ADAPTING TO CLIMATE CHANGE IN THE OCEAN STATE: A STARTING POINT

RHODE ISLAND CLIMATE CHANGE COMMISSION

2012 PROGRESS REPORT

NOVEMBER 2012

Table of Contents

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Representative Christopher R. Blazejewski, District 2: Providence *Commission Co-Chair*

Representative Arthur Handy, District 18: Cranston
Working Group Co-Chair Key Infrastructure and Built Environment

Senator Susan Sosnowski, District 37: New Shoreham, South Kingstown
Working Group Co-Chair Natural Resources and Habitat

Representative David A. Bennett, District 20: Warwick
Working Group Co-Chair, Human Health and Welfare

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Jared Rhodes (Designee), RI Division of Planning
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Michael Lewis, RI Department of Transportation
Peter Healey (Designee), RI Department of Transportation
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Jon Reiner, Town of North Kingstown
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INTRODUCTION

The Rhode Island Climate Risk Reduction Act of 2010 (RIGL 23-84) established the Rhode Island Climate Change Commission, a standing Commission comprised of twenty-eight representatives from the Rhode Island General Assembly, executive agencies, business organizations, environmental organizations, and community groups. The Commission's mandate is to:

- Study the projected impacts of climate change on Rhode Island
- Identify and report methods of adapting to these climate change impacts in order to reduce likely harm and increase economic and ecosystem sustainability
- Identify potential mechanisms to mainstream climate adaptation into existing state and municipal programs including, but not limited to, policies plans, infrastructure development and maintenance.

The Commission serves to review and advance legislative recommendations, coordinate and foster climate adaptation planning and programs across Rhode Island, facilitate the "mainstreaming" of climate change and adaptation policies in existing state and local law and policy, and increase the capacity of decision-makers and citizens to prepare for and proactively adapt to the consequences of climate change.

This 2012 progress report of the Rhode Island Climate Change Commission summarizes its work since its inaugural meeting in December 2011. Specifically, this report:

- Summarizes key climate risks and social, economic, and environmental vulnerabilities to them, as well as current and projected impacts upon human health and welfare, public and private infrastructure, and the natural environment
- Identifies current private and public climate change adaptation initiatives
- Highlights adaptation needs yet to be addressed
- Outlines the Rhode Island Climate Change Commission's next steps for 2013

At its inaugural December 2011 meeting, the Commission established three working groups:

- Key Infrastructure and the Built Environment
- Natural Resources and Habitat
- Human Health and Welfare

Building upon the efforts of similar climate risk assessments in Massachusetts and Connecticut, these working groups reviewed and summarized the key climate risks and vulnerabilities that will increasingly affect Rhode Island and southern New England, and adaptation efforts already in underway at the local, state and regional level. The working group summaries included in this report detail the results of their efforts. Each working group brought significant expertise to their issue through active participation by Commission members and the input of scientists, government officials and public and private interest representatives. The Commission and its

working groups will continue to seek such external feedback and recommendations to further support its work and advance its mission.

The initial work of the working groups has also helped acquaint Commission members about climate change risks and adaptation strategies. This in turn will help the Commission communicate about the emerging climate imperatives to all Rhode Islanders and their elected leadership.

2011-2012 ACTIONS

2011	
November 21	Organizational Session to plan Commission's First Meeting
December 6	Inaugural Meeting of RI Climate Change Commission
December 14	Next Steps Meeting with Organizers
2012	
January 6	Meetings of each of the three Working Group Co-chairs
February 8	Human Health Working Group Meeting
February 17	Key Infrastructure and Built Environment co-chairs Meeting
February 24	Natural Resources and Habitat Working Group Meeting
March 16	Key Infrastructure and Built Environment Working Group meeting
April 3	Co-Chair joint meeting
April 25	Full RI Climate Commission Meeting, Presentation of Draft Progress Report
May 30	Submittal of draft 2012 Progress Report
September	Work Group Co-Chairs Meeting
October	Final Draft Reviewed by Work Group Co-Chairs
Nov 13	Public Release of 2012 Progress Report

The following section briefly summarizes observed and projected climate change impacts upon Rhode Island and New England. Subsequent sections review and discuss the findings to date of the Commission's working groups. Appendix A reviews climate change assessment and adaptation initiatives important to Rhode Island.

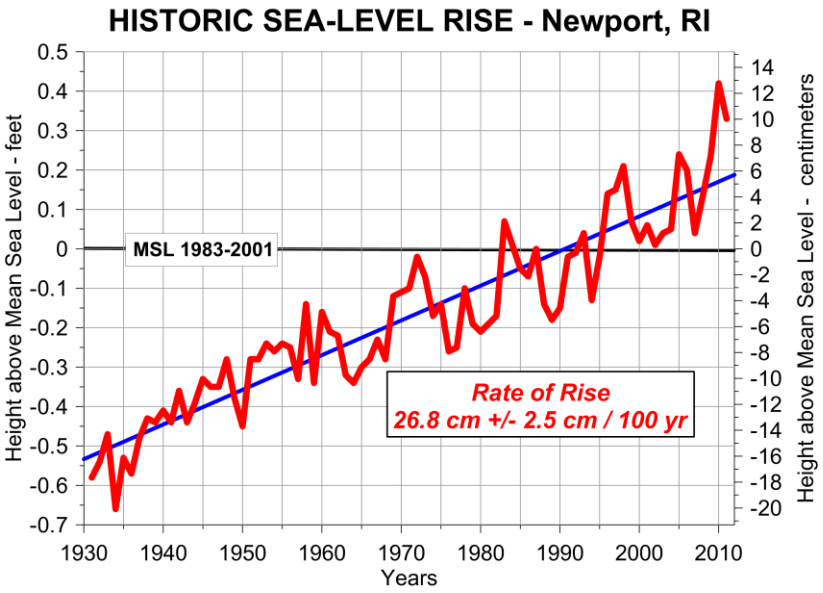
CLIMATE CHANGE IN RHODE ISLAND

The impacts of climate change upon Rhode Island's built and natural environments are wide-ranging, discernible and documented, and, in many cases growing in severity. The climatological sciences with increasing temporal and spatial accuracy project substantial future impacts upon Rhode Island, including stronger, more frequent hurricanes and Nor'easters, greater frequency of other extreme weather events such as heat waves. Also scientifically observed and projected are rapid alterations to terrestrial and aquatic ecosystems, their structure and function, and the natural resource values they generate and sustain.

The climate dice are now loaded to a degree that a perceptive person old enough to remember the climate of 1951–1980 should recognize the existence of climate change, especially in summer. Summers with mean temperature in the category defined as cold in 1951–1980 climatology, which occurred about one-third of the time in 1951–1980, now occur about 10% of the time, while those in the hot category have increased from about 33% to about 75%.[1]

Rhode Island is just beginning to feel the impacts of a shifting local climate, as summarized in Table 1.[1] Average air temperatures have increased 1.7°F from 1905 to 2006, and Narragansett Bay temperatures have risen four degrees at the surface since the 1960s. Since 1962, the number of days for which temperatures exceed 90°F in the Northeastern U.S. has nearly doubled.[2] Southern and inland regions of the Northeast now experience up to 20 days of temperatures above 90°F each year, with about two days above 100°F in urban regions. Average sea level has risen ten inches since the 1930's, and the rate of sea level rise is accelerating (Figure 1). The frequency of intense rainfall events is increasing, while hot and dry spells are lengthening.

Figure 1: Difference between average sea level at Newport, R.I., from 1983 to 2001 and mean annual sea level plotted for each year between 1930 and 2011. The blue trend line shows a 10.6 inch (26.8cm) increase in sea level per century. *Graph courtesy of Jon Boothroyd, 2012. Data from: http://tidesandcurrents.noaa.gov/sltrends/ sltrends_station.shtml?stnid=8452660*



[1] Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I.

[2] Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Rhode Island report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS).

Table 1. Summary of observed global, regional, and state climate change impacts and drivers.[3]

	OBSERVATIONS OF RECENT CHANGE		
	Global	**US Northeast**	**Rhode Island**
Increased air temperatures	0.74°C (1.33°F) in last 100 years	0.83°C (1.5° F) since 1900	0.94° C (1.7°F) from 1905 to 2006
Increased marine water temperatures	Consistent increase since the 1960's, with 2007 as the warmest year on record	Average annual increase of 1.2°C (2.2°F) since the 1970's	2.2 C (4°F) at surface of Narragansett Bay since the 1960's
Sea Level Rise	• Average rate of increase of 1.8 mm (0.07 in) per year during the 20th century - a rate greater than that of the preceding eight centuries. • Rate nearly doubled to 3.4 mm (0.13 in) annually between 1993-2003	-	• 2.6 mm (0.1 in) rise per year since 1930 at Newport's tide gauge • Between 1990 and 2009 this rate increased to 3.6 mm (0.14 in) per year
Increased Storminess	Increased Severity of tropical cyclones since the 1970s.	Increased severity of tropical cyclones in the North Atlantic	-
Changing Precipitation	Rainfall increased in mid-latitudes and decreased in the subtropics of the Northern Hemisphere over the last 50 years	5-17 percent increase in regional precipitation over the last century	• Increased 3 mm (0.12 in) per year (rain and snow) • Annual wind speed at T.F. Green Airport has significantly declined since at least the 1960s
Ocean acidification	Surface pH is 0.1 units lower than pre-industrial levels	-	-

Our state is beginning to discern the impacts of climate change upon Rhode Island's economy. Rhode Island farmers are experiencing lengthened seasons but less predictable rainfall patterns. The most common fish species in Narragansett Bay are shifting from cold-water, bottom-dwelling species to warm-water, water column species. Increased jellyfish populations and large algal blooms are threatening the quality of Rhode Island's aquatic outdoor recreation assets upon which tourism and boating industries rely.[4] Scientists are studying the relationship between ocean acidification and carbon dioxide ($C0_2$) emissions. Many of these climatological, oceanographic, ecological, and economic changes and transformations are occurring more rapidly than anticipated.[5]

Climate change may also produce unexpected benign impacts. For example, warm weather tourism in Rhode Island could increase in the spring and fall, and new recreational and commercial fisheries may emerge as warm water tolerant finfish populations become established in Rhode Island's coastal and adjacent ocean waters. But these possible benefits will be overwhelmed by the many emerging deleterious impacts, impacts that will tend to interact synergistically.

In sum, Rhode Island will experience warmer air and water temperatures, more extreme weather events such as droughts, intense precipitation, severe storms and flooding, increasing

[3]Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I., p. 7.
[4] Ibid.
[5] Ibid.

rates of sea level rise, shorter winters and longer summers, and less snowfall and ice coverage.[6]

Climate change has the potential to pose significant risks for Rhode Island's water, wastewater, surface transportation, and energy infrastructures and utilities, our natural environment, and our health, welfare, and economic well-being. The Commission's three working groups have begun to catalogue and further specify these risks upon our environment, infrastructure and economy, and to describe what's being done to address and adapt to these risks. Many of these adaptation actions were initiated for other reasons, but climate change provides additional justification to further advance and expand these steps.

KEY CLIMATE CHANGE VULNERABILITIES AND RISKS

Sea level rise, warming air and water and increased storminess have distinct and multiple consequences depending upon which facet of society, environment, and economy one looks at. The Commission has identified four major risk categories as top concerns for Rhode Island: 1) wastewater infrastructure vulnerability due to projected sea-level rise, increased severity of storm events, and increased precipitation and flooding; 2) impacts upon our drinking water supplies due to seal-level rise, storm surges and increased inland flooding; 3) energy infrastructure vulnerability resulting in prolonged loss of power and hazards resulting from downed lines; 4) public health and safety risks to coastal populations due to flooding and storm surges, and public health and safety risks to urban populations due to heat waves and flooding.

