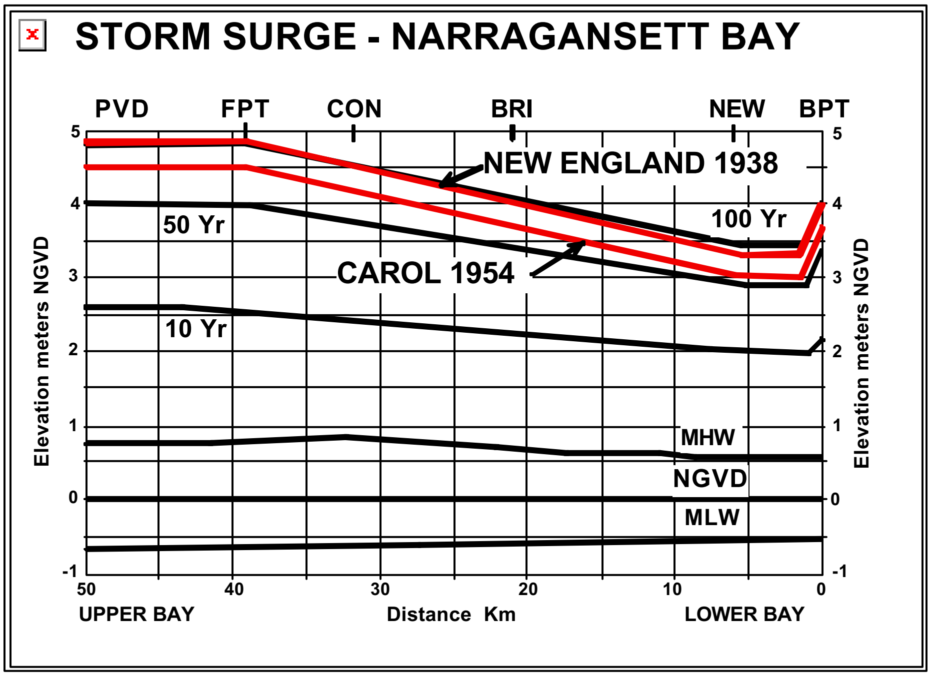
Source: Vallee, 1998

2. The Hurricane of 1938, which originated in the far-eastern Atlantic, was one of the most powerful and devastating storms in New England history. Its wind speed reached record highs of more than 120 mph and resulted in flood tides of more than 12 feet above the normal high water line in Greenwich Bay (Journal-Bulletin, 1979). At the time of the storm, the phase of the moon and the autumnal equinox combined to produce one of the highest tides of the year, and the storm surge coincided almost exactly with it from ebb to flood (Brown, 1979), exacerbating the storm's impact, destroying 700 Warwick homes and wrecking the fishing village of Scalloptown in East Greenwich (Journal-Bulletin, 1979). The erosion and changing coastline also had an impact on various habitats within the bay.

3. In 1954, Hurricane Carol became the most destructive storm to hit New England since the Hurricane of 1938. Sustained winds of 80 to 100 mph caused $3 million worth of property damage in Warwick and flash flooding in Apponaug (Journal-Bulletin, 1979). Due to its exposure to southeast winds, Oakland Beach was the most heavily battered section along upper Narragansett Bay. Due to its location, Greenwich Cove escaped the full force of the hurricane.

4. In 1991, Hurricane Bob caused a storm surge of 5 to 8 feet along the Rhode Island shore and generated winds of 75 to 100 mph, which downed trees and power lines. In Greenwich Bay , many boats were damaged when they were torn from their moorings (Vallee and Dion, 1998).

Figure 4. Storm-surge elevations for Narragansett Bay for various events. PVD – Providence downtown, FPT – Fields point, CON – Conimicut Point, BRI – Bristol, NEW – Newport, BPT – Brenton point. From U.S. Army Corps of Engineers, 1993.



820.2 Extra-tropical storms

1. Extra-tropical storms are events that occur from October through May and tend to last longer than hurricanes, and thus have greater potential for erosion and property destruction. Rhode Island experienced four severe extra-tropical storm events since 1991 (Table 3).

Table 3. Historical extra-tropical storm losses for Rhode Island

Year	Deaths [United States (Rhode Island)]	Total losses for United States
1888	400+	Unknown
1978	99 (26)	$202 million ($15 million in R.I.)
1991	33	$200 million
1992	19 (1)	$1 to $2 billion
1993	270 (0)	$3 to $6 billion
1996	187 (0)	$3 billion

Source: NOAA, Pogue, 2002

820.3 Floods

1. Floods in the Greenwich Bay area are produced by torrential rainfalls, thunderstorms, and snowmelts that inundate streets, basements, and riverbanks. A 2004 National Climate Data Center report (2004) counted 46 floods in Rhode Island since 1993. Seven of these occurred in Kent County, including the floods of 1979, 1982, and 1983.

Section 830
Vulnerability assessment

830.1 Critical facilities

1. Critical facilities are government-approved sites that provide public safety and protection in the event of a natural hazard emergency. Examples of facilities that municipalities may identify as critical are:

- Public infrastructure: Fire stations, police stations, schools, city and town halls, hospitals, and bridges with utilities
- Utilities: Sewer treatment plants and lift stations, water pump stations, and water towers
- Preparedness: Red Cross-approved shelters, evacuation routes, and traffic control points

830.1A Warwick

1. Aside from a number of bridges, none of Warwick's critical facilities are located in a flood or SLOSH zone within the Greenwich Bay watershed. There are 3,123 acres of FEMA-designated flood zones in the Greenwich Bay watershed (Table 4). Of these 3,123 acres, 1,967 acres are land-based flood zones, representing 15% of the land in the Greenwich Bay watershed. In 1999, there were 1,383 at-risk structures in Warwick, with most of these structures located in the areas of Oakland Beach and Buttonwoods Cove. A 1999 projection placed Warwick property losses at $53 million, were a severe hurricane to hit the city (Raford, 1999).

Table 4. Area of FEMA flood zones in the Greenwich Bay watershed

FEMA Flood Zone	Acreage	Percent of Flood Zone
AE Zones	1,353	43%
VE Zones	1,031	33%
X500 Zones	452	15%
A Zones	287	9%
Total	**3,123**	**100%**

Source: Rhode Island Geographic Information System

830.1B East Greenwich

1. The only critical facility identified in the East Greenwich part of the watershed is the East Greenwich Wastewater Treatment Facility (WWTF) adjacent to Greenwich Cove. It is located in a hurricane evacuation area (SLOSH B Zone). A flood could cause sewage overflow into the bay. If the WWTF malfunctions, the lower Water Street area might need to be evacuated.

830.2 Marinas and shorefront debris removal

1. Greenwich, Apponaug, and Warwick coves contain some of the highest density marina and boating facilities in the state. In 2003, there were at least 33 marinas or yacht clubs with more than 3,419 boat slips. In addition, a substantial proportion of the shoreline around the bay is characterized by high-density residential development. In this type of area, people and property are at greater risk during storms. Recreational and commercial boats are at great risk since many of them are located in high velocity (VE) zones at marinas, on moorings, on land, and at yacht clubs. Boats can sustain and cause damage. The boats and boat debris that are transported by storm surge and waves batter inland properties. Other facilities of concern include diesel tanks used to fuel boats in Greenwich Cove. The U.S. Coast Guard has loaned Warwick an oil boom to contain a fuel spill.

2. Most docks and dry racks are not able to protect boats in strong hurricane conditions. The best solution is to take boats out of the water and away from VE zones. However, mandatory removals are not often recommended due to the human safety risks (FEMA, 2002d).

3. Massive amounts of debris accumulated along coastal areas during the 1938 and 1954 hurricanes, specifically on the shores of Oakland Beach, Apponaug Cove, Chepiwanoxet, and Potowomut (Journal Bulletin Company, 1979). East Greenwich and Warwick manage storm debris by designating storage sites that may be used in the event that landfills cannot be immediately accessed. If owners of the debris can be identified, they are financially responsible for clearing the material. East Greenwich has designated the Bear Swamp Road highway garage, and Warwick has chosen several school, athletic, and park locations.

830.3 Residential areas

1. Heavily populated areas along the north shore of Greenwich Bay, including Oakland Beach, Buttonwoods, and Warwick Neck, are particularly vulnerable to storm hazards. In recent decades, a few properties in East Greenwich and Warwick have been repeatedly hit by storms and have collected on claims from three separate storm events.

830.4 Commercial areas and municipal services

1. East Greenwich and Warwick rely on residential and commercial property taxes to maintain municipal services. Natural hazards have the potential to destroy or interrupt these revenue flows—thus putting a larger burden on all taxpayers.

830.5 Risk assessment study

1. Warwick has conducted a vulnerability assessment based on the NOAA Coastal Services Center's Community Vulnerability Assessment Technique (Pogue, 2002). Assessment results ranked flooding, storm surge, and wind as the top three natural hazard threats to Warwick. This risk assessment could apply to East Greenwich as well due to the similarities and geographic locations of the two municipalities. The assessment attributed much of the coastal hazard vulnerability to inappropriately designed, built, and located communities.

Section 840
Natural disaster response and redevelopment

840.1 Evacuation

1. FEMA recommends that coastal communities use an eight-hour clearance time for well-publicized daytime evacuations. Nighttime evacuations should allot 10 hours for clearance. In addition to the actual evacuation time, officials must add the time required for dissemination of information to the public. USACE recommends that the evacuation be complete before the arrival of gale-force winds. In the Warwick/East Greenwich area, in the event of a weak hurricane, 17,000 to 20,000 people should evacuate, with 2,600 seeking public shelter; 30,000 should evacuate for a strong hurricane, with 4,000 seeking public shelter (Table 5). Based on the SLOSH maps, Warwick Neck, Oakland Beach, Buttonwoods, Apponaug Cove, Chepiwanoxet, and Potowomut would need to be evacuated before a hurricane.

Table 5. Populations, evacuation predictions, and shelter capacities based on 1990 census data (USACE, 1995).

Municipality	Vulnerable population	Population evacuating surge areas	Population evacuating non-surge areas	Shelter demand	Shelter capacity
Warwick					
Weak hurricane	16,270	17,840	1,150	2,420	3,980
Severe hurricane	28,760	25,700	2,880	3,770	3,980
East Greenwich					
Weak hurricane	790	720	210	220	300
Severe hurricane	1,240	1,010	540	310	300
TOTAL for severe hurricane scenario	**30,000**	**26,710**	**3,420**	**4,080**	**4,280**

840.2 Shelters

1. According to the American Red Cross, 25 percent of an evacuated population will seek public shelters in the event of most disasters. The total shelter capacity of the SAMP towns is 4,280 people.

2. There are three Red Cross–approved emergency shelters in the Warwick section of the Greenwich Bay watershed (Toll Gate, Pilgrim, Warwick Veterans high schools).

3. There are two emergency shelters approved by the American Red Cross in East Greenwich that can shelter 800 people (Carr, 2003). The current shelter capacity results in a deficit of at least 1,200 spaces for sheltering in the town in accordance with FEMA's stipulations (Carr, 2003). The town is cooperating with the Red Cross in order to register and approve other shelters.

840.3 CRMC response

1. Section 180.3 of the RICRMP outlines the CRMC post-hurricane- and post-storm-permitting procedures. Specifically, CRMC shall impose a temporary moratorium to remain in effect for a maximum of 30 days from the disaster declaration to provide adequate time to assess damages, determine changes in natural features that may change vulnerability to damage, and identify mitigation opportunities. For more information, see the CRMP, 1997, *as amended.*

Section 850
Hazard preparedness programs

1. There are several federal, state, and local programs for natural disaster mitigation and response and redevelopment for the Greenwich Bay area (Table 6). CRMC is mandated to set policy and permitting activities in the coastal zone. Municipalities, in conjunction with RIEMA, have their own emergency response plans that include evacuation information, shelter locations, debris removal sites, priorities for the replacement of public and private facilities, and FEMA post-storm intervention mechanisms. Local officials are responsible for determining the local permits necessary for rebuilding, as well as for implementing the required flood construction standards dictated by the location of the structures within flood zones. CRMC has its own emergency post-storm response procedures, including emergency permitting, and works with FEMA, RIEMA, and local officials to ensure that immediate intervention occurs and to prevent haphazard redevelopment within flood prone areas.

Table 6. Hazard mitigation authorities and programs

Authority	Program
FEDERAL	
Federal Emergency Management Agency (FEMA)	FEMA is the independent federal agency responsible for leading America's efforts to prepare for, prevent, respond to, and recover from disasters. The Mitigation Division partners with communities and manages the National Flood Insurance Program and oversees FEMA's mitigation programs. http://www.fema.gov/
• National Flood Insurance Program (NFIP)	The NFIP is a FEMA program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for state and community floodplain management regulations that reduce future flood damages.
• Pre-Disaster Mitigation Grants	FEMA's Pre-Disaster Mitigation (PDM) Program provides funds to assist states and local governments in implementing cost-effective hazard mitigation activities that complement a comprehensive mitigation program. Municipalities can request grants from that allocation if they have a mitigation strategy approved.

Authority	Program
• Hazard Mitigation Grant Program (HMGP)	FEMA's Hazard Mitigation Grant Program (HMGP) provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.
STATE & LOCAL	
Rhode Island Emergency Management Authority (RIEMA)	RIEMA carries out the emergency management programs in the state and coordinates disaster response and recovery activities of state agencies and municipalities with FEMA. Their responsibilities include: **Pre-disaster**: Organization, planning, coordination, education, and training for emergency preparedness and management, including the Emergency Operations Plan (EOP). **Post-disaster**: Coordinating disaster response and recovery of state agencies and municipalities with FEMA and any other necessary federal agencies. http://www.riema.ri.gov/
Rhode Island Statewide Planning Program	ıe Statewide Planning Program coordinates the review and approval of local comprehensive plans, amendments, and updates thereto. Rhode Island uses the state comprehensive plans to create disaster-resistant communities by considering natural hazards in all land use decisions. p://www.planning.ri.gov/
Coastal Resources Management Council (CRMC)	CRMC is mandated to set policy and permitting activities in the coastal zone, and has emergency post-storm response procedures, including emergency permitting. CRMC works with FEMA, RIEMA, and local officials to ensure that immediate intervention occurs and to prevent haphazard redevelopment within flood prone areas. http://www.crmc.state.ri.us/
Rhode Island State Building Commission	The building commission administers the state building code, which sets standards for residential and commercial infrastructure to withstand natural hazards.
State Hazard Mitigation Committee	The committee reviews grants, develops programs and policies on hazard mitigation implementation, coordinates and integrates hazard mitigation efforts among state agencies, and analyzes existing state and local hazard mitigation actions and policies. The committee wrote the state comprehensive hazard mitigation plan that addresses all natural disasters.

Authority	Program
Municipal Hazard Mitigation Committees	Municipal hazard mitigation committees encompass government, the public, and private business, and ensure municipal eligibility for the FEMA Pre-disaster Mitigation Grant Program. Warwick and East Greenwich are drafting hazard mitigation plans.
Municipal Harbor Management Commissions	Municipal harbor management plans have an emergency response that describe potential hazards and the role of the harbormaster in response to hazard events.

850.1 Federal pre-natural disaster mitigation

1. FEMA, through the Disaster Mitigation Act of 2000, emphasizes the need for state, local and tribal entities to coordinate mitigation and planning efforts.

2. The FEMA Mitigation Division manages the National Flood Insurance Program (NFIP) (Table 7), which consists of programs for flood insurance, floodplain management, and flood hazard mapping. Approximately 20,000 U.S. communities have adopted and enforced floodplain management programs through the NFIP. Participation provides federally backed flood insurance to those in vulnerable areas in return for land-use/construction performance standards.

Table 7. NFIP Summary for Warwick and East Greenwich from 1978-2003

Municipality	Number of NFIP Policies	NFIP Coverage	Total Premiums	Number of Claims	Total Payments
East Greenwich	120	$20,514,400	$96,986	31	$138,277
Warwick	1,718	$220,393,200	1,186,293	382	$918,783

Source: FEMA, 2003

3. Through the NFIP, FEMA produces flood hazard maps. FEMA defines the Special Flood Hazard Area (SFHA) as an area of land that would be inundated from a flood having 1 percent chance of occurring in any given year[5]. Development is permitted within the SFHA provided that it complies with local floodplain ordinances that meet minimum federal requirements. Communities participating in the NFIP must obtain flood insurance for insurable structures within the SFHA in order to protect federally funded investments and assistance used for acquisition and/or construction. Warwick and East Greenwich have been identified as having a Special Flood Hazard Area and have been issued a Flood Insurance Rate Map.

[5] A 100-year flood provides the theoretical basis for flood zone mapping and regulation. Theoretically, this event has a 1 percent chance of occurring in any one year. However, given the erratic and unpredictable nature of extreme weather events, there could be more than one event in a year or none at all. In effect, this complicates flood management planning.

4. The FEMA Community Rating System (CRS) allows community residents to gain credit points that result in discounts on NFIP premiums. When communities go beyond the minimum standards for floodplain management, the CRS can provide discounts of up to 45 percent off flood insurance premiums for policyholders in that community. Warwick and East Greenwich are currently not rated under this system.

5. After November 1, 2004, local governments applying for FEMA Pre-Disaster Mitigation (PDM) funds through Rhode Island must have an approved local mitigation plan, and the state must have an approved standard state mitigation plan, in order to compete for local mitigation project grants.

850.2 State and local roles

1. In 1998, Rhode Island was named a showcase state for natural disaster resistance and resilience. The *Rhode Island Showcase State Executive Order* is listed in the appendix.

2. Section 150 of R.I. Coastal Resources Management Program (RICRMP) defines a coastal buffer as a land area adjacent to a shoreline (coastal) feature that is, or will be, vegetated with native shoreline species and which acts as a natural transition zone between the coast and adjacent upland development. A coastal buffer zone differs from a construction setback in that the setback establishes a minimum distance between a shoreline feature and construction activities, while a buffer zone establishes a natural area adjacent to a shoreline feature that must be retained in, or restored to, a natural vegetative condition (CRMP, 1997, *as amended*).

3. The establishment of a coastal buffer zone is based on the CRMC legislative mandate to preserve, protect and, where possible, restore ecological systems in the coastal zone. The CRMP incorporates coastal buffer zones because buffers aid in flood control by reducing the velocity of runoff and by encouraging infiltration of precipitation and runoff into the ground rather than allowing runoff to flow overland and flood low lying areas. In addition, coastal buffer zones often occupy the flood plain itself and thus add to coastal flood protection. The determination of the inland boundary of this zone must balance this mandate with property owners' rights to develop and use their property. The coastal buffer zone is generally contained within the established construction setback (RICRMP Section 150, CRMC, 1997, *as amended*).

4. Drainage areas or systems enable runoff to travel to waterways and the coast. Runoff is a function of the infiltration capacity of the soil, the amount of vegetation, and the extent of development. Drainage becomes a flooding problem in areas where runoff is increased due to heavy rain and where natural drainage systems have been altered as a result of development.

5. Building codes and standards regulate the design, construction, and maintenance of buildings. The R.I. State Building Code meets insurance industry health and safety standards that help protect people and property in the event of a natural disaster.

6. Section 300.3 of the RICRMP addresses CRMC's flood zone construction guidelines and permitting.

7. Oakland Beach is designated as a Class A critical erosion area in the CRMP; therefore, setbacks are required. The CRMP defines a setback as the minimum distance from the inland boundary of a coastal feature at which an approved activity or alteration may take place (CRMP, 1997, *as amended*). For specific information on setback requirements, see the CRMP.

Section 860
Regulations, recommended actions, and research needs

1. Regulations, recommended actions, and research are needed to protect Greenwich Bay from natural hazards. In regulatory sections, plain text indicates current CRMP regulations, and underlined text indicates new regulatory language. Recommended actions and research needs may apply to federal agencies, state agencies, local governments, and non-government organizations. Recommended actions are presented in plain text.

860.1 Regulations

860.1A Policies

1. Reconstruction after storms

(a) When catastrophic storms, flooding, and/or erosion occur at a site under CRMC jurisdiction, and there is an immediate threat to public health and safety or immediate and significant adverse environmental impacts, the executive director may grant an emergency assent under Section 180 of the RICRMP.

(b) A CRMC assent is required of all persons proposing to rebuild shoreline structures that have been damaged by storms, waves, or other natural coastal processes in the Greenwich Bay watershed. When damage to an individual structure is greater than 50 percent of the total square footage of that structure, post-storm reconstruction shall follow all standards and policies for new development in the area in which it is located.

(c) Setback requirements from RICRMP Section 140 shall be applied.

(d) All construction within FEMA flood zones must follow the required construction standards for the flood zone in which the structure is located. Municipal officials need to certify that these standards are correct and present on any application for activity submitted to CRMC.

