RESILIENT RHODY

AN ACTIONABLE VISION FOR ADDRESSING THE IMPACTS OF CLIMATE CHANGE IN RHODE ISLAND

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Aerial view of Narragansett Bay, photo by Doc Searls
Cover Photo: Aerial view of Newport and Narragansett Bay, photo from Robinson R44 Helicopter by Michael Kagdis
Both photos courtesy of Wikimedia Commons

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

OFFICE OF GOVERNOR GINA M. RAIMONDO

July 2, 2018

Fellow Rhode Islanders,

Rhode Island is known for pristine oceanfront beaches, fresh seafood, Narragansett Bay's scenic and historic sites, beautiful woodlands, and strong communities. Fed by our deep-seated connections to the history and the natural resources around us, a culture of creativity flourishes here and contributes to a vibrant and prosperous Ocean State.

While we enjoy all that Rhode Island has to offer, our state and its best attributes are increasingly at risk from the impacts of climate change. We've already seen changes to our coastlines, waterways, and forests, and frequent, severe storms continue to put Rhode Island's infrastructure and residents at risk. While we have made great progress over the past decade by working collaboratively across agencies, it's time to do more — it's time to invest in priority projects and strengthen partnerships between the state and municipalities to empower our communities and prepare for a new climate reality.

Resilient Rhody is about actions we can take to protect our infrastructure and our natural resources, strengthen our economy, preserve the health of our environment, and keep Rhode Islanders safe. It's also about strengthening collaboration between state agencies, municipalities, and communities groups throughout Rhode Island. To overcome climate challenges now and in the future, we must work together.

Rhode Island is a leader in climate action: we are home to the nation's first offshore wind farm and recently announced plans to increase our offshore capacity by an additional 400 MW; we are electrifying our buses; and, Rhode Island currently boasts over 15,000 green jobs. The *Resilient Rhody* strategy complements our successful efforts to reduce greenhouse gas emissions, increase renewable energy generation, and create green jobs statewide. *Resilient Rhody* builds on climate resilience efforts that are well underway, and prioritizes published reports, existing tools, and established, effective plans to guide us toward a more resilient future.

Strong leadership at every level and robust, statewide engagement are key to achieving a climate resilient Ocean State, and I look forward to continuing to partner with all of you to accomplish that goal.

Sincerely,

Gina M. Raimondo
Governor

Governor Gina M. Raimondo signs the Action Plan to Stand Up to Climate Change Executive Order on September 15, 2017

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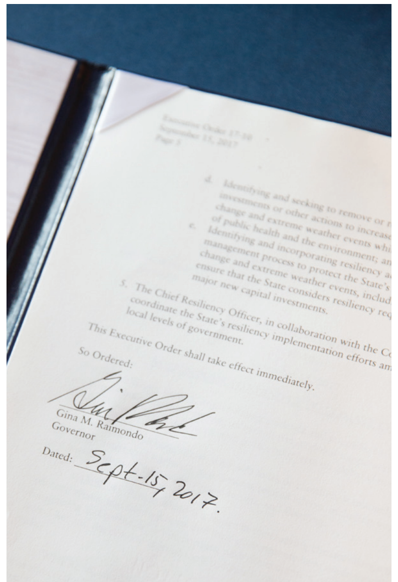


The signed Action Plan to Stand Up to Climate Change Executive Order

Resilient Rhody: The Statewide Climate Resilience Action Strategy

This strategy responds to changing weather and environmental conditions in Rhode Island caused by climate change and proposes bold yet implementable actions to better prepare the state for these impacts.

Rhode Island is already experiencing climate change, and the impacts are placing communities, coastlines, forests and aging, vulnerable infrastructure at risk.

Under the leadership of Governor Gina M. Raimondo, steps have been taken to begin the hard work necessary to address the effects of climate change. Now is the time to invest in priority projects, continue to work collaboratively across agencies, and reinforce the strong partnerships between the state and municipalities to empower and prepare communities for a new climate reality.

To accelerate actions and investments, Governor Raimondo signed an Executive Order on September 15, 2017 calling for the development of the state's first comprehensive climate preparedness strategy. Following nine months of collaborative work, Resilient Rhody lays the groundwork for collective action, involving state agencies, municipalities, and statewide organizations.

This Strategy will focus the state's attention on catalytic climate resilience actions both within government and together with business, academic, and nonprofit partners. Building on the climate leadership of state government, municipalities, and organizations, it leverages existing studies and reports to identify critical actions that move from planning to implementation. Action today will create a stronger and safer tomorrow.

> "Climate resilience" is defined as the capacity of individuals, institutions, businesses, and natural systems within Rhode Island to survive, adapt, and grow no matter what chronic stresses and weather events they experience. While the effects of climate change are felt across the state, these impacts are not equally distributed. Effective climate resilience requires a focus on environmental justice and equity to support local leadership for sustained interaction between community, business, and government.

The recommended climate resilience actions introduced throughout the Strategy are designed to protect the state against sudden and unexpected severe weather events and address underlying chronic stresses, such as rising sea levels, aging infrastructure, and competing development priorities. Effectively addressing climate change needs to leverage bold emission reduction targets and adaptation measures. The Strategy focuses on key climate adaptation actions and implementation will be in collaboration with the state's emission reduction targets. Developing the Strategy has led to many lessons learned, particularly the importance of increased collaboration between state agencies and statewide partners to facilitate shared goal setting.

Strategy Development Process

Resilient Rhody was developed under the leadership of Governor Raimondo in partnership with a wide range of state agencies, municipal officials and representatives, and statewide organizations. The team sought to create a climate resilience strategy driven by the following guiding principles:

STRATEGY GUIDING PRINCIPLES:

1. Prioritize actions and investments the state can make today
2. Leverage planning work already done by state agencies and statewide organizations.
3. Identify actions and investments ready for implementation in the near-term.
4. Recognize competencies that are shared among multiple state agencies.
5. Provide resources and tools to municipalities across the state.
6. Equitably reduce the burden of climate change impacts with particular attention to environmental justice communities across the state.

The strategy development process started with ten Resilience Roundtables (September–December 2017) across the state in partnership with local organizations and municipalities (see Figure 1). The goal was to listen to local and regional leaders, learn what has been done, understand what local assets are at risk, and hear future priorities for local climate resilience. Over 350 individuals attended the Resilience Roundtables, including municipal planners/staff, environmental organizations, community organizations, business owners, state employees, and residents.

Figure 1: Resilience Roundtable locations (September to December 2017)

The data and input gathered from the Roundtables were then organized and fed into five working groups:

(1) critical infrastructure and utilities;

(2) natural systems;

(3) emergency preparedness;

(4) community health and resilience;

(5) financing climate resilience projects.

Members of the working groups represented expert stakeholders on climate resilience and included state agency staff and statewide organization leaders. Each of the working groups led the drafting process for their respective chapters in the Strategy in close collaboration with the Chief Resilience Officer.

Structure of the Strategy

The Strategy is organized into six chapters, directly linked to input received at the Resilience Roundtables.

Chapter 1 provides the evidence base for why climate resilience is essential in Rhode Island by summarizing research and data on climate change impacts currently affecting the state as well as estimates and predictions for future impacts.

Chapters 2, 3, 4, and 5 introduce the four thematic areas at the core of the Strategy: critical infrastructure and utilities, natural systems, emergency preparedness, and community health and resilience.

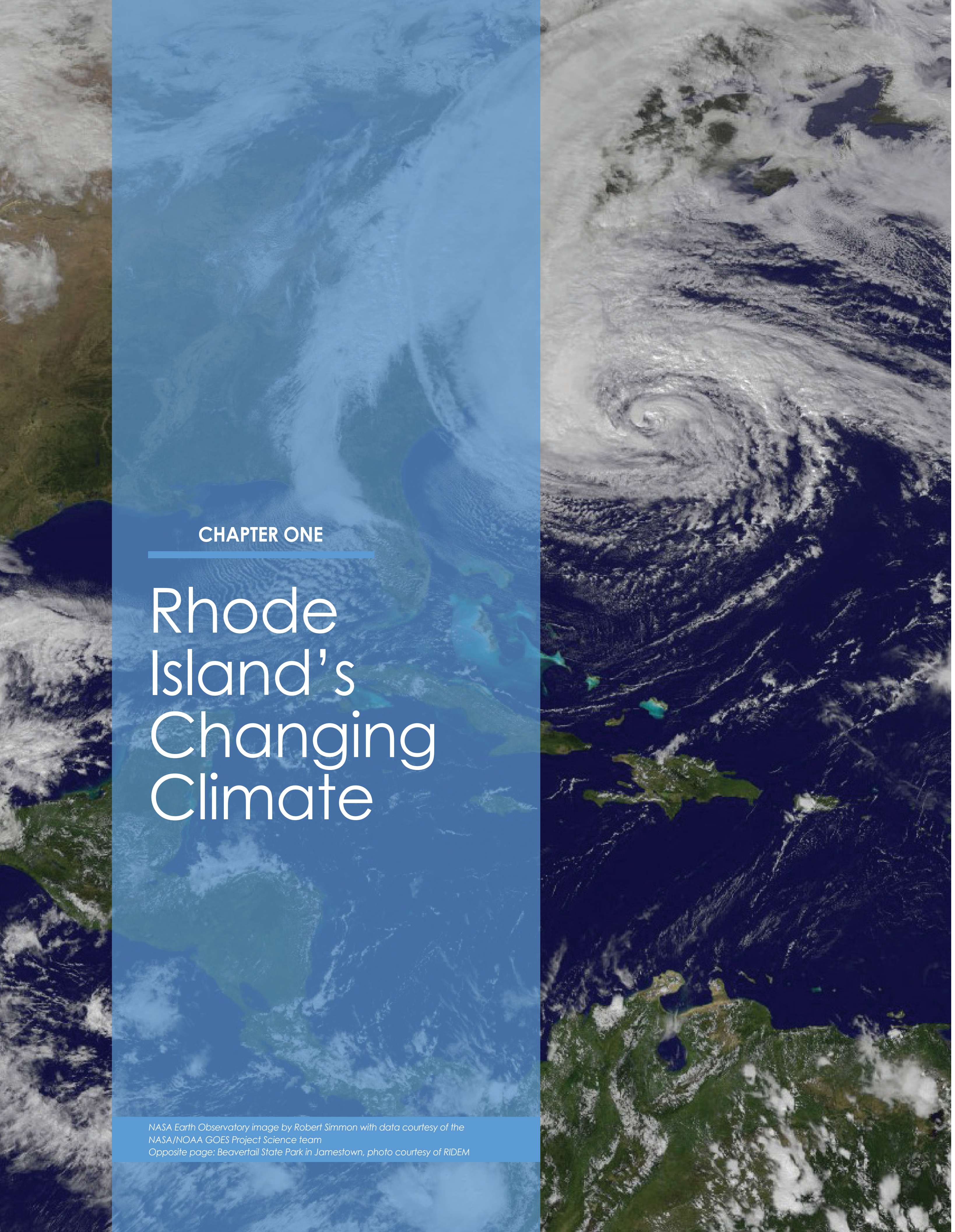
Each chapter identifies critical asset types and other factors vulnerable to climate change and provides actionable recommendations for strengthening climate resilience. While presented as discrete asset types and chapters, the actions will be implemented in collaboration with multiple state agencies.

The final chapter explores challenges and opportunities related to paying for climate resilience projects in Rhode Island and offers potential financing mechanisms that could support the implementation of the climate resilience projects and recommendations in previous chapters. A full list of actions and initiatives concludes the strategy and serves as the framework for implementation.

INTRODUCTION

Salty Brine State Beach in Narragansett, photo courtesy of RIDEM.

TIMELINE OF NATURAL DISASTERS AND SELECT STATE AGENCY REPORTS AND TOOLS



CHAPTER ONE

Rhode Island's Changing Climate

NASA Earth Observatory image by Robert Simmon with data courtesy of the NASA/NOAA GOES Project Science team
Opposite page: Beavertail State Park in Jamestown, photo courtesy of RIDEM

Climate change is one of the most pressing issues of our time and its effects are increasingly impacting Rhode Island.

There are no easy solutions, but local climate experts are using scientific data to assess the state's vulnerability and develop various climate scenarios that reach decades and centuries into the future.

The third National Climate Assessment defined vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. [It] is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." Vulnerability is a product of exposure to climate events, sensitivity to those impacts, and capacity to adapt and respond. Resilience has been defined as "a capacity for successful adaptation in the face of disturbance, stress, or adversity." Resilience is also the functional capacity of cities and communities to bounce back after an external shock.

In 2015, the Rhode Island Executive Climate Change Coordinating Council (EC4) charged the Science and Technical Advisory Board (STAB) to assess the state of knowledge on six manifestations of climate change in Rhode Island, which include:

- Sea level rise
- Warming air temperatures
- Warming water temperatures
- Storm frequency and intensity
- Changing Biodiversity
- Precipitation and inland flooding

STAB advises the EC4 on climate science matters and ensures the Council is aware of new emerging climate science. This informs the EC4's decisions and priorities and is key to understanding Rhode Island's path to resilience and the areas of highest vulnerability.

STAB completed a synopsis study on the state of knowledge of climate change and published their findings in the EC4's 2016 Annual Report. An update was released in 2017 based on new emerging science. This chapter presents an overview of those findings and further illustrates the challenges that Rhode Islanders are currently facing, and may face in the future, as a result of climate change.

RHODE ISLAND MANIFESTATIONS OF CLIMATE CHANGE

1. Sea Level Rise
2. Warming Air Temperatures
3. Warming Water Temperatures
4. Storm Frequency And Intensity
5. Changing Biodiversity
6. Precipitation and Inland Flooding

QUICK LOOK:
Sea Level Rise

- Sea Level has risen over 10 inches in Rhode Island since 1930
- The rate of sea level rise in Newport over the past 30 years has exceeded the global average mean for the same period
- NOAA projects a high sea level rise scenario for Newport of 2.20 feet by 2040, 8.99 feet by 2100 and a substantial increase in the frequency of nuisance tidal flooding

QUICK LOOK:
Warming Air Temperatures

- Over the past six decades the number of days over 80°F at T.F. Green Airport have been increasing
- Temperatures in Rhode Island have increased by more than 3°F since the beginning of the 20th century
- These increased temperatures are linked to higher levels of carbon dioxide and other greenhouse gasses in our air

Sea Level Rise

According to the Newport tide gauge, the historic rate of sea level rise from 1930 to 2016 (an 86-year period) is around 2.73 mm/year, or more than an inch per decade. In other words, sea level has risen over 10 inches in Rhode Island since 1930.

Global mean sea level from 1993 to the present has accelerated to 3.1 mm/year as measured by satellite altimetry.[1] Recent research confirms that if sea level continues to change at this rate and acceleration, sea level rise by 2100 will be more than double the amount if the rate was constant at 3 mm/yr.[2]

According to the Permanent Service for Mean Sea Level, the mean annual rate of sea level rise in Newport is 3.98 mm/year for the 30-year period from 1986-2016, a rate greater than the global average mean for the same period.[3]

In January 2017, the National Oceanic and Atmospheric Administration (NOAA) published revised projections for sea level rise globally and, in the United States, regionally. NOAA projects a high sea level rise scenario for Newport of 2.20 feet by 2040, 8.99 feet by 2100 and a substantial increase in the frequency of nuisance tidal flooding. NOAA recommends considering worst-case scenarios in coastal risk management due to the growing evidence of accelerated ice loss from Greenland and West Antarctica.[4]

Warming Air Temperatures

Carbon dioxide and other greenhouse gases are slowing the radiation of heat back into the atmosphere. This is slowly driving up temperatures, especially nighttime lows, as the blanket of greenhouse gases thickens.[5] Current levels of CO_2 equivalents have surpassed 400 parts per million, well above the pre-industrial level of about 280 ppm (in the years prior to 1850).

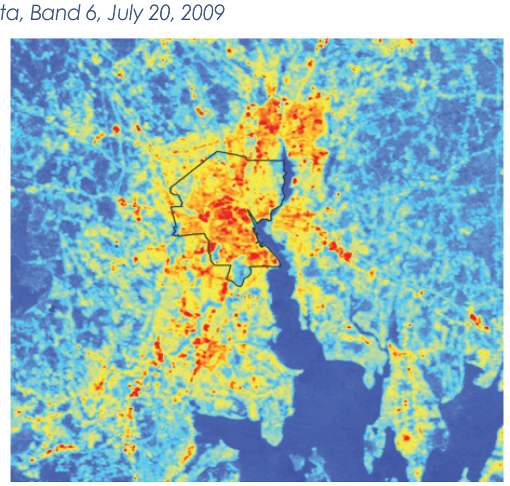
It appears that the late 20th and early 21st century were likely the warmest period the Earth has seen in at least 1200 years.[6]

The Paris Agreement set a target of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels."[7] Initial findings suggest that 1.5°C better characterizes the level at which "dangerous" climate changes begin. Current global averages are around 1°C degree above pre-industrial levels.

Surface temperatures warm, especially as sunlight hits dark surfaces like asphalt and dark roofing in areas of the state without substantial tree cover. As a result, the Urban Heat Island Effect is marked in Rhode Island, with some neighborhoods significantly hotter than others (see Figure 1.2). Over the past six decades the number of days over 80°F at T.F. Green Airport have been increasing (see Figure 1.3).[8] Human health risks rise dramatically in Rhode Island when temperatures exceed 80°F, as illustrated by heat-related records of emergency room admissions.[9] Populations vulnerable to heat-related illness and death include the disabled, elderly, children, communities of color, and low-income communities.