Flooding in 2010 closed the Warwick Sewer Authority treatment facility and discharged large volumes of untreated sewage into the Pawtuxet River.
(Photo Credit: RI DOT)

Our state's wastewater treatment systems are highly vulnerable to severe storms and accompanying storm surges, flooding, and sea level rise. Sewer pipes and sewage treatment plants generally are located within river and coastal floodplains and situated directly upon coastal and riverine shorelines. Wastewater treatment processes thus may be quickly flooded out, releasing untreated sewage directly into our natural waters and communities. As experienced along the Pawtucket River in the March 2010 floods, such massive, abrupt releases

[6] Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I., p. 7.

of sewage can have devastating impacts on aquatic ecosystems and resources and generate major threats to public health by widespread exposure to water-borne diseases.

More frequent and longer periods of drought have the potential to diminish water supplies, leading to severe shortages in drinking water, inadequate fire suppression ability, decreased agricultural production and reductions in water quality and aquatic habitat quality.

ADDRESSING CLIMATE CHANGE AND BEGINNING ADAPTATION

New initiatives are beginning to invest in climate change assessment and adaptation, including: revision of infrastructure design and construction standards; interagency and inter-government planning and coordination; public education and outreach; and research and monitoring. A goal of the Commission is to foster these activities and identify additional collaboration opportunities essential for climate change adaptation and resilience in Rhode Island.

Climate change adaptation programs and efforts: Completed, underway, or planned. Additional details are provided in Appendix A.

Central Bridge 182 in Barrington will be rebuilt with features to increase its resilience to sea level rise. (Photo Credit: RI DOT)

RECENT OR UNDERWAY

Infrastructure and Environmental Assessments

- Lessons Learned From Tropical Storm Irene, January 2012 (RI Senate Hearing: Commission on Housing and Municipal Government)
- Statewide Substation Flooding Assessment (National Grid)
- Bristol Stormwater extraneous flow assessments and mitigation (Bristol)
- Assessment and support of shoreline adaptation actions (Save the Bay)
- Assessing dams for catastrophic failure (RIDEM)
- Dead end road stormwater assessments; Culvert Assessments (Save the Bay)
- Transportation network SLR vulnerability assessments (RIDOA Statewide Planning, RIDOT)
- Water Supply and Quality Study with Climate Change (RIDOH)
- N. Kingstown Sea Level Rise Pilot Study (N. Kingstown, RISPP, RISG, URI, CRMC, TNC)
- N. Kingstown Coastal Wetland Migration Study (N. Kingstown, CRMC, TNC, RISG, NBNERR)

Climate Adaptation Planning

- RI Asthma Plan: 2009-2014 (DOH, RIACC)
- Central Landfill Disaster Preparedness Plan (RIRRC)
- RI Aquatic Invasive Species Management Plan (CRMC, URI, RINHS)
- RI Water Resources Board Strategic Plan for Potable Water Supply (RIWRB)
- Community Vulnerability Assessments (USEPA)
- Municipal Natural Hazard Mitigation Plan updates (RIEMA, municipalities)
- Health Impacts of Climate Change: Implications for Resilient Communities (Providence)
- Hurricane and Flooding Evacuation Study (USACE, FEMA, RIEMA)
- RI Streamflow Depletion Methodology for Determining Sustainable Withdrawals (RIDEM)

- Structural Concept and Contingency Plan to Inundation of the Block Island Ferry Terminals and Roadway Systems (New Shoreham, Interstate Navigation, CRMC, CRC)
- Revisions to North Kingstown Comprehensive Plan Revisions add Sea Level Rise Adaptation(RISPP, NK, RISG, URI, CRMC, TNC)

State Design and Construction Codes and Standards

- Updated State Building Code (minimum freeboard heights for coastal properties) (RIBCC)
- 2010 Stormwater Design and Installation Standards Manual (expanded requirements for low impact development strategies) (RIDEM, CRMC)
- Development of Transportation Infrastructure Climate Change Adaptation Strategy (RIDOT)

State and Local Legislation, Agency Programs, and Policies

- Addressing Climate Change for Habitat Protection and Land Trusts (URICRC/EDC, TNC, S. Kingstown Land Trust, CRMC)
- Bills introduced - Enabling Authority for Municipal Stormwater Management (RI General Assembly)
- Climate Ready Estuaries Study of Climate change Vulnerabilities in the Pawtuxet River Watershed (NBEP)
- Combined Sewer Overflow Abatement Project (NBC)
- Stormwater Mitigation Program (NBC)
- Sustainable Energy Management Program: Wastewater Treatment Facilities (RIDEM, NBC, National Grid, URI, USEPA, RI Manufacturers Extension Service)
- Trees 2020 (Groundwork Providence, City of Providence)
- Adoption of Section 145: Climate Change Policy into RI CRMC's Coastal Resources Management Plan
- RI 2010 Ocean Special Area Management Plan: Chapter 3, Climate change, research and monitoring (CRMC)
- RI Comprehensive Planning and Land Use Act of 2011: Requires climate change adaptation and sea level rise consideration in local comprehensive plans (RISPP)
- Proposed RI Shoreline Erosion and Inundation Special Area Management Plan (CRMC)

Inter-Agency Coordination and Outreach

- Coastal Training Program Workshops on climate change (NBNERR, RIDEM)
- Climate change resilience in under-served communities (ECRI, funded by National Wildlife Federation and RI Foundation)
- Reverse 9-1-1 (various municipalities)
- RI Flood Awareness and Climate Change Task Force (RISG, CRMC, RIBCC, RIEMA, RIFMA)
- Sea Level Rise Inundation Mapping and Visualizations (RISG, URI, CRMC, RISPP, TNC)
- Shoreline Change Maps (CRMC)
- StormSmart Coasts RI web portal (RISG, CRMC, RIBCC, RIEMA)
- Flood Mitigation Working Group (RIEMA)
- RI Climate Change Portal Web Site (RISG, URI Coastal Institute, Brown Univ.)
- Stormwater Solutions Project (URI Coop Extension, RIDEM)
- Updated Coastal Flood Insurance Rate Maps (FEMA)

Research and Monitoring

- Ambient Monitoring of RI fresh, coastal, and marine waters (RIDEM, NBC, RIDOH, EPA, URI, Brown Univ., NBEP, NBNERR, NOAA)
- RI Ocean Special Area Management Plan Research and Monitoring (CRMC)
- Salt Marsh Climate Change Sentinel Monitoring (NBNERR)
- URI Climate Change Collaborative and Climate Change Portal Web Site (URI, RISG)
- Vector surveillance for mosquito-borne and tick-borne diseases (RIDOH)
- Watershed Counts climate change indicators (NBEP, URI Coastal Institute)

PLANNED

Assessments

- RI Wastewater Treatment Infrastructure Climate Change Vulnerability Assessment (RIBRWCT/RIDEM)
- RI Comprehensive Wildlife Conservation Strategy: 2013 update to include climate change (RIDEM)

NEXT STEPS FOR THE RHODE ISLAND CLIMATE CHANGE COMMISSION

In 2013, the RI Climate Change Commission proposes to undertake the following:

- **Track climate change assessment and adaptation activities and update members**. Maintain a list of current activities and initiatives of Commission member institutions and others, thereby promoting efficiency, less duplication of efforts and collaboration to advance statewide efforts advancing adaptation to climate change. Utilize quarterly electronic communication to solicit updates from different organizations, which will be compiled and distributed. Updates will be posted to a designated website and/or listserv to Commission members, other agencies, organizations, and stakeholders.
  Lead – Rhode Island Sea Grant

- **Identify legislative initiatives that support climate change issues.**

- **Convene Working Groups** to enhance collaboration, recommend priorities, and support existing efforts. The Working Group Co-Chairs will convene the three groups to facilitate discussion on issues, opportunities, and priorities. The working groups will serve as a forum for communications about theme-specific activities, and be called together by a member or Co-chair as needed.
  Lead – Working Group Co-chairs

- **Convene the RI Climate Change Commission** twice annually to report out status of ongoing activities of agencies, organizations, and private sector, identify synergies (interagency, cross-sector), identify and assess opportunities to advance work through new priorities and opportunities for additional resources to support enhanced resilience of people, economy and environment.
  Lead – Working Group Co-chairs.

KEY INFRASTRUCTURE & BUILT ENVIRONMENT WORKING GROUP

PROGRESS REPORT

INTRODUCTION

THE WORKING GROUP

The Key Infrastructure and Built Environment Working Group consists of representatives from community planning, transportation, energy, buildings and structures, water supply and emergency management. The Working Group is co-chaired by Representative Arthur Handy, Associate Director of the Division of Planning, Kevin Flynn, and the Chief of the Statewide Planning Program, Jared Rhodes. Other members include:

James Boyd, Coastal Resources Management Council
Kenneth Burke, RI Water Resources Board
Michelle Burnett, RI Emergency Management Agency
John Carter, RI Builder's Association
Paul Fournier, Greater Providence Chamber of Commerce
Janet Freedman, Coastal Resources Management Council
Grover Fugate, Coastal Resources Management Council
Michael Lewis, RI Department of Transportation
John Leyden, State Building Code Commission
Jon Reiner, Town of North Kingstown
Alexander Taft, National Grid
Arthur Yatsko, RI Realtors Association
Jen Zolkos, American Institute of Architects, Rhode Island Chapter

To identify the vulnerabilities to climate change of the state's key infrastructure and built environment, staff of the Division of Planning's Statewide Planning Program held interviews with representatives from several key sectors. The interviews sought to determine the threats facing the sector given the predicted climate changes and to identify existing projects, resources and data that may assist in the further assessment of actual vulnerabilities. From the interviews, an initial infrastructure vulnerability assessment was completed as summarized below.[7]

CLIMATE VULNERABILITIES

BUILDINGS AND STRUCTURES

Sea level rise may put a number of coastal structures at risk for permanent inundation. Structures that have been raised above the flood plain may remain intact, but access to such structures will be limited.

Increased storm surge levels and stronger, more frequent storm events and heavier precipitation have the potential to increase the frequency of storm related flood damage and extend flood damage to structures lying outside of existing flood zones in both coastal and riverine areas. This could result in the loss of a greater number of structures, especially considering that structures outside of current flood zones have not been built to the same level of flood protection as those within flood zones. In addition to structural

[7] Interviewees were: Kenneth Burke and Kathleen Crawley, RI Water Resources Board; Michelle Burnett and Jessica Stimson, RI Emergency Management Agency; Janet Freedman and James Boyd, RI Coastal Resources Management Council; Peter Healey and Courtney Danella, RI Department of Transportation; Jane Kenney Austin, Save the Bay; Sarah Kite, Krystal Noiseux and Mike McGonagle, RI Resource Recovery Corporation; John Leyden, State Building Code Commission; William Patenaude, RI Department of Environmental Management; Jon Reiner, Town of North Kingstown; Pam Rubinoff, Coastal Resources Center, RI Sea Grant; Alexander Taft and John Stavrakas, National Grid; Tom Uva and Pamela Reitsma, Narragansett Bay Commission.

damage and loss, building related illnesses may increase due to mold build-up cause by untreated or poorly treated water damage. (Additional information on the associated public health risks can be found in the section on Public Health and Safety.)

Historically, most of Rhode Island's development has occurred along the coast and rivers; therefore the potential for the damage of a large number of homes and structures is substantial. A recent study determined that there are 2,705 housing units less than 1 situated meter (3.28 feet) above the Mean High Water (MHW) elevation along the Rhode Island shoreline (Strauss et al., 2012).[8] Rhode Island's historic coastal and riverine villages, such as Wickford and Pawtuxet, are at particular risk, consisting of older buildings being located in vulnerable coastal areas. Sea level rise and storm-related flooding have the potential to displace a significant number of residents and cause the closing of a number of businesses and institutions, either permanently or for significant periods of time.