(i) Construction in coastal high hazard flood zones (V zones) as defined by federal flood insurance rate maps, shall follow the regulations as listed in Section 300.3 of the RICRMP, as amended.

(ii) Construction in areas of coastal stillwater flood hazards (A zones), as defined by flood insurance rate maps, shall follow the regulations listed in Section 300.3 of the RICRMP, as amended.

(e) A CRMC maintenance assent is required to repair structures where less than 50 percent of the total square footage of the structure has been destroyed by storms, waves, or natural processes.

(f) CRMC encourages post-storm reconstruction applicants to increase setbacks further from the coastal feature than the previous development without expanding the footprint.

2. Marinas that are expanding or replacing piers or docks shall meet the new construction requirements for marinas.

3. When concentrated losses occur, CRMC may issue special 30-day permits to marinas and other marine operators for removing debris such as sunken or burning vessels and materials on wetlands, in the coves, and in Greenwich Bay.

4. Wetlands and coastal buffers, which are significant in shielding flood-prone areas from storm damage, shall be considered priorities for preservation.

860.1B Prohibitions

1. Filling, removing or grading is prohibited on beaches, dunes, undeveloped barrier beaches, coastal wetlands, cliffs and banks, and rocky shores adjacent to Type 1 and Type 2 waters, including in the Greenwich Bay watershed, unless the primary purpose of the alteration is to preserve or enhance the area as a natural habitat for native plants and wildlife or for beach replenishment.

2. Post-storm reconstruction is prohibited from occurring within the setback area of V flood zones when damage to an individual structure is greater than 50 percent of the total square footage of that structure.

860.1C Standards

1. A significant amount of construction within Rhode Island's coastal zone has the potential to fall within a FEMA-designated flood zone. The approximate limits of the flood zones and the associated base flood elevations are shown on FEMA's Flood Insurance Rate Maps, which are commonly available at municipal building departments. CRMC requires all applicants proposing construction within flood hazard zones to demonstrate that applicable portions of the R.I. State Building Code (RISBC), specifically RISBC-8, which contains requirements for flood zone construction, are addressed.

2. When considering applications for the construction of residential, commercial, industrial, and recreational structures, including utilities such as gas, water, and sewer lines, in high hazard areas, these actions should be consistent with state policies as contained in the hazard mitigation plan element of the state guide plan (CRMC, 1997).

3. Piling standards need to be adapted to accommodate the 100-year flood rule to protect boats and coastal assets.

4. Marinas are required to update facilities to the current design and building standards when they apply for significant expansions of 25% or more.

860.2 Recommended Actions

860.2A General

1. CRMC should develop strict construction standards for new or expanding marinas in the V-flood zone.

2. Develop Good Samaritan legislation to allow marinas to assist in debris removal and towing boats that are on fire or in danger of sinking.

3. Municipalities and marinas should pursue discussions with FEMA regarding agreements for accepting debris and oils collected by marinas after storm events.

4. Improve boat-ramp accessibility and conditions to ensure rapid and safe removal of boats and debris after hazard events.

5. CRMC should identify shoreline locations with sediment sources that should not be stabilized (i.e. bulkheads and seawalls).

6. Efforts should be made to utilize and preserve wetlands, which serve as natural flood abatement and storage areas, through measures such as buffer zones, preservation, and/or acquisition programs (See Section 390.8 in the Habitat and Environmental Assets Chapter of this SAMP).

7. The chambers of commerce should consider initiating business alliances to implement the Institute for Business and Home Safety *Open for Business: A Disaster Planning Toolkit for the Small Business Owner*.

860.2B Boating

1. Marinas should consider following the structural guidelines referenced in the book *Marinas and Small Craft Harbors* by Waterfront Design Associates.

2. Municipalities should consider designating several locations within Greenwich Bay to place wrecked boats and debris prior to insurance assessments.

3. The private marine sector should consider taking a leading role in removing vessels from high-risk zones and clearing debris from the waters and wetlands after a storm.

4. CRMC should develop a marina call list to be part of the natural hazard warning system and incorporated within the RIEMA notification process.

5. Where possible, boats should be removed from high-hazard areas and dry-docked in non-flood zone areas well in advance of the storm so as not to clog evacuation routes.

860.2C Municipalities

1. Municipalities should continue to strictly enforce construction standards in coastal high-hazard flood zones (V zones) and coastal stillwater flood hazards (A zones), as defined by flood insurance rate maps and buffer zones.

2. Municipalities should consider establishing plans for debris removal in wetlands. Temporary (60-day) storage sites should be identified by municipalities and should be located near areas where large amounts of debris are expected to accumulate. These sites should be listed with local and state civil defense offices as part of the coordination process. Sites in Greenwich Bay that might be considered include:

   i. Goddard Memorial State Park boat launch and parking lot (Warwick)
   ii. Oakland Beach parking lot and boat ramp (Warwick)
   iii. T.F. Green Airport parking lots (Warwick)
   iv. Thayer Arena (Warwick)
   v. Parking lot behind Mickey Stevens Sports Complex (Warwick)
   vi. Former East Greenwich landfill
   vii. Local businesses

3. Municipalities, in conjunction with CRMC, RIDEM, and the RI Resource Recovery Corporation (RIRRC), should develop debris-removal policies that designate responsibilities and allocate resources. These policies should address removal of debris on shores and in navigable waters before a storm to mitigate impacts during natural hazard events. In addition, the policies should consider having contracts in place with local marinas to use their technical resources for salvaging and rescuing boats. Issues to be identified in advance include liability and billing rates.

4. Municipalities should formally adopt and implement multi-hazard mitigation strategies to gain points under the FEMA Community Rating System and generate economic and environmental benefits. As of February 2005, Warwick has submitted its hazard mitigation plan to FEMA for review. It is expected that official plan adoption will be completed by the summer of 2005.

5. When mitigation strategies are approved, adopted, and FEMA funding comes available, municipalities should post signs clearly marking evacuation routes.

6. Municipalities and state government should identify any additional priority sites to purchase land after hazard events.

7. Public and private tree maintenance programs should be implemented to ensure that trees downed during natural disasters do not destroy or damage power lines and infrastructure.

8. Structures located within flood zones AE and VE should be inventoried and rated for risk levels in a natural hazard event.

9. Municipalities and RI Economic Development Corporation should create a communications strategy with regional and state tourism councils to prevent tourism losses after hazard events.

860.2D Education

1. RIEMA and the U.S. Army Corps of Engineers should offer a short course for municipal officials on the importance of proper structures to mitigate hazards.

2. Municipalities should establish permanent hotlines so the public can report marine debris and locate boats following a natural disaster to maintain the safety and navigation of Greenwich Bay waters.

3. Boat owners should be educated on properly securing boats to moorings and in dock slips to reduce boat and infrastructure damage.

4. More information on coastal erosion should be provided to the general public, specifically to coastal landowners and real estate agents dealing in coastal properties.

5. CRMC should educate the public within its jurisdiction about bypassing time-consuming permitting procedures and obtaining CRMC permission letters that allow applicants to trim trees near homes, businesses, and power lines.

6. Locations of all evacuation routes and traffic control points in shore areas and in flood zones V and A should be publicized so communities are informed regarding natural disasters.

860.3 Research needs

1. A study should be conducted on the potential impacts of predicted sea level rise on the Greenwich Bay watershed.

Section 870
Literature Cited

Boothroyd, J.C. (1999). Geologic processes, Chapter 4, *in* Coastal Resources Management Council, ed., *Special area management plan for the Salt Ponds of Rhode Island*: CRMC.

Boothroyd, J., C., and S. J. McCandless. (2003). Quarternary Geologic Map of the East Greenwich and parts of the Crompton, and Bristol Quadrangles, Rhode Island, RI: Open File Map 2003-01, Rhode Island Geological Survey STATEMAP Program, Glacial Morphosequence Map (scale: 1:24,000).

Boothroyd, J.C., J.P. Klinger, and C.L. Galagan (1998). Coastal geologic hazards on the south shore of Rhode Island: *in* Murray, D.P., (ed.), *Guidebook to field trips in Rhode Island and adjacent regions of Connecticut and Massachusetts, New England Intercollegiate Conference Guidebook*.

Box, C., J. Freedman, and J.C. Boothroyd. (2004). Shoreline protection structures in Greenwich Bay: Open File Map 2004-02, Rhode Island Geological Survey Map Series, 6 maps on 1997 orthophoto base, with supporting field digital images (scale: 1:2,000).

Brown, C.W. (1979). Hurricanes and Shore-Line Changes in Rhode Island. *In* B.L. Gordon (ed.): *Hurricane in Southern New England: An analysis of the great storm of 1938.*

Carr, J. (2003). DRAFT Strategies for Reducing the Risks from Natural Hazards in East Greenwich, Rhode Island.

Dein, M.G. (1981). A Quantitative, Photogrammetric Analysis of Narragansett Bay, Rhode Island Shoreline Changes, 1938-1975. University of Rhode Island Thesis.

Douglas, B.C. (1991). Global sea level rise: Journal of Geophysical Research, vol. 96, no. C4, p. 6981-6992.

FEMA (2003). A Nation Prepared Federal Emergency Management Agency Strategic Plan: Fiscal Years 2003 – 2008. Washington, D.C.: FEMA.

FEMA (2002a). National Flood Insurance Program Description. Washington, D.C.: FEMA.

FEMA (2002b). State and Local Plan Interim Criteria Under the Disaster Mitigation Act of 2000. Washington, D.C.: FEMA.

FEMA (2002c). Instructions for Using the attached Crosswalk Reference Document for the Review and Submission of Local Mitigation Plans of the State Hazard Mitigation Officer. *In:*

State and Local Plan Interim Criteria Under the Disaster Mitigation Act of 2000. Appendix A – Region VIII Plan Crosswalk.Washington, D.C.: FEMA.

FEMA. (2002d). Hurricane Preparedness Guidelines For Marinas. Washington, D.C.: FEMA.

FEMA. (1997). Multi Hazard Identification and Risk Assessment: A Cornerstone of the National
Mitigation Strategy. Washington, D.C.: FEMA.

Gordon, W.R. (1980). The Perception of Storm Hazard of Selected Rhode Island Barrier Beach Inhabitants. University of Rhode Island M.S. Thesis.

Gornitz, V., and S. Lebedeff (1987). Global sea-level changes during the past century. *In* D. Nummedal, O.H. Pilkey, and J.D. Howard (eds.), *Sea-level Fluctuations and Coastal Evolution: Society of Economic Paleontologists and Mineralogists, Special Publication No. 41*.

Hayes, M.O., and J.C. Boothroyd (1969). "Storms as Modifying Agents in the Coastal Environment," *In* Eastern Section, Society of Economic Paleontologists and Mineralogists (SEPM), *Coastal Environments, Northeast Massachusetts and New Hampshire*.

Hoffman, J.S. (1984). Estimates of future sea level rise. *In* Barth, M.C., and Titus, J.G., (eds.) *Greenhouse effect and sea level rise—A challenge for this generation*. New York: Van Nostrand Reinhold Co.

Hoffman, J.S., D. Keyes, and J.G. Titus. (1983). *Projecting Future Sea Level Rise; Methodology, Estimates to the Year 2100, and Research Needs*. Washington, D.C.: U.S. Environmental Protection Agency.

Journal-Bulletin. (1979). *Rhode Island Almanac.* Journal-Bulletin Co., Providence, R.I.

Keller, E.A. (1975). *Environmental Geology*. Columbus, Ohio: Charles E. Merrill Publishing Co.

Kennedy, S. and V. Lee (2003). *Greenwich Bay: An Ecological History*. Narragansett, R.I.: Rhode Island Sea Grant.

Olsen, S., D. Robadue, and V. Lee. (1980). *An Interpretive Atlas of Narragansett Bay.* Narragansett, R.I.: University of Rhode Island Coastal Resources Center.

Nicholls, R.J., and S.P. Leatherman. (1994 in press). Global sea-level rise. In K. Strzepek and J.B. Smith (ed.). *As Climate Changes: Potential Impacts and Implications*. Cambridge: Cambridge University Press.

Nichols, R.L. and A.F. Marston. (1939). Shoreline Changes in Rhode Island Produced by Hurricane of September 21, 1938. *Bulletin of the Geological Society of America* **50**:1357-1370.

Pogue, P. (2002). DRAFT Warwick Multi-Hazard Mitigation Strategy. Rhode Island Emergency Management Agency.

Raford, N. (1999). The Use of GIS in Flood Hazard Analysis: A Report for the City of Warwick and Project Impact. Providence: Brown University.

Titus, J. and C. Richman. (2001). Maps of Lands Vulnerable to Sea Level Rise: Modeled Elevations along the U.S. Atlantic and Gulf Coasts. *Climate Research 18: 205-228.*

U.S. Army Corps of Engineers, New England Division (1993). Rhode Island Sea, Lake, and Overland Surges from Hurricanes (SLOSH) Study. Waltham, Mass.: USACE Technical Data Report.

U.S. Army Corps of Engineers. (1995). Rhode Island Hurricane Evacuation Study, Technical Data Report.

U.S. National Oceanic and Atmospheric Administration. (2004). U.S. Storm Events Database. National Climatic Data Center. http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

Vallee, D. (2003a). *Tracks of Major Land Falling Tropical Cyclones in Southern New England 1900-1959.* Taunton, Mass.: National Weather Service, National Oceanographic and Atmospheric Administration.

Vallee, D. (2003b). *Tracks of Major Land Falling Tropical Cyclones in Southern New England 1960-1999.* Taunton, Mass.: National Weather Service, National Oceanographic and Atmospheric Administration.

Vallee, D.R. and M.R. Dion. (1998). Southern New England Tropical Storms and Hurricanes, A Ninety-Eight Year Summary (1909-1997). Taunton, Mass.: National Weather Service, National Oceanographic and Atmospheric Administration.

Chapter 9
Regulations

Table of Contents

Figures

Section 900
Introduction

1. The Rhode Island Coastal Resources Management Program (RICRMP) should be referred to for specific regulatory requirements on any activities that occur within the Greenwich Bay watershed. All applicants shall follow applicable requirements as contained in the RICRMP, including and specific requirements listed under water types in RICRMP Section 200 and additional Category B requirements in RICRMP Section 300, the requirements and prerequisites in Section 320 for Inland Activities and Section 335 for Public Access, and any regulations in this SAMP chapter.

Section 910
Coastal Buffer Zones (RICRMP Section 150)

910.1 Definition

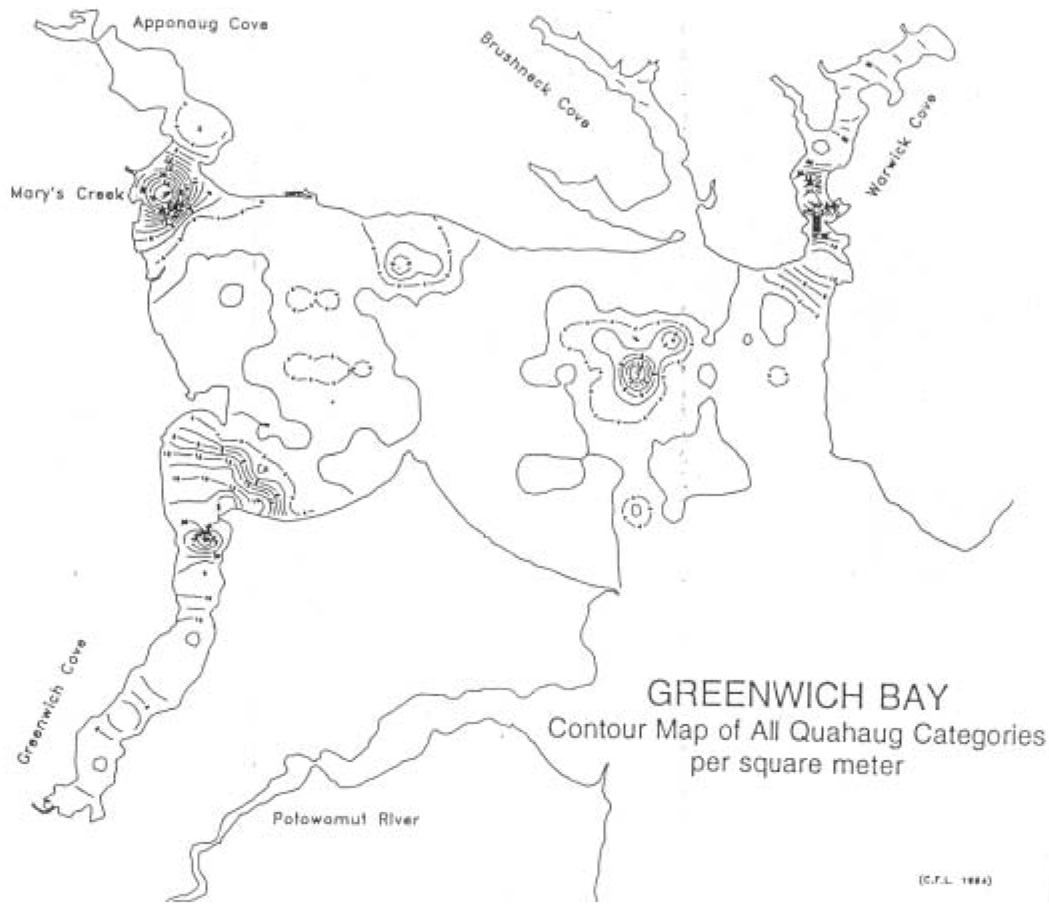
1. A *coastal buffer zone* is a land area adjacent to a shoreline (coastal) feature, tributary to Greenwich Bay, or freshwater wetland in the Greenwich Bay watershed that is, or will be, vegetated with native shoreline species and which acts as a natural transition zone between the coastal and riparian areas and adjacent upland development. A coastal buffer zone differs from a construction setback (RICRMP Section 140) in that the setback establishes a minimum distance between a shoreline feature and construction activities, while a buffer zone establishes a natural area adjacent to a shoreline feature that must be retained in, or restored to, a natural vegetative condition. The coastal buffer zone is generally contained within the established construction setback.

2. *Land trusts* are organizations incorporated pursuant to R.I. Gen. Laws §7-6-1, et. seq., or organizations meeting the definition of "charitable trust" set out in R.I. Gen. Laws §18-9-4, or organizations duly existing as private nonprofit organizations in other states or the District of Columbia among whose purposes is the preservation of open space, as the term is defined in the SAMP. Further, all organizations must have been granted preliminary status as tax-exempt corporations under Section 501 (c) (3) of the Internal Revenue Code and its regulations, as they now exist or may hereafter be amended.

3. A *native vegetated area* is a previously landscaped area or lawn adjacent to a shoreline (coastal) feature, tributary to Greenwich Bay, or freshwater wetland in the Greenwich Bay watershed where native coastal or riparian species have been restored voluntarily.