Physical infrastructure is vulnerable to rising temperatures as well, including roads, electrical grids, power plants, and rail systems.[10]

Figure 1.2: Land surface temperatures: Landsat 5 TM data, Band 6, July 20, 2009



Source: Landsat 5 TM data for surface temperature, Band 6, July 20, 2009, GloVis, US Geological Survey, https://glovis.usgs.gov/

QUICK LOOK:
Warming Water Temperatures

- Over the past 50 years, the surface temperature of the Bay has increased from 2.5° to 2.9°F
- Warming water temperature in Narragansett Bay are causing many changes in ecosystem dynamics, which are affecting fish, invertebrates, and plankton
- In 2013, water temperatures in the Wood River exceeded the preferred temperature (<20°C) for native Brook Trout for a full month

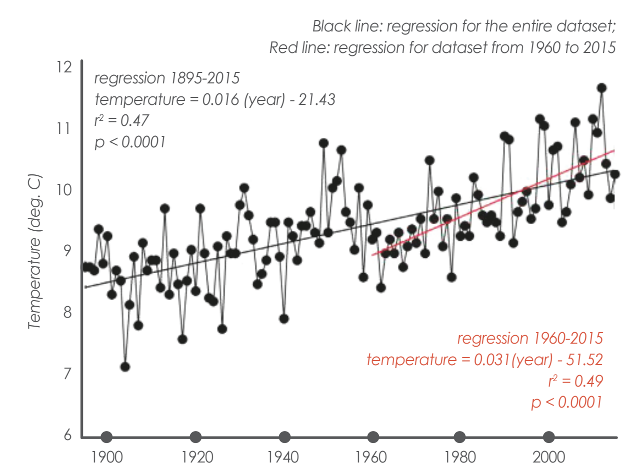
Warming Water (Marine and Fresh) Temperatures

As the atmospheric CO_2 and air temperatures increase, water in Narragansett Bay gets warmer and more acidic. Over the past 50 years, the surface temperature of the Bay has increased from 1.4° to 1.6°C (2.5° to 2.9°F). Winter water temperatures in the Bay have increased even more, from 1.6° to 2.0°C (2.9° to 3.6°F).[11] A detailed discussion of trends, variability, and future expectations for fresh and marine water temperature can be found in the *Narragansett Bay Estuary Program 2017 Technical Report* along with a discussion on potential consequences of increases in acidity (pH), which could adversely affect larval stages of valued shellfish.[12]

Warming water temperature in Narragansett Bay are causing many changes in ecosystem dynamics, which are affecting fish, invertebrates, and plankton.[13] (see Figure 1.4)

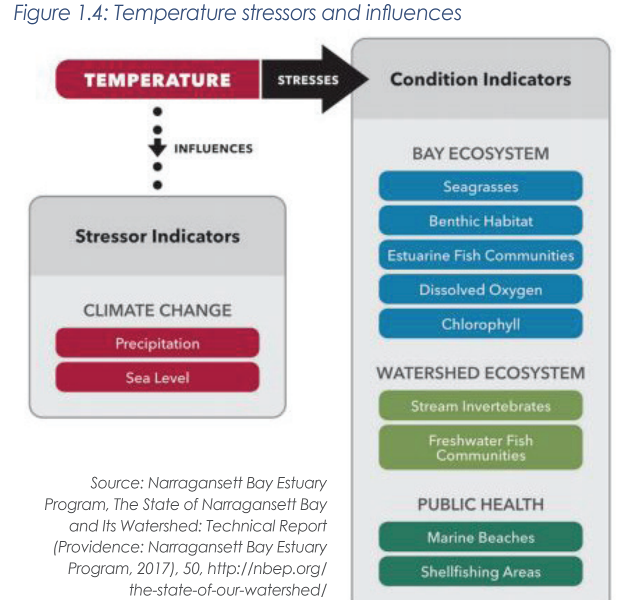
Water temperatures in our freshwater ecosystems are also warming, which will have a negative impact on species of fish that prefer cold water rivers and streams, especially in the summer. In 2013, water temperatures in the Wood River exceeded the preferred temperature (<20°C) for native Brook Trout (Salvelinus fontinalis) for a full month.

Figure 1.3: Annual mean air temperatures at Warwick, Rhode Island (1895-2015)



Source: Narragansett Bay Estuary Program, The State of Narragansett Bay and Its Watershed: Technical Report (Providence: Narragansett Bay Estuary Program, 2017), 54, http://nbep.org/the-state-of-our-watershed/

Figure 1.4: Temperature stressors and influences



Source: Narragansett Bay Estuary Program, The State of Narragansett Bay and Its Watershed: Technical Report (Providence: Narragansett Bay Estuary Program, 2017), 50, http://nbep.org/the-state-of-our-watershed/

QUICK LOOK:
Storm Frequency and Intesity

- Studies of the Atlantic Basin show that storms are also likely to be more intense and have higher rainfall rates
- Predicted changes in storm activity could change the frequency and intensity of associated storm surges, high winds, and precipitation events, causing serious implications for both coastal and inland communities and infrastructure systems in Rhode Island

QUICK LOOK:
Changing Biodiversity

- Climate change is altering the ecology and distribution of plants and animals in Rhode Island
- Cold-water iconic fishery species (e.g., cod, winter flounder, hake, lobster) are moving north out of Rhode Island waters
- Changes in the abundance and annual cycle of animals are expected to increase vector-borne diseases transmitted by ticks and mosquitoes

Storm Frequency and Intensity

The relationship between tropical storm activity and climate change in the Atlantic Basin is being assessed by evaluating the statistical relationship between the historical hurricane record and sea surface temperatures and by modeling hurricane activity using future climate projections. It is generally accepted that records of tropical cyclones impacting the United States are too short to assess long term trends. [14] Thus, analyses of trends in activity over the last 120 years of observation records do not provide compelling evidence that the Atlantic Basin is experiencing a substantial increase in the number of storms. However, while no detectable change has been identified using observations, it is plausible that undetectable changes in intensity are occurring. [15]

The physics shaping the global climate are complicated, making it hard to predict how climate change will influence the intensity, frequency, and geographical distribution of hurricanes. Some effects of climate change, like rising sea surface temperatures, are thought to favor hurricane development and intensification. Other meteorological effects of climate change (e.g., increasing upper troposphere temperature, vertical wind shear) are believed to be unfavorable for hurricane formation. [16]

Since neither the observational record nor the governing physics provide a clear indication of how climate change will impact hurricane activity, modeling studies are useful for predicting changes. Globally, these studies predict an increase in hurricane intensity of 2% to 11%, a poleward migration in the latitude at which storms reach maximum intensity, an increase in tropical cyclone rainfall rates, and a decrease in the frequency of weaker tropical storms. Studies of the Atlantic Basin show that storms are also likely to be more intense and have higher rainfall rates. [17] Recent studies of Hurricane Harvey (2017) concluded that extreme rainfall was partially attributable to climate change. [18]

While the impact of climate change on the frequency of storms in the Atlantic Basin remains uncertain, the predicted changes in storm activity could change the frequency and intensity of associated storm surges, high winds, and precipitation events, causing serious implications for both coastal and inland communities and infrastructure systems in Rhode Island.

Changing Biodiversity

Climate change is altering the ecology and distribution of plants and animals in Rhode Island (see Figure 1.5). These changes have occurred in three primary ways: (1) shifts in the use of space and geographic distributions of plants and animals, (2) changes in the timing of fruiting, flowering, and leaf-out in plants and timing of migration and reproduction in animals, and (3) changes in the behavior, ecology, and physiology of individual species. [20]

QUICK LOOK:
Precipitation and Inland Flooding

- Intense rainfall events have increased 71% since 1958
- RI's average annual precipitation has increased more than 10 inches since 1930
- More frequent and intense Nor'easters and "bomb cyclones" riding on top of rising seas are contributing to coastal flooding as damaging as that associated with hurricanes

In southern New England, spring is arriving sooner, and plants are flowering one week earlier when compared to 150 years ago. [21] For woody plants, leaf-out is occurring 18 days earlier than in the 1850s. [22] Changes in the timing of leaf-out, flowering, and fruiting in plants can be very disruptive to plant pollinators and seed dispersers.

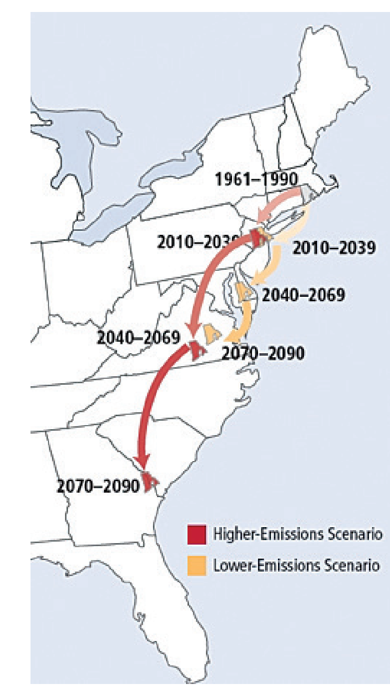
Changes in the timing of annual migratory cycles have also been observed in Rhode Island birds. A 45-year, near-continuous monitoring record of fall migration times for passerine birds in Kingston shows a 3 days/decade delay in the departure time of 14 species of migratory birds. [23]

Sea level rise will also affect coastal habitats that are important for biodiversity. For example, salt marshes, a critical habitat for fish and shellfish, will either drown or migrate landward. [24]

Warming sea water temperatures are leading to shifts in the timing of ecologically significant events in Narragansett Bay, such as the winter/spring phytoplankton bloom. [25] The fish species occurring in Narragansett Bay are also changing as waters warm. Cold-water iconic fishery species (e.g., cod, winter flounder, hake, lobster) are moving north out of Rhode Island waters [26] and warm-water southern species are becoming more prevalent (e.g., scup, butterfish, squid). [27] Narragansett Bay fisheries, once centered around bottom-dwelling fish and invertebrates, are now dominated by fish that occur throughout the water column. [28]

Changes in the abundance and annual cycle of animals are expected to have a profound effect on public health. Cyanobacteria blooms, a toxic alga, in aquatic systems are expected to increase as well as the prevalence of vector-borne diseases of humans that are transmitted by ticks and mosquitoes.

Figure 1.5: How climate change is altering the ecology and distribution of plants and animals in Rhode Island

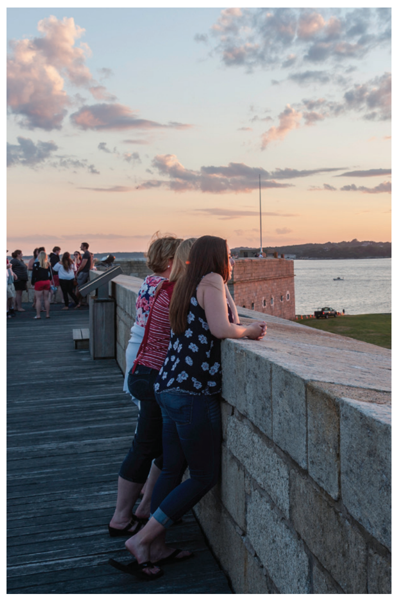


Source: Peter C. Frumhoff, James J. McCarthy, Jerry M. Melillo, Susanne C. Moser, and Donald J. Wuebbles. Confronting climate change in the US Northeast: A report of the northeast climate impacts assessment (Cambridge, MA: Union of Concerned Scientists, July 2007), www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf

Precipitation and Inland Flooding

Climate change is expected to contribute to more intense and wetter precipitation events, now and into the future. [29] Over the past 80 years, Rhode Island and southern New England have experienced a significant increase in both flood frequency and flood severity, including a doubling of the frequency of flooding and an increase in the magnitude of flood events. [30] Intense rainfall events (heaviest 1% of all daily events from 1901 to 2012 in New England) have increased 71% since 1958. [31]

Recent research suggests an increase in rainfall volume from future convective storms across the US. More frequent and intense Nor'easters and "bomb cyclones" riding on top of rising seas are contributing to coastal flooding as damaging as that associated with hurricanes. [32] While multiple climate change models suggest that greenhouse gas increases will result in increased precipitation in Rhode Island, and observed increases in precipitation across the northeastern United States are greater than predicted models. [33] Trends of increasing precipitation in the 20th century may mask risks related to episodic and severe drought, such as the 1960s drought.



Above: Fort Adams State Park in Newport, photo courtesy of RIDEM
Far above: Bike camp, photo courtesy of the Woonasquatucket River Watershed Council

From Vulnerability to Resilience

These six manifestations of climate change in Rhode Island all have implications for the state's population. Moreover, some citizens in Rhode Island are far more vulnerable to these impacts than others. As described nearly 20 years ago by two pioneers in climate vulnerability:

> The lesson from climate change is a more general one: risks do not register their effects in the abstract; they occur in particular regions and places, to particular peoples, and to specific ecosystems. Global environmental risks will not be the first insult or perturbation in the various regions and locales of the world; rather, they will be the latest in a series of pressures and stresses that will add to (and interact with) what has come before, what is ongoing, and what will come in the future...Recognizing and understanding this differential vulnerability is a key to understanding the meaning of climate change. [34]

Low-income and minority Rhode Islanders are already less able to prepare for, deal with, and recover from weather disasters. Major snow or windstorms, heat waves, and flooding are events that some households can anticipate by evacuating or hiring support before, during, or after the storm. Some households have high-quality constructed homes with adequate and responsive insurance coverage to recover from damages, while others live in mobile homes, in floodplains, in uninsulated buildings on streets that do not get plowed frequently, or in places where summer heat is oppressive and inescapable. To build a more sustainable Rhode Island, state and local governments need to incorporate the vulnerability and resilience of different individuals and groups to a changing environment and climate in the planning of buildings, streets, communities, and response actions after major natural disasters.

Understanding the science of climate change is crucial, but not enough. Policymakers and practitioners also need to consider how inequality and structural conditions affect Rhode Islanders' access to resources that transform vulnerability into resilience.

CHAPTER 1: REFERENCES

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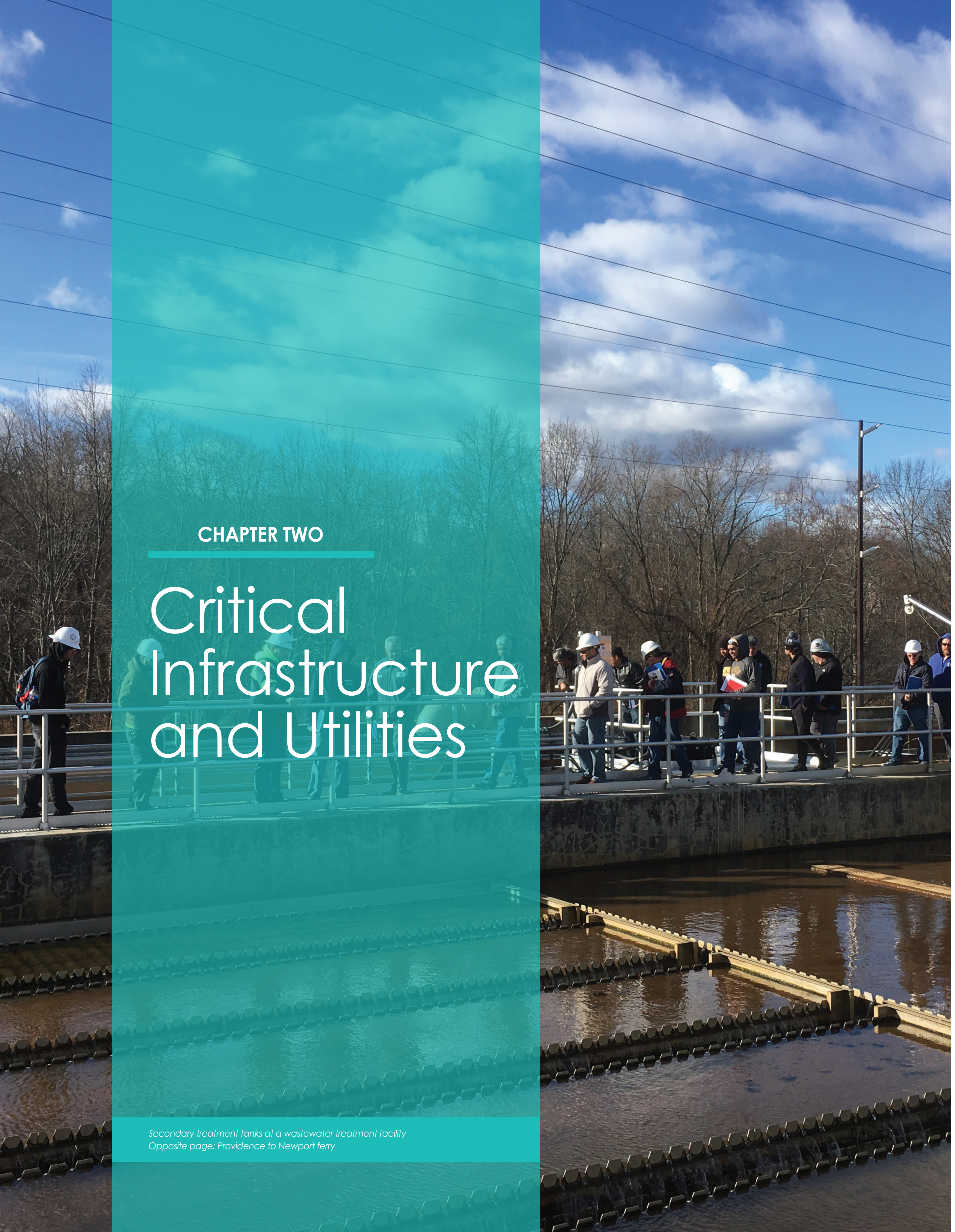


CHAPTER TWO

Critical Infrastructure and Utilities

Secondary treatment tanks at a wastewater treatment facility
Opposite page: Providence to Newport ferry

Critical aspects of Rhode Island's infrastructure and utilities are at increased risk due to the impacts of climate change.

This includes the state's wastewater treatment facilities, ports, electrical grid, and fueling supply. To further strengthen climate resilience, vulnerabilities across the water, power, and transportation sectors require targeted interventions. This chapter identifies nine priority asset types, building on the *Rhode Island Critical Infrastructure Program Plan* and input received at the 10 Resilience Roundtables.

The *Rhode Island Critical Infrastructure Program Plan*, administered by the Rhode Island Emergency Management Agency (RIEMA), outlines how the state's 16 sectors of critical infrastructure work as a group to identify risks and hazards. The sector-based strategies are focused on building resilience and mitigating the effects of hazards on infrastructure, including roadways and transportation systems, water and wastewater capacity, dams, food supply, energy supply, as well as government and other critical facilities used to secure and assist residents during times of disaster.

Figure 2.1: Priority asset types for climate resilience

SECTOR	ASSET TYPE
WATER	DRINKING WATER SYSTEMS WASTEWATER TREATMENT FACILITIES DAMS STORMWATER INFRASTRUCTURE PORTS
POWER	ELECTRIC GRID FUEL SUPPLY
TRANSPORTATION	ROADS, BRIDGES, AND CULVERTS PUBLIC TRANSPORTATION

WATER

Drinking Water Systems

OVERVIEW OF VULNERABILITY

Surface water reservoirs supply approximately 85% of the public water in Rhode Island, with the Providence metro area (approximately 60% of Rhode Islanders) receiving water from the Scituate Reservoir. Other parts of the state rely primarily on surface reservoirs or combined surface and groundwater supplied by public and private wells.

Drinking water systems are inherently vulnerable to changing patterns in temperature and precipitation. Rising temperatures and precipitation concentrated into fewer, more extreme rain/snow events may impact the quantity and quality of Rhode Island's drinking water. Impacts will vary by geography, season, and source of supply.

Coastal surface and groundwater supplies are vulnerable to sea level rise, which heightens the risk of storm surges. Aquidneck Island's primary reservoir is highly vulnerable to storm surge from hurricanes and coastal storm events. Sea level rise and other hydrologic changes may cause saltwater to creep inland, intruding into well water, a risk also present in parts of Rhode Island's south coast.

Precipitation trends suggest Rhode Island will experience more frequent extreme dry periods of

Scituate Reservoir

various duration. Dry periods in the July - September timeframe will impact groundwater supplies, agriculture, and streamflow. Areas with water storage (i.e., reservoirs) will be less impacted.

CURRENT AND PLANNED RESILIENCE INITIATIVES

Rhode Island Water 2030, adopted by the State Planning Council in 2012, outlines the actions for the state and others to ensure there is drinking water for today and the future. [1] The plan identifies strategies essential to maintaining existing and protecting future water supplies, including private wells, and sets forth the Rhode Island Drought Mitigation Framework.