TRANSPORTATION NETWORKS AND INFRASTRUCTURE

Sea level rise may lead to the permanent inundation of some of Rhode Island's transportation infrastructure, including port facilities, access roads, bridges, railroad tracks, airports, bike paths, ferry terminals and drainage systems. Such permanent breaks in the transportation network may lead to isolated communities that are disconnected from the rest of society and have no access to goods, services and employment. Inundation of the state's ports and railroads may reduce interstate access, affecting economic viability and potentially limiting imports and exports. Sea level rise may also reduce navigational clearances for the state's bridges, additionally limiting access.

Road damage in Hopkinton from the 2010 floods.
(Photo Credit: RI DOT)

Stronger, more frequent storms may damage and destroy transportation infrastructure by erosion, precipitation that overwhelms stormwater infrastructure, storm surges, wave activity, and heavy snow accumulation. Shoreline erosion may also present major threats to public safety. Matunuck Beach Road in South Kingstown, which provides the sole access and emergency evacuation routes for 240 residences, could be severed due to a combination of long-term erosion of the beach and the coastal bluff that fronts the roadway because of storms and sea level rise, and the sudden substantial erosion losses caused by storms.

Heavier precipitation rates may overwhelm the storage and conveyance capacities of rivers, dams, and stormwater systems, increasing the probability of large-scale flooding of river areas during major storms, as well as flash-floods that render roadways and highways temporarily impassable, as was experienced in the floods of March 2010. Flooding can limit neighborhood access to emergency responders and reduce evacuation opportunities. Transportation rights-of-way are also some of the primary utility corridors in the state, carrying gas, electric, telecommunications and sewer infrastructure above and beneath the road surface. Any effect to the transportation network, including the undermining of rights of way due to coastal erosion, will also impact essential utilities.

ENERGY INFRASTRUCTURE

Sea level rise may inundate electricity infrastructure along the coast, including distribution and transmission stations and customer equipment. Permanent inundation may lead to the relocation of energy infrastructure, such as electrical transfer stations and natural gas pipelines. Stronger and more frequent storms and heavier precipitation could increase temporary flooding of energy infrastructure, as well as damaging utility poles and transmission towers.

[8] Strauss, B., R. Ziemlinski, J. Weiss and J. Overpeck. 2012. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. Environmental Research Letters 7 (2012) 014033 12pp.

Flooding of customer basements, due to storm surges, sea level rise or increasing groundwater levels, may occur prior to the flooding of a building's occupied space and can affect gas service to an entire community. Flooding at customer premises may cause long-term, neighborhood wide gas service disruptions, as bringing flooded areas back into service requires that each building be reconnected to the system one at a time. Unprotected electrical equipment, including transformers and natural gas transmission and distribution stations, may be more susceptible to increased flood damage.

The permanent inundation of Rhode Island's maritime ports could significantly impact on the shipment of coal and petroleum products, including oil, diesel and gasoline, throughout Rhode Island and southern New England as the region's fossil fuel imports are primarily transported by ship.

Warmer overall temperatures, longer periods of intense heat, and increased heat island effects may also increase building cooling demands upon Rhode Island's electrical system.

WATER SUPPLY

Sea level rise may lead to saltwater intrusion of public and private drinking supplies, especially in the southern portion of the state and on Aquidneck Island. The availability of potable water may be severely limited and relocation of infrastructure may become necessary. Additionally, increased storm surges and more storms may increase instances of temporary inundation of drinking water supplies, by fresh and/or saline waters, that will require costly treatment to meet drinking water standards. The surface water reservoirs located on Aquidneck Island may be susceptible contamination due to inundation due to their location on the coast and within urbanized watersheds. Southern and Eastern Rhode Island have numerous coastal wells, vulnerable to saltwater intrusion. Potential mitigation strategies may include the removal of biological contaminants in areas with combined sewage and well systems. Increased snowfall rates may also increase winter-time road salt applications.

More intense droughts may deplete groundwater supplies, impacting potable water availability and fire suppression capabilities. Additionally, loss of hydraulic pressure in a water supply system can increase water contaminant concentrations in delivered water. The public health risks related to water supply are discussed in the Human Health and Welfare Section below.

FLOOD CONTROL AND STORMWATER INFRASTRUCTURE

More frequent storm events and heavier precipitation may overwhelm the capacity of dams and stormwater systems, causing flash flooding in neighborhoods and potential large-scale flooding of riverine areas. Pre-1975 development was not required to include separated infrastructure for stormwater; therefore older communities may be more vulnerable to increased flooding due to stormwater.

Heavier precipitation rates will place greater stresses upon Rhode Island's many dams. The Rhode Island Department of Environmental Management (RIDEM) maintains an inventory of the state's 669 dams, along with individual dam risk assessments that identifies the damage that its failure could cause. Currently, 97 dams in Rhode Island have been classified by RIDEM as "high hazard," meaning that failure or improper operation of these dams could result in a loss of human life. RIDEM classifies 81 dams as presenting "significant hazard," meaning that failure or improper operation would not lead to loss of human life but would lead to substantial economic and infrastructure losses. Alarmingly, 19 "high hazard" dams and 3 "significant hazard" dams have been deemed "unsafe," meaning that the condition is such that an unreasonable risk of failure exists.

Recognizing the need for increased investments in dam maintenance and upkeep, in 2011 the Rhode Island House of Representatives passed Resolution H 5430 in support of federal legislation to eliminate the Federal Energy Regulatory Commission's regulation of hydroelectric installations of less than two megawatts. Such a change in FERC oversight of Rhode Island dams, would give RIDEM primary regulatory oversight of the operation and maintenance of existing dams with a greater emphasis upon dam safety and maintenance.

WASTEWATER INFRASTRUCTURE

Waste water treatment facilities (WWTF's) and pump stations are generally sited at lower elevations, putting them at increased risk for permanent or temporary inundation by floods or sea-level rise. Temporary inundations of WWTF's did occur in Warwick, West Warwick and Cranston during the storms in March of 2010, resulting in total shutdown of the wastewater system and the expenditure of millions of dollars to return the damaged infrastructure to operation. During major precipitation events, valves that transport stormwater from Providence to the Narragansett Bay Commission WWTF at Fields Point must be closed to prevent Providence from being back-flooded through the sewer collection system. This could result in untreated sewage being discharged into the Providence River. Storm surge threats to upper Bay WWTF's and the Providence Metro Region could be expected to increase over time.

Most of the state's wastewater conveyance and treatment infrastructure cannot be easily relocated to higher elevations. WWTF infrastructure incorporates measures to address flooding impacts and ensure continuous compliance with discharge and operations requirements. In order to address flood hazards, federal and state regulations require WWTF's to design facilities capable of withstanding the impact of 100-year storm events. Droughts can also create operational issues for wastewater conveyance and treatment.

Many Rhode Islanders rely upon on-site wastewater treatment systems (OWTS), primarily in suburban and rural areas. About 6,000 OWTS are located near the coast and are vulnerable to sea level rise inundation and rising groundwater form increased precipitation. Rising groundwater may pose a contamination threat to properties which utilize groundwater wells and OWTS's.[9]

SOLID AND HAZARDOUS WASTE

Sea level rise, stronger storm surges, more frequent storm events and heavier precipitation could inundate solid waste transfer stations, necessitating direct hauls of solid waste to the Central Landfill. Additionally, stronger storm surges and more frequent storm events may increase coastal erosion threats to capped landfills or superfund sites that are located near the coast. Loss of surface transportation access in and out of flooded communities due to flooding would require establishment of temporary local waste storage/transfer sites areas. The risks of temporary or permanent inundation could increase for private operators that generate or store hazardous wastes, including the industrial facilities connected to Rhode Island's maritime ports.

Warmer temperatures could result in an increase of leaf and yard waste, and a greater number of strong storms could result in more storm-related debris, requiring additional transport vehicles and possibly straining the state's debris management processing system. Coastal communities may need to invest more in debris handling capabilities and plans.

TELECOMMUNICATIONS

Sea level rise, increased storm surge levels, more frequent storm events and heavier precipitation may cause the permanent or temporary inundation of telecommunications infrastructure. Much of this infrastructure is connected to the transportation networks and energy infrastructure, and would be subject to many of the same vulnerabilities. Prolonged disconnections from telecommunications service may impact states businesses, especially those in high-tech industries.

EXISTING EFFORTS

A full list of the existing efforts addressing the adaptation of key infrastructure and the built environment can be found on pages 6-8 and the Appendix A of this report. Many efforts currently underway address climate change adaptation as it pertains to critical infrastructure and Rhode Island's urban regions. However, a few key areas still need to be addressed.

[9] The New England Onsite Wastewater Training Center, located at URI, is in the process of launching a research initiative to address OWTS adaptation methods to climate change.

First, it may be useful to updated data related to the effect of increased precipitation and more frequent storm events on the state's riverine areas. As seen during the March 2010 storms, the state's riverine areas are susceptible to sizable damages from heavy precipitation, Nor'easters, and hurricanes. Updated flood maps would assist in properly assessing the potential impacts to key infrastructure and the built environment in riverine areas, updated flood maps are essential. Another data need is location-specific hydrographs for Rhode Island's rivers. Location-specific hydrographs for key locations would increase the precision and timeliness of river flood elevations which may help manage and protect surface transportation facilities vulnerable to closures or damages form flooding.

Second, the RI Senate's Housing and Municipal Government Committee's recommendations related to the state's telecommunications infrastructure deserve close attention.

Third, RI WWTF's are operated primarily by municipalities and/or private companies. While the Narragansett Bay Commission has been assessing their system's vulnerabilities to climate change impacts, smaller WWTF's need to be assessed as well. One option would be to onvene other municipal and regional sewer authorities to discuss and plan such assessments.[10]

Finally, climate adaptation planning for coastal and riverine communities located in highly vulnerable areas deserve concerted discussion statewide. We need to explore opportunities to convene cities and towns in collaboration with state agencies to examine vulnerable areas and discuss policies for future climate adaptation projects.[11]

PRIORITIES FOR THE KEY INFRASTRUCTURE AND BUILT ENVIRONMENT WORKING GROUP

The Key Infrastructure and Built Environment Working Group of the Rhode Island Climate Change Commission will continue to identify the risks posed by climate change to infrastructure and the built environment, as well as the most suitable climate change adaptation strategies for Rhode Island. Being tasked with looking at many sectors and many vulnerable resources, as described above, it is clear to this Working Group that it will not be possible in the short term to complete vulnerability and risk assessments for all types of vulnerable infrastructure. With this in mind, the Working Group will conduct a condensed, qualitative prioritization exercise, based on the knowledge and expertise of our members, to determine which vulnerability and risk assessments should be tackled first.

This Working Group will continue to assess the complete spectrum of possible climate change impacts, how many people could be impacted, the socio-economic consequences of such impacts, and whether particular communities and populations are vulnerable. The goal will be to identify the most vulnerable infrastructures, communities, and populations. Then the Working Group will consider how to move the highest priority vulnerability and risk assessments forward, including how ongoing assessments are meeting the most critical needs, sources of funding for assessment and actual adaptation, data availability, lead particular risk assessments and adaptation planning efforts.

The Working Group will help determine the methodology, data sources, and available resources for completing the climate change impact and adaptation assessments. The Working Group will continue to monitor the inundation modeling and mapping efforts undertaken in North Kingstown.[12]

Many of the Working Group member agencies are already addressing adaptation to climate change. These initiatives will benefit many economic sectors and stakeholders and thus would benefit from the additional support from the Working Group. To support

[10] The RI Bays, Rivers, and Watersheds Coordination Team will fund and oversee a statewide assessment of the climate vulnerabilities of RI's WWTF's in FY 2013.