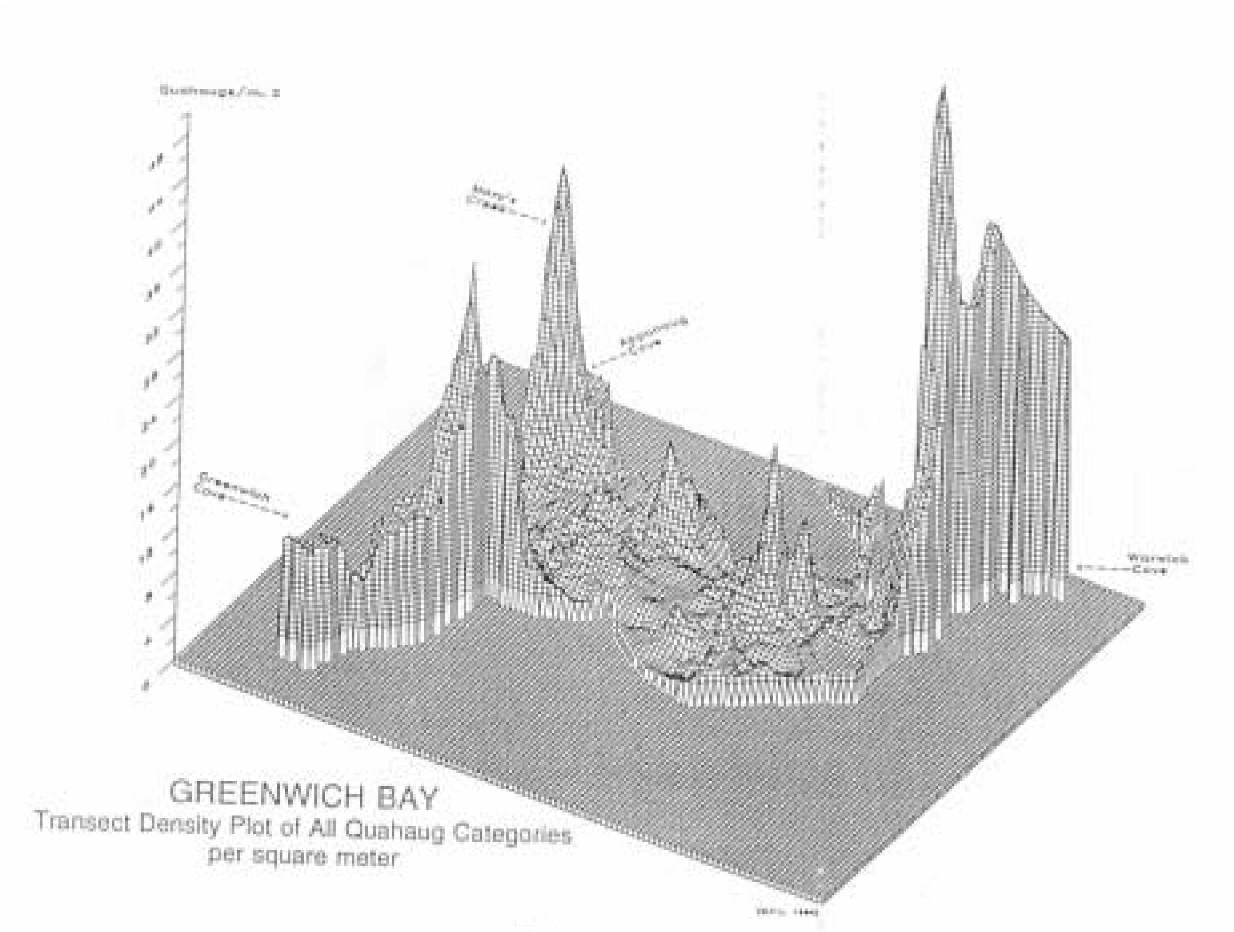
4. Mary's Creek and Baker's Creek are *critical areas* in the Greenwich Bay coastal zone. Mary's Creek is a coastal wetland complex feeding one of the most productive quahog grounds in Greenwich Bay (Figures 1 and 2). Baker's Creek is a coastal wetland complex that provides valuable habitat for migratory birds. Gorton Pond's shoreline provides habitat for at least three regionally rare plant species.

Figure 1. Contour map of quahog density in Greenwich Bay



Source: Ganz et al. 1994

Figure 2. Transect density plot of quahogs in Greenwich Bay



Source: Ganz et al. 1994

910.2 Policies

1. CRMC will update and develop standards for coastal buffer zone management specifically within suburban areas. Once completed, the CRMC will amend the Special Area Management Plan to adopt the new standards.

2. CRMC encourages the establishment of native vegetated areas along shorelines, tributaries, and wetlands in the Greenwich Bay watershed where designated coastal buffer zones or areas of existing undisturbed natural vegetation (non-landscaped areas) are not present. CRMC shall issue a certificate to property owners recognizing that they have voluntarily planted a native vegetated area on their property. Property owners holding a certificate may make alterations to the native vegetated area and will not be subject to the coastal buffer zone regulations unless these regulations are triggered by alterations to existing structures or new development on the lot.

3. It is the CRMC's policy to develop conservation easements for the Greenwich Bay watershed that permanently restrict development, such as docks, in coastal buffers.

4. No land shall be subdivided unless it can accommodate the required coastal buffer zone.

910.3 Prohibitions

1. New structures are prohibited within the coastal buffer zone required around critical areas unless part of a buffer management plan.

2. Alterations to an existing structure or structures on a residential lot that result in the expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more are prohibited without the establishment of the coastal buffer zone required in that area.

910.4 Standards

1. All coastal buffer zones shall be measured from the inland edge of the most inland shoreline (coastal) feature. In instances when the coastal feature accounts for 50 percent or more of the lot, CRMC may grant a variance to the required buffer width.

2. *Coastal buffer zone requirements for new residential development.* The minimum coastal buffer zone requirements for new residential development bordering Rhode Island's shoreline are contained in Table 2a of RICRMP Section 150. The Coastal Buffer Zone requirements are based upon the size of the lot and the CRMC's designated Water Types (Type 1 - Type 6). Where the buffer zone requirements noted above cannot be met, the applicant may request a variance in accordance with this SAMP. A variance to 50 percent of the required buffer width may be granted administratively by CRMC's executive director if the applicant has satisfied the burdens of proof for the granting of a variance. Where it is determined that the applicant has not satisfied the burdens of proof, or the requested variance

is in excess of 50 percent of the required width, the application shall be reviewed by the full council.

3. *Coastal buffer zone requirements for alterations to existing structures on residential lots.* All calculations for the requirements of a coastal buffer zone shall be made on the basis of structural lot coverage. Structural lot coverage shall mean the total square foot area of the structure(s) on a lot or parcel (RICRMP §300.3.A.5).

Where alterations to an existing structure or structures result in the expansion of the structural lot coverage such that the square footage of the foundation increases by less than 50 percent, no new coastal buffer zone shall be required.

Where alterations to an existing structure or structures result in the expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more, the coastal buffer zone requirement shall be established with a width equal to the percentage increase in the structural lot coverage as of August 8, 1995, multiplied by the value contained in Table 2a of RICRMP Section 150.

Coastal buffer zones shall not be required when a structure is demolished and rebuilt on the existing footprint. Where a structure is demolished and rebuilt and will result in an expansion of the structural lot coverage such that the square footage of the foundation increases by 50 percent or more, a coastal buffer zone shall be established with a width equal to the percentage increase in a structure's footprint, multiplied by the value contained in Table 2a of RICRMP Section 150.

Where the applicant demolishes a structure, any contemporary or subsequent application to rebuild must meet applicable setback requirements.

Structures that are less than 200 square feet in area are excluded from these requirements.

In addition, the CRMC executive director shall have the authority to grant a variance to this requirement for category "A" assents in accordance with the burdens of proof for variances contained in the SAMP.

910.5 Variances

1. Applicants desiring a variance from the coastal buffer zone standards shall make such request in writing and address in writing the six criteria below. The application shall then be granted an assent only if CRMC finds that:

   a. The proposed alteration conforms to applicable goals and policies in parts two and three of the RICRMP.

   b. The proposed alteration will not result in significant adverse environmental impacts or use conflicts, including but not limited to, cumulative impacts.

c. The applicable standard cannot be met due to conditions at the site in question.

d. The modification requested by the applicant is the minimum variance to the applicable standard necessary to allow a reasonable alteration or use of the site.

e. The requested variance to the applicable standard is not due to any prior action of the applicant's predecessors in title.

f. The standard will cause the applicant an undue hardship due to the conditions of the site in question. In order to receive relief from an undue hardship, an applicant must demonstrate, among other things, the nature of the hardship and that the hardship is shown to be unique or particular to the site. Mere economic diminution, economic advantage, or inconvenience does not constitute a showing of undue hardship that will support the granting of a variance. For a new residential development or alterations to existing structures on residential lots, the inability to construct a residential home larger than 1,400 square feet, which is the average square footage of a single-family Warwick home, or expand a residential home beyond 1,400 square feet does not constitute an undue hardship.

2. Relief from a standard does not remove the applicant's responsibility to comply with all other RICRMP requirements.

3. In those instances where a variance would be rendered unnecessary if a variance for a setback were acquired from the local municipality, the applicant must first approach the municipality and exhaust his remedies there prior to requesting approval for a CRMC variance.

Section 920

Shoreline Features (RICRMP Section 210)

Policy

1. CRMC supports local efforts to adopt wetlands, streams, and shorelines by providing technical and permitting assistance when needed.

920.1 Coastal Beaches (RICRMP Section 210.1)

920.2A Policy

1. It is CRMC's policy to protect horseshoe crab spawning areas. Beaches along Potowomut Neck from Sandy Point to Beachwood Drive, the northern shore of Chepiwanoxet Point, the southern shore of Buttonwoods Cove from the cove entrance to Ode Court, and at Warwick City Park are recognized as horseshoe crab spawning areas.

920.2B Prohibitions

1. Shoreline structures and activities that directly disturb horseshoe crab spawning or contribute to beach erosion along horseshoe crab spawning areas are prohibited.

920.2C Requirements

1. Applicants for shoreline structure construction and maintenance and beach nourishment in the vicinity of horseshoe crab spawning areas shall limit activities during the months of May through July that may impact spawning.

920.2 Coastal Wetlands (RICRMP Section 210.3)

920.1A Policies

1. CRMC supports wetland restoration programs in salt marshes and contiguous freshwater or brackish wetlands adjacent to coastal waters if significant degradation of wetland functions and values can be demonstrated.

2. CRMC shall pursue restoration efforts or support efforts of Warwick or nongovernment organizations to restore tidal wetland areas identified by the SAMP or the State Habitat Restoration Plan. These efforts will help achieve the Governor's Narragansett Bay and Watershed Planning Commission goal of restoring 100 acres of coastal wetland by 2008.

Section 930
Areas of Historic and Archaeological Significance (RICRMP Section 220)

930.1 Policies

4. Preserve cultural, historical and archeological resources of the Greenwich Bay watershed.

5. Educate the public about the value of cultural, historical, and archeological resources of the Greenwich Bay watershed.

6. Conduct research to assist with the identification and preservation of cultural, historical and archeological resources of the Greenwich Bay watershed.

930.2 Standards

6. Applications for major activities within the Greenwich Bay watershed shall be forwarded to RIHPHC for review and comment as part of the standard CRMC regulatory process.

7. Applicants for activities proposed along the Greenwich Bay shoreline will have to perform archeological investigations when required by RIHPHC. Though other areas may exist and RIHPHC reserves the right to require additional information and potential studies, these areas are identified to give applicants a sound idea of areas of concern.

8. CRMC will await the response of RIHPHC prior to completion of its own staff review and subsequent council decision. Unless a variance is granted, CRMC will incorporate the RIHPHC guidance into its regulatory decision-making and permit stipulations. Applicants are encouraged to contact RIHPHC prior to filing with CRMC in order to expedite permitting.

9. Where possible, those sites identified by RIHPHC as having potential historical or archeological significance will be incorporated into the buffer zone by extending the boundary of the buffer where appropriate.

10. The state and municipalities will ensure that cultural, historical, and archeological assets are not compromised by runoff.

Section 940
In Tidal and Coastal Pond Waters, on Shoreline Features and Their Contiguous Areas (RICMRP Section 300)

940.1 Residential, Commercial, Industrial, and Public Recreational Structures (RICRMP Section 300.3)

940.1A Policy

1. The CRMC will identify and grandfather existing quahog facilities on Greenwich Cove that have been in existence since 2000. Grandfather permits will be issued to those facilities as long as 75% of the facility is used by commercial fishermen. Once the facility falls below the 75% commercial fishing occupancy level, this permit will be null and void.

940.2 Recreational Boating Facilities (RICRMP Section 300.4)

940.2A Definitions

1. A person is considered to be living aboard their boat if they inhabit their boat while berthed or moored on Greenwich Bay for six or more months of any given 12-month period.

940.2B Prohibitions

1. The discharge of sewage, whether treated or untreated, from boats into tidal waters is prohibited.

2. Boats with people living aboard are prohibited from mooring or berthing in all tidal waters in Greenwich Bay unless they are within the boundaries of a marina that provides pumpout capability directly to boats. The boat shall be tied into the pumpout system at all times while it is moored or berthed.

940.2C Standards

1. All new or expanding marina facilities in Greenwich Bay shall provide marine pumpout capability in each slip that can accommodate a boat larger than 40 feet. All marinas should have pumpout capability in each slip that can accommodate a boat larger than 40 feet by 2014.

2. Marina pumpout facilities shall be placed in a convenient location for boaters to maximize the pumpout facility's use, such as at a fuel dock.

940.3 Treatment of Sewage and Stormwater (RICRMP Section 300.6)

940.3A Policy

1. It is CRMC policy to require sewer tie-ins to available sanitary sewer lines in the Greenwich Bay watershed. Inadequately treated wastewater from ISDS contributes to water-quality impairments in Greenwich Bay. It is important that these sources be mitigated through planned sewer extensions and mandatory tie-ins to new and existing sewers.

940.3B Prerequisites

1. Applications to construct or alter a WWTF or to construct, alter, or extend sanitary sewer lines in the Greenwich Bay watershed shall include a plan for mandatory sewer tie-ins in residential and commercial developments.

940.3C Prohibitions

1. The installation or replacement of existing ISDS is prohibited in areas where sanitary sewers are available in the Greenwich Bay watershed. Properties shall be tied in to the available sanitary sewers in these instances.

2. New expanded development shall not be allowed where sanitary sewers are available unless the property is tied in to the sewer system.

940.3D Standards

1. Mandatory sewer tie-in plans shall at least include location maps, draft ordinance language, enforcement provisions, and implementation schedules that will be used to create a mandatory sewer tie-in program.

2. Sewer tie-in plans shall include measures that make sewer tie-ins mandatory on land parcels that abut the portion of street or highway with a sewer line or within any new subdivisions that abut the sewer easement.

3. The mandatory sewer tie-in program shall be implemented and sewer tie-ins begin to be required within one year after completing WWTF improvements and sewer extensions for the areas within the Greenwich Bay watershed that currently have sewers and any new sewer extensions.

940.4 Dredging and Dredged Material Disposal (RICRMP Section 300.9)

940.4A Policy

1. It is CRMC policy to facilitate public and private dredging needs while providing appropriate protection to shellfish, finfish, and other natural resources in Greenwich Bay and its coves.

940.4B Standards

1. Prior to any improvement dredging project, applicants shall be required to remove any significant shellfish in the sediments and transplant the shellfish to a RIDEM/CRMC–approved site. Appropriate sites include spawner sanctuaries, quahog resource preserves, or sites deemed appropriate by the RIDEM Division of Fish and Wildlife and CRMC.

2. Prior to any maintenance dredging project, applicants shall be required to make the proposed dredging area available for RIDEM, CRMC, or other groups, such as the Rhode Island Shellfishermen's Association, to remove any significant shellfish present in the sediments and transplant them to a RIDEM/CRMC–approved site. Appropriate sites include spawner sanctuaries, quahog resource preserves, or sites deemed appropriate by the RIDEM Division of Fish and Wildlife and CRMC.

940.5 Submerged Aquatic Vegetation and Aquatic Habitats of Particular Concern (RICRMP Section 300.18)

940.5A Policy

1. The following areas are designated as quahog resource preserves:
   c. Mary's Creek and the area delineated by the northern and southern edge of the Mary's Creek salt marsh due east to the federal navigation channel
   d. The area delineated by the shoreline and lines from Long Point due west and the southernmost point of Chepiwanoxet Point due south

940.5B Prohibitions

1. New structures and facilities are prohibited within quahog resource preserves.

Section 950
Protection and Enhancement of Public Access to the Shore
(RICRMP Section 335)

950.1 Policy

1. It is CRMC policy to fully utilize RICRMP Section 335 to continue to protect and provide for new public access sites as part of the ongoing permit process. CRMC shall ensure that all permitted activities maintain public access at CRMC-designated ROWs to Greenwich Bay and its coves. Where appropriate, CRMC shall require applicants to provide access of a similar type and level to that which is being impacted as the result of a proposed activity or development project.

2. It is CRMC policy that marinas, prior to seeking expansions, exhaust all options for making full use of existing in-water footprints.

3. It is CRMC policy to work cooperatively with RISAA, Warwick, East Greenwich, and nongovernment organizations to identify and adopt CRMC-designated ROWs on Greenwich Bay and its coves as part of the Adopt-A-ROW Program. The Adopt-A-ROW Program encourages citizen involvement with the cleanup and maintenance of public ROWs.

4. It is CRMC policy to work with the municipalities to identify and designate additional public ROWs listed in their harbor management plans. The municipalities and CRMC shall prioritize ROWs in areas with more limited access, such as Apponaug Cove, Warwick Neck, and the western and northern shore of Greenwich Bay. CRMC designation provides added enforcement, protection against encroachment, and limited liability protection for private landowners.

5. It is CRMC policy to encourage marinas along Greenwich Bay and its coves to voluntarily include provisions for public access in their permits. Marinas receive limited liability protection under state law if public access is stipulated in their CRMC permits (R.I. Gen. Laws §32-6-5).

6. CRMC recognizes that, due to public safety, security, or environmental considerations, certain sites may not be appropriate for development of facilities that encourage physical access to the shoreline. It is CRMC's policy to consider these issues during its ROW designation process. In the Greenwich Bay watershed, areas not appropriate for facilities that encourage physical access include, but are not limited to, salt and brackish marshes, such as Mary's and Baker's creeks and upper Brush Neck Cove; barrier beaches; and shallow silty waters.

7. It is CRMC policy to provide Warwick and East Greenwich with signs for posting at CRMC-designated ROWs. CRMC shall provide signs as needed at the request of the municipalities.

8. It is CRMC policy, in cooperation with Warwick and East Greenwich, to educate residents about their rights in respect to accessing the shore. Education shall include posting and maintaining a list of CRMC-designated ROWs at East Greenwich Town Hall and Warwick City Hall. In addition, CRMC recommends that citizens who wish to be involved in preserving public access:

- Clean up public access sites and beaches
- Participate in Adopt-A-Spot programs
- Participate in local harbor management processes
- Gather information necessary to designate public ROWs
- Report the unlawful blockage of any public ROW to CRMC and/or to local officials

950.2 Prohibitions

1. CRMC prohibits Warwick and East Greenwich from abandoning CRMC-designated ROWs along Greenwich Bay and its coves by unless new equivalent access is provided.

950.3 Standards

1. In cases where a CRMC-designated ROW exists on or adjacent to a land parcel where new structures are being proposed, applicants will survey their property line adjacent to the ROW. Any infringement on the ROW by the proposed activity will be eliminated.

2. Residential docks along Greenwich Bay and its coves should maintain reasonable access along the shoreline by providing access over the dock or at least a 5-foot clearance (above mean high water) under some portion of the dock.

Section 960
Natural Hazard Mitigation

960.1 Policies

1. Reconstruction after storms

(a) When catastrophic storms, flooding, and/or erosion occur at a site under CRMC jurisdiction, and there is an immediate threat to public health and safety or immediate and significant adverse environmental impacts, the executive director may grant an emergency assent under Section 180 of the RICRMP.

(b) A CRMC assent is required of all persons proposing to rebuild shoreline structures that have been damaged by storms, waves, or other natural coastal processes in the Greenwich Bay watershed. When damage to an individual structure is greater than 50 percent of the total square footage of that structure, post-storm reconstruction shall follow all standards and policies for new development in the area in which it is located.

(c) Setback requirements from RICRMP Section 140 shall be applied.

(d) All construction within FEMA flood zones must follow the required construction standards for the flood zone in which the structure is located. Municipal officials need to certify that these standards are correct and present on any application for activity submitted to CRMC.

(i) Construction in coastal high hazard flood zones (V zones) as defined by federal flood insurance rate maps, shall follow the regulations as listed in Section 300.3 of the RICRMP, as amended.

(ii) Construction in areas of coastal stillwater flood hazards (A zones), as defined by flood insurance rate maps, shall follow the regulations listed in Section 300.3 of the RICRMP, as amended.

(e) A CRMC maintenance assent is required to repair structures where less than 50 percent of the total square footage of the structure has been destroyed by storms, waves, or natural processes.

(f) CRMC encourages post-storm reconstruction applicants to increase setbacks further from the coastal feature than the previous development without expanding the footprint.

2. Marinas that are expanding or replacing piers or docks shall meet the new construction requirements for marinas.

3. When concentrated losses occur, CRMC may issue special 30-day permits to marinas and other marine operators for removing debris such as sunken or burning vessels and materials on wetlands, in the coves, and in Greenwich Bay.

4. Wetlands and coastal buffers, which are significant in shielding flood-prone areas from storm damage, shall be considered priorities for preservation.

960.2 Prohibitions

1. Filling, removing or grading is prohibited on beaches, dunes, undeveloped barrier beaches, coastal wetlands, cliffs and banks, and rocky shores adjacent to Type 1 and Type 2 waters, including in the Greenwich Bay watershed, unless the primary purpose of the alteration is to preserve or enhance the area as a natural habitat for native plants and wildlife or for beach replenishment.

2. Post-storm reconstruction is prohibited from occurring within the setback area of V flood zones when damage to an individual structure is greater than 50 percent of the total square footage of that structure.

960.3 Standards

1. A significant amount of construction within Rhode Island's coastal zone has the potential to fall within a FEMA-designated flood zone. The approximate limits of the flood zones and the associated base flood elevations are shown on FEMA's Flood Insurance Rate Maps, which are commonly available at municipal building departments. CRMC requires all applicants proposing construction within flood hazard zones to demonstrate that applicable portions of the R.I. State Building Code (RISBC), specifically RISBC-8, which contains requirements for flood zone construction, are addressed.