In 2013, *SafeWater RI: Ensuring Safe Water for Rhode Island's Future*, developed by the Rhode Island Department of Health, assessed the vulnerability of water utilities to five hazards: drought, sea level rise, coastal flooding, riverine flooding, and hurricanes. The project found that "three water treatment plants owned by Newport Water Division, Jamestown Water Division, and Bristol County Water Authority are already at risk from coastal flooding and this risk will only increase in the coming years." [2]

The University of Rhode Island (URI) Department of Geosciences also has two ongoing studies. The Scituate Reservoir Modeling study (to be completed in 2018) involves developing and/or integrating models of (1) Scituate Reservoir impacts on drinking water supply, and (2) downstream Pawtuxet River flooding. The models will incorporate climate change projections, water supply demands, reservoir capacity, and operable reservoir spilling. The final report will identify projects and procedures to mitigate downstream flooding via spillway management without adverse impacts on safe yield. The Saltwater Intrusion into Coastal Aquifers study (to be completed in 2019) considers the impacts of saltwater intrusion into the coastal zones of Rhode Island. The final report will identify potential mitigation measures and provide information for environmental managers to evaluate possible impacts of major mitigation measures on coastal environments.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Assist water suppliers in developing local Emergency Interconnection Programs to address supply vulnerability among small systems throughout the state. Emergency Water System interconnections provide redundancy of supply and the ability to address water emergencies rapidly and efficiently across water supply districts.
- Assess the vulnerability of near coastal drinking water reservoirs to storm surge and sea level rise.
- Advance common goal setting and communication between water suppliers that manage reservoirs and downstream municipalities. Ensure downstream flood mitigation via proactive spillway management without adverse impacts on safe yield.
- Ensure that all major suppliers have current contingency contracts for the purchase of emergency supplies and have established emergency interconnection/distribution process.

CHAPTER TWO

Wastewater Treatment Facilities

OVERVIEW OF VULNERABILITY

Rhode Island is home to 19 major wastewater treatment facilities that treat close to 120 million gallons of residential, commercial, and industrial wastewater every day. Around 250 pumping stations are in place to transport sewage across hilly terrain to these treatment systems. As water naturally flows downhill, designers of wastewater collection and treatment systems use gravity as often as possible to transport sewage in underground sewer lines over long distances, as well as across short distances within the successive treatment steps of a wastewater treatment facility.

In Rhode Island, most of our wastewater systems are in floodplains to take advantage of gravity-fed flows. This infrastructure was designed to withstand and continue operations at certain levels of flooding. However, threats from increased flooding due to climate change will make existing flood protections inadequate, as seen in 2010 when four wastewater facilities and multiple components of collection systems experienced varying degrees of flooding. These threats include:

- Increases in groundwater levels and street flooding from precipitation can increase flows through underground sewer collection systems. This brings additional flow to the treatment systems exceeding what those systems are generally designed to handle;
- Overwhelmed and submerged wastewater pumping stations and treatment systems by external flows in coastal and riverine areas; and
- Related impacts to energy and transportation systems that threaten vital needs for power and delivery of important chemicals, as well as safety concerns related to the well-being of those who operate and maintain these systems.

Smaller residential and commercial onsite wastewater systems are also threatened by natural hazards, both from overland flooding and storm surge as was experienced during Hurricane Sandy (2012), as well as from changes to groundwater levels. Additional study is needed to better understand the impact of climate change on onsite systems and the steps necessary to protect their physical integrity and operational efficiency.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In 2017, the Rhode Island Department of Environmental Management (RIDEM), in collaboration with the Office of Housing and Community Development and local communities, completed a study on the *Implications of Climate Change for RI Wastewater Collection & Treatment Infrastructure.* [3] This study is a planning tool intended to help state and local officials, as well as the general public, better understand the projected implications of climate change on the state's 19 public wastewater treatment systems. While it focused on municipal treatment plants and major pump stations, the study did not include wastewater infrastructure owned by private entities or onsite systems with subsurface disposal. As part of this study, RIDEM's Office of Water Resources (OWR) developed guidance for future upgrades

The Warwick Wastewater Treatment Facility after the Great Floods of 2010

Above: Heavy incoming flows overwhelm influent structures at the West Warwick Wastewater Treament Facility during the Great Floods of 2010. Far above: The Bucklin Point Wastewater Treatment Facility in East Providence

and new construction to factor in a changing climate. The OWR also began including a requirement to assess resilience as part of major wastewater treatment facility permit reissuances.

The study has led to several local efforts across the state. In 2017, the Warwick Sewer Authority completed a reconstruction of its protective berm, increasing its height to protect the treatment system from floods like those of 2010. They are also working to make vulnerable pumping stations more resilient to flooding. The Town of Narragansett also built a berm in 2016 to protect their coastal wastewater treatment facility from storm surge. Like Warwick, Narragansett is leading the way on elevating and hardening wastewater collection systems. The Town of Smithfield is currently studying and budgeting for resilience efforts at both their treatment and collection system.

Owners of several other facilities are currently building off the RIDEM study with their own analyses to determine necessary steps toward more resilient infrastructure. This includes the Narragansett Bay Commission which owns and operates Fields Point in Providence, the state's largest facility, and Bucklin Point in East Providence.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Accelerate treatment system and pumping station hardening projects identified in *Implications of Climate Change for RI Wastewater Collection & Treatment Infrastructure* to include the installation of submarine doors; elevated, watertight protections of motor control centers; waterproofing and elevated instrumentation, windows, hatches, and vents; and installation of standby power systems.
- Provide additional fuel-storage capacity at major wastewater systems where it is necessary to maintain self-sufficient standby power during times of long-term power grid outages.
- Expand flood modeling/mapping efforts within inland areas to enhance the recommendations in *Implications of Climate Change for RI Wastewater Collection & Treatment Infrastructure*. Data should include statewide precipitation projections that can be used for other sectors as well.

Dams

OVERVIEW OF VULNERABILITY

Rhode Island has 668 inventoried dams. Each dam is classified by hazard, which relates to the probable consequences of failure or misoperation of a dam; this is distinct from the current condition or the likelihood of failure. Of particular concern is the hazard level of a significant portion of Rhode Island's dams. There are currently 96 dams (14%) classified as high hazard, 81 dams (12%) classified as significant hazard, and 491 (74%) classified as low hazard (see definitions in Figure 2.2).

Overtopping is the primary cause of dam failures and increasing precipitation and severity of storms may increase the likelihood of overtopping on several of the state's dams. Many of the dams are over 100 years old and are unable to safely pass excess water generated from storms, which could cause the dams to overtop.

The vulnerability of dams is further impacted by a lack of clear ownership. In some cases, there is no clear legal title. Development downstream of high hazard and significant hazard dams also poses a critical risk.

Dam at the John L. Curran Management Area

CURRENT AND PLANNED RESILIENCE INITIATIVES

RIDEM has the statutory responsibility to inspect dams, determine their condition, and order the owner to make repairs or other necessary action to make a dam safe. In 2017, RIDEM retained an engineer to study the capacity of high hazard and significant hazard dams to safely withstand a 500-year storm. The findings from the study (completed in Spring 2018) will be used to determine what actions are necessary if a dam does not have the requisite capacity.

Figure 2.2: Hazard classifications for dams

HAZARD LEVEL	DEFINITION
HIGH HAZARD	A failure or misoperation will result in a probable loss of human life.
SIGNIFICANT HAZARD	A failure or misoperation will result in no probable loss of human life but can cause major economic loss, disruption of lifeline facilities or impact other concerns detrimental to public health, safety, or welfare. Examples of major economic loss include washout of a state or federal highway, washout of two or more municipal roads, loss of vehicular access to residences (e.g., A dead-end road whereby emergency personnel can no longer access residences beyond the washout area), or damage to a few structures.
LOW HAZARD	A failure or misoperation will result in no probable loss of human life and low economic losses.

Source: Interagency Committee on Dam Safety, Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams (Washington, DC: Federal Emergency Management Agency, October 1998), www.fema.gov/media-library-data/20130726-1516-20490-7951/fema-333.pdf.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Prioritize remediation actions and investments identified in RIDEM's 2017 dam hazard study to ensure compliance and downstream safety.
- Establish a notification system for dam safety to coordinate the actions of officials at the federal, state, and local levels. The system should use the process developed by the National Weather Service for severe weather, including a dam advisory, a dam watch, and a dam warning.
- Develop Emergency Action Plans (EAPs) for all statewide high hazard and significant hazard dams. Responding to an emergency at a dam without an EAP increases the risk to life and property yet many statewide dams do not have plans filed. RIDEM and RIEMA have been working to increase the number of filed EAPs but a more robust program is needed to ensure compliance.

A flooded street in West Warwick during the Great Floods of 2010

Stormwater Infrastructure

OVERVIEW OF VULNERABILITY

Stormwater runoff is a widespread source of water quality degradation in Rhode Island. Most water quality impairments are known or suspected to be caused in part by stormwater. Stormwater impacts include pathogen contamination resulting in beach closures and closure of shellfish growing areas, nutrient enrichment of water bodies resulting in algal blooms (e.g., potentially toxic cyanobacteria blooms), elevated levels of other pollutants (e.g., metals), stream bank erosion, aquatic habitat alterations from higher high flows and lower low flows, and deposition of sediment.

The degree to which stormwater impacts water quality and contributes to downstream flooding is a function of the amount of impervious cover in a watershed and how stormwater is managed for quality and quantity.

Much of the state's stormwater infrastructure was built at least 75 years ago and was designed for less intense storms. These systems suffer from decades of deferred maintenance, which has reduced their ability to control stormwater. Climate change further challenges the capacity and performance of these drainage systems. Submerged outfalls, undersized culverts, and unmapped floodplains are documented problems that occur across Rhode Island's cities and towns. Capacity in existing local stormwater systems will likely be exceeded as storm patterns change, threatening additional damage to property and water quality.

Development pressure in the state will continue to result in the conversion of natural areas to impervious surfaces. This increase in impervious surface along with increases in precipitation will put additional stress on existing drainage systems, thus contributing further to flooding and water quality issues. Water quality impairments are seen in a watershed when untreated impervious cover reaches more than 8-10%. Rhode Island's urban areas range from 34% to 58% impervious cover. Given the relationship between impervious surfaces and stormwater pollution, it is not surprising that most urban rivers, lakes, and ponds in Rhode Island suffer from stormwater-related water quality impairments, such as unacceptable sanitary quality for shellfishing and/or swimming and excessive algae growth and/or cyanobacteria blooms.

CURRENT AND PLANNED RESILIENCE INITIATIVES

The Rhode Island Department of Transportation (RIDOT) and 34 of Rhode Island's municipalities are regulated under the state's general stormwater management permit issued by RIDEM, known as the Municipal Separate Storm Sewer Systems (MS4) permit. This permit requires municipalities to establish programs to manage their drainage systems to prevent water pollution. In locations where RIDEM studies known as Total Maximum Daily Loads (TMDLs) have found stormwater is contributing to water quality impairments, the permit also requires municipalities to undertake enhanced stormwater management practices, including construction of retrofits. Many municipalities and RIDOT struggle to comply with the permit's requirements due to limited capacity, resources, and expertise.

CHAPTER TWO

Green infrastructure in the parking area for the Bristol Town Beach

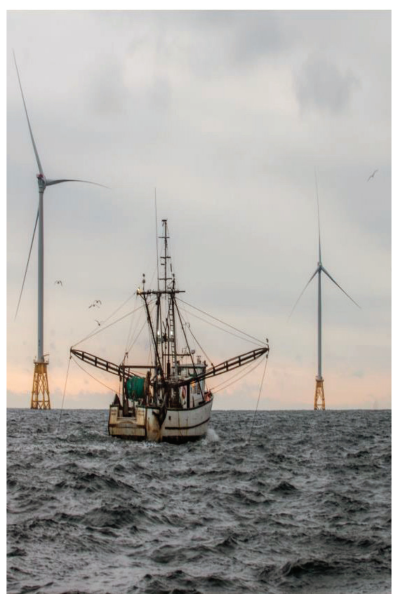
Given the extensive network of state-owned or -maintained roads, bridges, and parking areas, RIDOT has significant stormwater management responsibilities. RIDOT manages an estimated 25,000 catch basins and 3,800 outfalls. RIDOT recently embarked on a 10-year strategic program to improve stormwater management consistent with a federal consent decree issued in 2015.

RIDEM and the Coastal Resources Management Council (CRMC) have also been requiring the implementation of Low Impact Development (LID) strategies in projects that these agencies permit. LID is a site planning and design strategy intended to maintain or replicate pre-development hydrology using site planning, source control, and small-scale practices integrated throughout the site to prevent, infiltrate, and manage runoff as close to its source as possible. RIDOT has offered to provide municipalities and nonprofit organizations engineering designs for these kinds of green infrastructure. Use of these strategies helps to reduce off-site runoff and will help mitigate potential impacts of increased precipitation and precipitation intensities caused by climate change.

The major obstacle to improved stormwater management is the lack of adequate, sustainable funding at the state and local levels to support needed retrofitting and ongoing maintenance of stormwater infrastructure. Future updates to permit requirements will further strain municipal budgets. To address local funding shortfalls, RIDEM has partnered with municipalities interested in exploring the feasibility of establishing sustainable local or regional funding sources, such as a stormwater enterprise or utility fund. Additional information about stormwater funds is included in Chapter 6: Financing Climate Resilience Projects.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Work with local governments to establish sustainable revenue sources for the operation and maintenance of local stormwater management systems (e.g., applying asset management approaches commonly used with wastewater and drinking water systems) to ensure drainage systems are functioning as designed/intended and repaired/upgraded as needed.
- Encourage the use of green infrastructure to enhance the capacity of traditional stormwater systems to provide multiple community and ecosystems benefits to enhance water quality and provide multiple community benefits.
- Update the Stormwater Design and Installation Standards Manual/Rules to reflect changing precipitation patterns.
- Use Total Maximum Daily Loads (TMDLs) and other watershed plans to identify areas of existing impervious surface that can be removed and to prioritize retrofitting of existing drainage systems.
- Identify existing stormwater management structures that are subject to frequent coastal and riverine flooding and take steps to mitigate the impacts of this flooding on stormwater infrastructure and its performance.
- Update the state land use plan, Land Use 2025, to include climate change and resilience topics as well as stormwater water management needs, policies, and actions for stormwater utility districts.
- Develop a bridge loan at Rhode Island Infrastructure Bank to provide upfront capital to communities and organizations who are RIDOT and RIDEM reimbursement stormwater grant recipients.



Above: A commercial fishing boat passes by Rhode Island's offshore wind farm, photo courtesy of RIDEM
Far above: Commercial fishing boats docked at the Port of Galilee in Narragansett

Ports

OVERVIEW OF VULNERABILITY

Maritime transportation plays a critical role in the Rhode Island economy, providing products, raw materials, and revenue from scrap metal and other exports. The Port of Providence supplies Connecticut, Massachusetts, and Rhode Island with petroleum products and handles bulk and break-bulk cargo; in 2010, this cargo totaled approximately 3.1 million tons. Numerous ancillary businesses depend on the Port's functionality, including trucking companies, rail service, manufacturing companies, ship repair facilities, marine pilots, and dredging companies, generating more than $200 million in economic benefits for the region and over 2,400 jobs.

Along the Quonset waterfront, there is a robust shipbuilding industry that consists of nuclear submarine building, commercial shipbuilding, ship overhaul, and offshore construction logistics tenants. The Davisville waterfront features a vibrant automotive import facility as well as heavy lift facilities for large/unique cargo utilized regularly by the wind industry. Since flooding from major storms and associated damage will cause both short- and long-term disruptions in the state economy, public and private sectors have a significant stake in assessing proactive measures to avoid post-storm decline.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In 2015, RIDOT funded URI researchers to conduct a study, Stakeholder vulnerability and resilience strategy assessment of maritime infrastructure: *Pilot Project for Providence, RI*. The project investigated resilience at the Port of Providence to stimulate dialogue around long-term planning. [4]

In 2004, the Quonset Development Corporation (QDC) installed a new emergency generator and transformer for the port area. The area is significantly elevated on a reinforced concrete platform, which allows water to pass beneath it freely and operate during severe storm surges/hurricanes. Building on these resilience improvements, the Davisville pier pump station and Pump Station DS-55 had emergency bypass connections installed in 2017, which allows for portable self-contained diesel pumps to take over operations. These stations can be bypassed indefinitely during a catastrophic failure of the power grid and/or failure of emergency backup generators to ensure the flow of sewage even during a cataclysmic event.

The QDC, in coordination with the CRMC, kicked off a significant modernization of Pier 2 in excess of $100 million to upgrade the existing structure by replacing the steel sheet piling around the perimeter. This upgrade protects the interior from further erosion caused by perforations in the existing sheet piles which were built in the late 1950s. The second phase of this project will be to install a one-foot curb around the surface perimeter of the pier to protect against wave action. These upgrades will make Pier 2 a viable trade hub for the next 50 years and fulfill Quonset's mission of providing jobs and trade for years to come.

The Port of Galilee is another economic hub for Rhode Island, especially in its role as the state's largest commercial fishing port. It also serves as the landing point for the Block Island Ferry. The Port supports thousands of jobs and a diverse fleet (e.g., fishing vessels, ferries, charter boats, recreational craft). There are more than 1,200 active commercial fishers in Rhode Island and the commercial fishing industry generates around $200 million in annual sales and supports about 7,000 jobs. Recent upgrades ensure that new docks will be raised to the highest possible grade to accommodate sea level rise. Future planned resilience projects include raising the bulkhead to a higher grade in one of the lowest areas in the Port to prevent water from breaching, as it does currently on "moon tides."

Commercial fisherman unloads squid at the Port of Galilee in Narragansett, photo courtesy of RIDEM

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Strengthen storm resilience and post-storm recovery at the ports through strategic partnerships and planning. Shipping lines will turn to ports that rapidly resume normal operations after hurricanes. Rhode Island and cities like Providence and East Providence should approach storm resilience and climate change as a business opportunity through inclusion of resilience planning. For example, state agencies should support the ports in developing pre-contracts for debris removal after hurricanes or businesses could implement data backup mechanisms to help the ports resume operations more quickly after a storm.
- Establish a new collaborative partnership between the state and port community to understand the economic implications of severe weather events and benefits of storm resilience planning.

Above: Power lines
Far above: A flooded power substation in Westerly during the Great Floods of 2010, photo courtesy of Doug Kerr, Creative Commons License

POWER

Electric Grid

OVERVIEW OF VULNERABILITY

In recent years, Rhode Island has experienced many severe weather-related events, including floods, blizzards, extended heat waves, extreme cold snaps, and hurricanes. One of the most direct energy security impacts of major storm events is power outages. Rhode Islanders face several kinds of costs from power outages: costs customers pay power utilities to restore service, costs cities and towns pay in additional emergency services, and costs associated with lost wages and business revenue. The increasing need for electricity restoration following storms is directly contributing to the rising cost of storm response.