[11] The Narragansett Bay Estuarine Research Reserve will participate in a federally-funded New England regional effort that will enable a Rhode municipality to explore in-depth climate resilient strategies. RI Sea Grant and the URI Coastal Resources Center will convene a quarterly municipal forum in November 2012 to engage discussion and exchange among RI communities and programs.

[12] These projects include the North Kingstown and Coastal Resources Center's *Sea Level Rise Pilot Study* and the Division of Planning and RI Department of Transportation's *Transportation Network Vulnerability Assessment*.

these efforts, the Working Group will assist in determining essential inputs to the assessments, such as incorporating future refinements (increased precision) to projections of key climate drivers, insights into obstacles and barriers to pro-active climate change adaptation, and strategies for building constituent and stakeholder support for climate change adaptation.

In other cases, agencies have identified climate change risks and adaptation priorities, but have yet to begin formal risk and vulnerability assessments. For example, the RI Coastal Resources Management Council (CRMC) has adopted a policy to review its internal policies, plans and regulations to plan for and adapt to climate change and sea level rise, and the State Building Code Commission is looking at further revisions to the State Building Code to adapt to climate change. While CRMC and the Building Code Commission conduct risk and vulnerability assessments to inform their policy decisions, the Working Group can serve as a resource to the State Building Code in developing the amendments.

NATURAL RESOURCES AND HABITATS WORKING GROUP

PROGRESS REPORT

INTRODUCTION

ABOUT THE WORKING GROUP

The Natural Resources and Habitats Working Group of the Rhode Island Climate Change Commission consists of representatives from environmental agencies and organizations, non-profits, and academia.

Janet Coit, Department of Environmental Management
Janet Freedman, Coastal Resources Management Council
Scott Millar, Department of Environmental Management
Meg Kerr, Environment Council of Rhode Island, Narragansett Bay Estuary Program
Rich Hittinger, Alliance Environmental Group
Judith Swift, University of Rhode Island, URI Coastal Institute
Q Kellogg, University of Rhode Island, URI Coastal Institute
Michelle Burnett, Emergency Management Agency
Jane Austin, Environment Council of Rhode Island, Save the Bay
Lew Rothstein, University of Rhode Island, Graduate School of Oceanography
Ken Raposa, Narragansett Bay National Estuarine Research Reserve
Jeremy Collie, University of Rhode Island, Graduate School of Oceanography

This Working Group is co-chaired by Senator Susan Sosnowski, Ames Colt of the RI Bays, Rivers, and Watershed Coordination Team, and Jane Austin of Save the Bay.

ISSUE OVERVIEW

Climate change and coastal and marine acidification pose substantial and diverse risks to the productivity and sustainability of Rhode Island's natural resources and habitats. The primary drivers of these risks across terrestrial and aquatic environments are:

- Increasing air and water temperatures,
- Alterations to precipitation patterns and hydrologic cycles
- Sea level rise and coastal inundation
- Ocean acidification

These drivers affect directly the physiological health of individual plant, animal, and insect species and populations and their habitats. Major deleterious changes can be expected from synergistic interactions between alterations to physiology, habitat quality, and overall ecosystem structure and function.[13]

Salt marshes provide habitat for many animals, as well as protect coastal waters from pollution and limit erosion. R. Hancock

One goal of the Rhode Island Climate Change Commission is to identify and characterize the immediate and long-term consequences of Climate Change to our natural environment, economy, infrastructure, and public health and welfare. This initial report from the Natural Resources and Habitats Working Group surveys briefly the environmental consequences of climate change and coastal and marine acidification. It also catalogues initiatives underway in Rhode Island to respond to a warming climate, altered weather patterns, rising seas, and an acidifying ocean.

[13] cf. Cahell, A. E. et al. Does Climate Change Cause Extinction? 2012. Proceedings of Royal Society. rspb.royalsocietypublishing.org.

ENVIRONMENTAL IMPACTS & RISKS

TERRESTRIAL ENVIRONMENTS

Rising air and water temperatures change the way plants and animals grow and behave, and these changes manifest uniquely among different species. Of fundamental concern is the alteration of "relationships between climate and the regular seasonal progression of biological events, such as the migration of animals, the flowering of plants," or the blooming of phytoplankton.[14] As these phenological relationships are transformed, they in turn modify other ecological relationships such as predator/prey relationships and food web dynamics.

As temperatures increase, species assemblages, communities, and habitats have the potential to be disrupted. For example, as a result of temperature increases, Rhode Island may lose some species of trees, like apple and maple trees, which prefer colder climates. However, individual species may propagate or migrate northward in different ways and at different rates. Community relations between plants, animals and insects that depend upon or interact beneficially with each other will be disrupted or cease entirely.

The plants, animals, and insects that will thrive in a warming Rhode Island climate are appearing in Rhode Island's water and lands, and will continue to arrive in greater numbers. For example, the productivity and geographic spread of invasive plants and insects such as Black–swallow Wort and Hemlock Wooly Adelgid have historically been inhibited by winter die off. [15] As winter temperatures increase, these invasive species may expand in population and geographic range. Invasive plant species such as Norway Maple, Garlic Mustard, and Mile-a-Minute Vine are becoming established or expanding. Response to and eradication of invasives should be considered as part of climate adaptation efforts. For example, efforts are underway in the City of Providence's Blackstone Park to eradicate invasive Norway Maples, which will over time replace native plant and tree species.

FRESHWATER ENVIRONMENTS

Rivers, lakes, ponds, and streams provide essential habitat values and numerous recreational uses and benefits to Rhode Islanders. Rhode Island will experience a significant increase in intense rain events and decreasing ice coverage and snowfall. As a consequence, Rhode Island's rivers, lakes, ponds, and streams may experience more intense and frequent droughts and floods. Increased flooding has the potential to degrade water quality, lower dissolved oxygen (DO) concentrations, and aggravate eutrophication. Stormwater runoff may increase water column stratification and pollutant loadings which, coupled with warmer water temperatures may trigger harmful algal blooms (HAB's).

Invasive species are already widespread in Rhode Island's freshwater environments, including lakes, ponds, and wetlands. It was estimated that 59% of recently surveyed Rhode Island waterbodies were found to be inhabited by one or more invasive species.[16]

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[14] Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki B.L. and Henry, K.M. 2009. The impact of changing climate on phenology, productivity, and benthic-pelagic coupling in Narragansett Bay. Estuarine, Coastal and Shelf Science 18:1-18.

[15] The Black-swallow Wort, a member of the milkweed family, once introduced quickly overtakes native plants and floral habitats. It out-competes other milkweed species that provide food for insects such as the Monarch Butterfly, boosting mortality rates among insect larvae. The spread of the Black-Swallow Wort will poses substantial risks to regional Monarch Butterfly populations, an important pollinator in Rhode Island. The Hemlock Wooly Adelgid weakens and kills the eastern hemlock (*Tsuga Canadensis*), an important staple to New England forests.

[16] Rhode Island Department of Environmental Management. 2012. RI Freshwater Lakes and Ponds: Aquatic Invasive Plants and Water Quality Concerns Report. See also, Aquatic Nuisance Species Task Force. 2007. Rhode Island Aquatic Invasive Species Management Plan.

For example, the Asian Clam is a freshwater clam species found in some Rhode Island lakes and ponds and the Pawtuxet River. This invasive bivalve thrives in waterbodies with degraded water quality and crowds out native bivalves. If the Asian Clam comes to dominate RI's freshwater systems, even with concerted attempts at eradication, some waterbodies may end up less well-suited for the restoration of native freshwater species.

ESTUARINE & COASTAL ENVIRONMENTS

Rhode Island's coastal estuarine environments are experiencing increased water temperatures, alterations in storm and wind patterns, sea level rise and coastal inundation, and marine and coastal acidification.[17] Coastal and estuarine flushing rates may slow due to diminished wind speeds and changes in prevailing wind directions.

Estuarine and coastal species may be particularly vulnerable to climate change. Many commercially and ecologically important cold-water marine species found in Narragansett Bay and adjacent ocean waters live within the southern extent of their habitat ranges, such as the Atlantic Cod and Winter Flounder. Over the last 40 years in Narragansett Bay, many cold-water and demersal species appear to have declined in population, and pelagic and warm-water species populations appear to have increased.[18] These changes in species ranges and populations can be statistically linked to rising water temperatures and climatically-driven changes to predation/prey relationships, phytoplankton phenology, and planktonic biomass.[19]

Cold-water marine species may be locally extirpated due to temperate range shifts, increased disease mortality and facilitated introductions of invasive species. Ecological impacts of climate change may include declines in adaptive and reproductive fitness, and alterations to biomass productivity and propagation rates.

There is the additional challenge of gaining insight into how individual species and ecological communities will respond and adapt to both climate change and coastal and marine acidification. The state may experience a decline in the overall viability and productivity of many of Narragansett Bay's natural resources. However, climatic and acidification consequences may also be benign, such as the emergence of commercial and recreational fisheries based upon warm-water tolerant species.

FISHERIES IMPACTS: THE AMERICAN LOBSTER

Climate change may exacerbate disease onset and spread in many coastal and marine species that we value in Narragansett Bay, as exemplified by growing incidences of invertebrate diseases in Narragansett Bay that have been observed since the 1980's. But the appearance and rapid spread of lobster shell disease in southern New England lobster populations may be most sobering example of how climatic changes to physical and chemical habitat parameters deleteriously affect a marine species of leading human importance.[20]

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[17] Heffner, L., Williams, R., Lee, V., Rubinoff, P., and Lord, C. 2012. Climate Change & Rhode Island's Coasts: Past, Present, and Future. Coastal Resources Center and Rhode Island Sea Grant, University of Rhode Island, Narragansett, R.I.

[18] Collie, J.S., Wood, A.D. and Jeffries, H.P. 2008. Long-term shifts in the species composition of a coastal fish community. Canadian Journal of Fisheries and Aquatic Sciences 65:1352-1365.

[19] Nixon, S.W., Fulweiler, R.W., Buckley, B.A., Granger, S.L., Nowicki, B.L. & Henry, K.M. (2008). The impact of changing climate on phenology, productivity and benthic-pelagic coupling in Narragansett Bay. *Estuarine, Coastal and Shelf Science*. Volume 82, Issue 1, 20 March 2009, Pages 1–18

[20] Cob, J.S. and Castro, K.M. 2006 Shell Disease in Lobsters: A Syntheses. Prepared for the New England Lobster Research Initiative.

First seen in Long Island Sound in the 1980's, lobster shell disease has been observed in lobster populations in Narragansett Bay since the 1990's, with severe outbreaks documented in 2000-2005. Today, lobster shell disease is prevalent among lobster populations in Narragansett Bay and directly offshore, most notably in females. Lobster shell disease diminishes lobster growth and reproduction and increases susceptibility to infectious diseases. The etiology (causes) of lobster shell disease is complex. Lobster shell disease is primarily caused by a particular bacterium becoming established in the pores of the outer lobster carapace shell and creating lesions through the consumption or dissolution of the shell. The responsible bacterium has been present historically in New England coastal and marine waters. Research strongly suggests that elevated water temperatures, hypoxia, and toxic substances are important drivers for lobster shell disease. Additionally, shell disease has not been observed in lobsters from the colder waters of the Gulf of Maine. [21]

By 2100, coastal and estuarine water temperatures are projected to be 3-8 °F higher on average than present. The potential impacts of such elevated temperatures will significantly increase the risk of economic extinction of the American Lobster in Rhode Island waters. NOAA data has already shown the decreasing value of the American Lobster harvest in Rhode Island, from just over $23 million in 2005 to $11.5 million in 2009.[22]

WETLAND ENVIRONMENTS

Marshes, fens, bogs, and swamps are critical habitats that serve as transition zones between land and water areas, or salt and fresh water systems. Wetlands will be degraded by water temperature increases, sea-level rise and coastal inundation, and shifting hydrological regimes (including water depth, hydroperiods, and flow dynamics).