2. When considering applications for the construction of residential, commercial, industrial, and recreational structures, including utilities such as gas, water, and sewer lines, in high hazard areas, these actions should be consistent with state policies as contained in the hazard mitigation plan element of the state guide plan (CRMC, 1997).

3. Piling standards need to be adapted to accommodate the 100-year flood rule to protect boats and coastal assets.

4. Marinas are required to update facilities to the current design and building standards when they apply for significant expansions of 25% or more.

Section 970
Pest Management and Fertilizer Use on Golf Courses and Public Properties

970.1 Policy

1. It is CRMC policy with the assistance of the Natural Resources Conservation Service (NRCS) and URI-CE to require municipal and state programs to use integrated pest management (IPM) or less-toxic pesticides and watershed-friendly fertilizers, such as controlled-release fertilizers, in public parks, along highways, and on other public properties within 200 feet of a shoreline (coastal) feature.

2. It is CRMC policy to work cooperatively with the four golf courses in the Greenwich Bay watershed to help them achieve a Green Golf Course designation. CRMC in cooperation with URI-CE will work with golf course superintendents to help their courses meet standards and certify those courses as Green Golf Courses.

970.2 Standards

1. A Green Golf Course should:
   g) Maintain at least 0.25-inch height cut on greens
   h) Plant velvet bentgrass on greens
   i) Use IPM or other alternative practices to pesticides
   j) Use controlled-release fertilizers
   k) Install the most current irrigation technology
   l) Educate members and golfers on the benefits of green golf course practices

   (Johnston and Golob 2002; Shuman, 2002; Rottenberg, 2003)

Section 980
Technical Assistance

980.1 Policy

1. It is CRMC policy to provide technical assistance to nongovernment organizations disseminating public education and outreach materials on the contributions pet and wildlife wastes make to bacterial contamination in Greenwich Bay, including problems with bird feeding along the Greenwich Bay shoreline and tributaries.

Section 990
Literature Cited

Ganz, A., N. Lazar, and A. Valliere. (1994). *Quahaug management project, phase I–Greenwich Bay.* Wakefield: R.I. Department of Environmental Management, Division of Fish, Wildlife, and Estuarine Resources, Coastal Fisheries Lab.

Johnston, W.J. and C.T. Golob. (2002). Nitrogen leaching through a sand-based golf green. *USGA Turfgrass and Environmental Research Online 1*(19): 1-7.

Rottenberg, R. (2003). *Green golf courses: a study of maintenance practices in Rhode Island.* Unpublished bachelor's thesis, Brown University, Providence.

Shuman, L.M. (2002). Nutrient leaching and runoff from golf courses. *USGA Turfgrass and Environmental Research Online 1*(17): 1-9.

Appendix A
Greenwich Bay Technical Advisory Committee
Members and Meeting Dates

Greenwich Bay Technical Advisory Committee Meetings

10:00 a.m. - 12:00 p.m., Thursdays
Warwick Sewer Authority
300 Service Road, Warwick, RI

Date	Topic
January 13, 2003	Preliminary Meeting (GSO URI)
April 10, 2003	Management Framework
April 24, 2003	Water Quality (1st review)
July 10, 2003	Water quality (2nd review)
August 7, 2003	Hazard Mitigation (1st review)
September 11, 2003	Water Quality (3rd review)
September 25, 2003	Hazard Mitigation (2nd review)
October 9, 2003	Cultural (1st review)
October 16, 2003	Habitat (1st review)
November 13, 2003	Habitat (2nd review) - EG Town Council Chambers
November 20, 2003	Economic Investment (1st review)
December 4, 2003	Economic Investment (2nd review)
December 18, 2003	Recreational Use
January 16, 2004	Recreational Use

Greenwich Bay Technical Advisory Committee Members

Habitat and Environmental Assets Chapter Reviewers

Dave Beutel, Rhode Island Sea Grant Fisheries Extension
Jon Boothroyd, URI Geology Department
Rick Enser, R.I. Department of Environmental Management
Dennis Erkan, R.I. Department of Environmental Management
Wenley Ferguson, Save the Bay
Janet Freedman, R.I. Coastal Resources Management Council
Art Ganz, R.I. Department of Environmental Management
Frank Golet, URI Natural Resources Science
Lisa Gould, R.I. Natural History Survey
Dan Goulet, R.I. Coastal Resources Management Council
Grace Klein MacPhee, URI Graduate School of Oceanography
Andrew Lipsky, U.S. Department of Agriculture
Eugenia Marks, Audubon Society of Rhode Island
Rick McKinney, U.S. Environmental Protection Agency
Steve Medeiros, R.I. Saltwater Anglers Association
Chris Powell, R.I. Department of Environmental Management
David Reis, R.I. Coastal Resources Management Council

Water Quality Chapter Reviewers

Mark Brush, Virginia Institute of Marine Science
Dave Burnett, R.I. Department of Health
Chris Deacutis, R.I. Department of Environmental Management
Art Ganz, R.I. Department of Environmental Management
Dan Geagan, City of Warwick
Linda Green, URI Cooperative Extension
Megan Higgins, R.I. Coastal Resources Management Council
Angelo Liberti, R.I. Department of Environmental Management
Joe Migliore, R.I. Department of Environmental Management
Don Pryor, Brown University
Chris Stewart, Southern Rhode Island Conservation District
John Torgan, Save The Bay
Heidi Travers, R.I. Department of Environmental Management
Dan Urish, URI
Ray Wright, URI

Cultural and Historic Assets Chapter Reviewers

John Brown, NITHPO
Paul Robinson, R.I. Historical Preservation and Heritage Commission

Economic Assets Chapter Reviewers

David Burnett, R.I. Department of Health
Beth Collins, R.I. Economic Policy Council
Greg Fleury, City of Warwick, Parks and Recreation
Art Ganz, R.I. Department Environmental Management, Fish & Wildlife
Townsend Goddard, R.I. Economic Development Corporation
Ken Payne, R.I. Senate Policy Office
Lauren Slocum, Central RI Chamber of Commerce
Steve Wright, Rhode Island Parks

Recreational Use Chapter Reviewers

Jeff Baris, City of Warwick
Cathy Bradley, Town of East Greenwich
Dave Burnett, R.I. Department of Health
Beth Collins, R.I. Economic Policy Council
Art Ganz, R.I. Department of Environmental Management
Dan Geagan, City of Warwick
Dan Goulet, R.I. Coastal Resources Management Council
Janet Freedman, R.I. Coastal Resources Management Council
Mike Keyworth, R.I. Marine Trades Association
Steve Medeiros, R.I. Saltwater Anglers Association
Neil Ross, Consultant
Chris Ruhling, Brewers Yacht
Bob Sutton, R.I. Department of Environmental Management
Lee Whitaker, Town of East Greenwich
Steve Wright, Rhode Island Parks

***Natural Hazards Chapter Reviewer*s**

Scott Avedisian, City of Warwick
Jon Boothroyd, URI Geology Department
Janet Freedman, R.I. Coastal Resources Management Council
Dan Geagan, City of Warwick
Pam Pogue, R.I. Emergency Management Agency
Bill Sequino, Town of East Greenwich
Lee Whitaker, Town of East Greenwich

Appendix B
Greenwich Bay Citizens Advisory Committee and Public Meeting Dates

Greenwich Bay Citizens Advisory Committee Meetings

6 or 6:30 – 9 p.m. Wednesdays
Warwick Sewer Authority
300 Service Road, Warwick, RI

Date	Topic
October 8, 2003	Overview
October 22, 2003	Water Quality
November 5, 2003	Water Quality
November 19, 2003	Water Quality/Habitat
December 3, 2003	Cultural & Historical Assets/Public Access
December 17, 2003	Habitat
January 7, 2004	Hazard Mitigation
January 21, 2004	Economic Investment
February 4, 2004	Public Access
February 18, 2004	Recreational Assets
March 3, 2004	Next Steps
May 5, 2004	Mapping

Joint Greenwich Bay SAMP CRMC Subcommittee and CAC Meetings

6 or 6:30 – 9 p.m. Wednesdays
Warwick Sewer Authority
300 Service Road, Warwick, RI

Date	Topic
June 23, 2004	Role of Greenwich Bay SAMP CRMC Subcommitee
July 14, 2004	Habitat and Environmental Assets and Cultural and Historic Assets
July 21, 2004	Economic Assets
July 28, 2004	Water Quality
August 4, 2004	Water Quality
September 8, 2004	Natural Hazard Mitigation
September 15, 2004	Recreational Use
September 29, 2004	Recreational Use
October 6, 2004	Framework for Management

Greenwich Bay SAMP Goals & Objectives Public Meeting

Wednesday, Feb. 9, 2005,
Warwick Sewer Authority
300 Service Road, Warwick, RI
6:30 – 9 p.m.

Appendix C
Quaternary Geologic Maps of the Greenwich Bay Watershed

Quaternary geologic maps and associated materials are available electronically, courtesy of J. Boothroyd and B. Oakley, University of Rhode Island, on the associated compact disc:

- Quaternary Geologic Map of the Greenwich Bay watershed and adjacent area (scale:1:24,000).
  <EG-BRI-CRO_24k_2005.bmp>
- Quaternary Geologic Map 3D views.
  <GBay-Quat-angle-view-text.bmp>
  <GBay-Quat-angle-view-no-text.bmp>
- Quaternary Map Poster Presentation
  <GSA-Urban-mapping_Denver_2004-CRMC.pps>
  <GSA-Urban-mapping_Denver_2004-CRMC.bmp>

Appendix D
Benthic Geologic Maps and Sidescan Sonar Data for Greenwich Bay, Rhode Island

Benthic geologic maps, side-scan sonar data, and associated materials are available electronically, courtesy of J. Boothroyd and B. Oakley, University of Rhode Island, on the associated compact disc:

- Benthic Geologic Habitats Map of Greenwich Bay (scale: 1:10,000)
  <GBay_Benthic_Geologic_Habitats_10k_2005.bmp>
- Side-Scan Mosaic of Greenwich bay (scale 1:10,000)
  <GBay_SideScan_Mosaic_10k_2005.bmp>
- Side-Scan Poster Presentation
  <GBay_Benthic_Geologic_Habitats_2005-RINHS.pps>
  <GBay_Benthic_Geologic_Habitats_2005-RINHS.bmp>
- Bottom Sediment Samples from Greenwich Bay
  <Shepard-grainsize-sa-si-cl_GBay.bmp>
- Folder with 10 side-scan images (some with parts A and B), 3 enhanced aerial images, explanatory figure captions.

Appendix E
Application of the Greenwich Bay ecosystem model to the development of the Greenwich Bay SAMP

Application of the Greenwich Bay ecosystem model to the development of the Greenwich Bay SAMP

Document prepared in fulfillment of a subcontract with CRC
Dr. Mark J. Brush
August 2004

- **Initial analyses**

Before addressing the simulations requested by RIDEM and CRC, two analyses were performed in response to comments at my presentation to RIDEM and CRC at the University of Rhode Island in June 2003. A question was raised as to the significance of oxygen consumption by nitrification of ammonia entering the bay from the East Greenwich waste water treatment facility. Input of BOD from the plant was considered in the original model (Brush 2002), but not nitrification.

Average seasonal NH_4^+ concentrations over the standard model year (5/96-5/97) were computed using plant monitoring data as done for dissolved inorganic nitrogen (DIN) by Brush (2002, Fig. 4-12a). Loading of NH_4^+ to Greenwich Cove was calculated from these seasonal concentrations and daily plant flows. The oxygen required for complete conversion of this NH_4^+ to NO_3^- was computed using an O_2:N molar ratio of 2 (Day et al. 1989) and compared to the total oxygen loss from Greenwich Cove excluding those due to water circulation. As Brush (2002) found for BOD, the potential oxygen demand by nitrification is very small when compared to the total oxygen demand in Greenwich Cove, although it is higher than for plant BOD (Fig. 1).

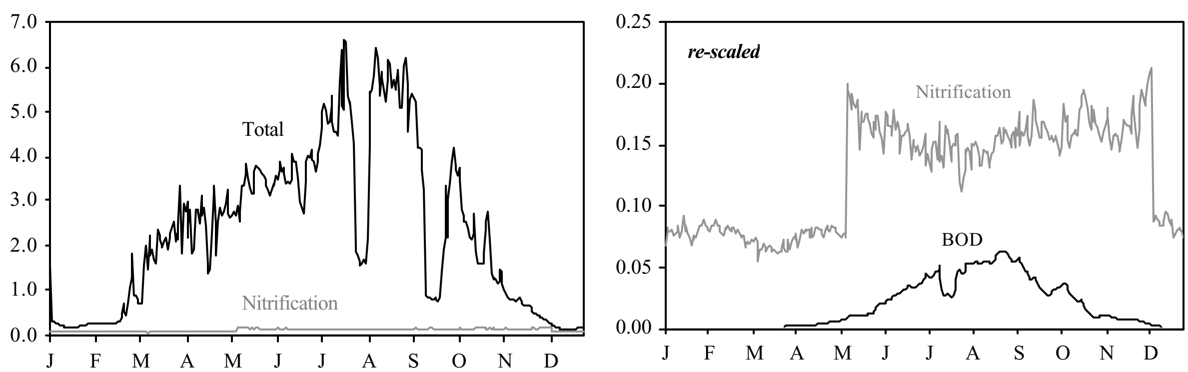


Fig. 1. Oxygen demand in Greenwich Cove due to nitrification of treatment plant ammonia compared with other sinks. The panel to the right is re-scaled to compare the demands due to nitrification and plant BOD.

A second question from June 2003 was whether Greenwich Bay experiences hypoxia due simply to the physics of the system aside from any effects of nutrient enrichment on phytoplankton dynamics. A suggestion was made to run the model without phytoplankton to see if hypoxia develops in the absence of primary producers. The model was run without phytoplankton or macroalgae. While this alleviated oxygen problems in most of the system, hypoxia developed to a small degree in Greenwich Cove and to the same degree in Warwick Cove as in the standard model run (Fig. 2).

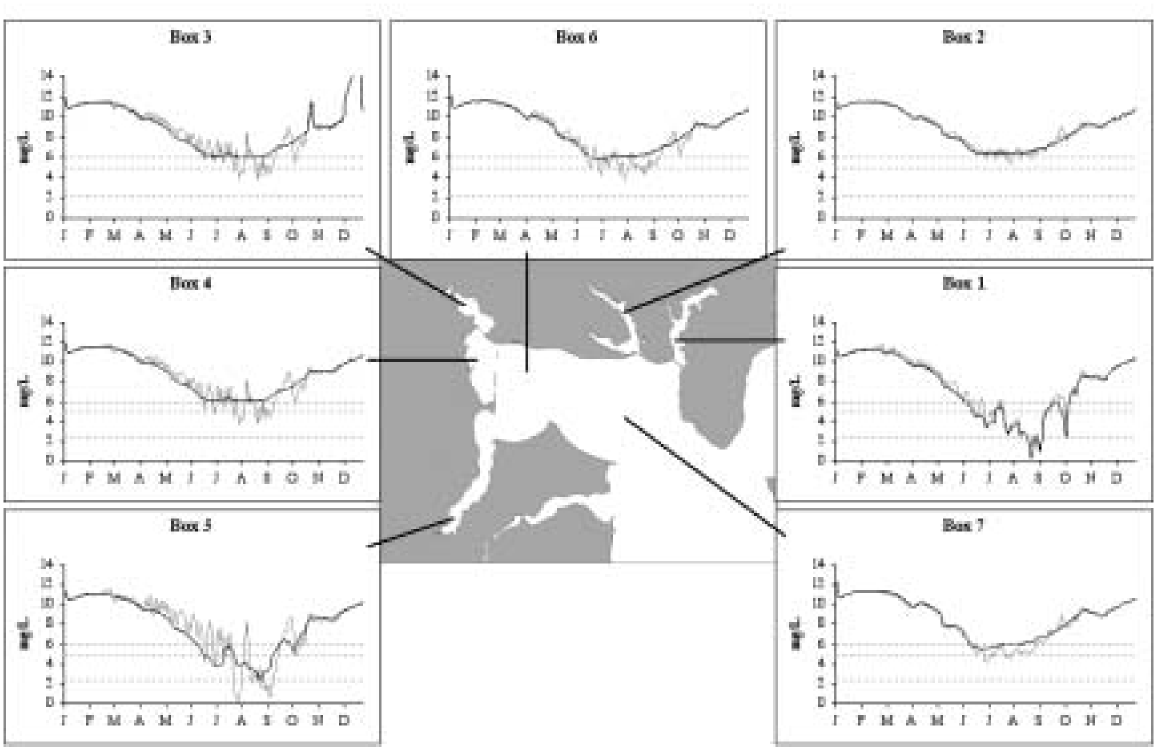


Fig. 2. Modeled concentrations of bottom water dissolved oxygen in a run without primary producers (black line) compared to the standard model run (grey line). In this and all figures, the horizontal dashed lines represent reference oxygen concentrations of 2.3, 5, and 6 mg/L.

Hypoxia appears to be a standard feature of Greenwich and Warwick Coves, which helps explain why the model predicts only limited improvements in these coves in several nutrient reduction scenarios run to date. While this hypoxia is due in part to the physical circulation of water in the system, the model suggests that the large populations of clams in these two coves are also responsible for the hypoxic events (Fig. 3).

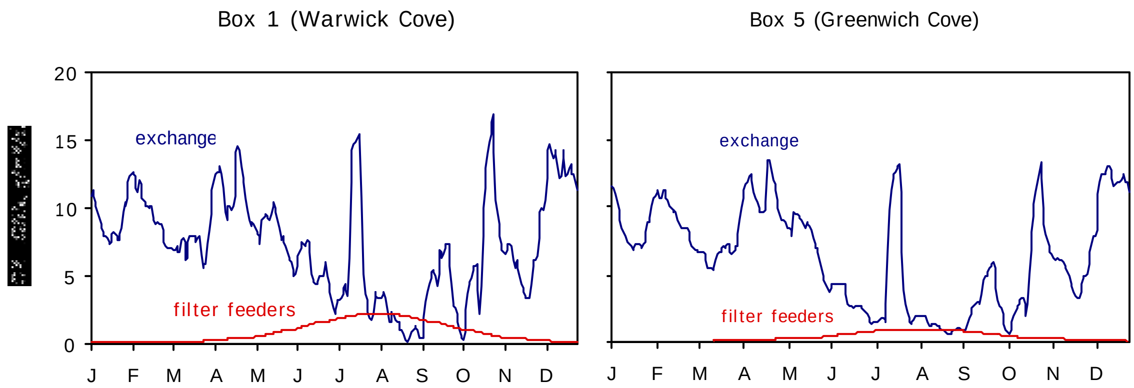


Fig. 3. Modeled oxygen losses due to water exchange (physical circulation) and filter feeders in a model run without primary producers. Other losses were insignificant.

- **Pre-colonial Runs**

The model was calibrated to represent pre-colonial conditions using Nixon's (1997) estimation of prehistoric nutrient inputs to Narragansett Bay. His estimate for atmospheric loading of 5 mmol DIN m^{-2} y^{-1} was combined with bay surface area and annual precipitation from the standard model run to compute an average pre-colonial concentration for DIN in rain of 4.14 µM. This concentration was multiplied by daily precipitation (from the standard year) in the model to obtain daily atmospheric loading rates. Calculation of an average concentration in this way (rather than simply applying a constant loading rate of 5 mmol DIN m^{-2} y^{-1}) retained seasonal and event-scale (e.g. storms) dynamics in model forcing functions, which thus increased realism and allowed for the best comparison to model output from the standard year. This method assigns all deposition as wetfall, while the standard model includes dryfall, but any effects of this change should be minor. Atmospheric deposition of dissolved inorganic phosphorus (DIP) and organic nutrient forms was assumed to be 0 as in Nixon (1997).

Nixon (1997) estimated that prehistoric watershed nutrient inputs of DIN and DIP were 1-5 and 0.06 mmol m^{-2} (watershed area) y^{-1}, respectively; the midpoint of 3 was used for DIN. As above, these rates of input were combined with watershed areas and daily freshwater inputs from the standard model run to compute average concentrations of DIN and DIP in incoming freshwater.

Nixon (1997) suggested that there may have been a substantial input of dissolved organic nitrogen (DON) from the prehistoric watershed; however, estimates of this input are quite variable, none exist specifically for Narragansett Bay, and the amount of this DON that was bioavailable is uncertain. Due to these factors, I felt it best to exclude this term as done by Nixon (1997). Nixon (1997) also states that there may have been a large prehistoric input of desorbable P as rivers entered the bay. However, it is likely that the overwhelming majority of this P would have entered the bay from the major rivers such as the Blackstone and Taunton, rather than the small streams entering Greenwich Bay, so these inputs were also ignored. In the absence of DON and desorbable P inputs, the pre-colonial runs presented here can be considered conservative.