Examples of climate-related power outages include:

- Multiple utility substations, including a major substation in Westerly, were flooded in 2010;
- During Hurricane Sandy (2010), nine substations went out of service, 1,433 sections of wires went down, and 63 poles were broken. In addition, approximately 120,000 electricity customers and 1,200 natural gas customers lost service. Five days passed before National Grid was able to restore electric power to 100% of the state's utility customers. [5]

Electric grid-related risks fall into two broad categories. Some risks stem directly from damage to power generation facilities and transmission/distribution infrastructure, such as flooding or inundation of energy infrastructure, downed poles and wires, and damaged pipelines. [6] There are also indirect risks resulting from power outages that affect residents and businesses, such as loss of heat or air conditioning/ventilation and resulting health impacts and potential loss of life, lost business revenue, and macroeconomic impacts.

Utility workers repairing damaged power lines in West Kingston

The increasing frequency of extreme weather events and the ongoing possibility of future natural or manmade disasters also pose serious energy security risks to Rhode Island, particularly the state's dependence on natural gas. Nearly all in-state electric generation relies on natural gas as a fuel source. Natural gas is not a fuel indigenous to New England; it originates primarily from production in the Appalachian region, the Gulf Coast, and to a lesser extent, Canada, with the vast majority arriving by pipeline. Should natural gas transmission and distribution infrastructure become threatened by natural disasters, the state's reliance on natural gas may become a vulnerability. For example, during a 10-day cold snap in 2017-2018, Rhode Islanders incurred an additional $34 million in natural gas costs. These costs reflect both greater consumption and a surge in prices from increased demand across New England.

CURRENT AND PLANNED RESILIENCE INITIATIVES

The Office of Energy Resources (OER), Division of Public Utilities and Carriers (DPUC), and Public Utilities Commission (PUC) play key roles in overseeing energy assurance and resilience in Rhode Island. Agency responsibilities related to energy security encompass a broad range of activities, such as monitoring the state's liquid fuel supply during storm events and overseeing ongoing reliability planning and investment by the state's electric and gas distribution companies. PUC Docket No. 4600 Framework incorporates resilience into cost-benefit calculations to guide future grid investments. These agencies, in collaboration with other key stakeholders, have been and will continue to prepare for threats to the energy system and critical infrastructure.

National Grid, the electric and gas distribution company that services 99% of Rhode Island residents and businesses, submits an annual Infrastructure, Safety, and Reliability (ISR) Plan to the PUC for regulatory review. [7] The ISR Plan is a program of capital investment and other spending to address electric and natural gas system safety and reliability. One category of capital investment covers improvements, repairs, and maintenance of infrastructure like poles, wires, and other structures. This category includes capital projects related to resilience (e.g., substation hardening). Another category of capital investment covers innovative solutions for resilience preparation, like non-wires alternatives and distributed generation investments by private parties.

The PUC has also ordered investor-owned utilities to manage a "Storm Fund," a mechanism for recovering storm restoration expenses as a result of extraordinary storms. [8] This fund effectively spreads the unpredictable costs of storm recovery across years.

Rhode Island has already laid the foundation for a long-term energy resilience strategy and this includes the *Energy Assurance Plan* (EAP) and the *Rhode Island State Energy Plan*. The EAP was developed in 2012 through an American Recovery and Reinvestment Act - State

A charging station for electric vehicles

Energy Program Grant. It contains information necessary to address the health, safety, and economic viability of energy customers and takes initial steps to identify risks to the state's energy system. [9] Adopted in October 2015, the *Rhode Island State Energy Plan* identified energy security as one of three themes of the Energy 2035 vision. Based on the findings from the EAP, the Plan recommended the formation of a working group charged with developing short- and long-term strategies for mitigating critical infrastructure energy security risks and investing in power resilience solutions. [10]

Using funding from the Hurricane Sandy Community Development Block Grant Disaster Recovery (CDBG-DR), the OER commissioned a report on resilient microgrids released in 2017. [11] The report includes several policy recommendations for accelerating the deployment of microgrids and identified potential critical infrastructure host sites for microgrid implementation. Microgrids are localized electricity networks with a local power source and sometimes battery storage that can disconnect and operate independently from the larger grid. Benefits of microgrids include autonomous operation during external power outages, mitigation against grid disturbances, and strengthened grid resilience.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Design and implement a comprehensive, targeted strategy addressing energy security vulnerabilities at the municipal or facility level, based on findings of the *Energy Assurance Plan*. This strategy should address risks specific to discrete critical infrastructure assets, including hospitals, police and fire stations, water and sewage treatment plants, senior centers and nursing homes, shelters, correctional facilities, fueling stations, and grocery stores. Smart energy security investments at these locations and energy resilience solutions could alleviate the impacts of power outages and fuel supply disruptions in energy emergencies. Examples of such solutions are backup generation, fuel reserves, distributed generation, combined heat and power, energy storage, and microgrids.
- Act on the policy recommendations outlined in the OER report, *Resilient Microgrids for Rhode Island Critical Services*, and remove market barriers to implementing microgrids at critical facilities.
- Modernize the grid and complementary efforts through the Power Sector Transformation initiative currently under review at the PUC, as recommended by the state energy plan and the House Energy Security Resolution Report. [12] The initiative includes recommendations for the utility business model, grid connectivity and meter functionality, distribution system planning, and beneficial electrification. These facets will help accelerate the integration of non-conventional resources and support the development of a more resilient, reliable, efficiency, and flexible electric grid.
- Reduce the number and extent of power outages as described in *Division Docket No. D-17-45: Review of National Grid Storm Preparedness and Restoration Efforts Related to the Storm of October 29-30, 2017*, including: [13]
  - Supplement weather forecasting services with additional tools to achieve more accurate storm forecasts.
  - Develop a mechanism to rapidly adjust weather classifications based on actual, current impacts and review classification system, planned resources, and staging locations based on classifications. A utility's emergency response plan should incorporate methods to rapidly adjust when storm impacts are more severe than anticipated.
  - Consider enhancements to existing vegetation management programs. Strategic tree removal, for example, can mitigate power outages due to tree-related downed power lines.
  - Enhance communications systems to respond quickly to changes in storm severity from what was predicted. Better communication systems and protocol are needed to properly convey changes in urgency and actions both internally and to the public.
  - Improve guidelines and contracts for mutual aid to allow for more appropriate magnitude and timing of crew additions in the state.

CHAPTER TWO

Fuel Supply

OVERVIEW OF VULNERABILITY

Five of Rhode Island's six fuel terminals are in Providence and East Providence, at the mouth of the Providence River. These terminals comprise approximately 90% of the state's petroleum infrastructure. Severe weather events could adversely affect the marine terminals and disrupt fuel supply. Terminals outside of the hurricane barrier are especially at risk. The marine terminals require electricity to maintain product offloading and rack services. Direct impacts of delays in fuel distribution include lost revenues, disability of critical services like public transit and emergency services, and associated macroeconomic consequences. Indirect impacts include loss of heating capability for homes and businesses using fuel oil and may result in loss of life. For example, during Blizzard Nemo in February 2013, all of the fuel terminals lost electrical power for two days and were unable to provide gasoline, diesel, heating oil, and jet fuel to gas stations, homes, and airports. [14]

The Port of Providence

CURRENT AND PLANNED RESILIENCE INITIATIVES

The OER monitors energy security and energy assurance issues related to severe weather events. As such, the OER keeps in close communication before, during, and after storms with fuel terminals regarding the adequacy of their fuel supplies to meet demand from homeowners, businesses, and municipalities. [15]

Fuel terminals have emergency plans for severe weather events. Several terminals have pre-wired their facilities for back-up generators, which are in flood protected areas, to operate their main office and some terminal pumps. In addition, the terminals have made provisions to access standby generators that can be mobilized and manually hooked into the terminal power feed in the event of a prolonged outage. Provisions have also been made to elevate or remove vulnerable equipment. Fuel terminals are considered priority customers for re-establishing power during outages to avoid and limit possible disruptions.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Ensure fuel terminals have undertaken all appropriate hardening and resilience measures to protect their facilities from future storms and have made provisions to restore operations after storms. This includes continuing strategic long-term planning for improving the resilience of marine terminals.
- Develop a Petroleum Set-Aside Program, as recommended by the *Energy Assurance Plan*, to ensure essential public needs are met during a severe fuel shortage. This program should specify best practices to ensure fuel delivery to priority end-users, such as hospitals, police and fire stations, water and sewage treatment plants, senior centers and nursing homes, shelters, correctional facilities, fueling stations, and grocery stores. This program should also define best practices and prioritize critical infrastructure assets.

Above: Plows clear snow from Interstate 195
Far above: The Horton Farm Bridge in East Providence

TRANSPORTATION

There are numerous environmental and natural threats to our state's transportation sector. With over 400 miles of coastline and large inland watersheds, Rhode Island's transportation and transit infrastructure (e.g., roads, bridges, intermodal facilities, culverts) and systems are vulnerable.

To date, several state agencies, municipalities, and partner institutions have worked together to identify and quantify current and future threats to this sector and have developed, or are in the process of developing, strategies to address them. According to these assessments, hundreds of miles of roads, numerous bridges, and other systemwide infrastructure are vulnerable to these climate related threats.

The protection and resilience of the transportation sector is crucial. Residents of the state and region, along with visitors coming to Rhode Island for tourism or business, rely on this sector to provide access to jobs, goods, communities, emergency services, education, recreation, and healthcare.

Transportation and transit infrastructure are critical assets and provide access to other asset classes. Therefore, it is important to approach the preservation and improvement of the state's facilities and systems through an asset management lens. At the federal level, the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) both require states to actively engage in asset management planning for major transportation sector asset categories. At the state level, the Rhode Island Public Transit Authority (RIPTA) and Division of Statewide Planning are developing a Transit Asset Management Plan, moving toward completion in 2019. RIDOT has also completed an initial *Transportation Asset Management Plan* (TAMP), designed to weigh risks such as climate and resilience along with funding, economic development, safety, and political will.

Roads, Bridges, and Culverts

OVERVIEW OF VULNERABILITY

Transportation vulnerability can be organized into two components: exposure and vulnerability. Exposure is an analysis of the assets in raw terms potentially exposed to inundation, whereas vulnerability is an attempt to determine what implications the exposure holds for the transportation system.

EXPOSURE

To date, the most comprehensive analysis of transportation infrastructure exposure and vulnerability was conducted by the Division of Statewide Planning in 2016. Since this analysis was conducted, best estimates for sea level rise by 2100 have grown from seven to 10 feet. However, the project did not include riverine inundation, a vital component for understanding the full extent of exposure. Nonetheless, the project found that 175 miles of roadway could be exposed to inundation with seven feet of sea level rise. Under current conditions, a 1% storm surge event could flood up to 337 miles of roadway in Rhode Island. With seven feet of sea level rise, in addition to a storm surge event, 573 miles of roadway could be exposed. In addition, there are 90 bridges that could cause concern if exposed to seven feet of sea level rise, because of either freeboard heights or accessibility. Under conditions of a 1% storm surge event plus seven feet of sea level rise, 163 bridges could be impacted.

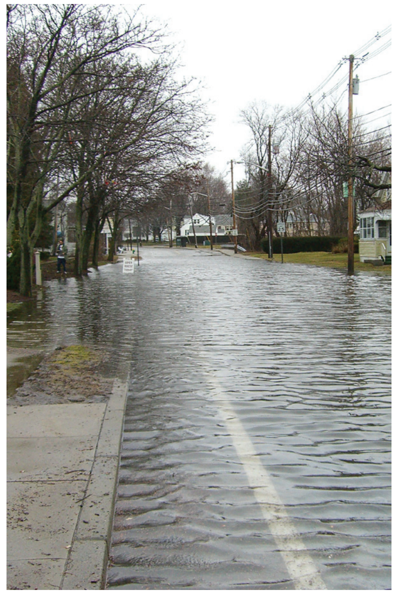
Sea level rise estimates require additional upward adjustment and do not consider riverine flooding. In addition to roads and bridges, there is significant overlap between water-related infrastructure and transportation infrastructure in Rhode Island. In certain locations, culverts are part of the basic transportation infrastructure; culverts over five feet are inspected as bridges and roads in low-lying areas subject to flooding may have multiple culverts in place to handle the volume of flow. With increasing frequency and intensity of storms, sea level rise, and other climate impacts, culvert capacity and integrity may be called into question, which could have a direct impact on the road and bridge transportation network.

VULNERABILITY

The transportation assets of greatest concern are those in the East Bay region, though coastal populations mean that all coastal municipalities will face difficulties in developing storm surge resilience as most of the exposed assets are local roads. The most critical assets to the state's transportation system will not be exposed to sea level rise, but a comprehensive analysis needs to be undertaken.

Considering the major riverine flooding event in 2010, riverine inundation is likely to present as much of a challenge as sea level rise. During just one storm in 2010, sections of 40 major arterial roads and highways were closed with many incurring significant structural damage and sections of Interstate 95 were shut down for three days, restricting north-south movement in the state. The modeling of riverine impacts has begun but is not yet complete.

Construction of the Providence River pedestrian bridge



A flooded street in Warwick

CURRENT AND PLANNED RESILIENCE INITIATIVES

The Division of Statewide Planning published two reports on transportation assets in 2015 and 2016: *Vulnerability of Transportation Assets to Sea Level Rise and Vulnerability of Municipal Transportation Assets to Sea Level Rise and Storm Surge.* [16] These reports remain the most comprehensive review, to date, of the vulnerability of the state's transportation assets, but they require addition and revision. Variability of estimates over time is an ongoing problem for planning efforts. In addition, the STORMTOOLS data set, upon which the project was based, did not contain information about riverine flooding. As a result, a significant portion of the expected impacts of climate change are not addressed. However, the reports remain valuable because of their comprehensiveness as well as their basic analysis methodology which can be applied as new data become available. The reports also lay out some components of how state policy might seek to address climate resilience efforts.

RIDOT is developing an Environmental Resiliency Tool that will allow the department, local governments, and other state agencies to assess the unique environmental risks associated with asset management in a coastal state. This project will focus on assessing the risks using Geographic Information System (GIS) models and overlaying the data with asset inventories and the 10-year state *Transportation Improvement Plan* (TIP) processes. Initial risks include sea level rise and storm surge with the opportunity to add other risks (e.g., inland flooding) as new data become available.

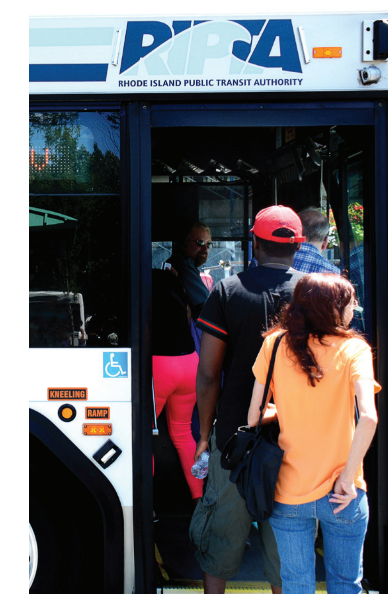
The transit master plan process (initiated in Spring 2018) will generate a detailed program of statewide public transportation investments across a range of modes, including ADA accessible on-demand micro-transit, traditional bus service, Bus Rapid Transit, commuter and intercity bus and rail, paratransit, and public ferry services. The Plan will also identify future hubs and intermodal transfer points, all designed with sea level rise projections in mind. The Bicycle Mobility Plan (BMP) will guide the development of new bicycle-related policies, programs, and infrastructure projects over the next 10 years and beyond. The candidate projects presented in the BMP offer a range of improvements that will improve the bike network and encourage cycling as a transportation choice.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Develop a *Transportation Asset Management Plan* for RIDOT assets that integrates future climate risks into a comprehensive asset management approach for transportation assets to ensure adequate investment and a state of good repair.
- Align the Transportation Improvement Program and *Transportation Asset Management Plan* processes to ensure asset management and risked-based planning for infrastructure maintenance and new projects.
- Update the state land use plan, Land Use 2025 [17], to include climate change and resilience actions for transportation infrastructure and updated goals and priorities set by the Long-Range Transportation Plan.

Public Transportation

OVERVIEW OF VULNERABILITY

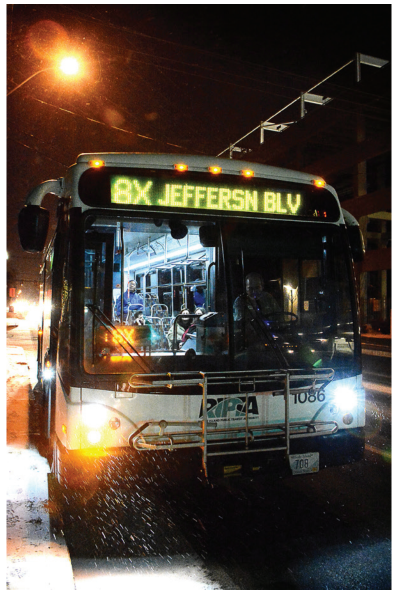


Passengers waiting and boarding RIPTA buses
Photos courtesy of RIPTA

Approximately 15,000 Rhode Islanders rely on public transportation to get to work each day, most riding on RIPTA's statewide bus network. In 2017, RIPTA provided more than 16 million rides overall, including 3 million rides taken by low-income seniors and individuals with disabilities. Service is provided statewide, centered around transit hubs in Providence, Newport, and Pawtucket. At a minimum, limited service is provided in all but three of Rhode Island's 39 municipalities. A fleet of more than 300 buses and vans travels nearly 10 million miles annually, consuming more than 2.3 million gallons of fuel in the provision of this service.

The Division of Statewide Planning's 2015 technical paper *Vulnerability of Transportation Assets to Sea Level Rise* identifies vulnerable transit routes and bus stops. [18] Based on this research, at seven feet of sea level rise, 50 miles of RIPTA route segments and 204 bus stops could be exposed. At seven feet of sea level rise plus a 1% storm surge event, this increases to 119 miles of routing and 753 bus stops exposed. Among bus stops, RIPTA's Newport Gateway hub is the network's most vulnerable asset. Recent resilience enhancements have minimized the hub's vulnerability in the mid-term (i.e., until approximately 2050) but based on current projections this facility will have to be relocated to an upland location prior to 2100. RIPTA's Providence and Pawtucket hubs are planning for future improvements that will take into consideration both short- and long-range sea level rise projections.

CHAPTER TWO



Above: Photo courtesy of RIPTA
Far above: Interstate I-95 near the Providence Place Mall

Other than its hubs and the roadways traveled by RIPTA buses, the public transportation network's most significant assets are its vehicles. RIPTA's asset management planning efforts include assessment of potential vulnerabilities associated with the location of its fleet storage, maintenance, and fueling facilities to minimize the impact of sea level rise. Despite these efforts, the greatest potential threat to Rhode Island's public transit system may be operational. If its transit vehicles cannot be fueled/charged due to extreme weather, RIPTA will be unable to aid in evacuation efforts.

Executive Order 15-17 (2015) and the *Greenhouse Gas Emissions Reduction Plan* call for transitioning toward a zero-carbon transportation sector with considerable focus on vehicle electrification and public-sector leadership in implementing clean transportation strategies. [19] RIPTA is studying potential paths for achieving a zero-emission transit system, for which electrification is currently the most viable option. If Rhode Island's public transportation fleets are to be converted to electric power, additional investments will be needed (i.e., a substantial one-time investment in electric power supply infrastructure at transit facilities) to ensure sufficient charging capacity and operational redundancy during extreme weather events.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In 2012, Hurricane Sandy inflicted substantial damage to the Newport Gateway Center, RIPTA's southern hub and point of entry for tens of thousands of Newport visitors each year. This storm event underscored the importance of transit infrastructure resilience. Reconstruction of the hub integrated forward-looking resilience enhancements, including structural reinforcement and green infrastructure designed to reduce surface runoff and mitigate future flooding impacts.