Inundation of coastal and salt marshes may pose significant risks to Rhode Island's natural environment. Rising sea level has the potential to amplify salinization of coastal groundwaters, which will in turn degrade brackish wetlands. Salinization will in turn alter wetland vegetative communities and their capacities as nursery and juvenile habitats. Coastal wetlands may migrate inland with sea level rise and inundation over the next fifty to one hundred years. But such landward shifts will be constrained by hardened shorelines and coastal development. Some coastal wetlands will simply shrink and disappear, along with their values as storm buffer zones and habitats.

LOOKING AHEAD

There are many individuals, industries, and coastal communities that depend upon Rhode Island's natural environment, including those involved in outdoor recreation, farming, aquaculture, commercial fishing and recreational fishing. This Working Group will identify those groups most likely to be affected and how to help those groups to prepare for the impacts they are likely to experience. In the meantime, a series of steps such as supporting existing climate change assessment and adaptation efforts can be taken at various levels to avoid some of the worst risks to Rhode Island's natural environment.

[21] Glenn, R. P. and T. L. Pugh. 2005. Observations on the chronology and distribution of lobster shell disease in Massachusetts coastal waters. pp. 141-155. In, M. F. Tlusty, H. O. Halvorson, R. Smolowitz, and U. Sharma (eds.), Lobster Shell Disease Workshop. Aquatic Forum Series 05-1. New England Aquarium, Boston, Massachusetts, U.S.A.

[22] National Marine Fisheries Service, National Oceanic and Atmospheric Administration. 2011. Fisheries Economics of the US, 2009.

HUMAN HEALTH AND WELFARE WORKING GROUP

PROGRESS REPORT

INTRODUCTION

ABOUT THE WORKING GROUP

The Human Health and Welfare Working Group consists of representatives from public health, universities, and Water Resources Board. The Working Group is co-chaired by Representative David Bennett, Robert Vanderslice of the RI Department of Health and Timmons Roberts of Brown University. Other members include: Ken Burke and Kathleen Crawley of the RI Water Resources Board.

HUMAN HEALTH AND WELFARE

INCREASED HEAT AND DROUGHT

While climate change projections show that average temperatures may increase, the greatest risks to Rhode Islanders' health, safety and welfare may be due to more frequent, more intense, and longer heat waves (Frumhoff et al 2007).[23]

PUBLIC HEALTH RISKS

Increased average temperatures, with later frosts and weaker winter freezes may extend the season and geographic range of disease vectors such as ticks and mosquitoes which may lead to increased incidences of Equine Encephalitis, West Nile Virus, and Lyme Disease, and subsequently increased exposure to pesticides.

Temperature increases may also promote pollen, algae and pathogen growth, which could increase exposure to toxic algae blooms and pathogens, as well as occurrences of hay fever and asthma. Warmer ocean temperatures may increase exposure to waterborne pathogens while also increasing jellyfish populations, leading to reduced opportunities for water- and beach-based recreation.

Coalition for Water Security

Drought will impact surface water and groundwater quality. The degree of this effect will be a function of many factors, drought severity being one. When surface water reservoirs are depleted, one may expect increasing water temperatures, changing water chemistry, a re-suspension of dissolved solids (turbidity) and increased opportunities for bacteria and algae growth that will require additional treatment. For groundwater systems, the wells are at a fixed elevation. During drought (or short-term dry spells), these systems are subject to drawing down on a water column that is closer to their intake screens, increasing the susceptibility of these

[23] Frumhoff, P. C., J. J. McCarthy, J. M. Melillo, S. C. Moser, and D. J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Rhode Island report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists.

systems to “running dry”, or the pumps getting air bound due to the groundwater cone of influence being lower (and closer to the screens). Depending on the surrounding soils, this could have impacts on the amount of iron and manganese that are “stripped” across the gravel wells, impacting quality.

Similarly, self-supplied users (residential) may experience conditions where their pumps are air bound (or close to it). In many instances where residential self-supplied users also have septic systems in relative close proximity to their drinking water wells, there may be an increased likelihood that (treated) effluent has a shorter path to travel (vertically) to get to the screen in the drinking water well because of the drop in the ground water table.

AIR QUALITY RISKS

More days of extreme heat are likely to decrease air quality and increase the number of heat emergency alert days. Extreme heat may restrict the healthful activities of Rhode Island residents, such as walking and outdoor recreation. Worsening of the “heat island” effect may have an adverse impact on air quality in urban environments, which can negatively affect populations that are most vulnerable to heat-illness and heat-related death. These vulnerable groups include infants, elderly, individuals with special needs, and socially isolated people. Decreased air quality and hotter summers may provoke asthma episodes, increase hospital visits and mortality for those with heart and/or lung disease and cause more heat-related disorders for people who work outside, such as construction workers, landscape and maintenance workers, public works and park employees, and police.

Frequent and/or longer periods of drought may decrease water availability, which could lead to shortages in drinking water in parts on the state. Droughts may also lead to inadequate fire suppression ability and decreased agricultural production.

It should also be noted that public safety, including emergency management services may be seriously impacted during heat emergencies. Sharp increases in power demands due to use of air conditioning units may cause electrical brownouts and/or blackouts, which can create multiple and cascading disasters, including health services interruptions and communication breakdowns.

HUMAN WELFARE RISKS

There are numerous possible and likely economic impacts of intensified heat and drought. Clinics and public health infrastructure, businesses, hotels and hospitality facilities and other public service buildings that lack air conditioning may have to consider adjusting their hours of operation. While there may be an increase in some waterfront related activities and industries in the summer, there may also be a decrease in tourism due to jellyfish populations and a decrease in winter activities due to warmer temperatures. Summer athletic activities and recreation may suffer with prolonged heat and insect pests.

More intense rainstorms may be anticipated, as are extreme snowfall events; both of which drive upland flooding in the state, especially in river valleys that have been heavily developed. The following table summarizes Health, Safety and Welfare impacts of more severe precipitation and flooding events that could potentially impact Rhode Island as the climate shifts here:

HEALTH	More severe **precipitation events and flooding** can cause: • Extended season (later die-off, not greater populations) and geographic range of disease vectors (i.e. mosquitoes *which breed in standing water)* • Increased moisture damage to buildings causing increasing problems with mold growth, decay, rodent and insect infestations, impacts on indoor air quality in homes, schools and businesses • Increased exposures to chemical disinfectants and biocides, pesticides and other products used to address moisture-related building damage. • Increased surface water runoff *Possible outcomes:* • Increased Encephalitis, and emerging Dengue Fever • Increased exposure to toxic algae blooms • Increased exposure to chemical agents used to address flood damage, mold and pest problems. • Exacerbation of asthma and other respiratory disease due to decreased indoor air quality. • Increased potential for water-borne disease outbreaks during and after floods • Increased exposure to water contaminants in marine recreation areas
SAFETY	Heavier **precipitation** events cause: • Increased nutrients entering the freshwater and saltwater systems • Stress on water treatment and sewer systems • Less efficient/effective replenishment of natural water storage systems *Possible outcomes:* • Increased chance for drinking water contamination • Potential for sewer system failure, people unable to remove waste from homes • May increase stored water supplies used during high demand • Damaged crops, livestock, spoiled perishable food due to power outages
	Public safety can degrade rapidly in **flood** emergencies *Possible outcomes:* • Roads and facilities become inaccessible (PRIORITY) • Sewage treatment plants can release untreated sewage • People may be stranded in their homes • Emergency management capabilities may be stressed

WELFARE	Likely economic impacts of more **severe precipitation events and flooding** include: • Increase overflow from combined storm and wastewater treatment systems, impacting recreational beach water quality- loss of tourism revenue • More frequent closure of conditional shellfish areas due to contamination • More precipitation could mean longer growing season or flooding of crops, depending on intensity and timing. • Loss of damaged crops and livestock

INCREASED STORMINESS AND SEA LEVEL RISE

Hurricanes and Nor'easters can bring tidal surge; hurricanes can bring substantial damages of several types all at once—high wind after soaking rains. This table summarizes the potential impacts of storm intensity and sea level rise on Rhode Islanders' health, safety, and welfare.

HEALTH	Increase in **storm intensity** can cause: • Flash floods • Increased surface water runoff • Building damage, debris *Possible outcomes:* • Increased potential for water-borne disease outbreaks during and after floods • Increased exposure to water contaminants in marine recreation areas • Mental health effects such as anxiety resulting from displacement under emergency circumstances, and physical trauma from flooding
SAFETY	Accelerated **sea level rise** can cause: • Coastal flooding and increased nutrients entering the freshwater and saltwater systems • Compromised integrity of coastal water treatment and sewer systems *Possible outcomes:* • Increased chance for drinking water contamination both from surface runoff and saltwater intrusion of reservoirs • Potential for sewer system failure, people unable to remove waste from homes • Medical care infrastructure in coastal floodplains may be at risk • Contaminated drinking wells as saltwater moves landward
SAF	Public safety can degrade rapidly in **storm** emergencies

ETY	*Possible outcomes:* • Downed trees make roads and facilities inaccessible (PRIORITY) • Fallen tree limbs can knock out power • Flooded sewage treatment plants can release untreated sewage • People may be stranded in their homes if roads are blocked with debris • Emergency management capabilities may be stressed
WELFARE	Likely economic impacts of more **severe storms and sea level rise** include: • Increase overflow from combined storm and wastewater treatment systems, impacting recreational beach water quality and causing closures- loss of tourism revenue • Storm damage threats to shellfish aquaculture operations • Coastal tourism areas may be threatened by increase in sea level rise

Together, prudent planning is needed for Rhode Island to prepare for these three sets of risks. Fortunately, the state's next steps can build upon a series of existing efforts.

LOOKING AHEAD:

The Human Health and Welfare Working Group:

State agencies may consider reviewing their activities to address potential climate risks, including floods greater than the "100 year" normal, long heat waves, and coastal storm surge sea level rise. The state may examine opportunities to support programs to outreach to vulnerable populations. Working with churches and community organizations is crucial to reach many of these individuals. Municipal authorities and public service workers have a special role to play, as do utilities and other major institutions such as schools, charities, and universities. Common actions adopted around the country are emergency alert systems to warn the sick and elderly of coming disasters (including heat, flooding, hurricanes, Nor'easters), emergency cooling centers during heat waves, prohibiting utilities from turning off service during heat and cold emergencies, and subsidies for purchasing fans and air conditioners. These interventions have been shown to save lives. It is beneficial for state and municipalities to work together when identifying and implementing policies.

To adapt to increased flooding and severe weather, it will be critical to reduce and manage stormwater runoff. Existing incentives and requirements for property owners and municipalities to reduce impervious surfaces (roofs and paved areas) spawn immediate and long-term public benefits, as will tree planting and the installation of rain gardens and other technologies to reduce the number and severity of flooding events.

On storms and sea level rise, significant storm events – tropical storm Irene and super storm Sandy - provide a dramatic example of shoreline erosion and inundation issues Rhode Island may face in the coming years, as storms have the potential to intensify.