The East Greenwich treatment facility was removed for the pre-colonial runs; this included inputs of freshwater, DIN, DIP, and BOD to Greenwich Cove. Further, Nixon (1997) estimated that freshwater inputs from the watershed to Narragansett Bay may have been approximately 90% of current inputs, so watershed flows in the model were reduced by this amount.

The pre-colonial concentrations of DIN and DIP at the mouth of Greenwich Bay (required to compute offshore nutrient inputs) were estimated from current concentrations near the mouth of Narragansett Bay as in Nixon (1997). Annual average surface and bottom nutrient concentrations at the mouth of Narragansett Bay were computed using data from stations at the mouth of the East and West Passages from the 1972-73 bay survey (Kremer and Nixon 1978). As for watershed inputs, the most realism and comparability is achieved by allowing forcing functions to follow realistic seasonal patterns, based on those from the standard run. To accomplish this, the annual offshore nutrient cycles from the standard run were multiplied by the ratio of pre-colonial and current annual average offshore concentrations.

In addition to the offshore inputs of nutrients, the offshore concentrations of chlorophyll and O_2 needed to be adjusted to reflect pre-colonial conditions as they influence the output of the model and would most certainly have been different during pre-colonial times. The average annual, pre-colonial chlorophyll concentration at the mouth of Greenwich Bay was estimated from the most recent regression between N loading rate and chlorophyll concentration from the 1981-83 MERL eutrophication gradient experiment (Nixon et al. 2001). Using Nixon's (1997) average prehistoric N loading rate to Narragansett Bay of 0.82 mmol m^{-2} d^{-1}, I computed the average annual chlorophyll concentration to be 2.1 mg m^{-3}. This annual average was converted into an annual cycle as done for the offshore nutrients.

Unfortunately, it is practically impossible to determine what the pre-colonial annual cycle of O_2 at the mouth of Greenwich Bay would have been. In the absence of a better approach, the offshore O_2 concentrations were forced to follow saturation concentrations based on temperature and salinity. Unfortunately, this eliminates any fluctuations in O_2 that would have occurred due to plankton blooms and declines. Since offshore O_2 has been shown to influence O_2 in Greenwich Bay by past model runs, we must therefore compare output from this pre-colonial run to a run of the present-day model with saturated offshore O_2 concentrations.

The difference between the standard model run in Brush (2002) and the standard run with saturated offshore O_2 is shown for comparison in Figure 4. Small differences exist between these runs and must be kept in mind when analyzing results from the pre-colonial runs. The largest difference exists in the outer bay (Box 7) which has the greatest connection with the upper West Passage.

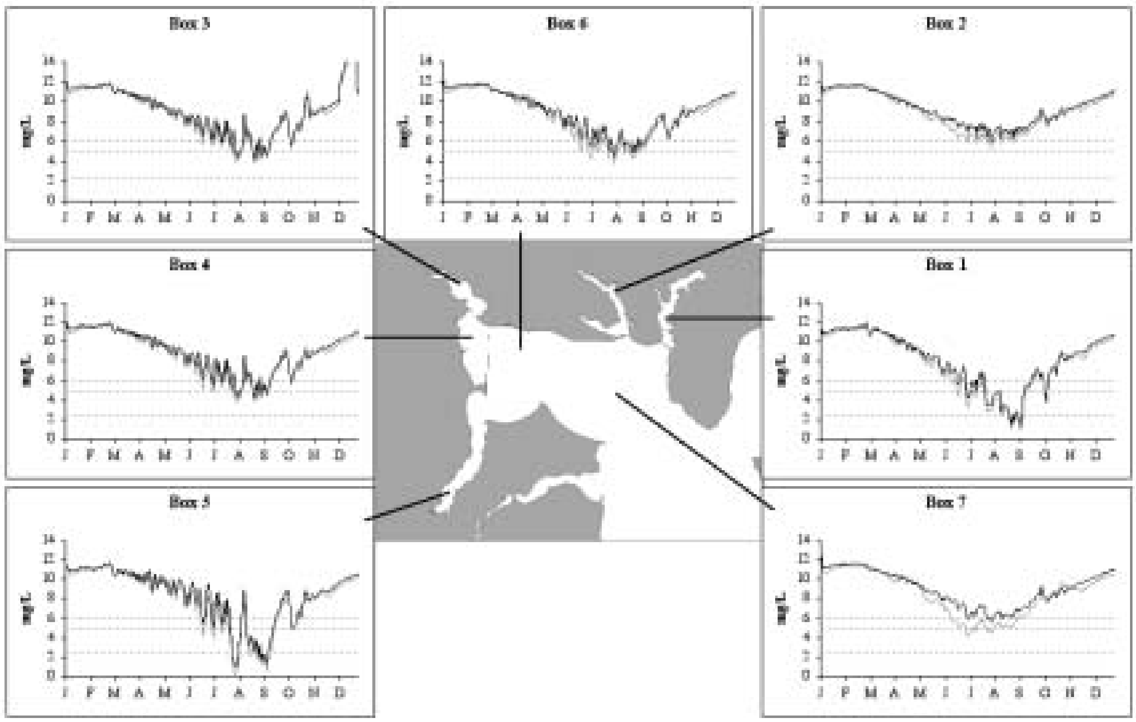


Fig. 4. Concentrations of bottom water O_2 from a run of the model with offshore O_2 concentrations set at saturation values (black line) compared to the standard model run (grey line).

Results of the pre-colonial run are shown in Figures 5 (surface chlorophyll) and 6 (bottom O_2). Large changes can be seen in phytoplankton concentrations and some improvement is evident in oxygen concentrations, except in Boxes 1 (Warwick Cove) and 5 (Greenwich Cove) for reasons discussed in Section 1 above. It is interesting to note that the model predicts pre-colonial annual phytoplankton production in Greenwich Bay to be 153 g C m^{-2} y^{-1}, very close to the value of 130 g C m^{-2} y^{-1} computed for prehistoric Narragansett Bay by Nixon (1997). This seems a nice validation of the pre-colonial model.

A second pre-colonial run was performed to represent the best possible scenario that could be achieved with management in the Greenwich Bay watershed: reducing watershed loadings to prehistoric levels and eliminating the East Greenwich treatment plant. Since offshore O_2 concentrations were not changed in this run, results can be compared to those from the standard run (Figs. 7-8). As with past simulations, phytoplankton biomass was reduced in this run primarily in spring when watershed loadings are most important. There was no improvement in predicted O_2 concentrations.

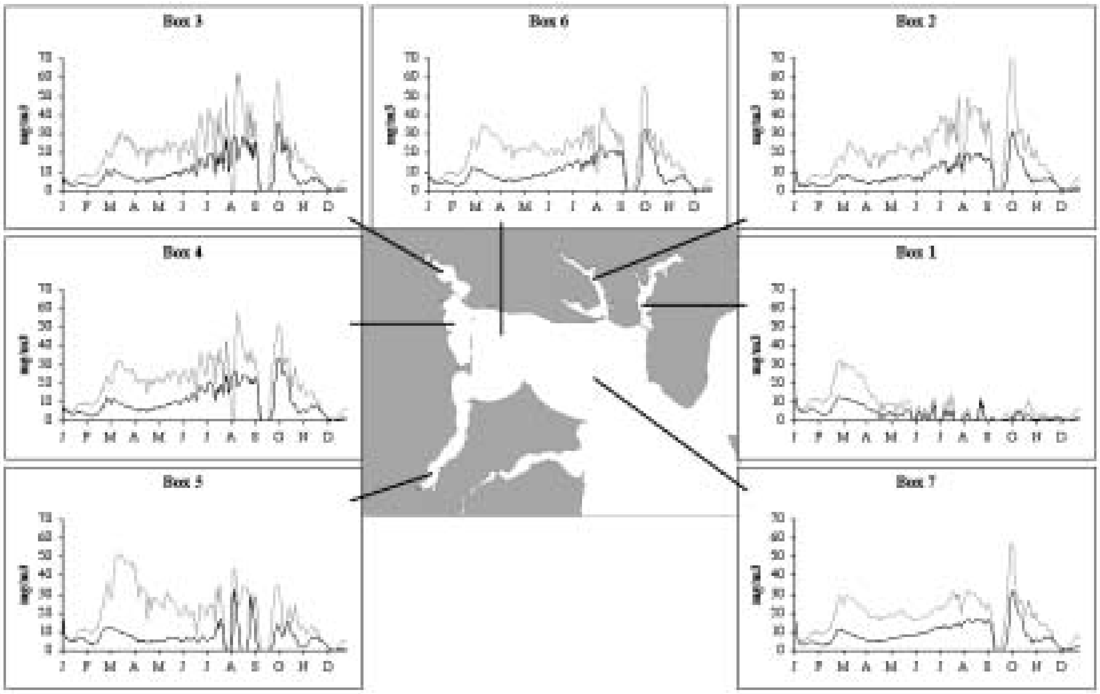


Fig. 5. Concentrations of surface chlorophyll-*a* from the pre-colonial run (black) compared to the standard run with offshore O_2 forced at saturating concentrations (grey).

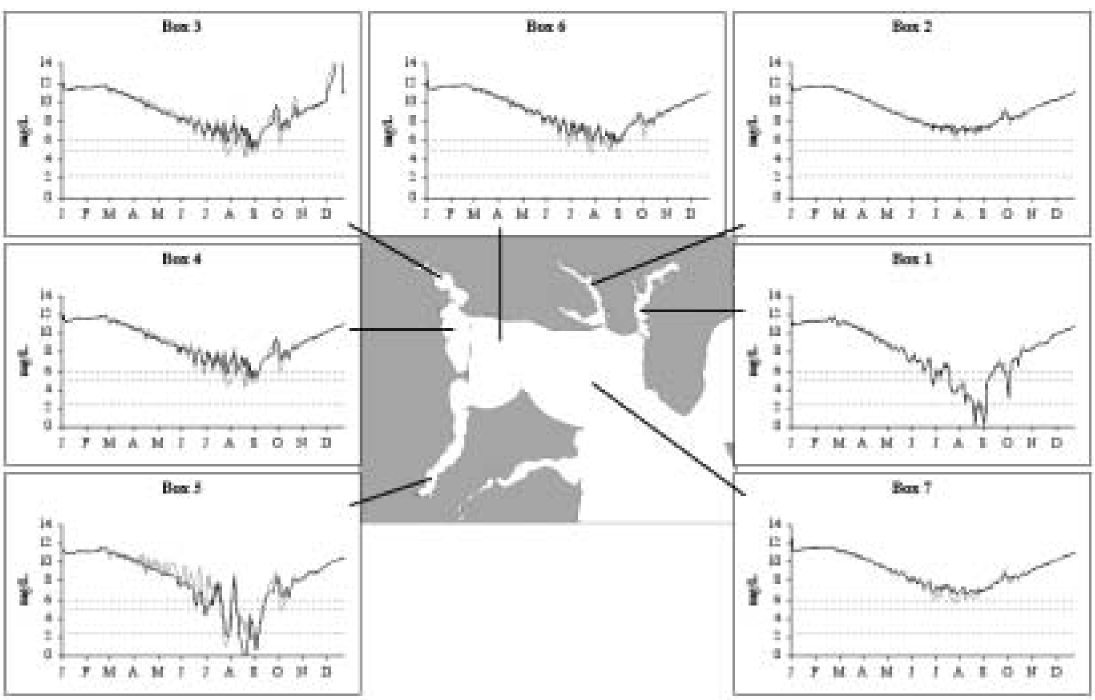


Fig. 6. As in Fig. 5, but for bottom O_2 concentrations.

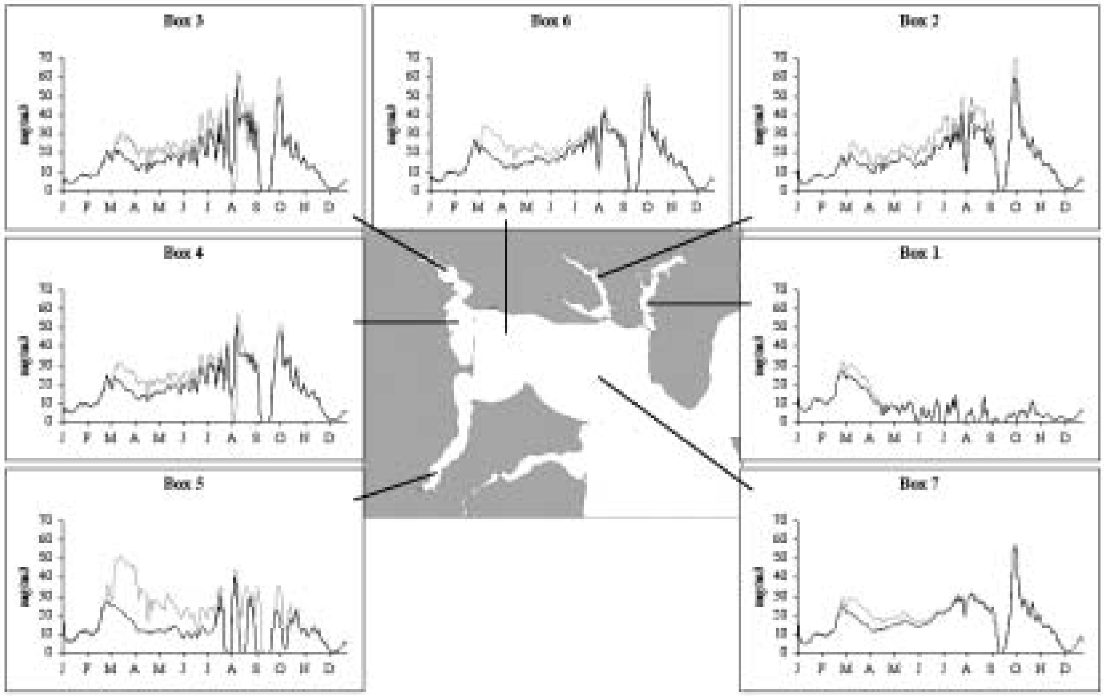


Fig. 7. Concentrations of surface chlorophyll-*a* with pre-colonial watershed inputs (black) compared to the standard run (grey).

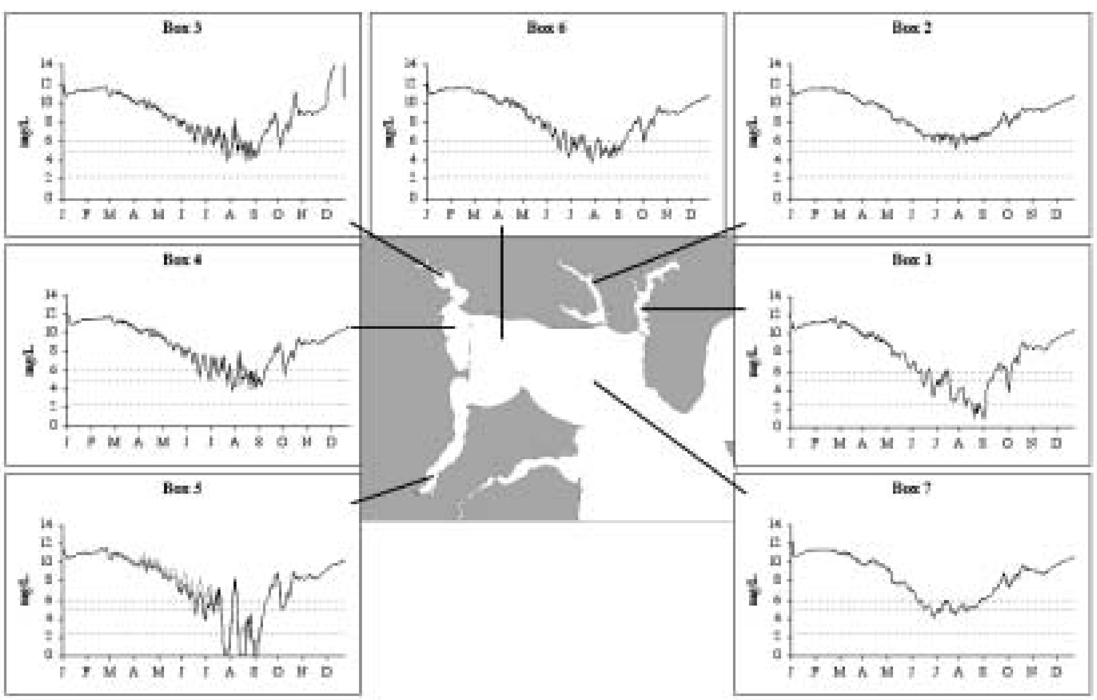


Fig. 8. As in Fig. 7, but for bottom O_2 concentrations.

- **5-Year Runs**

The model was configured to run for 5 years under both current and pre-colonial conditions to examine long-term effects on sediment carbon pools. Due to constraints of computer memory, the time step (dt) had to be decreased from the value of 0.03125 days (3/4 hour) used in the standard run to 0.0833 days (2 hours). Output was nearly identical to that from the standard run with the exception of O_2 and sediment carbon in Boxes 2 (Brush Neck/Buttonwoods Cove) and 3 (Apponaug Cove), so overall the change of dt did not compromise the results. Despite the affect of time step on results in Boxes 2 and 3, they were nevertheless sufficient to address changes in sediment carbon pools.

Results of the 5 year run under current conditions are given in Figures 9-11 for phytoplankton, O_2, and sediment carbon. The model is in steady state over an annual cycle, with output from years 2-5 mirroring that from year 1. There is no change in sediment carbon pools as this too is in steady state over the annual cycle. This is not to be taken as representative of the actual system, however. As discussed in last year's meeting, the sediment carbon pool in the model was designed to represent labile organic carbon deposited from the water column and was calibrated to be in steady state over the annual cycle. This highly simplified pool does not include refractory organic material that may accumulate (or decline) from year to year, and the degree to which the pool reflects reality can be debated.

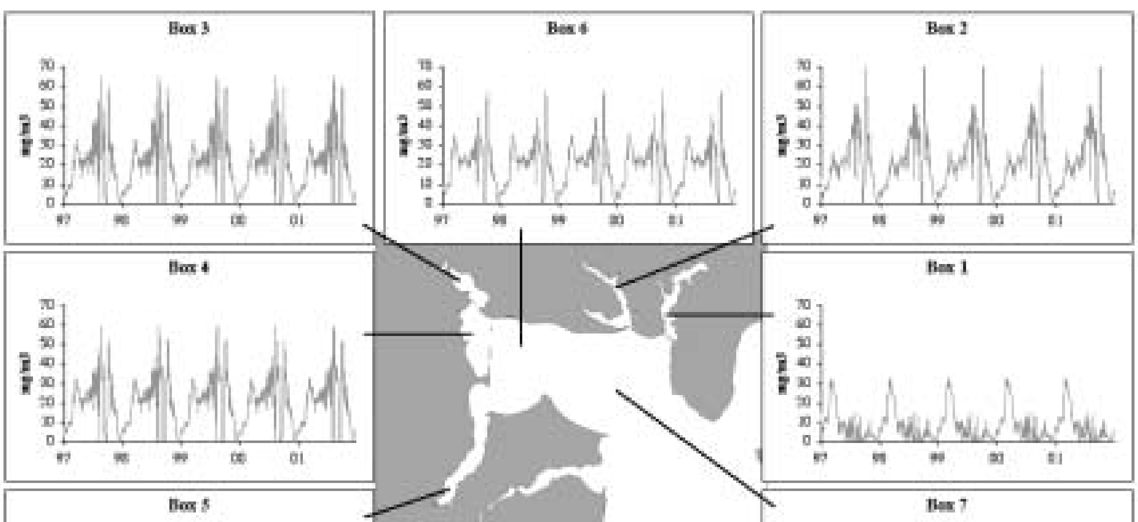


Fig. 9. Concentrations of surface chlorophyll-*a* from the 5-year simulation under current conditions.