The 2016 *Greenhouse Gas Emissions Reduction Plan* establishes a role for the transportation sector in meeting Rhode Island's adopted greenhouse gas emissions reduction targets and sets vehicle-miles traveled (VMT) reduction targets of 2% by 2035 and 10% by 2050 and electrification targets of 34% by 2035 and 76% by 2050. [20] Public transportation is a key means of reducing VMT and provides the additional benefits of supporting active transportation and enhancing the mobility of vulnerable populations.

In 2017, RIPTA led a public process for updating Rhode Island's statewide *Human Services Transportation Coordinated Plan*. [21] RIPTA engaged with transportation-disadvantaged residents to identify top priorities for improving transportation options for seniors, individuals with disabilities, and low-income individuals throughout the state.

Rhode Island will receive approximately $14.4 million in Volkswagen settlement funds, which will give the state an opportunity to take important steps toward improving air quality and climate resilience, including the purchase of electric buses and the installation of electric vehicle infrastructure for private vehicles. Under the proposed plan, $10 million will be used to retire and replace approximately 20 diesel buses with new all-electric, zero-emission vehicles. Funds will also be used to install the necessary charging infrastructure for those new buses. RIPTA currently has 73 hybrid buses and with this investment, 36% of the bus fleet will be low and zero-emission vehicles. These investments also support the state's goals in the *Greenhouse Gas Emissions Reduction Plan* relating to VMTs and electric vehicles. In addition, $1.5 million will be used to develop a fast charging station network for light-duty electric vehicles, adding 15 to 30 charging stations in 2020.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Ensure continuity of RIPTA operations following extreme weather events through implementation of backup power generation at key facilities.
- Develop a *Transportation Asset Management Plan* for RIPTA assets that integrates a comprehensive asset management approach to ensure a state of good repair and investments that consider all future climate risks.

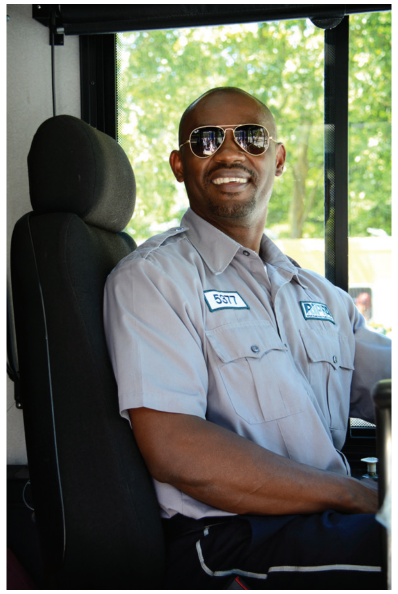


Photo courtesy of RIPTA

CHAPTER TWO

Above: The Arctic Dam in West Warwick during the Great Floods of 2010
Far above: Damage to road near the Warwick Mall

New Ways of Working: Recommendations Across All Critical Infrastructure and Utilities

To build more resilient infrastructure and to better protect existing infrastructure, Rhode Island must continue its efforts to build relationships, establish clear lines of communication, and strengthen coordination among public-sector entities and between the public and private sectors. The positive effects of these efforts are already evident. In early 2018, the Providence Water Supply Board was better able to manage overflow from the Scituate Reservoir's Gainer Dam thanks to its coordination with the National Weather Service and URI. On a larger scale, the existing Critical Infrastructure and Key Resources (CIKR) Advisory Group, a federal initiative that is administered in Rhode Island by RIEMA, provides an avenue for expanding coordination within and between infrastructure sectors with help from staff and managers at key private utilities and state agencies. A key component of the CIKR initiative is understanding and leveraging interdependencies among key infrastructure sectors to ensure that the state prepares for and recovers from climate-related events as quickly as possible. Continuing to recognize and capitalize on these interdependencies through this type of coordination is necessary to achieve stronger, more resilient infrastructure systems.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Ensure that data are consistent across agencies and municipalities. This is critical to maximizing limited resources and capacity. Updating, coordinating, and standardizing foundational resilience data including GIS layers (e.g., STORMTOOLS, critical infrastructure, precipitation projections) and related metadata should be centralized. Hosting coordinated data will provide support for municipal/agency decision-making on infrastructure/public facility investments.
- Develop a tracking system for implementation of identified actions to measure progress and demonstrate alignment with EC4 climate resilience goals.
- Build relationships and learn from climate adaption efforts in neighboring states to accelerate technical assistance to municipalities for local implementation. Rhode Island should look to the region for examples of how to model municipal and nonprofit partnerships that move from planning to prioritized project identification and funding.

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CHAPTER THREE

Natural Systems

Fort Wetherhill State Park in Jamestown
Opposite page: Durfee Hill Wildlife Management Area in Glocester
Photos courtesy of RIDEM

Natural systems are undeveloped portions of the environment that provide important functions and services to communities.

“Natural systems” describes many different scales and locations. Whether a large tract of contiguous inland forest or a small fringing salt marsh along a heavily developed shoreline, natural systems are the undeveloped portions of the environment that do not contain engineered or manmade components, but still provide important functions and services to communities. Coastal natural systems help to buffer coastal development from storms and flooding. Inland natural systems provide benefits in the form of carbon storage and flood abatement. Both coastally and inland, vegetation and soil intercept and treat stormwater and improve water quality.

Preserving these systems and the functions and services they provide is vital to increasing Rhode Island’s overall resilience to climate change and can be viewed as a two-fold effort. First, valuable components of natural systems must be protected from future development through regulations, acquisition, and incentives. Second, degraded natural systems must be enhanced and restored to increase their ability to adapt to changing conditions.

This chapter explores coastal and inland natural systems across the state and provides recommendations for the protection, enhancement, and restoration of systems vulnerable to climate change. Without intervention, climate change may cause significant and irreversible damage to some of these systems, which are key to the state’s environmental and economic health.

COASTAL

Natural or undeveloped shorelines are areas along the shore that do not contain structures or infrastructure and are composed of bedrock or unconsolidated sediments and vegetation. These shorelines provide a spatial buffer and protection for the built environment against erosion, coastal flooding, sea level rise, and storm surge. Vegetation is often a key component of this protective function, as root systems help to hold sediment in place and aboveground structures reduce the energy of incoming waves.

Natural coastal areas face many threats from the impacts of climate change such as increased storm surge, erosion, coastal flooding, and sea level rise. These areas are also often the first line of defense for coastal communities. The desirability of these areas for their natural beauty makes them highly susceptible to development pressure as well. Shoreline development can interfere with natural coastal processes and place additional stress on these already threatened areas.

Shoreline along Ninigret Pond from East Beach in Charlestown, photo courtesy of RIDEM

Coastal Wetlands

OVERVIEW OF VULNERABILITY

For the purposes of this Strategy, "coastal wetlands" includes tidally-influenced, vegetated salt and brackish marshes. Also addressed in this chapter are undeveloped low-lying coastal upland areas adjacent to coastal wetlands, which provide potential corridors for future inland marsh migration with sea level rise.

Coastal wetlands are important ecosystems that provide a range of valuable services to coastal communities. Vegetated coastal wetlands have been shown to reduce storm surge duration and height by providing storage area for water. For example, areas that contained wetlands had an average of 10% reduction in damages from Hurricane Sandy (2012) when compared to those without wetlands. Coastal wetlands were also predicted to have reduced wave heights during the storm across 80% of the northeastern coastal floodplain.

The frequency and duration of tidal flooding are critical factors that define the chemical, physical, and biological characteristics of coastal wetlands. Salt and brackish marsh vegetation communities are adapted to regular tidal flooding and varying degrees of salinity. Marshes are highly productive systems that increase in elevation via the accumulation of organic matter and sediments that are deposited by the incoming tides. Historically, this process of vertical accretion has allowed vegetated marshes to persist despite steady increases in sea levels over time. However, there is evidence that marsh accretion rates in Rhode Island are insufficient to keep pace with the increased rate of sea level rise due to climate change observed in recent decades. This is evident both from direct measurements of sea level rise and accretion rates, as well as observed changes in marsh vegetation communities over time.

As sea levels continue to rise and the area of tidal influence moves farther inland, it is anticipated that many marshes in the state will become permanently submerged and convert to subtidal habitat. As low-lying upland areas become tidally inundated more frequently, they will also likely convert to tidal wetland habitat. While some evidence of marsh migration or marsh transgression has been observed in Rhode Island, there is significant uncertainty as to the rate and extent to which new marsh areas will develop as sea levels rise. Development in these low-lying upland areas is an impediment to future marsh migration in many locations. State coastal regulations prohibit development in coastal wetlands, however low-lying upland areas that could serve as future marsh migration corridors are not always protected under current regulatory programs.

CURRENT AND PLANNED RESILIENCE INITIATIVES

There have been several coordinated efforts to assess the vulnerability of Rhode Island's coastal wetlands to sea level rise at multiple scales. The Sea Level Affecting Marshes Model (SLAMM) has been applied statewide to predict impacts of future sea level rise to coastal wetlands and low-lying upland areas. The resulting maps are available from the Coastal Resources Management Council (CRMC) and are being used as planning tools for managing coastal development. SLAMM results have also been used to identify areas at risk for future marsh loss and potential areas of marsh migration. Within marsh migration areas, the CRMC has worked with municipalities and nonprofit organizations to identify opportunities for management actions, such as land conservation or removal of structural barriers (e.g., abandoned foundations and failing walls).

Recent statewide monitoring efforts by Save The Bay and the Narragansett Bay Estuarine Research Reserve have focused on sea level rise impacts and marsh migration. *A Strategy for Developing a Salt Marsh Monitoring and Assessment Program for the State of Rhode Island* was also developed in 2016 by the Narragansett Bay Estuarine Research Reserve, Save The Bay, and the CRMC. [1] This strategy is being implemented with additional partners including the Rhode Island Natural History Survey and the Rhode Island Department of Environmental Management (RIDEM) and will track changes to these important habitats over time. Monitoring results will inform policy and management decisions.

In addition, multiple management practices have been implemented that could increase the resilience of coastal wetlands across the state. Some practices focus on improving in-marsh conditions through adjustments to hydrology or the addition of sediment to increase surface elevations. The goal of these practices is to provide short-term benefits and preserve existing marsh habitats. Other practices focus on preserving and managing low-lying upland areas to accommodate marsh migration as sea levels rise and include land conservation, adjustments to land use practices, and the removal of barriers to future marsh migration (e.g., derelict hardened structures). The goals of these practices are to provide long-term benefits, preserve coastal wetland functions amid changing environmental conditions, and minimize development in areas that will be tidally flooded in the future. *Rhode Island Coastal Wetland Restoration Strategy*, a framework for implementing these various practices, was developed in 2018 by the CRMC and the Rhode Island Natural History Survey. [2]

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Continue monitoring and assessment of coastal wetland habitats and management practices to evaluate and prioritize future actions. Statewide models, such as the Sea Level Affecting Marshes Model (SLAMM), should be updated to identify opportunities for restoration and assist in planning for future marsh migration. To minimize loss and preserve the benefits of coastal wetland habitats, conservation and management must be approached at multiple scales and timeframes.
- Identify opportunities for retreat and infrastructure removal on state-owned properties, which can serve as demonstration sites for shoreline adaptation. State agencies and their partners should continue to work with municipalities to identify opportunities for retreat, removal of derelict infrastructure, and enhancement of natural shoreline areas. Where possible, retreat rather than fortification should be emphasized as a coastal adaptation strategy. Implemented restoration projects should continue to be monitored to evaluate the effectiveness of different restoration practices.

Kenny Raposa from the Narragansett Bay Estuarine Research Reserve conducts a study on coastal marsh adaptation strategies, photo courtesy of RIDEM

Above: Charlestown State Beach Breachway
Far above: Misquamicut State Beach
Photos courtesy of RIDEM

Beaches and Barriers

OVERVIEW OF VULNERABILITY

Coastal beaches and barriers are dynamic systems that define much of Rhode Island's south-facing shore and are popular recreational destinations for residents and visitors. These habitats also provide a suite of other functions and values, such as the interception and treatment of upland stormwater runoff, aesthetic enhancement, and habitat for fish and wildlife.

Coastal beaches, dunes, and barriers also respond to storm surge, wave energy, and sea level rise. These features are comprised of sediment that has been eroded from the coastline and redeposited as sand, gravel, or cobble along the shore. In a natural state, these resilient features constantly shift sediment between offshore bars, the beach berm, sand dunes, and washover fans, creating a protective front line for the adjacent inland areas. Beaches and barriers migrate; if there is an ample supply of sediment they may accrete seaward. Rhode Island beaches are sediment starved, so they generally migrate landward.

Beaches and barriers are most resilient to sea level rise impacts when coastal processes are unimpeded, particularly in undeveloped areas. Risk for erosion impacts increase when development is present on barriers and lands adjacent to beaches. In these cases, beaches and barriers narrow rather than migrate. This process is exacerbated by the presence of hard shoreline structures, such as sea walls and revetments.

CURRENT AND PLANNED RESILIENCE INITIATIVES

Coastal regulations and policy currently protect undeveloped areas from human interventions that would reduce the effectiveness of beaches and dunes as storm buffers for the upland areas or downgrade their habitat value. Allowing washover fans to increase in height and extent is an important factor in increasing resilience to sea level rise.

After Hurricane Sandy (2012), the Town of Westerly undertook several initiatives to increase coastal resilience where inland migration was not an option. This included beneficial reuse of the overwash sediment that covered Atlantic Avenue and needed to be removed in order to open the road. The Town removed the sediment, screened it to remove debris, and restored dunes along ~2.5 miles of developed shoreline. The dunes were enhanced in front of state and town beaches and 71 private properties.

The Army Corps of Engineers replenished Misquamicut State Beach using 84,000 cubic yards of sand at a cost of $3.1 million. The CRMC together with Eastern Connecticut State University are currently monitoring the project to track sediment loss and migration and to determine the efficacy of the project. Various smaller beach replenishment and dune restoration projects have been completed throughout the state, including Save the Bay's project to remove infrastructure at road ends and create infiltration trenches and rain gardens as well as restore small dunes and reorient paths through dunes in order to diminish storm surge. Additionally, the Town of Middletown recently completed a project that reconfigured pathways through the dunes at Third Beach to minimize the formation of storm surge channels. Removable mats have been installed to provide access across the dunes and beach grass has been planted to enhance the accumulation of sand in the dunes. Snow fencing is also being used in the offseason.

East Beach in Charlestown,
photo courtesy of RIDEM

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Preserve the dynamic nature of beaches and barriers in future management of these critical natural systems. Differentiation between developed and undeveloped systems is necessary when considering management approaches. New development should be minimized in undeveloped beach and dune areas and retreat incentivized as a coastal adaptation strategy where possible.
- Develop initiatives for coastal resilience activities, such as monitoring existing pilot projects, developing offshore sand sources suitable for beach replenishment, prioritizing beaches to be re-nourished, and creating beach and barrier migration pathways through property acquisition and relocation of structures.

Above: Big River Management Area in West Greenwich
Far above: Wixaboxet Wildlife Management Area in West Greenwich
Photos courtesy of RIDEM

INLAND

Forests

OVERVIEW OF VULNERABILITY

Rhode Island's forests provide numerous economic, recreational, ecological, and human health benefits for the state. Approximately 55% of the state is forested (around 360,000 acres). These forests contribute to significant natural resources and ecological services, including drinking water sources. Additional benefits include soil health and conservation, carbon sequestration and improved air quality, and wildlife habitat. In urban areas, trees influence thermal comfort, energy use, and air quality by providing shade, transpiring moisture, and reducing wind speeds.

However, Rhode Island's urban and rural forests are susceptible to a changing climate and the impacts are already beginning to take shape. Around 26% of Providence's street trees are ash, which will need to be treated or removed due to infestation from the Emerald Ash Borer, a non-native insect, within the next 5-10 years. This reduction in tree canopy will have quality of life and direct environmental impacts in urban areas.

Evidence suggests that climate change may already be affecting Rhode Island's ecosystems, as plant and animal distributions change, ecological lifecycles are disrupted, and community compositions and structures are altered. Species and populations of plants and animals particularly vulnerable to changing climate, especially those with highly specialized habitat requirements or other narrow environmental tolerances, as well as currently isolated, rare, or declining populations with poor dispersal abilities and groups especially sensitive to pathogens. Changing precipitation patterns are also leading to moisture stress and drought

during the growing season and stressed forests and vegetation are at increased risk of blowdown during intense storms.

RIDEM has several large preserved forest tracts in the western part of the state that play an important role in providing recreation and associated natural resource benefits. Although there is more forest acreage in Rhode Island today than there was 100 years ago, few areas contain core habitats large enough to support the full complement of expected species. The age and structure of forests influence the composition of plant and animal communities that occupy these habitats. Fish and wildlife rely on habitat connectivity to find scarce resources, preserve gene flow, and locate alternatives to lost habitat. Connectivity is vital to maintaining plant and animal diversity, particularly given the uncertainties of climate change on future habitat conditions.

Arcadia Management Area in Exeter/Richmond/Hopkinton, photo courtesy of RIDEM

Planting and maintaining the health of existing trees in Rhode Island's urban environment is an adaptive strategy (e.g., to provide cooling via shade) as well as a mitigative strategy (e.g., to reduce carbon dioxide, which is absorbed during tree growth). Urban forests provide a multitude of benefits, including soil stabilization and flood mitigation in areas of high impervious surface. Ecological benefits include water quality, soil conservation, air quality, and wildlife habitat. Urban trees also give a sense of pride to communities and bring people together for planting, care, and recreation. Other benefits include aesthetic improvement and public health and welfare. These forests are an essential component of green infrastructure and provide food and cover for urban wildlife as well as migrant species needing to rest and refuel. However, the care and management of many urban forests can be complicated by natural and social factors, many of which are exacerbated by climate change, including insects and diseases, natural catastrophic events (e.g., ice storms, wind storms, hurricanes), invasive plants, development, air pollution, impaired soil health, lack of adequate management, and other social factors. As urban expansion continues, these challenges are likely to increase and new ones are likely to emerge.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In 2010, the Division of Forest Environment developed a forest action plan, *Rhode Island Forest Resources Assessment and Strategies: A Path to Tomorrow's Forests.* [3] The Plan established a vision, goals, and policies for the management of tree and forest resources within the state across three broad themes: (1) to maintain forestland area and minimize further fragmentation of forest resources through innovative land conservation and management techniques; (2) to monitor and respond to forest health threats to avoid unacceptable loses to the state's forest resources; and (3) to promote sustainable management of forests that provides a wide range of benefits. A 2015/2016 update to the plan included a resilience-focused addendum, "Forest Mitigation and Adaption to Climate Change." The addendum does not promote radical change from past policy, instead it builds on the findings and recommendation proposed in the original plan. The full forest action plan is due to be updated in 2020.