APPENDIX A: CLIMATE CHANGE ASSESSMENT AND ADAPATION ACTIONS

ARMY CORPS OF ENGINEERS, FEDERAL EMERGENCY MANAGEMENT AGENCY AND RHODE ISLAND EMERGENCY MANAGEMENT AGENCY: **HURRICANE AND FLOODING EVACUATION STUDY**

The Army Corps of Engineers New England District of the Army Corps of Engineers, the Federal Emergency Management Agency, the RI Emergency Management Agency, and other New England States have launched The New England Multi-State Hurricane Evacuation Study (HES). The project includes all twenty-one RI coastal communities. The products of this study will assist Rhode Island communities in climate change adaptation. Storm surge inundation mapping for RI was completed in July 2009. All of the RI coastal communities were asked to examine their current evacuation zones and identify areas that they felt should be enlarged or decreased based on the most recent SLOSH modeling. This product will be digitized and incorporated into new evacuation zones for all RI coastal communities. The project will also provide a Vulnerability Analysis, a Behavioral Analysis and a Transportation Analysis for CT, RI, and MA.

BRISTOL, RI: **STORMWATER EXTRANEOUS FLOW ASSESSMENTS AND MITIGATION**

In 2006, the Town of Bristol launched a program to inspect buildings for sump pump connections to its sewerage system. To date, approximately 350 properties have been identified as having at least one source (sump pump discharge, roof drainage, impervious surface and yard drainage etc.) of extraneous flow connected to the Town's sewer collection system. The Town has begun implementation of an extraneous flow source removal program in select areas, focusing on the removal and relocation of approximately 30 sources of inflow to the sewerage system. This program will increase the hydraulic capacity of the Town's sewerage system and its ability to convey wet-weather flows to its WWTF without sanitary sewer overflows and/or the disruption of conveyance and treatment processes. Continued implementation of such measures will help to curtail impacts on the Town's sewerage and stormwater management system from future increases in sea level and groundwater tables, as well as from increased precipitation frequencies and intensities.

COASTAL RESOURCES MANAGEMENT COUNCIL

- **ADOPTION OF CLIMATE CHANGE POLICY – SECTION 145**: In 2008, the RI Coastal Resources Management Council (CRMC) adopted findings and a policy concerning climate change and sea level rise (Section 145 of the RI Coastal Resources Management Plan). CRMC is currently developing additions and amendments to the RI CRMP to implement Section 145. www.crmc.ri.gov/climatechange/RICRMP_145.pdf

- **SHORELINE CHANGE MAPS:** Shoreline change maps for the entire coastline of Rhode Island have been developed. These maps are used for determining the CRMC's mandated erosion setbacks for development and identifying areas with high erosion rates. Combining the shoreline change maps with the coastal inundation maps gives a clearer picture of resources at risk, i.e. capped landfills that are now eroding. www.crmc.ri.gov/maps.html

- **RI OCEAN SPECIAL AREA MANAGEMENT PLAN (SAMP) WITH CLIMATE CHANGE, RESEARCH, AND MONITORING:** The Ocean SAMP lays out policies and recommendations to guide CRMC in promoting a balanced, ecosystem-based management approach to the development and protection of Rhode Island's ocean resources within the Ocean SAMP region. Chapter 3: Climate Change, outlines existing research and potential issues concerning changing climate on coastal and marine resources and activities of the Ocean SAMP region. An OSAMP Research and Monitoring program is being developed for implementation by CRMC and other institutions. www.crmc.ri.gov/samp_ocean.html

- **RHODE ISLAND EROSION AND INUNDATION SPECIAL AREA MANAGEMENT PLAN**: With seed funding from the RI Bays, Rivers, and Watersheds Coordination Team and the National Oceanic and Atmospheric Administration, CRMC is launching a Shoreline Erosion and Inundation Special Area Management Plan (SAMP) for the state's coastline to address coastal erosion and inundation along the entire Rhode Island coast, beginning with the South Coast.

COASTAL RESOURCES MANAGEMENT COUNCIL, THE NATURE CONSERVANCY, RI SEA GRANT, NARRAGANSETT BAY NATIONAL ESTUARINE RESEARCH RESERVE: **COASTAL WETLAND MIGRATION STUDY**

This project assesses the migration of coastal wetlands in all RI coastal communities (except North Kingstown) using the Sea Level Affecting Marshes Model (SLAMM) and protocols developed by the North Kingstown SLR inundation mapping project (see below). Results will inform policy makers and stakeholders on the development of new coastal policies and standards and identify upland areas requiring increased protection. http://seagrant.gso.uri.edu/climate/slr_tools.html

COASTAL RESOURCES MANAGEMENT COUNCIL (CRMC), UNIVERSITY OF RHODE ISLAND, RI NATURAL HISTORY SURVEY: **RI AQUATIC INVASIVE SPECIES MANAGEMENT PLAN**

Working in collaboration with an inter-institutional Working Group, the plan assesses the impacts and threats of aquatic invasive species in Rhode Island, and outlines prevention and management techniques.

www.anstaskforce.gov/State%20Plans/RI_SMP_Approved.pdf

ENVIRONMENTAL COUNCIL OF RHODE ISLAND (ECRI), NATIONAL WILDLIFE FEDERATION AND RI FOUNDATION: **EXPLORING CLIMATE CHANGE RESILIENCE STRATEGIES IN URBAN UNDERSERVED COMMUNITIES**

ECRI partnered with community organizations in Providence to explore residents' familiarity with climate change issues and develop recommendations to improve urban resilience. Report recommendations look at education, infrastructure, green space and permeable surfaces, food scarcity and access, toxics, cooling centers and adaptation for extreme heat events, energy and displacement. The work was funded by grants from the RI Foundation and the National Wildlife Federation.
www.environmentcouncilri.org/index.html

FEDERAL EMERGENCY MANAGEMENT AGENCY: **UPDATED COASTAL FLOOD INSURANCE RATE MAPS**

New coastal FEMA Digital Flood Insurance Rate Maps for the coastal communities of Washington, Kent, Newport and Providence Counties were rolled out in spring 2012, with Bristol County to follow in summer 2012. These communities have six months to adopt the new maps and corresponding ordinances so that they take legal effect in the fall and winter of 2012. While the updated FEMA maps do not account for sea level rise or other climate change phenomena, they are an improved starting point from which municipalities and the state can plan for adaptation.
www.starr-team.com/starr/RegionalWorkspaces/RegionI/Pages/default.aspx

NARRAGANSETT BAY COMMISSION

- **COMBINED SEWER OVERFLOW ABATEMENT PROJECT:** The Combined Sewer Overflow (CSO) Abatement Project is a three phase program designed to significantly reduce the discharge of sewage contaminated stormwater to the urban rivers of upper Narragansett Bay. The Project is designed to capture flows from a three month storm event; however, if deemed necessary, the system can be optimized to capture, collect, and treat sewage contaminated stormwater generated during

the first hours (the "first flush") of a storm event, which contains the most contaminated waters. In Phase I, a three mile, bedrock tunnel was built under the city of Providence to capture sewage contaminated stormwater flow from twelve CSO's in Providence. As flows decrease after a storm event, the stormwater collected in the CSO tunnel is pumped to the facility for full "secondary treatment". Since the CSO tunnel began operations in November 2008, it has captured 3.88 billion gallons of contaminated stormwater that would have otherwise been discharged directly into upper Narragansett Bay. Phase II of the Project is underway and consists of constructing two sewer interceptor pipes located along the Woonasquatucket and Seekonk Rivers, connecting 14 more CSO's to the CSO tunnel. Also included in Phase II is the separation of storm and sewer lines to eliminate two CSO's and the construction of a wetlands treatment facility.) Once Phase II has been completed and evaluated, NBC anticipates beginning Phase III of the CSO Abatement Project, which will include the design and construction of another deep rock tunnel to capture flow from CSO's in Pawtucket, Central Falls, Lincoln, Cumberland and portions of East Providence.
www.narrabay.com/en/About%20Us/Facilities/MajorInitiatives/CSO.aspx

- **STORMWATER MITIGATION PROGRAM:** The Narragansett Bay Commission (NBC) instituted a Stormwater Mitigation Program in 2003 with the goal of reducing stormwater flows into NBC's wastewater collection and treatment system. The Program requires developers and building contractors to develop Stormwater Management Plans, evaluating on-site opportunities to eliminate discharges that otherwise would be diverted into the wastewater system. Eliminating or reducing stormwater is accomplished by incorporating green infrastructure into the project design plans, utilizing Low Impact Design and stormwater best management practices.
www.narrabay.com/ProgramsAndProjects/Stormwater%20Mitigation%20Program.aspx

NARRAGANSETT BAY ESTUARY PROGRAM: CLIMATE READY ESTUARIES STUDY OF CLIMATE CHANGE VULNERABILITIES IN THE PAWTUXET WATERSHED

Focus on restoring dammed rivers to ease future climate change impacts, such as flooding due to increased precipitation. Narragansett Bay Estuary Program will develop an appropriate action plan and initiate a pilot program. www.nbep.org

NARRAGANSETT BAY ESTUARY PROGRAM, NOAA OFFICE OF MARINE ECOSYSTEM STUDIES: MONTHLY MONITORING OF COASTAL AND BAY WATERS

Monitoring occurs monthly for many key physical, chemical, and biological characteristics of the waters in Rhode Island Sound and Narragansett Bay, including East and West Passages, Mt. Hope Bay, and the Providence River. www.narrbay.org

NARRAGANSETT BAY ESTUARY PROGRAM, URI COASTAL INSTITUTE: WATERSHED COUNTS CLIMATE CHANGE INDICATORS

Watershed Counts is a broad coalition of agencies and organizations that have committed to work together to examine and report regularly on the condition of the land and water resources of the Narragansett Bay Watershed Region. Watershed Counts is facilitated by the URI Coastal Institute and the Narragansett Bay Estuary Program. The coalition's focal indicators reported in 2011 were climate change, impervious cover, beach closures, fresh water flow, and invasive species. In 2012, marine water quality, freshwater quality, open space and resource economics were added. These indicators will be used to describe the condition of the watershed region and then to communicate this information to the public and decision makers in order to inform and guide future management and development of the watershed. The indicators consider the region's interwoven economic and environmental assets www.watershedcounts.org/

NARRAGANSETT BAY NATIONAL ESTUARINE RESEARCH RESERVE

- **COASTAL TRAINING PROGRAM WORKSHOPS:** Climate change-related workshops have been delivered, including "Wastewater Treatment in the Face of a Changing Climate", in partnership with RI DEM and the Narragansett Water Pollution Control Association; "Planning for Community Climate Change Adaptation", in partnership with RI CRMC, RI Sea Grant, and ICLEI- Local Governments for Sustainability; and "Climate Literacy and NOAA in Rhode Island", in partnership with RI Sea Grant and NOAA's Regional Climate Services Office. The CTP, in partnership with RI DEM has also delivered several "Low Impact Development Site Planning and Design" workshops, which make the connection between land use planning and climate change by presenting how LID can be used to address increases of runoff from more intense storm events by decreasing impervious cover. The CTP will continue to coordinate with the organizations mentioned above, as well as new partners, to develop and deliver additional climate change-related workshops to decision-makers based on their needs as indicated through workshop evaluations and more formal needs assessments.

- **SALTMARSH SENTINEL SITE MONITORING:** The Sentinel sites program is a nationally coordinated effort to establish monitoring infrastructure within selected salt marshes in the 28 National Estuarine Research Reserves. They goal is to quantify marsh responses to sea level rise and climate change. Primary parameters include vegetation, hydrology, soils, and elevation. At NBNERR, the development of the Nag and Coggeshall salt marshes into NERR Sentinel Sites began in 2008 and both sites will be fully functional Sentinel Sites in 2012.