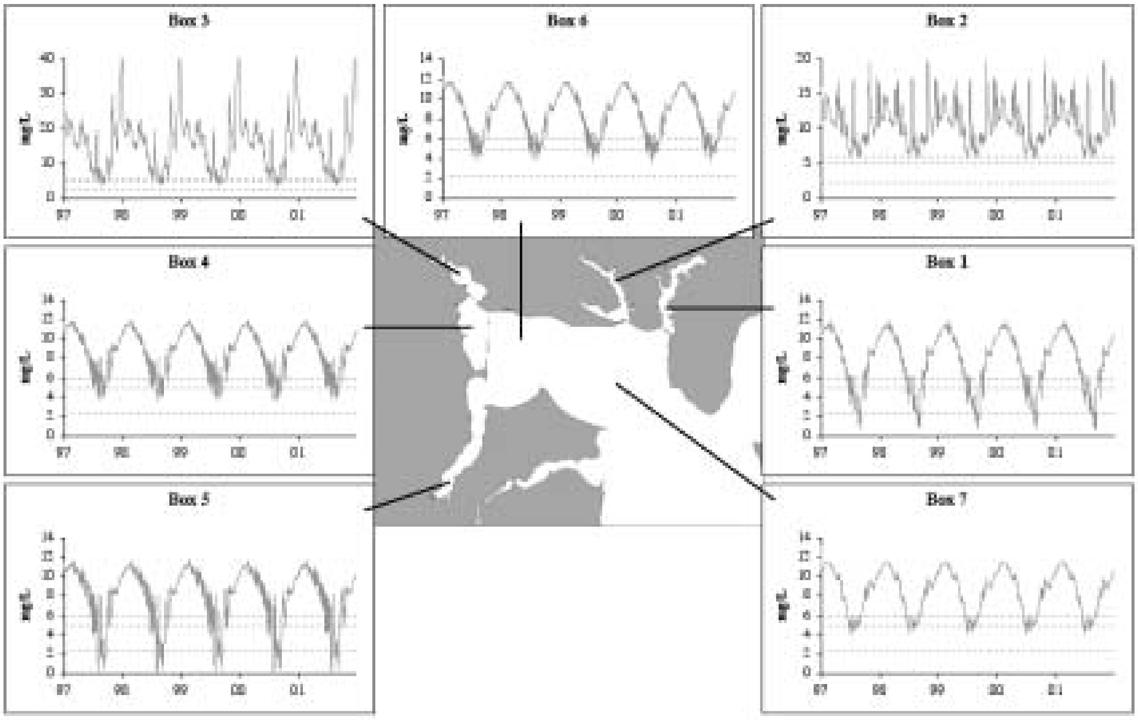


Fig. 10. As in Fig. 9, but for bottom O_2 concentrations.

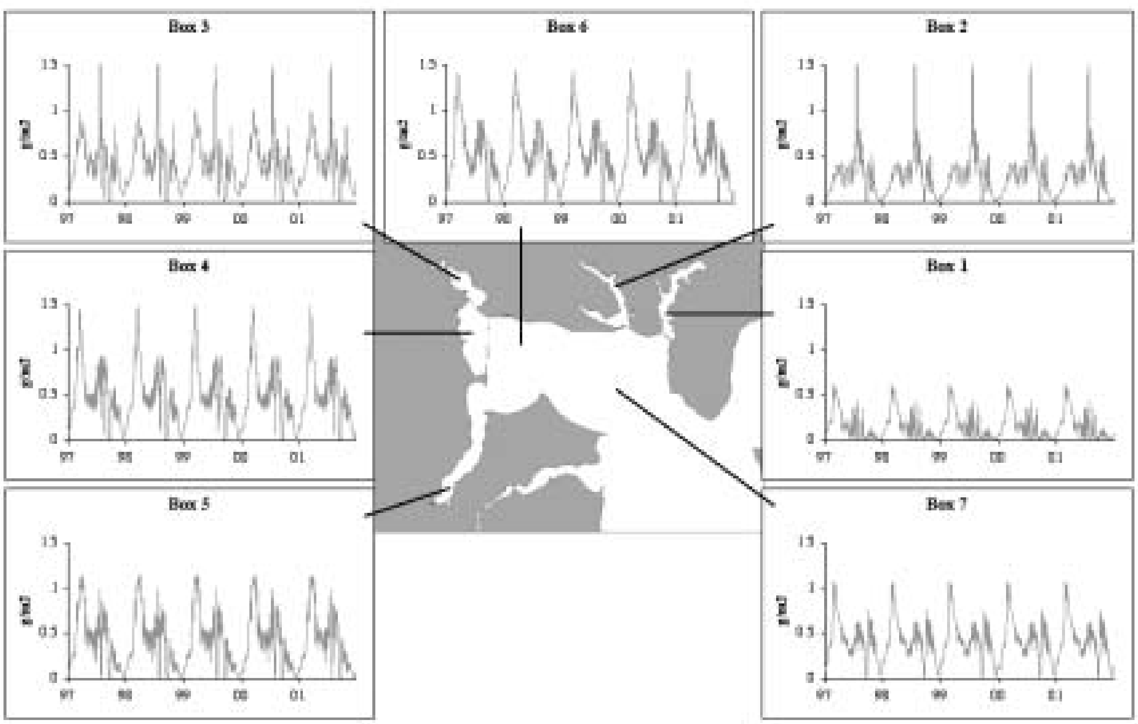


Fig. 11. As in Fig. 9, but for bottom layer sediment carbon concentrations.

To further demonstrate the operation of the model's sediment carbon pool, I ran the 5-year simulation after increasing initial sediment carbon concentrations by 10 and 100 times the values used in the standard run. Output from all three runs are plotted in Figure 12 below, and except for the very beginning of the run, results from the three simulations are identical. Results are given only for Box 5 (Greenwich Cove), but were the same in all spatial elements.

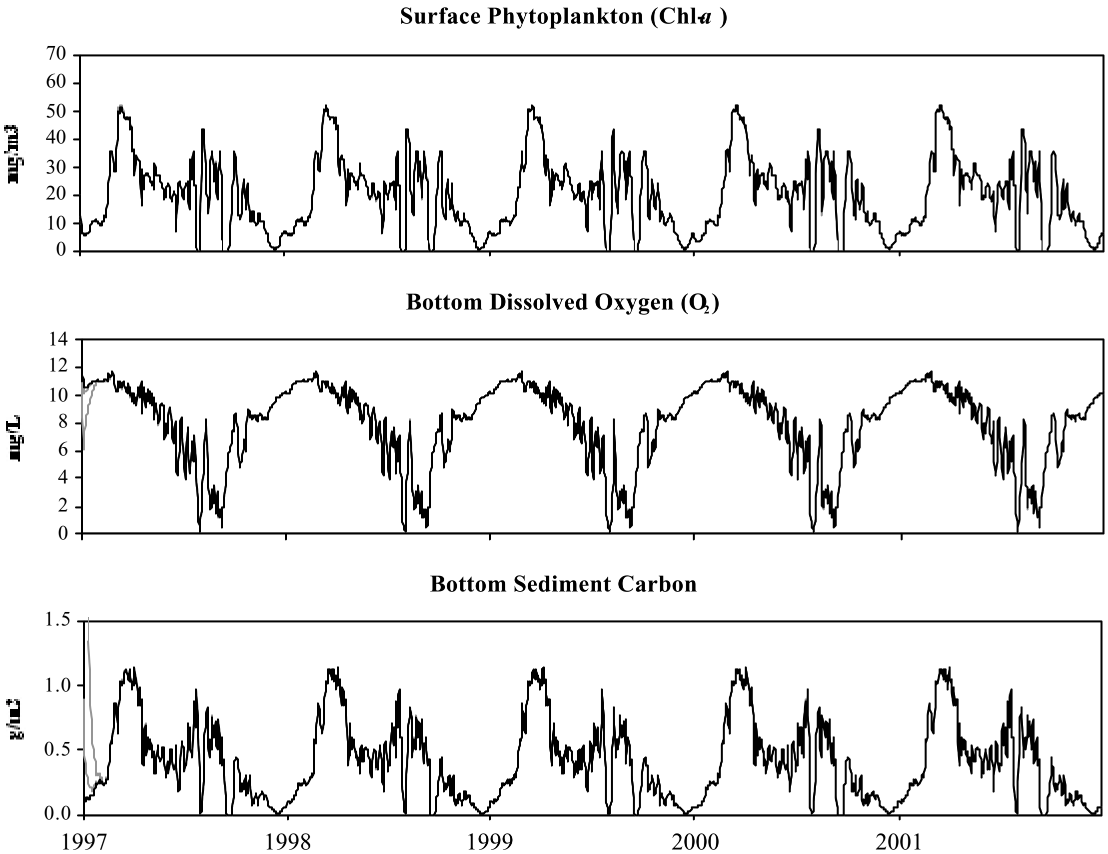


Fig. 12. Output for Box 5 (Greenwich Cove) from the 5-year simulation under current conditions and using 1, 10, and 100x the initial sediment carbon concentrations in the standard model run. Output from the three simulations is indistinguishable.

If we focus on sediment carbon concentrations at the start of the run, we get a clear picture of what is happening (Fig. 13). Regardless of the initial concentration imposed, sediment respiration quickly returns these concentrations to those from the standard run (i.e. those that are in steady state over the annual cycle).

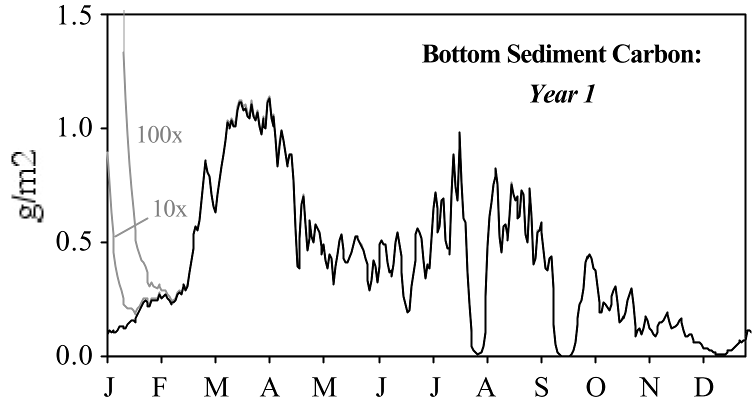


Fig. 13. Predicted sediment carbon concentrations in Greenwich Cove from the first year of the 5-year run under current conditions and using 1, 10, and 100x the initial concentrations from the standard run (black line).

Results of the 5 year run under pre-colonial conditions are given in Figures 14-16 for phytoplankton, O_2, and sediment carbon. Values are again in steady state with no changes in sediment carbon pools, except for rapid adjustment to a lower average concentration because the initial values were those from the standard run. Recall that O_2 concentrations must be compared to the run with saturated offshore O_2 (Fig. 4).

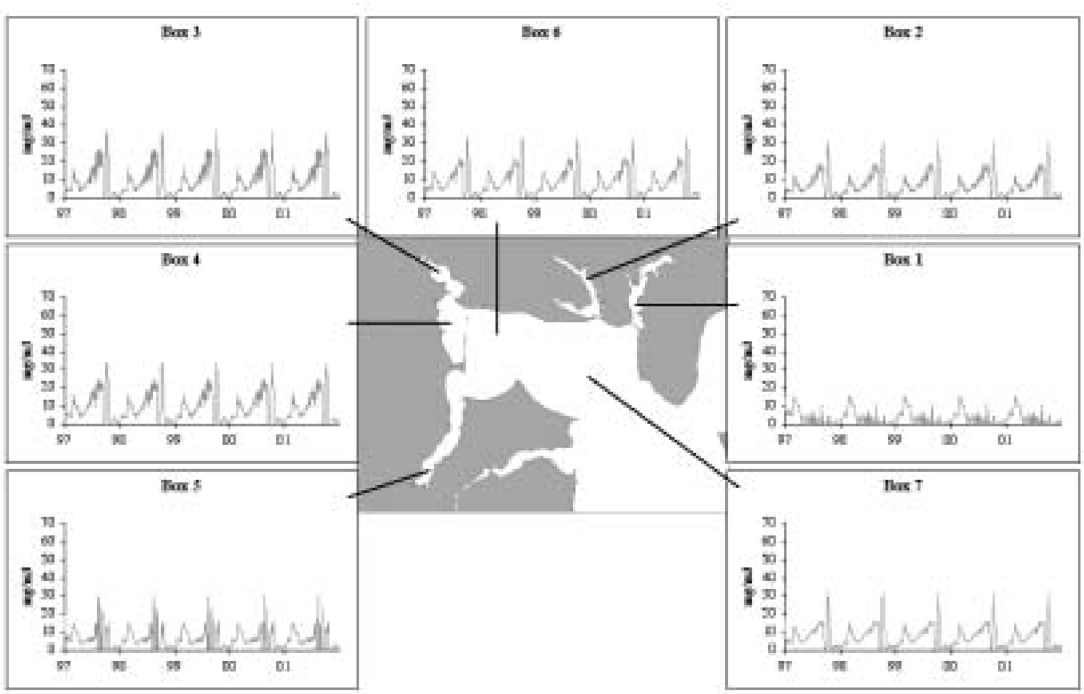


Fig. 14. Concentrations of surface chlorophyll-*a* from the 5-year simulation under pre-colonial conditions.

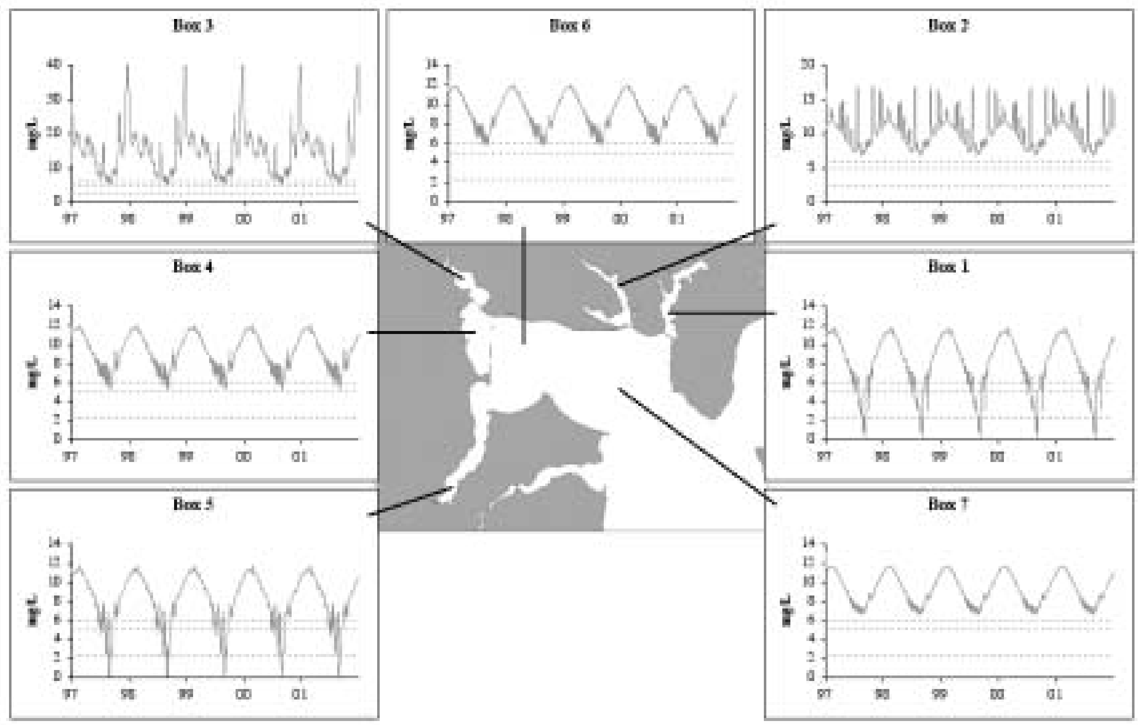


Fig. 15. As in Fig. 14, but for bottom O_2 concentrations.

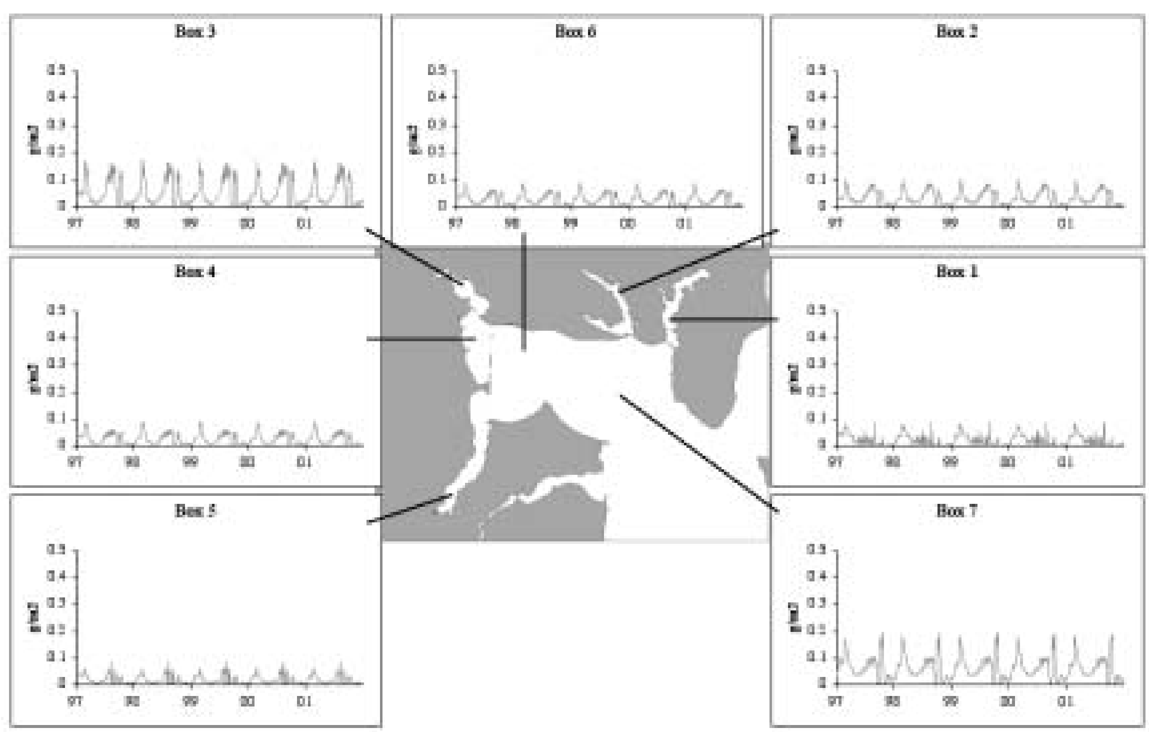


Fig. 16. As in Fig. 14, but for bottom layer sediment carbon concentrations.

A final 5-year simulation was run starting at current conditions and switching to pre-colonial watershed loadings (as in Figs. 7-8) at the start of the second year. This run was done to test the model's ability to demonstrate a response to nutrient reductions during a multi-year run, including effects on sediment carbon pools. Results are given in Figures 17-19 for phytoplankton, O_2, and sediment carbon. The model predicts small changes in each parameter after the first year as the system adjusts to its new steady state. Reduced phytoplankton biomass in years 2-5 (Fig. 17) leads to reduced sediment carbon concentrations in those years (Fig. 19). However, none of the 5-year runs predicted any long-term, steady declines in sediment carbon as accumulated organic matter is gradually respired away – rather, changes in this pool are rapid and quickly adjust to new steady state conditions due to the way it was formulated.

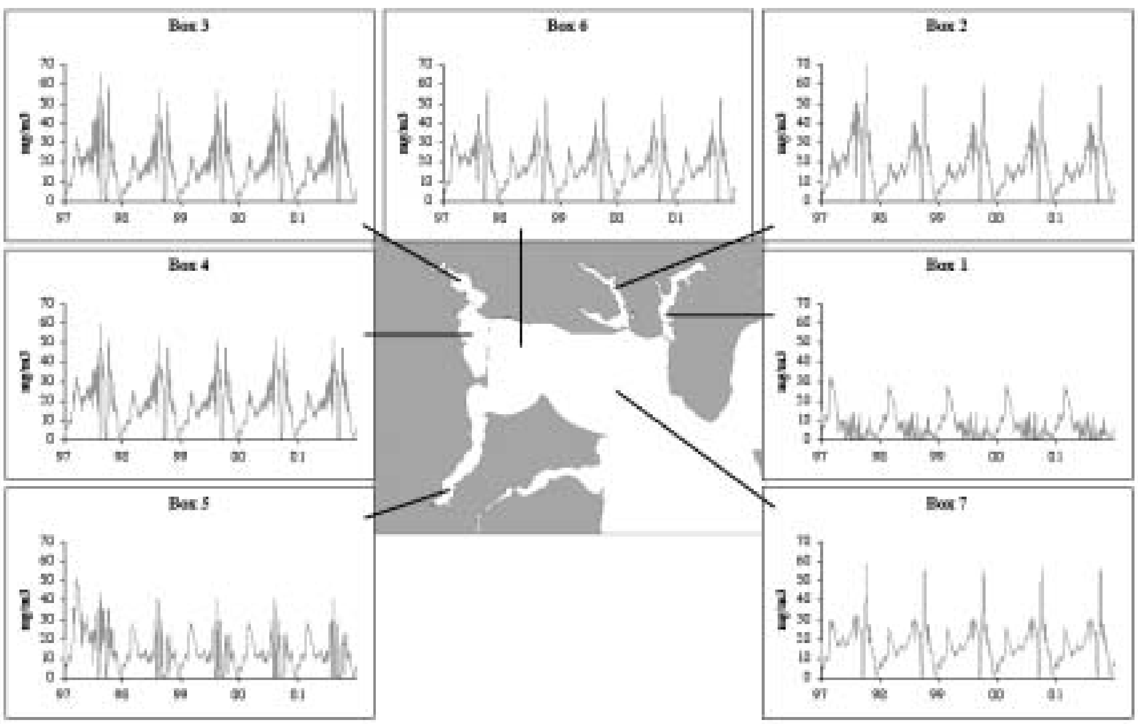


Fig. 17. Concentrations of surface chlorophyll-*a* from the 5-year simulation starting at current conditions and switching to pre-colonial watershed nutrient loading in the second year.