George Washington Management Area in Glocester, photo courtesy of RIDEM

The Division of Forest Environment also led a study in 2014 to assess Rhode Island's forest canopy cover from late 2013 to 2014. [4] The resulting report, *i-Tree Canopy Cover Assessment and Tree Benefits Analysis Report*, highlighted the significance of canopy cover and the important role trees place in the state's environmental, economic, and aesthetic well-being.

In 2015, RIDEM with assistance from the Rhode Island Chapter of the Nature Conservancy and the University of Rhode Island (URI) published a comprehensive plan that provides direction to and coordination of wildlife conservation efforts. [5] The *Rhode Island Wildlife Action Plan* brought in millions of dollars in matching funds for conservation of non-game species and their habitats. It also established new local and regional partnerships and increased support for statewide conservation priorities.

Other conservation efforts have included the Rhode Island Woodland Partnership (RIWP), a collaboration among foresters, landowners, conservationists, and professionals who represent public agencies, small businesses, and nonprofit organizations. In 2015 and 2017, RIWP issued two position papers on the role of forests in mitigating and adapting to climate change in Rhode Island and the importance of preventing the loss of the state's forests. [6]

In 2016, the New England Governors and Eastern Canadian Premiers (NEG-ECP) adopted Resolution 40-3 *Resolution on Ecological Connectivity, Adaptation to Climate Change and Biodiversity Conservation*, which promotes the importance of maintaining and restoring ecological connectivity to boost the resilience of the region's native ecosystems and biodiversity and provide sustainable economic and social benefits. The resolution instructed impacted New England states, which includes Rhode Island, to elevate ecological connectivity in their respective activities and plans. The impacted states are charged with collaborating to promote the vitality of the region's forested landscape and provide recommendations to the NEG-ECP through 2020.

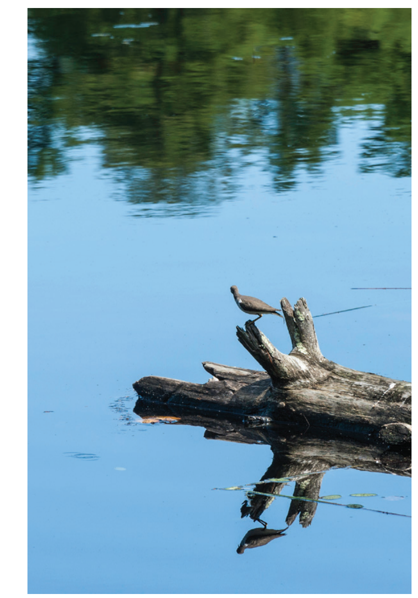
RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Encourage protection of significant portions of the remaining intact forest cover in Rhode Island and conserve the landscape values of larger, unbroken tracts of land. This will require considerable collaboration with private landowners, who own about 72% of the forested land area in Rhode Island, as well as creative sustainable investment ideas.
- Incentivize the creation of Forest Stewardship Plans to help protect soil and water quality, fish and wildlife habitat, timber and other wood products, and outdoor recreation. Landowners with completed/updated Forest Stewardship Plans can take advantage of the Farm, Forest, and Open Space Act, which can provide significant reductions in property taxes.
- Support municipalities in developing urban tree inventories and implementing urban forest master plans with a goal toward mitigating increased urban heat.

Water Resources (Rivers and Streams, Lakes and Ponds, Wetlands)

OVERVIEW OF VULNERABILITY

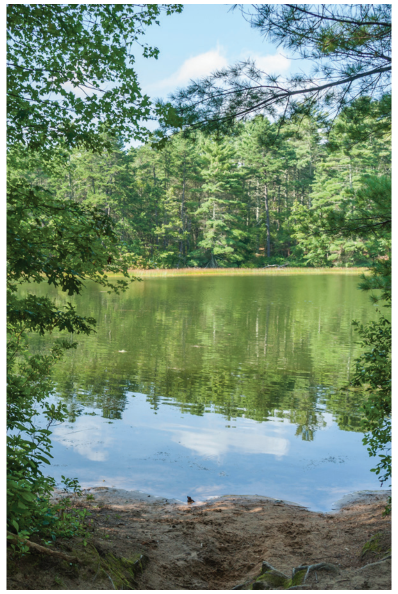
Rhode Island's landscape includes hundreds of freshwater lakes and ponds covering around 20,749 acres. These waterbodies provide multiple recreational opportunities, important aquatic habitat, and a reliable source of drinking water supply for a majority of residents. RIDEM estimates 75% of lakes 20 acres and larger are manmade impoundments. Forty-three reservoirs, lakes, or ponds covering 7,823 acres, or 37% of the statewide lake acreage, are designated as public drinking water sources. This includes the state's largest freshwater body, the Scituate Reservoir, which provides water to the Providence metro area (about 60% of Rhode Island's residents) and several surrounding suburban communities. Surface drinking water reservoirs supply 85% of public water in Rhode Island.



Arcadia Managment Area,
Above: Breakheart Pond in Exeter
Far above: Stepstone Falls in West Greenwich
Photos courtesy of RIDEM

Rivers and streams cannot be disconnected from lakes and ponds because most are manmade, formed by impounding rivers. Rhode Island has about 1,400 miles of rivers and streams, of which 86% are small headwater streams. Climate change is recognized as a threat to all aquatic habitats with cold water streams, freshwater marshes, and vernal pools among the most vulnerable upland resources.

Freshwater wetlands exist in areas where the groundwater table is close to the surface and often in proximity with rivers, lakes, ponds, and streams. An estimated 88,052 acres (approximately 12.8% of the state) are composed of freshwater wetlands, including swamps, marshes, bogs, and fens, with forested swamps the most abundant wetland type. Freshwater wetlands will be affected by climate change due to changes in hydrology. The hydroperiod of vernal pools may shorten, affecting the breeding success of species dependent on this habitat, such as amphibians. Changing conditions may also bring about shifts in the plant community as previously wetter areas dry out. For example, marshes and swamps may contract inward toward areas where water



Black Farm Wildlife Management Area in Hopkinton, photo courtesy of RIDEM

is deeper or more reliable. Larger wetlands may become fragmented and floodplain forests may suffer damage from more frequent intense storms. Maintaining healthy wetlands across Rhode Island is more important than ever given changing precipitation patterns.

Climate change can have a variety of impacts on water quality, quantity, and aquatic ecosystems. Water resources are highly vulnerable to impacts from warming water temperatures, changing precipitation patterns, greater storm water runoff, flooded wetlands, and increasing impacts to cold water habitats. This reinforces the need for long-term monitoring in waters and habitats that are most vulnerable.

With growing recognition of climate change impacts on riverine systems and floodplains, preservation and restoration of natural river systems are a critical means to promote resilience. These efforts must align with related flood prevention and mitigation activities occurring on the local and state level.

CURRENT AND PLANNED RESILIENCE INITIATIVES

Rhode Island Water 2030, published in 2012, addresses planning for all drinking water used in the state. It highlights the need to plan for the availability of water, to reduce the overall demand for drinking water, and to increase protection of all drinking water sources both public and private. [7] It also includes the state's drought management plan, which is overseen by the Rhode Island Water Resources Board (WRB) as advised by a Drought Steering Committee (DSC). In addition, Water 2030 incorporates aspects of the WRB's 2012 Strategic Plan which presents statewide and regional water resource management initiatives to address near-term and long-term needs. The Strategic Plan is supported by statewide assessments of risk and supplemental water supply options as well as a statewide assessment of water use and resource availability.

In the same year, RIDEM released a report on Rhode Island's freshwater lakes and ponds, *Rhode Island Freshwater Lakes and Ponds: Aquatic Invasive Plants and Water Quality Concerns* [8]. Recognizing that many of these sources supply drinking water for a majority of the state, the report was intended to drive an informed discussion on how to protect the state's freshwater resources.

The state released a water quality management plan, *Water Quality 2035*, in October 2016 to support statewide and coastal water quality and aquatic habitat management programs. [9] It stresses the need for careful management of fresh and salt water resources and describes existing known and potential pollution sources, management strategies and programs, and recommended actions for protection and restoration. With the plan completed, the state is now focused on implementation.

In a 2017 study of the Narragansett Bay watershed, the Narragansett Bay Estuary Program found that climate change is affecting air and water temperatures, precipitation, sea level, and estuarine fish communities. [10] The report also highlights the increasing rate of change being observed and projections for future climate impacts within watershed.

The *Rhode Island Freshwater Wetland Monitoring and Assessment Plan*, completed in 2006, guides wetland monitoring activities across Rhode Island. [11] RIDEM, in collaboration with CRMC and the Rhode Island Natural History Survey, utilized funding from the Environmental Protection Agency to implement the plan and refine wetland monitoring strategies. Recent efforts have focused on monitoring and assessing wetland resources near the coast and in other ecologically high value areas. Monitoring yields baseline data to measure changes in wetlands that may result from a changing climate or other stressors. This data helps to identify impacts presently occurring and informs planning for future restoration projects.

Round Top Wildlife Management Area in Burriville, photo courtesy of RIDEM

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Identify and assess inland riparian buffer conditions statewide (e.g., using aerial photos and field reconnaissance). Identifying and mapping small headwater streams and their riparian buffers should be a high priority. These areas can be more effectively protected by state and local land use policies/regulations once they are identified. The assessment can also be used to develop priority areas for buffer restoration and protection.
- Develop a comprehensive environmental monitoring strategy, prioritize gaps, and continue to strengthen coordination of upland water resource monitoring activities. Monitoring programs should be aligned with regional data collection strategies relating to climate change, aquatic ecosystems, and water quality.

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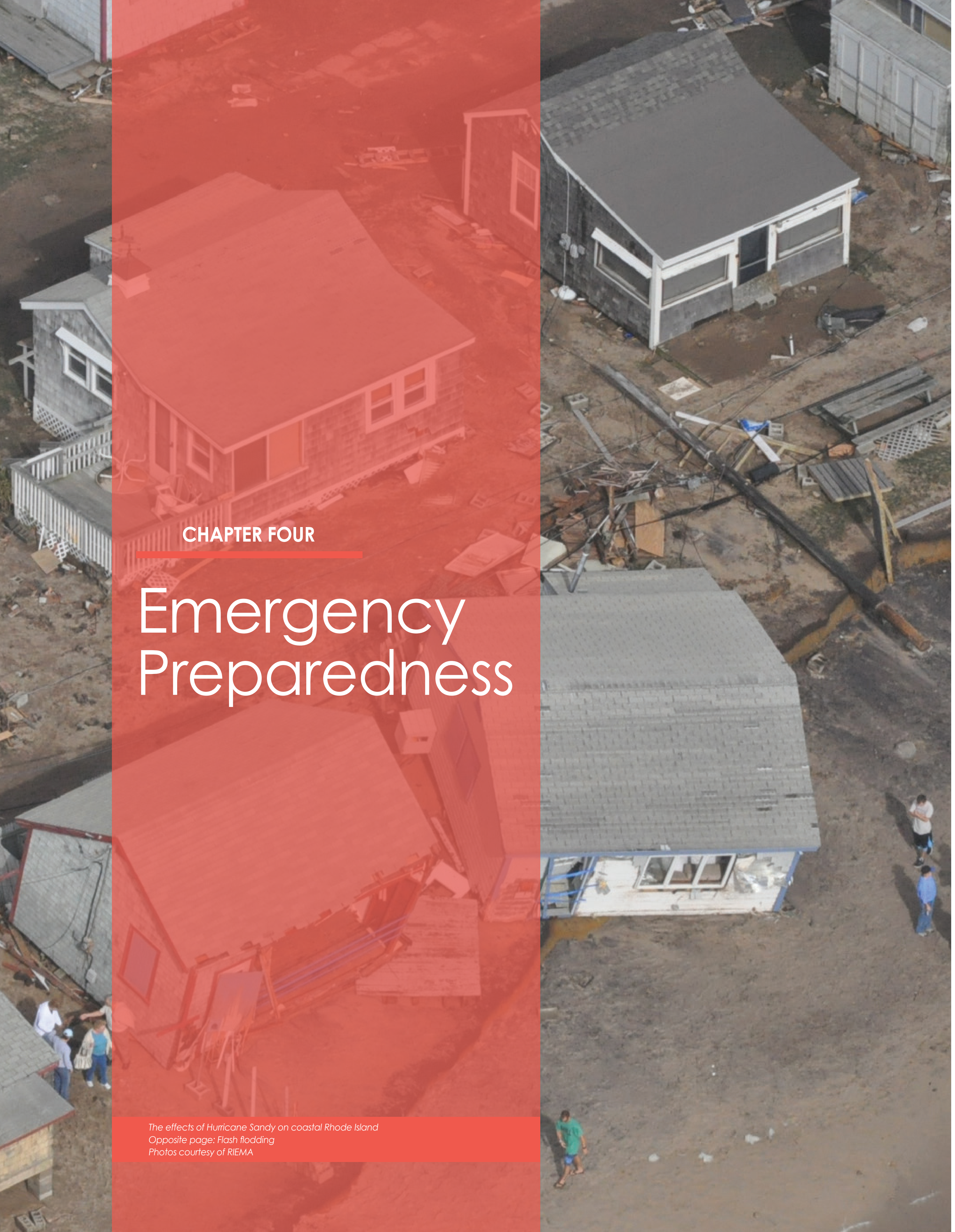


CHAPTER FOUR

Emergency Preparedness

The effects of Hurricane Sandy on coastal Rhode Island
Opposite page: Flash flooding
Photos courtesy of RIEMA

Preparedness and resilience efforts are necessary to protect the people, infrastructure, and economy of the state.

Rhode Island is already experiencing the effects of climate change in coastal communities with sea levels rising, more frequent flooding events, and increasing impacts on buildings and infrastructure. Preparedness and resilience efforts are necessary to protect the people, infrastructure, and economy of the state. The Rhode Island Emergency Management Agency (RIEMA) and others have taken steps to improve the state's resilience to climate change and future disasters through planning and preparedness activities, trainings and exercises, and adaptation and mitigation programs.

RIEMA is responsible for establishing, sustaining, and coordinating the resources of the federal, state, and local governments, nonprofit organizations, and the private sector to effectively meet the challenges faced during natural, human-caused, and/or technological incidents. These actions are listed in the Rhode Island Hazard Identification Risk Analysis (HIRA) and accomplished through the Governor's authority. The agency's primary goal is to create and oversee a comprehensive statewide system with an all-hazards approach in prevention, mitigation, response, and recovery. RIEMA is also responsible for strengthening the 31 core capabilities outlined by the National Preparedness Goal to reduce loss of life and property within the state during natural and/or man-made incidents.

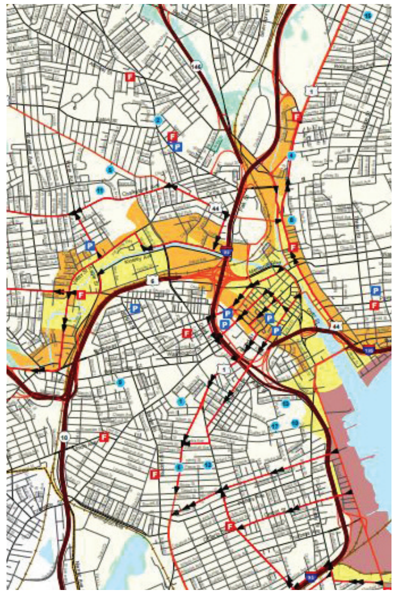
In addition, RIEMA administers the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Assistance grant programs that assist communities in taking mitigation actions that are long-term, cost-effective, and environmentally sound to protect life, property, and the environment from future disaster damages. The state assists municipalities with local mitigation planning to help identify policies, activities, and tools to reduce their risks from natural hazards. Through training and exercises, RIEMA is able to teach preparedness, response, and recovery strategies to minimize the impacts that severe weather events and climate change can have on communities, property, and infrastructure.

RIEMA implements this work in partnership with a wide range of agencies, organizations, and local communities, including FEMA, Rhode Island Department of Health (RIDOH), American Red Cross, and first responders. This chapter will explore climate change-related impacts on emergency systems and structures and the critical roles these entities play in strengthening resilience across the state in three specific areas: evacuation shelters and routes, building design and construction, and emergency services.

Evacuation Shelters and Routes

OVERVIEW OF VULNERABILITY

Many of Rhode Island's roads are located close to the shoreline and are vulnerable to damage from sea level rise and coastal erosion during storm events. (See Chapter 2: Critical Infrastructure and Utilities for additional information on the vulnerability of roads.) A 2015 study by the Rhode Island Statewide Planning



City of Providence evacuation map

Program identified roads under state jurisdiction that will be inundated by five feet of sea level rise. [1] There are ten locations that are considered the most vulnerable and nine are hurricane evacuation routes.

Rhode Island also has a high population of vulnerable individuals who depend on emergency shelters and services for basic needs during major storm events. If evacuation routes become impassable, emergency responders may be unable to reach vulnerable individuals in a timely manner. Preparing for sea level rise and coastal hazards by building resilience into roadways and transportation infrastructure is essential to protect vulnerable residents from isolation in the event of disasters.

CURRENT AND PLANNED RESILIENCE INITIATIVES

Rhode Island has completed a FEMA and US Army Corps of Engineers Hurricane Evacuation Study for the 21 coastal communities. This study includes assessment of evacuation zones, routes, and clearance times for each community.

The state's *Evacuation Plan* provides an operational framework for coordinating with local authorities to support safe and orderly evacuation from vulnerable zones. The Plan also requires that the cities and towns maintain their own local evacuation plans.