- **SYSTEM WIDE MONITORING PROGRAM:** The Narragansett Bay National Estuarine Research Reserve (NBNERR) has been regularly monitoring water quality, meteorology, and nutrient and chlorophyll concentrations at four locations around Prudence Island since 1995. NBNERR also has a biological monitoring component that focuses on macroalgae, submersed aquatic vegetation, salt marshes, invasive crabs, benthic infauna, and seals. Long-term monitoring of these biological resources will complement the abiotic component of SWMP to provide a more comprehensive understanding of how resources are changing in the Reserve and in Narragansett Bay in response to climate change. www.nbnerr.org/research.htm

NATIONAL GRID: **STATEWIDE SUBSTATION FLOODING ASSESSMENT**

National Grid has undertaken a comprehensive flooding assessment of all of its electric transmission and distribution substations. The most vulnerable locations have been identified and prioritized for the necessary actions to address the threat. In some instances this entails raising control house buildings and/or certain electrical control boxes within a substation to a height above design flood elevation. In other instances it may entail raising the actual foundation of the structure or being moved altogether. In addition, since recent flooding events, certain gas infrastructure assets are being reinforced or moved.

NEW SHOREHAM: **STRUCTURAL CONCEPT AND CONTINGENCY PLAN TO INUNDATION OF THE FERRY TERMINALS AND ISLAND ROADWAY SYSTEMS**

The Town of New Shoreham is developing a plan to respond to the potential inundation of the ferry terminals that serve to connect the island to the mainland. The plan will also examine climate change impacts to the roadway system which links the harbors, commercial and residential areas of the island. The plan incorporates the sea level rise scenarios developed by the RI Sea Grant and others. This project, when completed, may serve as a model for other island communities.

PROVIDENCE: **HEALTH IMPACTS OF CLIMATE CHANGE- IMPLICATIONS FOR RESILIENT COMMUNITIES IN PROVIDENCE**

The City of Providence has developed a preliminary report on the public health impacts of climate change, Building Resilience to the Public Health Impacts of Climate Change in Providence. The purpose of this project is to create a forum for city departments to engage with academic institutions, community leaders and state health officials to exchange ideas and develop priority actions for addressing the health impacts of climate change in Providence. The report begins to map City agencies tasked with working on issues related to climate change, research best practices from other cities, and make recommendations for collaboration among agencies to communicate, monitor, mitigate and adapt to the health impacts of climate change. This report summarizes the programs and services that City agencies and organizations have in place regarding the health impacts of climate change, including extreme cold- and heat-related illnesses, emergencies, injuries from accidents from storms or floods, water supply threats and water-borne illnesses, vector-borne disease, cardiovascular disease, and threats to food supply and agricultural resilience. www.providenceri.com/sustainability

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

- **ASSESSING DAMS FOR CATASTROPHIC FAILURE:** The RIDEM has classified all dams in the state based on the hazards that would be caused by catastrophic failure. Those dams whose failure would cause loss of human life or significant property and infrastructure damage are regularly inspected in accordance with state dam safety regulations, and their conditions are rated. Regulatory priority is given to those dams that would cause loss of life upon failure and are in the worst condition. The RIDEM has classified all dams in the state based on the probable damage caused by catastrophic failure.

- **COMPREHENSIVE WILDLIFE CONSERVATION STRATEGY UPDATE WITH CLIMATE CHANGE:** Will an overview of current impacts on wildlife due to climate change, direct human impact, and other stressors. It identifies species and habitats under greatest threat and address statewide monitoring and management techniques. A major new addition to the strategy will address climate change adaptation. www.dem.ri.gov/programs/bnatres/fishwild/pdf/swgplan.pdf

- **STREAM DEPLETION METHODS FOR WATER ALLOCATION**: RIDEM is developing methods for allocating water during dry periods.

- **STORMWATER SOLUTIONS PROJECT:** This URI Cooperative Extension initiative provides training and support for municipal wastewater and stormwater managers, decision-makers, etc. related to short-term and long-term climate/precipitation issues, as well as planning for variations in sea level.

- **WASTEWATER TREATMENT INFRASTRUCTURE CLIMATE CHANGE VULNERABILITY ASSESSMENT:** The RI Bays, Rivers, and Watersheds Coordination Team has committed funding for conducting a climate change vulnerability assessment of the state's wastewater treatment infrastructure. The assessment will examine Rhode Island's nineteen major wastewater treatment facilities, as well as the Narragansett Bay Commission's Combined Sewer Overflow Abatement Project (described above); major pump stations in Providence, Cranston, Westerly, West Warwick, Warwick, Bristol, Narragansett and South Kingstown; and two combined sewer overflow facilities in Newport. The assessment will also include watershed modeling analysis, a risk assessment and development of associated adaptation strategies. This project will be one of the first assessments of its kind in the country.

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT AND COASTAL RESOURCES MANAGEMENT COUNCIL: **UPDATED STORMWATER MANUAL WITH LOW IMPACT DEVELOPMENT METHODS**

In 2010, the Department of Environmental Management and the Coastal Resources Management Council formally adopted a revised and expanded Stormwater Design and Installations Standards Manual. The new manual requires low impact development methods on new construction and redevelopment projects to ensure a higher level of stormwater treatment, reduce overland runoff and recharge groundwater by requiring a greater percentage of stormwater infiltration. The new manual incorporates recent climate-change driven in precipitation rates and cycles.
www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/pdfs/desgnmnl.pdf

RI DEPARTMENT OF ENVIRONMENTAL MANAGEMENT, NARRAGANSETT BAY COMMISSION, NATIONAL GRID, UNIVERSITY OF RHODE ISLAND, US ENVIRONMENTAL PROTECTION AGENCY & RHODE ISLAND MANUFACTURERS EXTENSION SERVICE: **SUSTAINABLE ENERGY MANAGEMENT PROGRAM FOR WASTEWATER TREATMENT FACILITIES**

In 2008 the Rhode Island Department of Environmental Management (RIDEM), the Narragansett Bay Commission (NBC), the University of Rhode Island (URI), EPA Region I, the Rhode Island Manufacturers Extension Service (RIMES), and National Grid (the Project Team) initiated a Sustainable Energy Management Program for Rhode Island Wastewater Treatment Facilities (WWTF). Using a combination of EPA and ARRA grant funds the Project Team has worked with all 19 Rhode Island WWTF's to identify and implement energy management and renewable energy projects to make these facilities become more resilient to the energy related impacts of climate change. These efforts have resulted in the identification of more than 125 energy improvement opportunities. In addition to the resulting energy cost savings, these efforts also help to reduce the generation of greenhouse gases. www.narrabay.com/en/programsandprojects/nbc%20energy%20projects/

RI DEPARTMENT OF HEALTH

- **ASTHMA STATE PLAN 2009-2014:** Department of Health collaborated with Rhode Island Asthma Control Coalition (RIACC) to create this plan on how to improve asthma control among asthma sufferers, reduce asthma-related hospitalizations and emergency department visits, and reduce disparities among priority populations. www.health.ri.gov/publications/plans/2009-2014AsthmaStatePlan.pdf

- **VECTOR SURVEILLANCE FOR MOSQUITO-BORNE AND TICK-BORNE DISEASES:** A state-wide surveillance system is in place to track and monitor these diseases.

- **WATER SUPPLY AND QUALITY STUDY WITH CLIMATE CHANGE:** The Rhode Island Department of Health Office of Drinking Water Quality, has launched a new assessment called "SafeWater RI: Ensuring Safe Water for Rhode Island's Future" to assess changing environmental conditions (temperature, precipitation patterns, sea level rise, and storm surge) and their potential impacts on drinking water supplies and infrastructure, and to develop strategies to address these changing conditions.

RI DEPARTMENT OF TRANSPORTATION: **INFRASTRUCTURE PROJECTS INCORPORATE ADAPTATION STRATEGIES**

- **ROUTE 138 RECONSTRUCTION:** The Rhode Island Department of Transportation (RIDOT) is currently designing roadway improvements on Route 138 from Route 2 to Route 108 in the Town of South Kingstown that includes the replacement of the existing storm drain system. In conformity with the 2010 Rhode Island Stormwater Design and

Installation Standards Manual, the new infrastructure will accommodate a 25-year storm event based on the updated rainfall totals provided by the Northeast Regional Climate Center. It will also be designed to maintain runoff in each of the four watersheds within the project corridor, rather than conveying stormwater to adjacent watersheds. Overall, the project will infiltrate stormwater runoff from approximately 16.6 acres of existing impervious roadway surface, roughly one half of the existing roadway surface area. Stormwater from about 3.3 acres of new impervious surface will also be infiltrated into the ground, significantly reducing total stormwater runoff from renovated roadway.

- **REPLACEMENT OF CENTRAL BRIDGE NO. 182:** Originally constructed in 1939, this concrete bridge must be completely replaced due to its deteriorated condition. Clearance under existing conditions is approximately 6.2 feet at mean high water (MHW). Due both to past sea-level rise and in anticipation of additional sea-level rise due to climate change, the Town of Barrington has requested that RIDOT increase the bridge clearance by approximately 2 feet, to which RIDOT has agreed. The proposed bridge clearance will be approximately 8.5 feet at MHW. The raised structure will facilitate the passage of Town emergency vessels. Other elements in the new bridge design will include reducing stormwater runoff by removing excess pavement from a nearby roadway; providing offsite infiltration for; and armoring the bridge causeways to protect them from erosion and scour.

RI DIVISION OF PLANNING, NORTH KINGSTOWN, UNIVERSITY OF RHODE ISLAND, CRMC, THE NATURE CONSERVANCY: **NORTH KINGSTOWN SEA LEVEL RISE PILOT STUDY AND PLAN**

The Town of North Kingstown was selected as a pilot community to assess the effects of sea level rise on coastal communities. Phase 1 of the study identified critical assets impacted by various sea level rise scenarios, using sea level rise map overlays created by URI. It also looked for opportunities to incorporate actions into the town's hazard mitigation plan and comprehensive plan. The URI Coastal Resources Center has also been selected as a recipient of a RI Statewide Planning 2012 Planning Challenge Grant to develop with the Town of North Kingstown a comprehensive plan element addressing climate change adaptation. A training session on incorporating climate change adaptation into comprehensive plans will be developed to assist other Rhode Island communities and a communications strategy will be developed to educate residents. seagrant.gso.uri.edu/climate/slr_tools.html

RI DIVISION OF PLANNING AND RI DEPARTMENT OF: **TRANSPORTATION NETWORK SEA LEVEL RISE VULNERABILITY ASSESSMENTS**

The Rhode Island Division of Planning and the Department of Transportation are working together to refine initial sea level rise inundation mapping contained in *Transportation 2030 Report* and to identify bridges, roads, rail segments, airports and other intermodal facilities that may be impacted. To inform this process, the State of Rhode Island was awarded funding from the US Geologic Survey to obtain coastal LiDAR data with State funds used to upgrade the project to development of a statewide LiDAR data set. This information will be used to identify prioritized needs.

RI EMERGENCY MANAGEMENT AGENCY

- **HAZARD MITIGATION PLAN UPDATES**: State and local hazard mitigation plans form the foundation for a community's long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage. Mitigation plans create a framework for risk-based decision making to reduce damages to lives, property, and the economy from future disasters. State, Indian Tribal, and local governments are required to develop a hazard mitigation plan as a condition for receiving certain types of federal, non-emergency disaster assistance. The State of Rhode Island Hazard Mitigation Plan was updated in April 2011. Local Hazard Mitigation Plans must be updated every five years and the State

Plan every three years. The Rhode Island Emergency Management Agency is working to incorporate climate change adaptation planning into community and state hazard mitigation plans.
www.riema.ri.gov/documents/preparedness/RI_State_HM_Plan%20Final.pdf

- **FLOOD MITIGATION WORKING GROUPS:** Since the March, 2010 event, the Flood Mitigation Working Group, convened by RI Emergency Management Agency, meets quarterly to address planning and actions to reduce flooding.