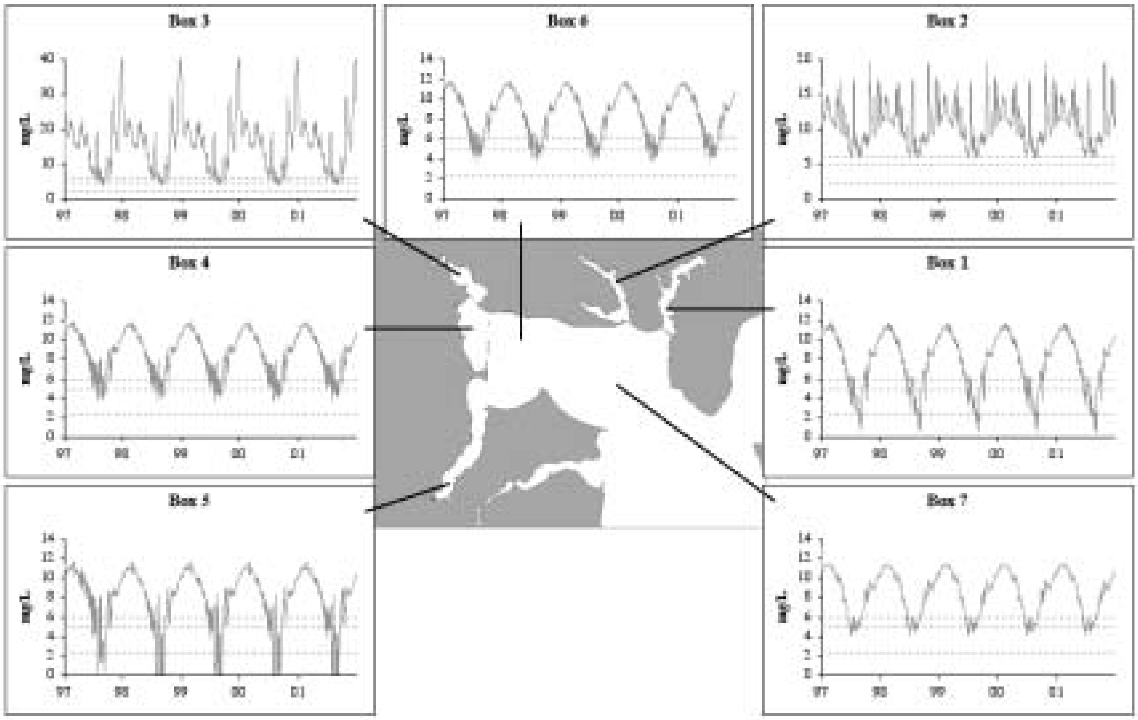


Fig. 18. As in Fig. 17, but for bottom O_2 concentrations.

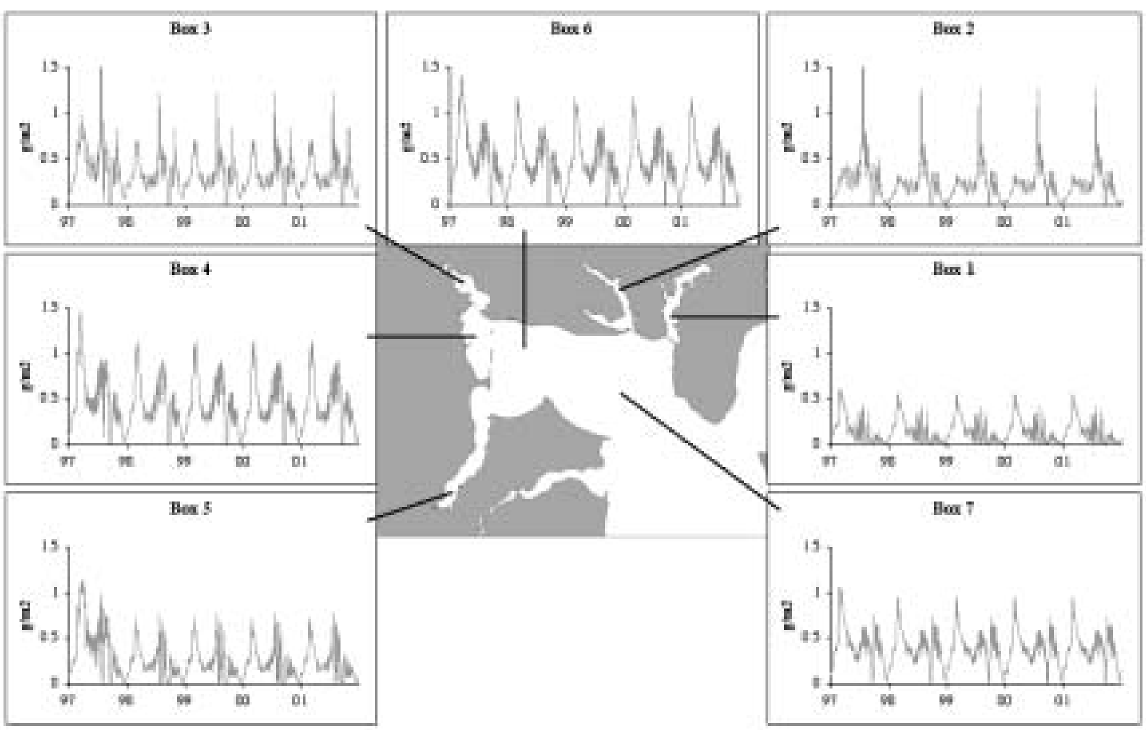


Fig. 19. As in Fig. 17, but for bottom layer sediment carbon concentrations.

- **Maximum Build-Out Scenario**

The model was run using estimates of flow and nutrient concentrations from the East Greenwich treatment facility after it is upgraded to tertiary treatment and running at full capacity. All other inputs remained the same; this scenario essentially represents the case where the treatment facility is fully upgraded, sewers are completed in Warwick, but no one hooks up to them.

The projected average rate of flow at the upgraded plant is 6.43 million L/day. This average flow was used to compute daily flows based on the annual cycle from the standard model run as described above for offshore nutrient concentrations. The projected DIN concentration in plant effluent is 5 mg/L; this value was input directly to the model. Plant DIP concentrations used in the standard run were very high and indicated a large point source of DIP in the watershed. This source still exists but is scheduled to go offline in 2005. However, without any information on what new plant DIP concentrations will be, they were left the same as in the standard run. Since Greenwich Bay and its coves are P-limited only in spring in certain cases (Brush 2002), the DIP concentrations used should have little effect on model output during summer when hypoxia occurs. No estimates for new plant BOD concentrations exist, but since this was an insignificant sink for O_2 in the standard run (e.g. Fig. 1), concentrations were not changed for this run.

Results from the maximum build-out run are presented in Figures 20 (phytoplankton) and 21 (dissolved oxygen). To address the issue with future DIP concentrations raised above, I also ran the model with plant DIP reduced to 100 μM. While predicted chlorophyll concentrations were lower in spring, oxygen concentrations were essentially identical to those in Figures 20-21 throughout the year.

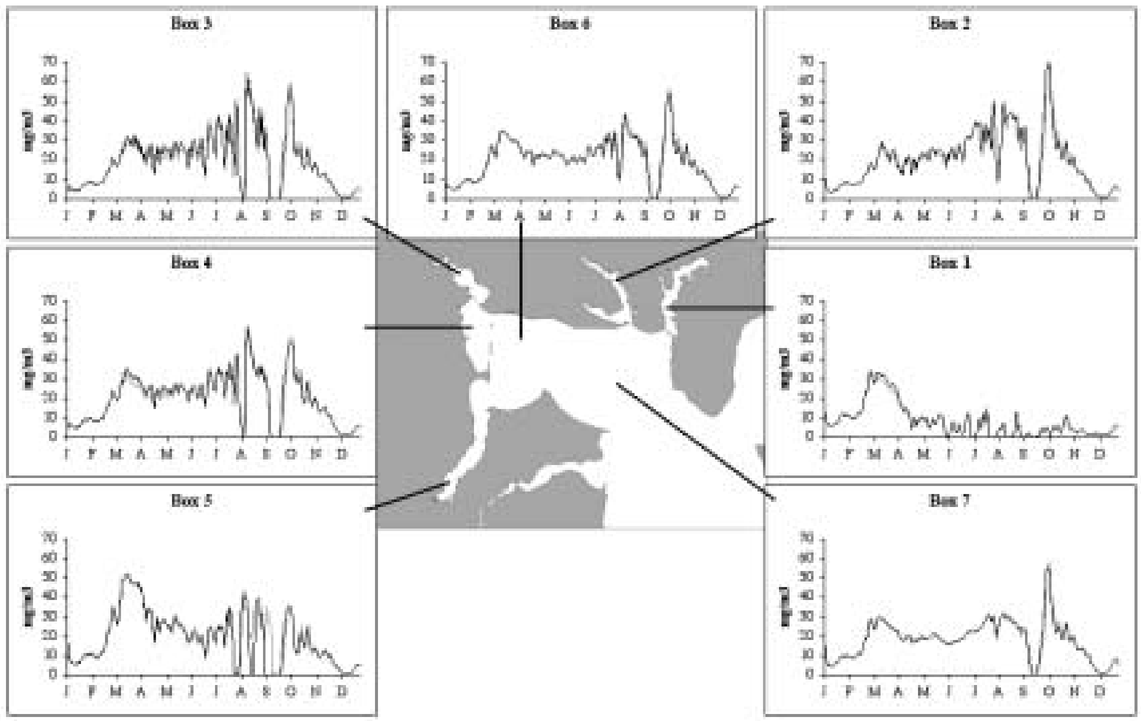


Fig. 20. Concentrations of surface chlorophyll-*a* from the maximum build-out run (black) compared to the standard run (grey).

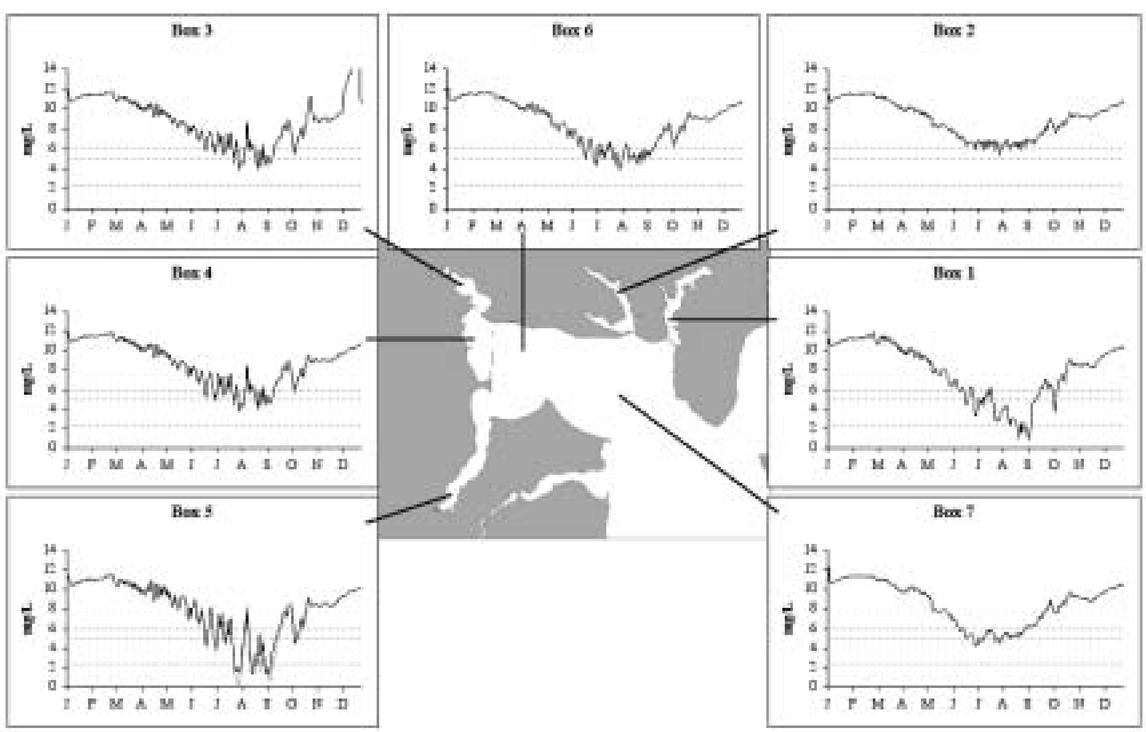


Fig. 21. As in Fig. 20, but for bottom O_2 concentrations.

- **Post-Sewering Scenario**

The final simulation performed was designed to reflect the situation after treatment plant upgrades and 100% tie-ins to the new sewer system in Warwick. Estimates of pre- and post-sewer N and P loadings to various sub-watersheds around the bay were obtained from Lora Harris (URI) and the SAMP budget. However, the model uses the nutrient inputs from the Granger et al. (2000) and Brush (2002) budget, and it was necessary to continue using this budget to be able to compare model output to the standard run.

Therefore, the percent reductions in watershed loading of N and P between the pre- and post-sewer SAMP budgets were used to reduce watershed DIN and DIP concentrations (and therefore loading) in the model by the same percentage. Note that the model contains a single input for watershed loading, and is not broken into separate inputs for the unsewered population, fertilizer application, and transport of atmospheric deposition as in the SAMP budget. The entire watershed loading in the model was reduced by the percentages described above.

Another complication was that the sub-watersheds used in the SAMP budget do not correspond to the spatial elements used in the ecosystem model. Prior to computing percent reductions, the SAMP inputs had to be distributed among the model elements by estimating the fraction of each sub-watershed area that exists in each of the model spatial elements. This calculation assumes that population density and location of new sewers are distributed evenly throughout each sub-watershed.

The model was run with these reduced watershed inputs together with the upgraded East Greenwich treatment facility inputs derived in the maximum build-out run. Results from the post-sewering run are given in Figures 22 (phytoplankton) and 23 (O_2 concentration). The model was also run with plant DIP reduced to 100 µM as in the maximum build-out scenario, with the same outcome as in that run.

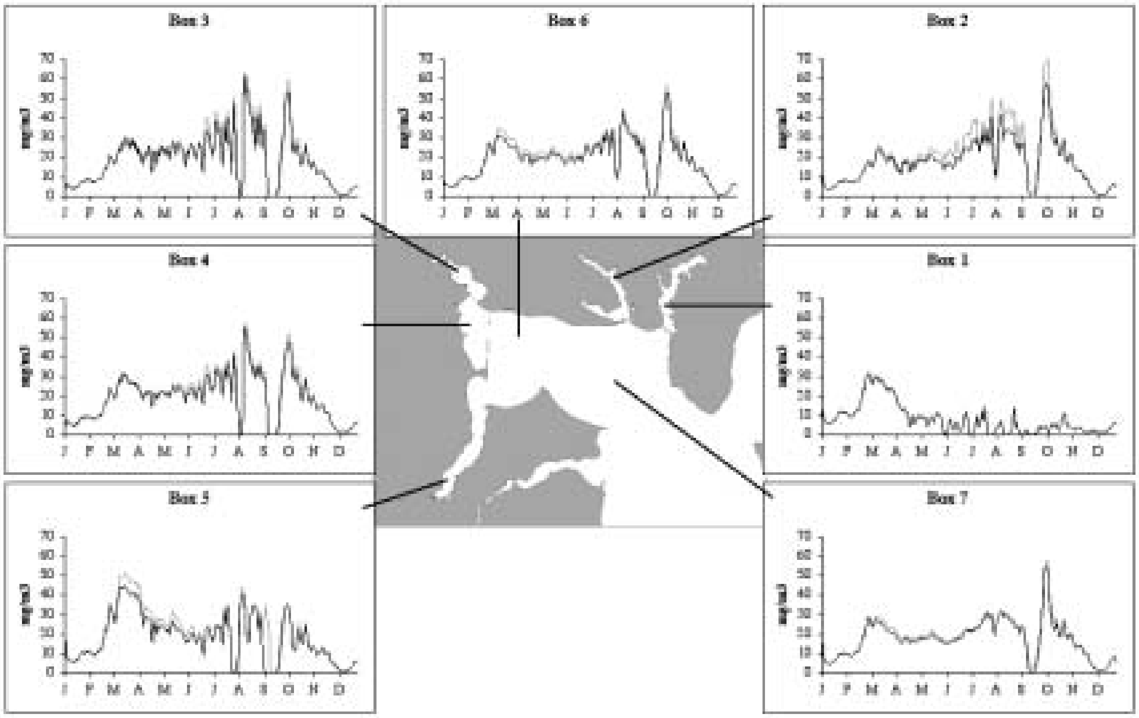


Fig. 22. Concentrations of surface chlorophyll-*a* from the post-sewering run (black) compared to the standard run (grey).

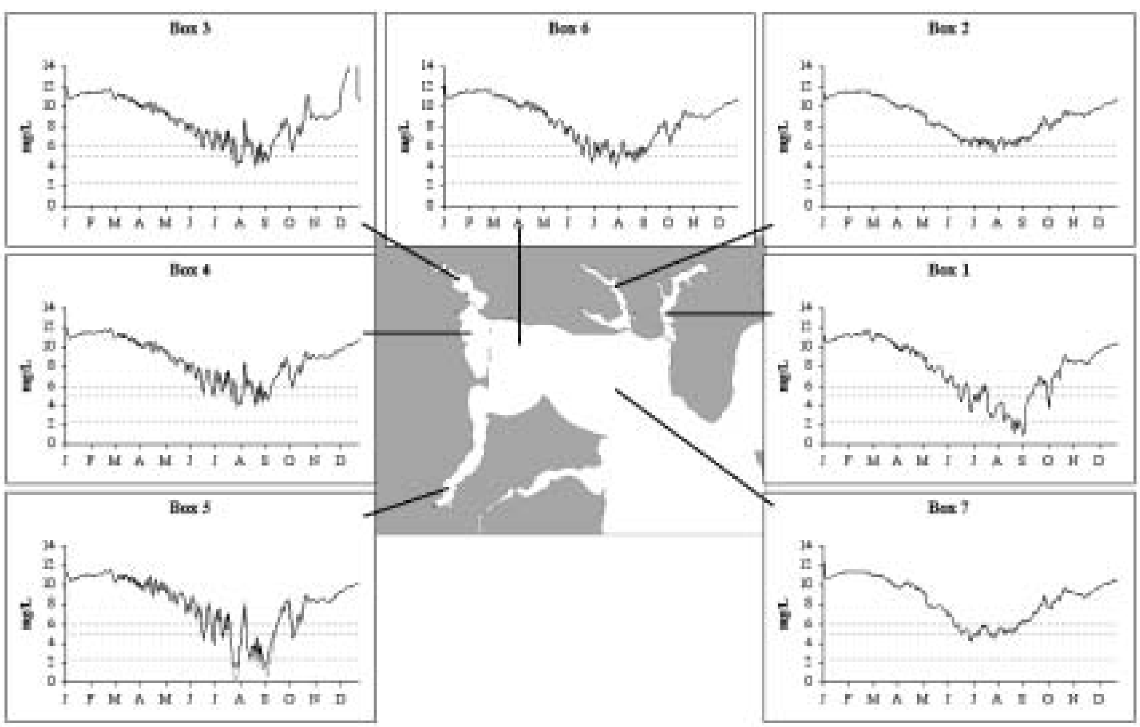


Fig. 23. As in Fig. 22, but for bottom O_2 concentrations.

- **Literature Cited**

Brush, M.J. 2002. Development of a numerical model for shallow marine ecosystems with application to Greenwich Bay, R.I. Ph.D. dissertation, University of Rhode Island, Kingston, R.I. 560 pp.

Day, Jr., J.W., C.A.S. Hall, W.M. Kemp, and A. Yáñez-Arancibia. 1989. Estuarine Ecology. John Wiley & Sons, New York. 558 pp.

Granger, S., M. Brush, B. Buckley, M. Traber, M. Richardson, and S.W. Nixon. 2000. An assessment of eutrophication in Greenwich Bay. Paper No. 1 in: Schwartz, M. (ed.), Restoring Water Quality in Greenwich Bay: A Whitepaper Series. Rhode Island Sea Grant, Narragansett, R.I.