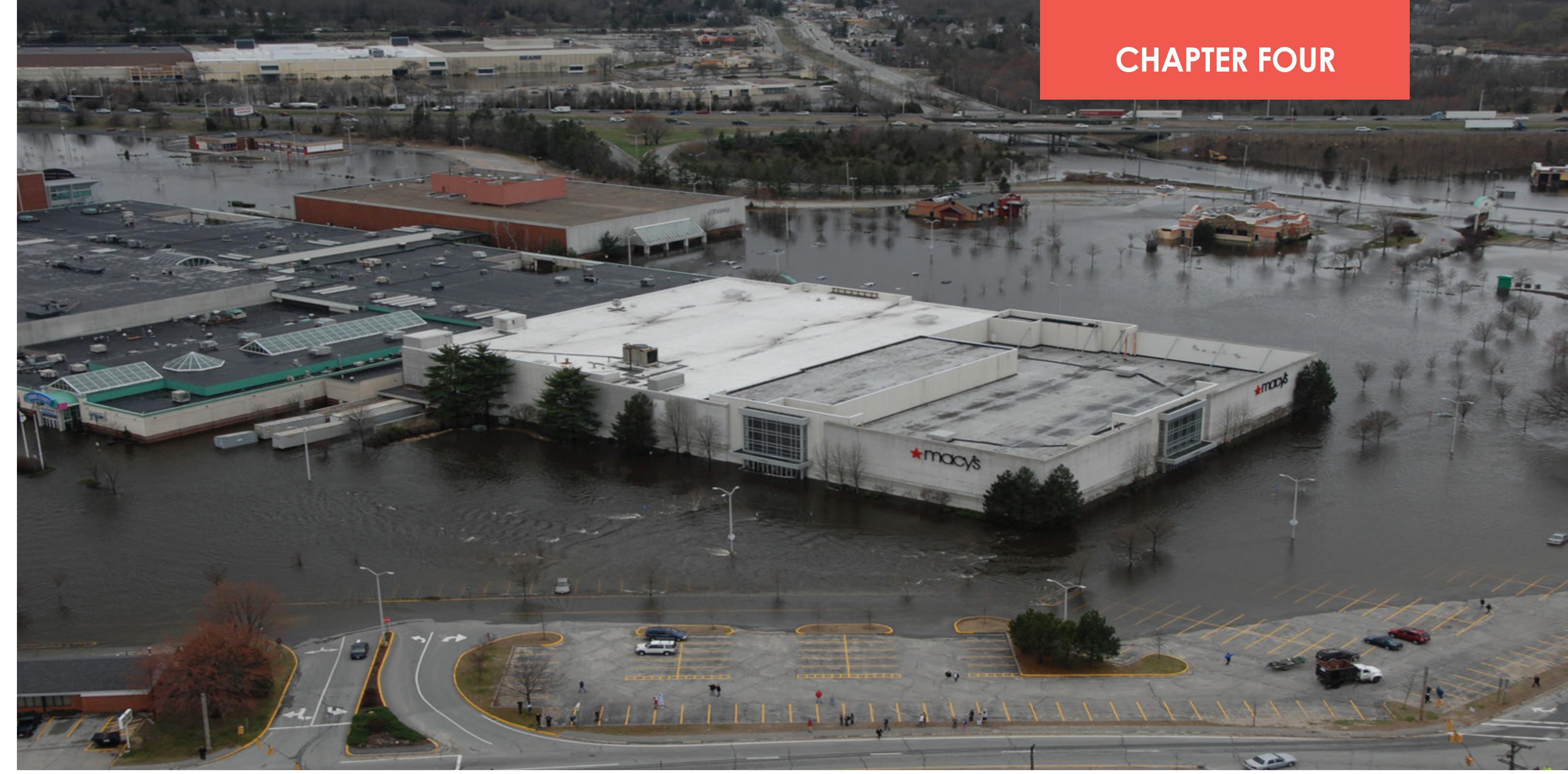
The *Shelter and Coordination Plan* outlines the operational concepts, responsibilities, procedures, and organizational arrangements necessary to support the sheltering needs of the population, including people with disabilities and individuals with access and functional needs.

Historically, shelters and warming/cooling centers have not been utilized to their full potential during times of disaster. As climate change impacts and severe weather events increase across the state, there will likely be greater demands placed on sheltering services. The American Red Cross last conducted shelter facility surveys in 2012 and these facilities need to be reassessed as soon as possible. Cities and towns often change their lists of shelters and warming/cooling centers, so it is crucial to have a current list of facilities and confirmation of sufficient sites with capacity for evacuation and overnight stays. All locations should also follow the sheltering guidelines laid out by the state.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Prioritize protection of the local fuel supply along evacuation routes during climate-related disasters. During Hurricane Irma (2017) in Florida, the large number of residents attempting to evacuate at the same time created a burden on the fuel supply and many evacuees were stranded without fuel, stalling their evacuation, and increasing calls for assistance from emergency services personnel.
- Inform residents of evacuation routes and shelter locations in the event of severe weather necessitating an evacuation. Some evacuation routes within the state have been altered, changed, and revised since the last update.
- Conduct a statewide reassessment of evacuation routes and the associated signage. Implementing a public outreach initiative to inform citizens about evacuation routes and shelter locations through homeowner associations, nonprofit organizations, and state and local governments will help citizens become more resilient to the impacts of a changing climate.

CHAPTER FOUR



Building Design and Construction

OVERVIEW OF VULNERABILITY

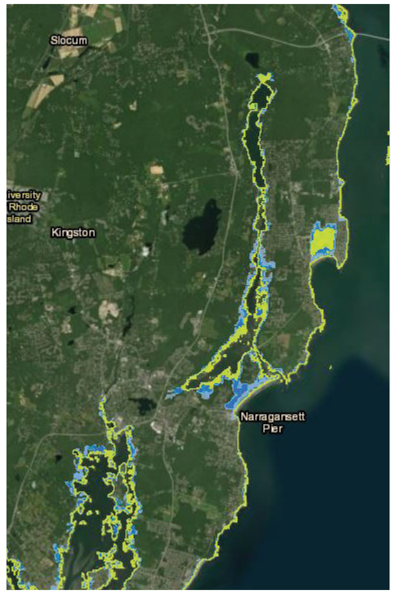
With increased frequency and intensity of storms, sea level rise, and other climate-related impacts, the infrastructure of critical facilities as well as residential and commercial buildings are at risk.

Building codes address a multitude of concerns including public health and safety and environmental protection. The codes set minimum requirements for building design and construction as well as offer enhanced protection against the threats of natural disasters. Proactive building codes can help make communities more resilient, sustainable, and livable while lowering the costs of mitigation actions for building owners.

Building codes act as a baseline for the insurance industry when estimating and managing risk. State and local governments that adopt and enforce updated codes ensure that the most current knowledge is a fundamental part of new buildings in their jurisdictions. Model codes adopted statewide, as well as their updates, provide straightforward guidance for state and local legislatures who want to have current building regulations. These codes represent the views of all relevant parties and are developed in a rigorous participatory process. All stakeholders involved in the process can offer amendments, such as how and where to build in flood plains and how to construct buildings that can better withstand natural and manmade disasters. In addition to vetting by the stakeholders, the state's process includes notice to the public. Rhode Island currently utilizes the 2013 Building Code and the 2017 International Building Code is available for adoption. Updated building codes allow buildings to be adapted, keeping a sense of community by reducing the number of outdated and unused buildings.

Rhode Island has 100% municipal participation in the National Flood Insurance Program (NFIP), which provides all communities

Above: The effects of Hurricane Sandy
Far above: The Warwick Mall during the Great Floods of 2010. Photos courtesy of RIEMA



Screenshot of the STORMTOOLS platform

an opportunity to participate in the Community Rating System (CRS) program. The CRS is an incentive program that rewards communities for going above and beyond the minimum regulations of the NFIP by providing credit points in the form of a discount for NFIP policyholders. The better the class, the higher the discount. Since the state Building Code is not currently up to date, CRS communities are in jeopardy of losing additional discounts that are only available to those who adopt and enforce the most current codes, which include disaster preparedness and recovery.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In May 2016, House Resolution R-8267 called on the state to investigate the feasibility and fiscal ramifications for implementing a Flood Audit Program. The intent was to develop a program similar to an energy audit, but specifically for flooding on a statewide level. Theoretically, flood audits would be performed to strengthen the resilience of residents and communities to coastal and inland flooding. This would be accomplished by assessing structures on a case-by-case basis and providing information, education, and a suite of mitigation recommendations to property owners who are at risk for flooding.

The CRMC, in conjunction with URI, is developing a visualization tool and a Coastal Environmental Risk Index (CERI) that summarizes the risks coastal areas face from storm induced flooding and the associated wave environment, sea level rise, and shoreline erosion/accretion. These risks represent the principal environmental variables that dominate the physical aspects of coastal vulnerability. The CRMC and URI are also collaborating to develop and provide easily accessible design elevation maps based on the STORMTOOLS platform. These maps will provide the CRMC applicants, state agencies, municipalities, and others with recommended design elevations that account for risks associated with extreme weather events and sea level rise. With this information, the user can decide whether they want to voluntarily exceed minimum elevation requirements for public and private structures and infrastructure.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Improve predictions of facility-level impacts of approaching storms. Predictions days before a storm makes landfall will assist facilities in their preparedness efforts. By developing a more resilient facility, the cascading effects to other facilities and services can be eliminated, resulting in a more resilient community that is better able to provide services to its residents before, during, and after major storms.
- Complete in-depth vulnerability assessments and three-dimensional visualizations of storm impacts for Rhode Island's critical facilities under any storm conditions, including unprecedented events, like Hurricane Harvey or Irma (2017).
- Develop more realistic storm preparedness training for facility managers and emergency managers. Traditionally, FEMA storm training simulations make trainees respond to impacts without considering when the impact would be triggered by a storm. Determining the exact storm force that causes an impact will allow training simulations to input impacts in the same chronological order as a real storm.

CHAPTER FOUR

Emergency Services

OVERVIEW OF VULNERABILITY

Support provided by emergency services is crucial to emergency preparedness and response during climate-related disasters. Emergency services personnel and facilities represent the first line of response in assisting residents impacted by disasters. The ability of police, fire, and emergency medical services (EMS) to operate during and immediately after disasters is highly dependent on the conditions of the roads, the availability of adequate equipment, staffing, and their facilities' resilience to the impacts of flooding, wind damage, and loss of power. Municipal-owned facilities, including police and fire stations, are often a hub for local disaster preparedness and many fire and police personnel are involved in emergency planning, management, and Emergency Operations Center (EOC) operations. Town facilities, such as schools and senior centers, are frequently used as warming/cooling centers and emergency shelters, while police and fire stations often serve as disaster response headquarters and EOCs.

The ability to provide essential services during and immediately following disasters is critical to the response and recovery of Rhode Island communities. Recent facility assessments in coastal communities have identified weather-related impacts as significant hazards to the functioning of emergency services with direct effects on communications and response. For example, radio antennas are vulnerable to damage from high-wind storms and access to sections of communities can be impacted by downed trees and flooded streets.

Above: A hurricane response exercise at Rhode Island Emergency Managment Agency
Far above: A FEMA briefing for Rhode Island Congressional staffers

Goddard Memorial State Park Farmers Market, photo courtesy of RIDEM

Food is also a critical component of emergency preparedness. The bulk of food consumed in Rhode Island is grown or processed elsewhere, in places like California and South America, which are predicted to experience extreme changes in weather because of climate change, including massive drought conditions already being felt today. This underscores the importance of efforts to increase reliance on locally and regionally produced foods, in line with the Food Solutions New England 50% by 2060 vision. However, the changing climate will also have measurable effects on food production in Rhode Island. It will alter soil quality, what crops can be sustainably grown, and what land is available for crop production. Irrigation practices on fields and livestock may also be impacted as well as changes in which pests and diseases affect crops and livestock.

Rhode Island is already seeing changes in the fish species available for wild harvest. This will affect management of the wild harvest seafood industry and the profitability of one of the state's largest and most iconic industries. Aquaculture will also likely be affected by warming waters and more virulent diseases.

In the event of catastrophic weather events, the ability to transport food to Rhode Islanders could be severely constrained, particularly to the islands which could be cut off from the mainland for long periods if bridges and waterways are impacted. Ensuring that all residents have equitable access to adequate, safe, and nutritious foods will continue to be a priority.

CURRENT AND PLANNED RESILIENCE INITIATIVES

In December 2017, Rhode Island accepted a FirstNet/AT&T plan to deliver a wireless broadband network to the state's public safety community. By subscribing to the service, fire, police, EMS, and other public safety workers have dedicated access to the information they need, when and where they need it. Municipalities can contact AT&T to subscribe to this resilience-building service.

RIEMA, RIDOH, and Powered for Patients rolled out the Powered for Patients (P4P) program during the summer of 2017. P4P is a nonprofit, public-private initiative that brings together key stakeholders to develop an action plan on safeguarding backup power and expediting power restorations for the state's critical healthcare facilities. All Rhode Island hospitals completed an emergency power supply system vulnerability assessment survey and the survey results identified best practices but also revealed some gaps that are being addressed. P4P produced a playbook that highlights national best practices and research on current disaster planning and response activities at Rhode Island's hospitals.

The Rhode Island Special Needs Emergency Registry (RISNER) is a voluntary registry managed by RIDOH to help first responders better respond to 911 calls regarding individuals with special medical needs. RISNER allows emergency managers to plan for and respond to larger-scale emergencies by providing assistance to keep individuals safely in their homes or appropriately supported in shelters. As a result, this program helps prepare communities for impacts from climate change, including major storms and inland and coastal flooding.

CHAPTER FOUR

The goals and activities spelled out in *Relish Rhody*, Governor Raimondo's food strategy, are a means to strengthen the local food system so that the state can be more self-reliant and withstand shocks as well as allow food businesses and producers to thrive.[2] Successful implementation of the food strategy will demonstrate progress toward building resilience.

RIDOH is seeking approval from the Food and Drug Administration to conduct biotoxin testing at the State Health Laboratories. If the State Health Laboratories can assess whether biotoxins have bioaccumulated in shellfish meats, then the state will be better prepared for current and emerging threats to public health and the state shellfish industry. Mapping regional resources supporting local food production and processes has already begun.

Local shellfish, photo courtesy of RIDEM

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Incorporate emergency service providers as essential stakeholders in municipal and statewide resilience planning efforts. This will ensure the challenges facing emergency services during disaster events are addressed in preparedness and recovery plans.
- Develop preparedness and resilience guidelines and best practices for emergency services. Such guidelines may include preparedness and resilience trainings and exercises, self-assessments of emergency response departments, and suggested changes to develop stronger, more resilient response capacity during natural or man-made disasters.
- Create standard impacts and response procedures for critical facilities and services. For example, fire, ambulance, and police department personnel cannot respond to emergencies when winds exceed 60 mph. Identify and establish best response and preparedness practices for critical facilities and emergency services.
- Provide state support to municipal emergency services to incentivize disaster preparedness and resilience building activities, such as hosting trainings on ensuring continuity in the operations planning of emergency response, providing grants to departments for the development of resilience strategies, and officially recognizing departments that are proactively engaging in disaster and resilience planning.

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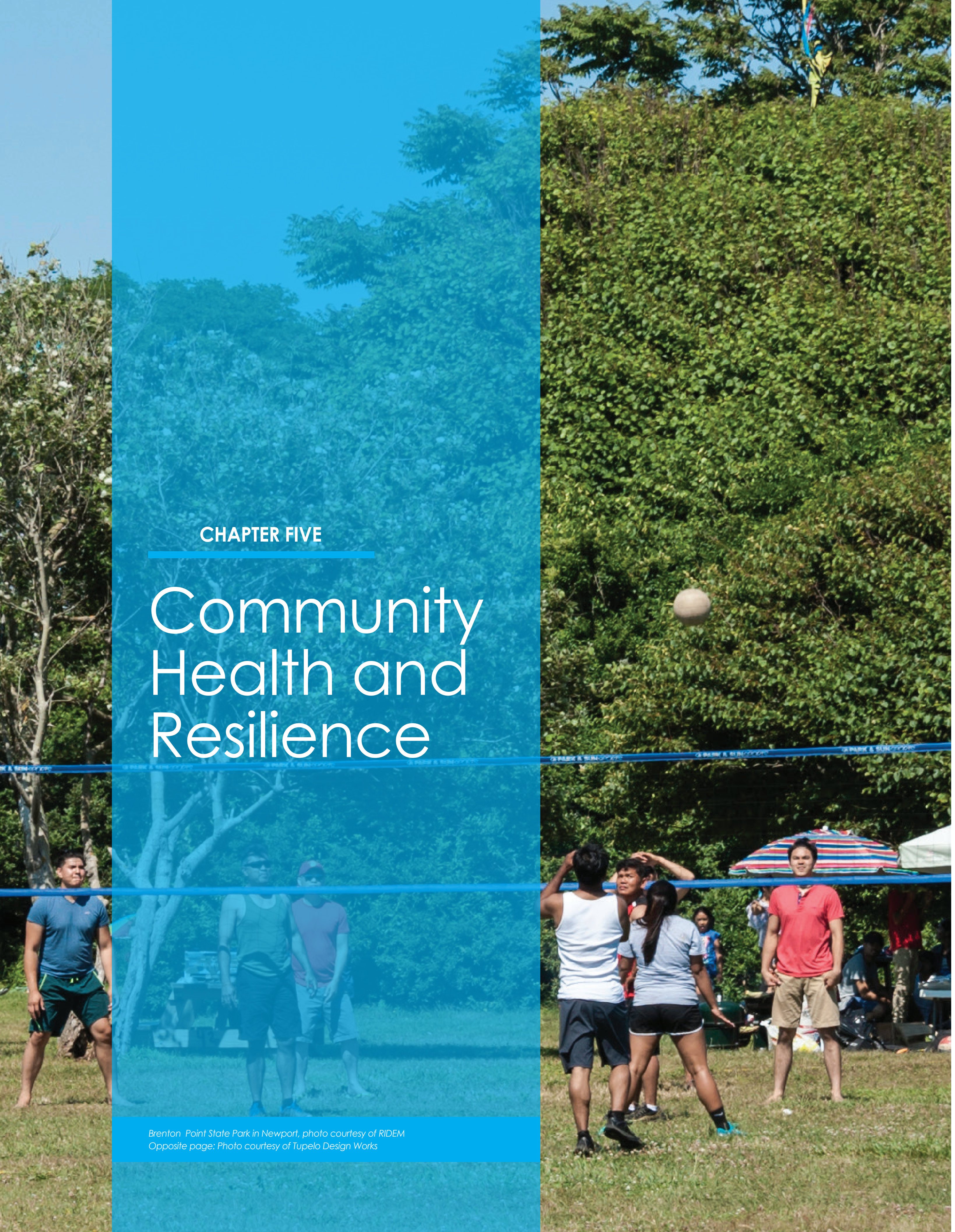


CHAPTER FIVE

Community Health and Resilience

Brenton Point State Park in Newport, photo courtesy of RIDEM
Opposite page: Photo courtesy of Tupelo Design Works

Community resilience reflects far more than being prepared for storms or other natural disasters.

To better understand the concept of community resilience, this chapter draws from academic literature and related initiatives around the country. Community resilience reflects far more than being prepared for storms or other natural disasters. The following three-part definition emphasizes how community resilience derives from social connectedness and equitable participatory processes, improving quality of life and reducing vulnerabilities, and an ability to anticipate and plan for shocks and then "bounce forward" after a disruption.

A resilient community...

- Has robust levels of social inclusion and connectedness, assures the meaningful and equitable involvement of community residents and stakeholders in proactive planning and participatory development, and maintains built environments that encourage social interaction and collaboration; [1]
- Considers foundational elements of community quality of life, such as greater access to jobs, more affordable housing, strengthened infrastructure and transportation, assured food security, and stronger social support systems; [2] and
- Anticipates problems, opportunities, and potentials for surprises, reduces vulnerabilities related to development paths, socioeconomic conditions, and sensitivities to possible threats, responds effectively, fairly, and legitimately in the event of an emergency, and recovers rapidly, better, safer, and fairer. [3]

Studies of community resilience also find that processes are most effective when a community leads. Through community resilience planning there is an opportunity to ensure that those most affected by an issue are empowered to shape the decisions that will impact their lives. The planning should result in fair distribution of the benefits and burdens of climate change and climate actions and the process itself should build resilience by cultivating community leadership, increasing connections between community members — which builds social cohesion — and cultivating community leadership. [4] Feedback received at the Resilience Roundtables echoed this concept when participants identified a need to "build local leadership for sustained interaction between community, business, and municipalities on climate resilience." [5]

Efforts to build community resilience also has other benefits. For instance, parks and open space can support resilience efforts by not only providing space for green infrastructure and stormwater management, but also generating sites in which people connect to each other and deepen their attachment to place.