RI GENERAL ASSEMBLY

The General Assembly has a long standing commitment to supporting initiatives that address climate change. Over the past several legislative sessions, the General Assembly has embraced a comprehensive approach to addressing energy costs and creating green jobs by eliminating regulatory barriers to investments in energy conservation and efficiency and promoting the growth of clean energy industries in Rhode Island.

- The Rhode Island legislature enacted the first regional, cap and trade program to reduce greenhouse gas emissions. The Regional Greenhouse Gas Initiative is a collaborative approach among Rhode Island and several states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York and Vermont) whereby participating states have capped carbon dioxide emissions from the utility sector and will reduce these emissions by 10% by 2018. The states sell the emissions allowances through auctions and apply the proceeds to energy efficiency, renewable energy programs and other clean energy technologies.

- In 2011, the General Assembly passed a landmark package of renewable energy bills to facilitate and promote the development of clean energy and the growth of jobs in our state including the creation of the Renewable Energy Coordinating Board. The legislation also promotes the development of alternative energy sources by facilitating the integration of small, renewable energy powered electrical generation into the state power distribution system. In 2012, the legislature continued to build upon this long standing commitment to clean energy by legislating a strong plan for annual investments in combined heat and power energy which is an environmentally friendly technology that captures wasted heat from an existing energy source.

- In 2011, the legislature made comprehensive changes to the RI Comprehensive Planning and Land Use Act, including the requirement that cities and towns include in their comprehensive plans the identification of areas that are vulnerable to the effects of sea-level rise, increased flooding, storm damage, drought, and other natural hazards. Additionally, municipalities are required to identify goals, policies, and implementation techniques that would help avoid or minimize the effects of natural hazards to public safety, infrastructure, and property.

- In 2012, the General Assembly passed legislation which establishes guidelines for cities and towns that enact local ordinances pertaining to porous parking surfaces for commercial properties. The legislation provides criteria for types of material, drainage and specifies that all projects must be in compliance with local ordinances. This legislation will assist municipalities in addressing storm water management by minimizing and preventing the polluted storm water runoff that normally occurs with impervious parking surfaces.

- The Senate Committee on Housing and Municipal Government's report on Tropical Storm Irene made the following recommend regarding Rhode Island's telecommunications infrastructure: 1) All appropriate entities should present at the state emergency management command headquarters during a classified storm event. 2) Utility companies and telecommunication companies should operate a municipality room twenty-four hours a day with a dedicated customer service representative to assist local leaders. 3) Utility companies and telecommunication companies should maintain up-to-date lists of critical facilities. While these recommendations were initially meant to address all types of hazard response

and recovery, they also will reduce post-storm damage and hardship.
www.rilin.state.ri.us/Documents/Tropical%20Storm%20Irene%20Report.pdf

RI RESOURCE RECOVERY CORPORATION: **CENTRAL LANDFILL DISASTER PREPAREDNESS PLAN**

The design of the Rhode Island Resource Recovery Corporation (RIRRC) Central Landfill facility accounts for large storm events and managing localized flooding on-site (The base designs use a 25-year storm event, as a minimum, for all surface water control structures.) These facilities include emergency overflows to the nearby waterways to minimize overtopping and inundation of the landfill's infrastructure. During the March 2010 storm event, these adaptation provisions functioned as intended, with no significant erosion, or failure of operations.

Further, RIRRC maintains a fleet of equipment on site, and therefore will be able to quickly return the site to full operations after storm events. RIRRC also maintains two fuel trucks with a combined capacity of 8,000 gallons of diesel fuel, which provides RIRRC a buffer of about three days of fuel supply while vital infrastructure is restored, or other fuel deliveries are resumed.

RI SEA GRANT, URI COASTAL INSTITUTE, BROWN CENTER FOR ENVIRONMENTAL STUDIES: **RI CLIMATE CHANGE PORTAL WEB SITE DEVELOPMENT**

This website will provide information on the impacts of climate change on Rhode Island's people, economy, landscape, and plant and animal life. The site will be designed to empower people to plan for and prepare for climate change. The target audience is the general public as well as community leaders and decision makers.

RI SEA GRANT, URI COASTAL INSTITUTE, CANCER PREVENTION RESEARCH CENTER, GRADUATE SCHOOL OF OCEANOGRAPHY, URI COMMUNICATIONS DEPARTMENT: **URI CLIMATE CHANGE COLLABORATIVE**

This is an interdisciplinary project that draws on research in public communications, behavior change, and climate change to help advance climate change adaptation. Project goals include: 1) develop a synthesis of climate change research relevant to coastal regions; 2) apply a public health behavior change model to coastal communities coping with climate change; 3) build the capability of academics, extension staff, and decision-makers to communicate climate change science and its implications to citizens and motivate them toward proactive behavior change; and 4) use Rhode Island as a living laboratory to start communities on the path to becoming more aware of climate change and thus more capable of incorporating adaptation into comprehensive community planning and decision-making. www.seagrant.gso.uri.edu/climate/index.html

RI SEA GRANT, URI ENVIRONMENTAL DATA CENTER, COASTAL RESOURCES MANAGEMENT COUNCIL, THE NATURE CONSERVANCY, STATEWIDE PLANNING: **SEA LEVEL RISE MAPPING AND VISUALIZATIONS**

Rhode Island Sea Grant collaborated with partners to developed statewide GIS overlay maps that depict sea level rise (1, 3, 5 foot) scenarios, and the 1938 hurricane inundation, to assist communities in planning for climate change adaptation. Using existing LiDAR data available prior to 2011, the maps use a "bathtub" model, which assumes the same rise of sea level along a given shoreline, (similar to what happens when a bathtub is filled). This model, created by combining high resolution maps, represents a conservative estimate of inundation extent. North Kingstown, piloted an effort in 2011 to use the maps to estimate potential impact to buildings and transportation infrastructure, as described below. Also available are visualizations (using photographic simulation) of the potential impact of sea level rise at key locations along Rhode Island's shores developed by the Coastal Resources Center. www.seagrant.gso.uri.edu/climate/index.html

RI SEA GRANT, COASTAL RESOURCES MANAGEMENT COUNCIL, RI BUILDING COMMISSION, RI EMERGENCY MANAGEMENT: **STORMSMART COASTS RI WEB PORTAL ON FLOOD PREPAREDNESS**

StormSmart Coasts is a national on-line network providing information on how to protect their communities from weather and climate hazards, both on State and Federal levels, before, during and after a storm. Rhode Island is the 7th state to complete a StormSmart Coast website specific to Rhode Island, with assistance from the Rhode Island Flood Awareness and Climate Change Task Force. The site has links for the City Council or Town managers; the building departments: public works; and the planning boards. www.ri.stormsmart.org/

RI STATE BUILDING CODE COMMISSION: **UPDATED STATE BUILDING CODE REQUIREMENTS**

The State Building Code (2011) requires a one (1) foot freeboard in all V and Coastal A-Zones. In addition, new construction (or substantially-improved structures) in Coastal A- Zones must be built to V- Zone standards. www.ribcc.ri.gov

RI STATE BUILDING CODE COMMISSION, RHODE ISLAND EMERGENCY MANAGEMENT AGENCY, RI SEA GRANT, RHODE ISLAND COASTAL RESOURCES MANAGEMENT COUNCIL, AND RHODE ISLAND FLOOD MITIGATION ASSOCIATION**: RHODE ISLAND FLOOD AWARENESS AND CLIMATE CHANGE TASK FORCE (RIFACCT)**

RIFACCT is a cooperative effort between state agencies, educational facilities and non-government organizations (Rhode Island State Building Code Commission, Rhode Island Emergency Management Agency, RI Sea Grant, Rhode Island Coastal Resources Management Council, and the Rhode Island Flood Mitigation Association) to inform the public on flood hazard issues and the disaster recovery. The first FACCT sheet is designed to familiarize property owners with state and local permitting procedures for repair or rebuilding structures and septic systems after a storm to ensure that reconstruction is done in a safe and timely fashion, and is compliant with local ordinances and state regulations. RIFACCT will be reconvened to update the State Building Code to develop the safest redevelopment regulations considering sea level rise. www.riema.ri.gov/prevention/floods/FACCT.php

SAVE THE BAY

- ASSESSMENT AND SUPPORT OF SHORELINE ADAPTATION ACTIONS: Assess and map areas most vulnerable to sea level rise, such as areas of the watershed with low lying infrastructure, undersized culverts, at-risk salt marshes, and coastal erosion. In these areas, Save The Bay advocates for adaptation techniques such as buffer enhancement, shoreline grading and planting, bioengineering erosion control, rebuilding intertidal shellfish reefs, and hybrid techniques (such as living shorelines). Save The Bay is collaborating with municipalities on coastal adaptation projects in Warwick, India Point Park in Providence, Narragansett, Newport and Bristol County. www.savebay.org

- CULVERT ASSESSMENTS: Save The Bay is assessing culverts and bridges in coastal areas for their ability to handle high flows due to tidal surge and floods and their impact on wildlife passage and water quality. According to Save the Bay, many of the culverts and bridge spans located in tidal areas are undersized and contribute to road flooding and damage. As sea level has risen, some culverts are now under water at high tide. Maps and photographs are being shared with the Commission to further illustrate the impacts.

- DEAD END ROAD STORMWATER ASSESSMENT: Save The Bay is conducting an in-house assessment of roads that dead-end on the coastline to identify areas where the pavement can be removed and stormwater can be infiltrated before it enters coastal waters throughout the Narragansett Bay watershed and Rhode Island's South Coast. Many of these road ends have

been washed out by erosion, are flooding at high tide and are exacerbating salt marsh erosion. Conceptual designs are being developed for swales and other bio-retention solutions for these areas.

TREES 2020, GROUNDWORK PROVIDENCE & CITY OF PROVIDENCE

Trees 2020 is an initiative to increase Providence's tree cover to 30% by the year 2020. The initiative encourages homeowners, land-owning institutions, and city-sponsored tree planting programs to plant over 40,000 trees by providing low-cost, resilient tree plantings. www.trees2020.org/

URI COASTAL RESOURCES CENTER, URI ENVIRONMENTAL DATA CENTER, THE NATURE CONSERVNACY, SOUTH KINGSTOWN LAND TRUST, AND THE COASTAL RESOURCES MANAGEMENT COUNCIL: **ADDRESSING CLIMATE CHANGE THROUGH HABITAT PROTECTION AND LAND TRUSTS**

This pilot project works with the South Kingstown Land Trust to identify and test tools that incorporate climate change considerations into conservation programs for land acquisition and management. Important tools used include habitat vulnerability assessment, Ecological Land Unit (ELU) evaluation, and sea level rise mapping. www.seagrant.gso.uri.edu/climate/habitat.html

WATER RESOURCES BOARD: **STRATEGIC PLANNING INITIATIVE FOR POTABLE WATER SUPPLY**

The WRB's recently approved Strategic Planning Initiative analyzed the State's water resources, particularly potable water supplies. WRB aggregated similar water supply systems into four different regions of the State. The WRB strategic plan identified a palette of initiatives that address short term and long term water supply needs, with a focus on critical water resources and vulnerable water supplies in both coastal and upland areas. The effects of climate change will be addressed through the WRB's water availability estimating and system vulnerability initiatives. www.wrb.ri.gov/policy_statutes_planning/WRB_StrategicPlan_031612.pdf

OTHER LOCAL EFFORTS

COMMUNITY VULNERABILITY ASSESSMENTS: U.S. Environmental Protection Agency's Safe Drinking Water, Clean Water Act, and Community Right to Know (toxic release inventory) have required community vulnerability assessments.

REVERSE 9-1-1: Many localities have "reverse 9-1-1" systems in place that could be used to warn residents about heat emergencies, floods or other immediate events.