Kremer, J.N. and S.W. Nixon. 1978. A Coastal Marine Ecosystem: Simulation and Analysis. Springer-Verlag, New York.

Nixon, S.W. 1997. Prehistoric nutrient inputs and productivity in Narragansett Bay. Estuaries 20(2):253-261

Nixon, S., B. Buckley, S. Granger, and J. Bintz. 2001. Responses of very shallow marine ecosystems to nutrient enrichment. Human and Ecological Risk Assessment 7(5):1457-1481.

Appendix F
Annual Nitrogen Budget Methods

An annual nitrogen budget was estimated for the Greenwich Bay watershed using available data and various estimation methods. The budget only considers dissolved inorganic nitrogen loadings. Total loadings and proportional loadings from different sources may vary over the annual cycle.

Attenuation Factor

An attenuation factor was used to estimate nitrogen loss while moving through the watershed for atmospheric deposition on the watershed and individual sewage disposal system (ISDS) discharges. To approximate denitrification/attenuation in the watershed, the relationships between export and land use and watershed size were examined for sixteen rivers in the United States (Table 1). No correlations were found.

Table 1. Dissolved inorganic nitrogen (DIN) exports, land use, and watershed size for sixteen U.S. rivers

River	Percentage of Nitrogen Inputs Exported in Streams	Watershed Area (km^2)	Population Density (Persons/km^2)	Land Use Percentage			
				Forest	Agriculture	Urban	Wetland
Penobscot	38	20109	8	83.8	1.5	0.4	5.2
Saco	32	3349	16	87.4	3.6	0.8	3.9
Kennebec	30	13994	9	79.6	5.9	0.9	3.6
Androscoggin	31	8451	17	84.6	4.8	1.1	3.4
Rappahannock	11	4134	24	61.3	35.9	1.4	0.2
James	11	16206	24	80.6	15.6	1.4	0.6
Susquehanna	23	70189	54	66.7	28.5	2.4	0.5
Potomac	19	29940	63	60.8	34.6	2.6	0.5
Hudson	25	11942	32	80.8	10.4	2.7	2.5
Delaware	32	17560	85	74.7	16.7	3.3	2.5
Connecticut	24	25019	65	79	9	4	4.7
Mohawk	23	8935	54	63.1	28	4.7	2.6
Merrimack	22	12005	143	74.7	7.8	8.7	3.1
Schuylkill	31	4903	293	48.1	38.4	10.2	0.7
Blackstone	33	1115	276	63.3	8.1	17.6	6.8
Charles	40	475	556	59.3	8.4	22.2	7.2
Average	**26.6**						

Source: U.S. Geological Survey

Boyer et al. (2000) reported that the mean export of DIN relative to loadings on the watershed was 25 percent after denitrification and uptake in the watershed, based on global measurements of river output and watershed inputs. This number falls within the 21 to 31 percent range found for the Woonasquatucket, Moshassuck, and Taunton rivers in Rhode Island (Granger et al., 2000) and is comparable to the 26 percent average computed from 16 U.S. rivers listed Table 1.

Narragansett Bay

The contribution of Narragansett Bay waters to Greenwich Bay nitrogen loadings was estimated by Granger et al. (2000). They estimated that **50 to 130 metric tons** of nitrogen per year enter Greenwich Bay from Narragansett Bay.

Individual Sewage Disposal Systems (ISDS)

An estimate of nitrogen loading to Greenwich Bay was calculated based on estimates of the unsewered population in the watershed, average annual inputs to ISDS, and treatment and attenuation factors. The number of unsewered households by sub-basin in the Greenwich Bay watershed was determined from the Lucht (2003) sewer prioritization analysis (Table 2). Census data from 2000 was used to determine average household size for each sub-basin and estimate the number of people served by ISDS. It is estimated that out of the 47,952 people living in the watershed, 38,517 are using ISDS. Each person is assumed to input an average of 13.4 g DIN per day (National Research Council, 1989). The annual average nitrogen load to ISDS is:

$$(38{,}517 \text{ persons} * 13.4 \text{ g N/day/person}) * 365 \text{ days} = 188{,}386{,}794 \text{ g N/year}$$

Three scenarios for ISDS inputs to Greenwich Bay were then estimated. First, inputs were estimated assuming that 75 percent of nitrogen is lost through natural processes before it reaches Greenwich Bay (Boyer et al., 2000):

$$188{,}386{,}794 \text{ g N/year} * 0.25 = 47{,}096{,}699 \text{ g N/year}$$

Second, inputs were estimated based on treatment and attenuation estimated by Valiela et al. (1997). Valiela et al. (1997) estimated that 40 percent of nitrogen is removed in the ISDS tank and leaching field, 34 percent of nitrogen is removed in the groundwater plume, and 35 percent is removed in the groundwater aquifer:

$$188{,}386{,}794 \text{ g N/year} * 0.60 * 0.66 * 0.65 = 48{,}490{,}761 \text{ g N/year}$$

Finally, inputs were estimated based on ISDS tanks and leachfield treatment estimates by Gold et al. (1990) and the attenuation rates from Valiela et al. (1997). Gold et al. found that 21 percent of nitrogen is removed in the leaching field, and used an EPA estimate of ISDS tank removal of 10 percent:

$$188{,}386{,}794 \text{ g N/year} * 0.9 * 0.79 * 0.66 * 0.65 = 57{,}461{,}552 \text{ g N/year}$$

Therefore, it is estimated that ISDS contribute anywhere from **47 to 57 metric tons** of nitrogen per year to Greenwich Bay.

To project the change in nitrogen inputs after the Warwick Sewer Authority completes its sewer extension, an estimate of the unsewered population assuming a 100% tie-in success to available sewers was calculated. A Geographic Information Systems (GIS) analysis was completed using ESRI-Arc software and coverages of the sewer construction areas provided by the Lucht (2003) study. Sub-basin coverages were clipped with the sewer construction areas to calculate the percent of the sub-basin that would be reached by the new sewers. This percentage was added to the portion of the sub-basin previously reached by sewers, and then multiplied by the size of the sub-basin to compute the number of sewered acres for each sub-basin. This area was then used in conjunction with population and household densities to compute the number of persons and households hooked up to the sewer (Table 3).

Based on this analysis, it is estimated that 17,103 people will not have access to sewers after construction is complete and 100% tie-in is achieved, an approximately 21,000 person or 56 percent decrease in population using ISDS. Estimated DIN loadings from ISDS would be **20.7 to 25.3 metric tons** per year.

Table 2. Calculation of total unsewered population prior to sewer extension using Lucht (2003) matrix

Sub-basin	Size in acres	Total Persons	Housing Units	Housing Density (houses per acre)	Household Size (persons per house)	Proportion of homes hooked up within each planning area	Sewered homes	Sewered people	Unsewered homes	Unsewered people
Brush Neck Cove	1654	10499	4266	2.58	2.46	0.16	682.56	1679.84	3583.44	8819.16
Gorton Pond	937	2068	905	0.97	2.29	0.51	461.55	1054.68	443.45	1013.32
Apponaug Cove	713	3351	1440	2.02	2.33	0.12	172.8	402.12	1267.2	2948.88
Lower Hardig	1244	4321	2074	1.67	2.08	0.47	974.78	2030.87	1099.22	2290.13
Upper Hardig	1805	8259	3826	2.12	2.16	0.04	153.04	330.36	3672.96	7928.64
Warwick Cove and Warwick Neck	1301	5536	2145	1.65	2.58	0.4	858	2214.4	1287	3321.6
Buttonwoods Cove	462	1754	806	1.74	2.18	0	0	0	806	1754
W. Watersheds North	700	2780	1314	1.88	2.12	0.01	13.14	27.8	1300.86	2752.2
Upper Maskerchugg	2115	1787	974	0.46	1.83	0	0	0	974	1787
Lower Maskerchugg	1689	4880	1914	1.13	2.55	0	0	0	1914	4880
Potowomut North	697	723	330	0.47	2.19	0	0	0	330	723
West Watersheds South	217	1994	1176	5.42	1.70	0.85	999.6	1694.9	176.4	299.1
Totals		**47952**	**21170**				**4315**	**9435**	**16855**	**38517**

Table 3. Calculation of unsewered population after sewer extension assuming 100% tie-ins to sewers

Sub-basin	Size (acres)	Total Persons	Housing Units	Housing Density (houses per acre)	Household Size (persons per house)	% Homes Tied-in	Percent New Sewer	Acres New Sewer	Total % land sewered	Sewered houses post-sewering	Sewered People after 100% Tie-ins
Brush Neck Cove	1654	10499	4266	2.58	2.46	16	74.3%	1228.5	90.3%	3851.1	9478.0
Gorton Pond	937	2068	905	0.97	2.29	51	27.3%	255.6	78.3%	708.5	1618.9
Apponaug Cove	713	3351	1440	2.02	2.33	12	69.5%	495.6	81.5%	1173.7	2731.2
Lower Hardig	1244	4321	2074	1.67	2.08	47	27.4%	340.8	74.4%	1543.0	3214.7
Upper Hardig	1805	8259	3826	2.12	2.16	4	9.4%	169.2	13.4%	511.6	1104.4
Warwick Cove and Warwick Neck	1301	5536	2145	1.65	2.58	40	82.4%	1072.2	100.0%	2145.0	5536.0
Buttonwoods Cove	462	1754	806	1.74	2.18	0	56.3%	260.1	56.3%	453.8	987.5
West Watersheds North	700	2780	1314	1.88	2.12	1	78.9%	552.3	79.9%	1050.0	2221.4
Upper Maskerchugg	2115	1787	974	0.46	1.83	0	20.6%	434.8	20.6%	200.2	367.4
Lower Maskerchugg	1689	4880	1914	1.13	2.55	0	35.8%	604.8	35.8%	685.4	1747.6
Potowomut North	697	723	330	0.47	2.19	0	20.3%	141.8	20.3%	67.1	147.1
West Watersheds South	217	1994	1176	5.42	1.70	85	0.0%	0	85.0%	999.6	1694.9
Totals		**47952**	**21170**					**5556**		**13389**	**30849**

Atmospheric Deposition

The contribution of atmospheric deposition to Greenwich Bay was estimated based on deposition rates, surface area, and an estimated attenuation rate. Based on measurements at Prudence Island, Fraher (1991) estimated that the wet and dry atmospheric deposition rate to Narragansett Bay is 0.79 to 1.29 metric tons (MT) of DIN/km^2/year.

The Greenwich Bay watershed covers 53.5 km^2 and the bay itself covers 12 km^2. The estimated direct contribution of atmospheric deposition to Greenwich Bay is:

$$(0.79 \text{ MT/km}^2\text{/yr} * 12 \text{ km}^2) = 9.5 \text{ MT N/year}$$
$$(1.29 \text{ MT/km}^2\text{/yr} * 12 \text{ km}^2) = 15.5 \text{ MT N/year}$$

For the indirect contribution of atmospheric deposition, it was also assumed that 75 percent of the nitrogen falling on the watershed is removed by natural processes (Boyer et al., 2000):

$$(0.79 \text{ MT/km}^2\text{/yr} * 53.5 \text{ km}^2) * 0.25 = 10.6 \text{ MT N/year}$$
$$(1.29 \text{ MT/km}^2\text{/yr} * 53.5 \text{ km}^2) * 0.25 = 17.3 \text{ MT N/year}$$

Therefore, atmospheric deposition contributes an estimated ***20 to 33 metric tons*** *of nitrogen per year to Greenwich Bay. Atmospheric deposition directly on Greenwich Bay accounts for 50 percent of that loading, or 10 to16 metric tons of nitrogen per year.*

East Greenwich Wastewater Treatment Facility (WWTF)

The East Greenwich WWTF is a direct nitrogen source to Greenwich Cove. The East Greenwich WWTF was estimated to be discharging approximately 16 metric tons of total nitrogen per year in the late 1990s (Table 4). Assuming nitrogen concentrations in the facility's effluent are constant, the plant could discharge 23 metric tons per year at full design capacity in the late 1990s. Current nitrogen loads from the plant are estimated to be **19.2 metric tons** per year. In 2001, the RIDEM issued a permit modification to the WWTF that specified both a maximum nitrogen concentration and an increased design flow. These new permit conditions would allow for a maximum nitrogen discharge of **11.8 metric tons** per year if the facility reached its new design flow rate.

Table 4. East Greenwich Wastewater Treatment Facility Loadings

	Late 1990s Conditions	Late 1990s Design Conditions	Existing Conditions	Existing Conditions with Denitrification	Maximum Potential Discharge with Denitrification and New Design Capacity
Flow (Millions of Liters/day)	3.22	4.69	3.87	3.87	6.43
Nitrogen concentration (mg/L)	13.59	13.59	13.59	5	5
Nitrogen Load (kg/day)	43.72	63.74	52.6	19.35	32.17
Nitrogen Load (Metric Tons/year)	**16**	**23**	**19.2**	**7.1**	**11.8**

Residential Lawns and Golf Courses

An estimate of nitrogen inputs from fertilizer use on lawns and golf courses was calculated. To estimate nitrogen inputs, the following assumptions were made:

- 34 percent of households fertilize their lawn (Valiela et al., 1997)
- 0.05 hectares is the average lawn size in a suburban coastal area (Valiela et al., 1997)
- 122 kg N/hectare/year is the average application rate by homeowners (Gold et al., 1990)
- 257 kg N/hectare/year is the average application rate by commercial applicators (Gold et al., 1990)
- 115 kg N/hectare/year is the average application rate on golf courses (Valiela et al., 1997)
- 25 percent of the population used a commercial applicator regularly
- 35 percent of nitrogen is removed during groundwater transport (Valiela et al., 1997).

Based on these assumptions, the average annual application rate for residential lawns was:

(21,170 households * 0.34) * 0.05 hectares/household = 359.9 hectares
(359.9 hectares * 122 kg N/hectare/year * 0.75) +
(359.9 hectares * 257 kg N/hectare/year * 0.25) = 56,054 kg N/year applied

The average annual application rate for golf courses was:

(115 kg N/ hectare/year * 133.1 hectares) = 15,307 kg N/year

Gold et al. measured that 2.5 percent of applied nitrogen is transported to groundwater. However, over-watering and excess fertilizer application increase the potential for nitrogen to run off into Greenwich Bay (Morton et al., 1988). Morton et al. found that with overwatering, approximately 13.5 percent of applied nitrogen was transported to groundwater. Using the loss rates calculated by Morton et al. and Gold et al., and assuming that 75 percent of the fertilizing population regularly overwaters their lawns and that golf courses are professionally managed and do not overwater, the estimate for nitrogen reaching Greenwich Bay would be:

[(56,054 kg N / year * 0.135 * 0.75) + (56,054 kg N/year * 0.025 * 0.25) +
(15,307 kg N/year * 0.025)] * 0.65 = 4,166 kg N/year

Alternatively, using loss rates estimated by Valiela et al., the estimate for nitrogen reaching Greenwich Bay would be:

(56,054 kg N/year + 15,307 kg N/year) *
(0.61 not lost as gas * 0.39 not lost in vadose) * 0.65 = 11,034 kg N/year

Therefore, it is estimated that fertilizers contribute **4 to 11 metric tons** of nitrogen annually to Greenwich Bay.

Boats

A worst-case estimate of the maximum potential discharge for nitrogen from boats to Greenwich Bay was made based on the number of boats with heads in Greenwich Bay and subtracting reported pumpout use. The 2003 Rhode Island Sea Grant and RIDEM Survey of Greenwich Bay Boating Facilities counted 4,022 total boats housed in Greenwich Bay, of which approximately 2,589 were estimated to have a boat head. It was assumed that each boat carried an average of two people per day, was used on the weekends during the summer months (June through September), and discharged its head either directly to Greenwich Bay or to a pumpout facility in Greenwich Bay. Each person was assumed to produce an average of 13.4 g DIN per day (National Research Council, 1989):

2,589 boats * 2 people/boat = 5,178 people
5,178 people * 13.4 g N/person/day = 69,385 g N/day
69,385 g N/day * 34 days = 2,359,096 g N/year

From this total, nitrogen discharged to a Greenwich Bay pumpout was subtracted. In 2002, 98,944 gallons (374,543 liters) of sewage were discharged to pumpout facilities in Greenwich Bay (Migloire pers. comm.). The average nitrogen content was estimated to be 1,800 mg/L (U.S. Army Corps of Engineers, 1999):

2,359,096 g N/year – [374,543 L * 1.8 g/L] = 1,684,919 g N/year

Therefore, it is estimated that only **1.7 metric tons** of nitrogen per year are discharged from boats in Greenwich Bay. Compliance with no-discharge requirements would eliminate nitrogen loadings from boats.

Literature Cited

Boyer, E.W., C.L. Goodale, N.A. Jaworski, and R.W. Howarth. (2002). Anthropogenic nitrogen sources and relationships to riverine nitrogen export in the northeastern U.S.A. *Biogeochemistry 57/58,* 137-169.

Fraher, J. (1991). *Atmospheric wet and dry deposition of fixed nitrogen to Narragansett Bay*. Unpublished master's thesis, University of Rhode Island, Kingston.

Gold, A.J., W.R. DeRagon, W.M. Sullivan, and J.L. LeMunyon. (1990). Nitrate-nitrogen losses to groundwater from rural and suburban land uses. *Journal of Soil and Water Conservation 45,* 305-310.

Granger, S., M. Brush, B. Buckley, M. Traber, M. Richardson, and S.W. Nixon. (2000). An assessment of eutrophication in Greenwich Bay. Paper No. 1. In: Schwartz, M. (ed.), *Restoring Water Quality in Greenwich Bay: A Whitepaper Series.* Rhode Island Sea Grant, Narragansett.

Lucht, J. (2003). Analysis of environmental threats and prioritization of mandatory sewer connections for the city of Warwick, Rhode Island. Draft Report prepared for the Warwick Sewer Authority.

Morton, T.G., A.J. Gold, and W.M. Sullivan. (1988). Influence of overwatering and fertilization on nitrogen losses from home lawns. *Journal of Environmental Quality 17*, 124-130.

National Research Council. (1989). *Recommended Dietary Allowances: Tenth edition*. Washington, D.C.: National Press.

U.S. Army Corps of Engineers. (1999). Design, construction, and operation: small wastewater systems. *Engineer Manual 1110-2-501*. Department of the Army, Washington, D.C

Valiela, I., G. Collins, J. Kremer, K. Lajtha, M. Geist, B. Seely, J. Brawley, C. H. Sham. (1997). Nitrogen loading from coastal watersheds to receiving estuaries: new method and application. *Ecological Applications 7*, 358-380.

Appendix G
Rhode Island Showcase State Executive Order

RHODE ISLAND SHOWCASE STATE EXECUTIVE ORDER
Executive Order 98-13 states that Rhode Island, under the leadership of the Rhode Island Emergency Management Agency, will do the following:

i. Identify state agencies and private sector entities responsible for implementing actions in each of the areas listed below (ii-xiv).
ii. Complete a statewide hazard analysis and risk assessment, and provide assistance to municipalities to identify their natural hazard risks.
iii. Develop partnerships with businesses to provide a private-public link for coordinated mitigation, preparedness, response and recovery. Partnerships should include businesses involved in recovery from natural hazard events (e.g. utilities, communications, food suppliers, and medical facilities) and those businesses that would impact the local and state economy.
iv. Promote and support enforcement of the latest version of the model building code as adopted by the State of Rhode Island and implemented without local amendments.
v. Address relevant hazards and the risks they pose in state-level land use decisions, including plans for state-owned property development. The state will also encourage the adoption of local land use plans that incorporate hazards into decision-making.
vi. Maintain a state emergency response plan develop a state post-disaster recovery plan. Provide technical assistance to municipalities for development of local recovery plans.
vii. Encourage communities to participate in the National Flood Insurance Program and the Community Rating System (CRS) and improve the present rating of those communities that currently participate. Provide technical assistance for preparation of CRS applications.
viii. Encourage communities to develop their Fire Suppression Rating System grade. Coordinate an Incident Command System and mutual aid agreements as appropriate.
ix. Develop programs to increase public awareness of the importance of mitigating the damage caused by natural hazards, through a coordinated effort with multiple stakeholders.
x. Support the incorporation of natural hazard reduction programs in the school curricula.
xi. Support the Institute for Business and Home Safety (IBHS) in the non-structural retrofit of non-profit childcare centers.
xii. Develop and conduct mitigation training for building, design and construction professionals.
xiii. Develop a set of public sector incentives to implement mitigation measures in collaboration with private sector financial incentives. Public sector incentives could include tax incentives and regulatory streamlining or acceleration of the permit process for those who implement mitigation activities.
xiv. Encourage the development of disaster resistant communities within the State through collaboration with the Federal Emergency Management Agency's Project Impact initiative.

(Governor Lincoln Almond, 1998)