This chapter is centered around the people of Rhode Island and what would help them be more resilient to the impacts of climate change. While discussing community resilience more broadly, this chapter also considers two key building blocks of any community – schools and housing.

Above: Exploring wetlands
Photo courtesy of the Audubon Society of Rhode Island
Far above: Campers from the Red Shed Bike Camp
Photo courtesy the Woonasquatucket River Watershed Council

OVERVIEW OF VULNERABILITY

Climate change threatens to expose and exacerbate pre-existing inequities; climate change is a risk amplifier. With respect to disasters, a review by the National Academies concluded:

> Past experiences have shown that the impacts of disasters are not experienced equally across a community, and recovery proceeds at different rates for different groups. People with fewer resources (financial and social) struggle to recover more than their more affluent and connected peers do. In effect, the social determinants of health are also the determinants of social vulnerability. This is an important point not only at the individual level but also at the community level: a community with large concentrations of vulnerable populations will be less resilient in the face of social and economic disruption and slower to recover. [6]

Given that community resilience is driven by such larger, structural factors, best practice also suggests short-term measures that prepare communities and reduce hazard vulnerability will be more effective when coupled with long-term actions that address these underlying social determinants of climate vulnerability.

In Rhode Island, there are differing vulnerabilities across the state. For instance, the Rhode Island Social Vulnerability Index points to concentrations of residents with compounding social and demographic factors that increase their vulnerability to climate exposures and negative health outcomes. [7] The Index identifies the state's urban areas as vulnerable, particularly in Providence, Pawtucket, Central Falls, and Woonsocket. When developing and prioritizing responses, climate resilience activities should recognize the range of vulnerabilities across individuals and communities.

Climate risks to communities include extreme weather events — like hurricanes and flooding — with immediate consequences, such as extensive damage to property and danger to personal safety. Longer term consequences also can take place including social and economic disruption,

population displacement, and mental trauma. These consequences affect a community's functioning and well-being and the impacts of disasters are felt differently across different communities and groups.

Sea level rise and climate-amplified storm events also have the potential to exacerbate community exposures to toxic and hazardous substances dangerous to human health. Many brownfield and superfund sites are located next to waterbodies where they are susceptible to climate impacts. Additionally, active industrial facilities that store, process, or use hazardous and/or flammable substances may be sited in locations susceptible to climate impacts. As a result, nearby communities may be particularly vulnerable during extreme weather events.

Schools

Schools are a cornerstone of Rhode Island communities. Young residents spend many hours each day learning within their walls. It is critical that schools can reopen quickly after a major storm or flood to minimize disruption to student learning. In some communities, schools also serve as emergency shelters. There are many reasons to prioritize making these asset types more climate resilient.

Rhode Island schools also need significant physical upgrades, which include components related to climate resilience. In fact, climate change can make existing problems in schools worse (e.g., with worsened indoor air quality due to mold growth or higher ozone levels outdoors, increased risk of exposure to toxic building materials post flooding, and greater need for reliable and effective heating and cooling). There is also potential for climate change to introduce new hazards, such as overcrowding due to displaced populations or the shifting geographic range of vector-borne diseases. [8] Certain children are more vulnerable than others to these climate-related impacts which exacerbates existing inequities. Research published in the *Journal of Environmental Research and Public Health* supports this conclusion, noting that:

> For example, poor indoor or outdoor air quality can cause or worsen respiratory illnesses, such as asthma, and is associated with headaches, dizziness, tiredness, and difficulty concentrating which can compound learning challenges for students with underlying neurocognitive disorders. Environmental exposures and sickness lead to missed school days and work days for their care givers.

Through the Northeast Collaborative for High Performance Schools, the Rhode Island Department of Education (RIDE) has already integrated robust standards related to energy efficiency and water use, indoor air quality, and other environmental considerations. As the state considers once-in-a-generation investments in school buildings, there is an opportunity to build on these efforts and align improvements to make all schools warm, safe, and dry in ways that also make them climate resilient. Further, there is an opportunity to design the improvements in ways that promote student learning about climate change and climate resilience (e.g., through green infrastructure, on-site renewable energy, emergency preparedness facilities).

Water quality testing
Photo courtesy of Save The Bay

Above: Community members from Rhode Island Local Initiatives Support Corporation (LISC)
Far above: A bicyclist travels along the East Bay Bike Path, photo courtesy of RIDEM

Housing

Healthy, affordable, and stable housing is another cornerstone of community resilience. Housing is vulnerable to climate impacts in a variety of ways. Communities both coastal and inland are at risk for flooding and other extreme weather impacts. As the climate continues to change, it becomes more difficult for residents to assess their flood- or storm-related risk, whether related to purchasing a home/signing a lease or related to their existing home.

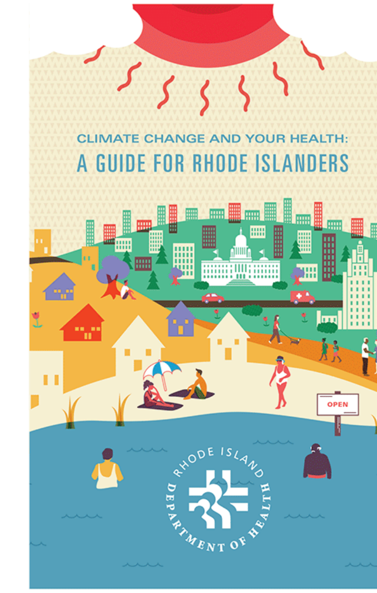
Climate change is expected to exacerbate issues like indoor air quality and temperature extremes, which will affect homes as well as schools. Better quality construction as well as certain retrofits to the existing housing stock can improve these issues and may also make homes better able to withstand storms. However, the return on investments for retrofits are often costly upfront while benefits are long range. This delay on financial return makes it difficult for homeowners, particularly those who are already housing cost burdened, to commit precious funds to retrofits. Continued support should be encouraged as well as increased marketing of programs by National Grid and the Rhode Island Office of Energy Resources that provide financial incentives for individuals and municipalities who engage in retrofits.

Following major disasters, like Hurricane Harvey (2017), Hurricane Sandy (2012), and Hurricane Katrina (2005), affected areas have seen significant population displacement. Academic research has found that such displacement particularly affects members of low-income, female-headed, and racial and ethnic minority households. This is in part tied to these populations' greater likelihood to rent rather than own a home. The human impacts of such displacement are of significant concern. Research on the effects of Hurricane Katrina found that displacement led to chronic stress, poor mental health outcomes, unemployment, loss of government benefits and access to primary health care providers, educational disruptions for children, and loss of fragile social support networks. [10] Without proactive planning, Rhode Island is vulnerable to such consequences.

National Examples of Local Resilience Planning and Action

Communities around the country are leading climate resilience planning and action efforts with a variety of different approaches that may be a model for action in Rhode Island:

- In Vermont, the statewide resilience planning process led to the creation of Community Resilience Organizations (CROs) or local teams that engage residents and town leaders in climate adaptation, disaster preparedness, and hazard mitigation. A backbone organization supports the local teams by sharing resources, providing technical assistance and capacity building, supporting fundraising, and hosting an annual training summit for town CROs teams across the state. [11]
- In New York City, a local nonprofit organization, WE ACT for Environmental Justice, hosted community forums in northern Manhattan to generate collective knowledge about how to prepare for climate change. Because this planning process was also a community-organizing and alliance-building process, the resulting plan transitioned naturally to action through an integrated set of community-driven resilience projects. [12]
- In Massachusetts, the state provides grants to municipalities to convene residents and stakeholders to complete vulnerability assessments and develop action-oriented resilience plans. Communities who complete the program are eligible for follow-up grant funding. [13]



Rhode Island Department of Health report on "Climate Change and Your Health: A Guide for Rhode Islanders"

There is a role for the state to support local level resilience planning and action. However, rather than set out a specific format or process, the most appropriate first step is to engage with local residents and stakeholders about what format or process best fits their community. Existing successful and complementary entities like the RIDOH Health Equity Zones should also be examined for synergies. These findings will inform a planned program and search for funding.

CURRENT AND PLANNED RESILIENCE INITIATIVES IN RHODE ISLAND

In 2015, RIDOH released the *Climate Change and Health Resiliency Report*, which describes major health effects of extreme heat and rising temperatures, air quality, extreme weather, water quality, vibrio, and mental health. [14]

Under the leadership of the School Building Authority at RIDE and in compliance with the School Construction Regulations, hundreds of projects worth millions of dollars have positively impacted school facility resilience across the state, including site improvements to address flooding, indoor environmental quality projects, and school siting away from hazards.

The School as a Teaching Tool protocol developed in partnership with the Rhode Island Environmental Education Association has encouraged the creation of school level "Green Teams," which include staff, students, and other stakeholders, to conduct school environment surveys and integrate environmental literacy into existing curriculum.

The *Aquidneck Island Resilience Strategy*, co-published in 2017 by the University of Rhode Island Coastal Resources Center and Rhode Island

StormReady celebration at the Rhode Island State House

Sea Grant, assesses resilience island-wide and specifically for three communities, with a focus on four key themes: transportation, island economy, emergency preparedness, and residential flooding. [15]

The Coastal Resources Center also partnered with the Narragansett Bay National Estuarine Research Reserve to create the online module series Providing Resilience Education for Planning in Rhode Island (PREP-RI). The modules target municipal decision makers and aim to increase capacity on local resilience to the effects of natural hazards and climate change, particularly sea level rise and storm surge. [16]

The City of Providence has established a Racial and Environmental Justice Committee out of their Office of Sustainability. It brings a racial equity lens to the city's sustainability work, including work related to climate resilience.

Dr. Nicole Alexander-Scott, the Director of RIDOH, will be the 2019 president of the Association of State and Territorial Health Officials (ASTHO). Her national ASTHO challenge will be "Building Healthy and Resilient Communities," which will prioritize scaling up place-based strategies, social cohesion, and community resilience.

The OneCranston Initiative, funded by the Working Cities Challenge, seeks to increase social cohesion among and between residents in the city with a focus on Cranston's growing low-income and minority populations.

Rhode Island is the first state in the country to have all municipalities recognized as "StormReady" by the National Weather Service. StormReady encourages communities to take a proactive approach to improving local hazardous weather operations by providing emergency managers with clear-cut guidelines on how to improve their hazardous weather operations.

In addition to StormReady efforts, Municipal Comprehensive Plans incorporate a natural hazard and climate change chapter, which provides a foundation for municipal decision making and community development.

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Develop technical assistance and statewide support for bottom-up, community-led groups to carry out planning and action to make their communities more climate resilient.
- Increase outreach to current and prospective homeowners and renters about property-related climate risks and how to reduce them. This could include incorporating climate resilience opportunities into existing social services outreach programs, strengthening real estate disclosure requirements to incorporate additional information related to climate risks, and increasing outreach through homebuyer education programs, which are mandatory for Rhode Island housing loans.
- Support existing proposals to make infrastructure upgrades to school buildings and recommend that resilience improvements be encouraged in projects that would be funded by the proposed $250 million bond proposed in Governor Raimondo's budget.
- Recommend that RIDE identify opportunities to integrate climate resilience into the school construction process, including actions to address storm and flooding vulnerabilities. The state should also identify school buildings located in flood zones and offer guidance on ways to increase resilience as part of local and state planning efforts.
- Expand K-12 education on environmental literacy, including climate-related emergency preparedness, by developing resources for school use and identifying how these concepts can be incorporated into existing state standards.
- Expand the Rhode Island Low Income Home Assistance Program (LIHEAP) to include cooling assistance for eligible low-income residents (e.g., air conditioning units, help with summer utility bills, emergency assistance to avoid shut-offs) and incentivize retrofits and weatherization for home and business property owners.
- Encourage all governmental entities involved in disaster recovery to draft appropriate restoration tools.

Saltwater fishing at Rocky Point State Park in Warwick, photo courtesy of RIDEM

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CHAPTER SIX

Financing Climate Resilience Projects

Groundbreaking of the Warren Wastewater Treatment Facility
Opposite page: Wastewater Treatment Operators at a flooded treatment plant during the Great Floods of 2010

Communities across Rhode Island face an urgent need to build climate resilient infrastructure that will survive extreme weather events.

As illustrated in earlier chapters, solutions to mitigate the risks of climate change are highly local. Every community in Rhode Island is facing a different set of climate risks given their unique critical assets and their own natural systems. At the end of the day, however, infrastructure and resilience go hand-in-hand, because to withstand potential climate impacts is to reduce the need to replace damaged assets after a future storm event. A recent study completed by the National Institute of Building Sciences highlights this point; they found that each dollar invested in protection against natural hazards results in six dollars in benefits, primarily by avoiding future disaster costs.[1]

Funding and financing is key to implementing resilience projects at every level in Rhode Island. Since each project requires upfront capital and often only realizes benefits over the long term, communities must pursue the most accessible and affordable ways to pay for their resilience projects. Therefore, resilience financing ought to unlock funds for communities to complete a project at a minimal cost while maximizing the benefits of the project. At the same time, resilience financing must cater to the local character of a community and have the capacity to manage the complex ecosystem of public and private financiers and investors.

As Rhode Island explores and adopts new and emerging financing for climate resilience, the state and quasi-public agencies, as well as local governments, need a comprehensive view of the options available for different types of projects. This chapter will present a roadmap for implementers to explore the existing and future financing options that may be available for their local resilience projects.

Barriers to Paying for Climate Resilience Projects

There are several barriers that prevent governments and other organizations from completing projects to increase the resilience of essential assets. These barriers, sometimes referred to as "market failures," complicate the process by hindering the ability of decision makers to act, even when the benefits of a project clearly outweigh the costs. There are five major barriers that commonly prevent the implementation of resilience measures:

1. **Difficulty obtaining grant funding**: Federal government and local grant programs are often insufficient to fully meet all project costs. Additionally, states and municipalities can find it difficult to comply with or understand matching and compliance requirements.
2. **Misaligned incentives**: The state and municipalities are often faced with a choice in which they must weigh competing incentives. For example, municipalities have a strong incentive to protect their tax base against the impacts of climate change and extreme weather, but also have a strong incentive to promote development that may be at risk to natural hazards. Similarly, both the state and

Above: Culvert replacement at Sachuest Point in Middletown
Far above: Site visit to Bucklin Point Wastewater Treatment Facility in East Providence

municipalities face disincentive to invest in large-scale resilience projects, such as flood control, because the return-on-investment timeline is uncertain.

3. **Lack of sustainable revenue streams:** A dedicated, sustainable revenue stream associated with resilience projects is rare. This makes it difficult for entities to repay costs associated with completing these projects. Additionally, many projects have clear benefits, but these benefits may not be easy to monetize. For example, flood mitigation measures that protect a commercial center from being inundated during a storm may increase property values in the protected area, but this benefit is not easily captured in the form of a revenue stream.

4. **Lack of upfront capital:** To complete a resilience project, an entity must have available capital ready to be deployed. Many entities simply do not have sufficient capital at one time to cover the costs of a project. In some instances, costs for just the design aspect of a project may exceed available capital. As noted in the first barrier, many federal grants require recipients to provide a non-federal match as a condition of receiving the grant. Even though this match is generally only a small portion of the total grant amount, many borrowers struggle to find those funds.

5. **Limited ability to borrow funds:** Nearly all entities face limitations in terms of the amount of debt that they can carry at any given time. Limitations may arise from legal restrictions, such as statutory limits, a poor credit rating, or insufficient revenue to repay additional debt. A limited ability to generate upfront capital creates challenges for an entity to acquire the debt finance needed to complete many resilience projects. Often, the nature of resilience projects creates additional difficulty for the entity issuing debt because of the lack of a sustainable revenue stream connected with the project.

Existing Climate Finance Mechanisms

Financing can enable entities to overcome many of the barriers that may otherwise prevent them from completing resilience projects. By financing a project, entities gain access to the large amount of upfront capital needed to cover construction costs. There are several existing financing tools that are available to provide capital for resilience projects. Figure 6.1 lists some financing tools that can be leveraged to complete resilience projects in each of the major sectors identified in previous chapters.

Figure 6.1: Table of existing climate financing mechanisms

CRITICAL INFRASTRUCTURE AND UTILITIES

FINANCE TOOL	WATER	POWER	TRANSPORTATION
CLEAN WATER STATE REVOLVING FUND	X	X	
DRINKING WATER STATE REVOLVING FUND	X	X	
USDA RURAL DEVELPMENT LOAN PROGRAM	X	X	
BONDS	X	X	X
RIIB STORMWATER ACCELRATOR	X		
EFFICIENT BUILDINGS FUND		X	
WATER INFRASTRUCTURE FINANCE AND INNOVATION FUND	X		
ELECTRIC/GAS RATEPAYER FUNDS		X	
ENERGY SAVINGS PERFORMANCE CONTRACTS		X	
POWER PURCHASE AGREEMENTS		X	
PROPERTY ASSESSED CLEAN ENERGY	X	X	
MUNICPAL ROAD AND BRIDGE REVOLVING FUND			X
TAX INCREMENT FINANCING	X	X	X

NATURAL SYSTEMS

FINANCE TOOL	COASTAL	INLAND
MITIGATION BANKING	X	X
LAND TRUST	X	X
CLEAN WATER STATE REVOLVING FUND	X	X
DRINKING WATER STATE REVOLVING FUND		X
BONDS	X	X

EMERGENCY PREPAREDNESS

FINANCE TOOL	COASTAL	INLAND
EFFICIENT BUILDINGS FUND	X	X
PROPERTY ASSESSED CLEAN ENERGY	X	X
MUNICIPLE ROAD AND BRIDGE REVOLVING FUND	X	
BONDS	X	X

COMMUNITY RESILIENCE

FINANCE TOOL	COASTAL	INLAND
EFFICIENT BUILDINGS FUND	X	
PROPERTY ASSESSED CLEAN ENERGY	X	X
BONDS	X	X
TAX CREDITS		X
FHA MORTGAGES		X

A completed public access restoration project at Mohegan Bluffs beach in Block Island, photo courtesy of RIDEM

Above: A water tank in Cumberland
Far above: Providence Mayor Jorge Elorza announces the "Lead Free Is The Way To Be" program with Providence Water and Rhode Island Infrastructure Bank

New and Emerging Financing Mechanisms

Although there are several financing tools currently available to provide capital for the completion of resilience projects, some entities may still struggle to overcome the barriers identified earlier. Traditional financing models do not help correct misaligned incentives or provide a sustainable revenue stream, and entities with limited borrowing capacity may not be able to utilize them. Several new financing models are emerging in response to these challenges and are intended to overcome them.

1. **Environmental Impact Bond:** [2] This financing tool utilizes the "Pay for Performance" or "Pay for Success" model that has been used to successfully deploy private capital in a variety of projects. Under this model, the return paid to the private investors depends heavily on the project's performance in meeting certain predetermined metrics. The primary benefit of this model is that it enables an entity to shift project performance risk to a private party and tie borrowing costs to the actual effectiveness of a project. This model has potential applications across multiple areas of resilience investment, including water, energy, and transportation infrastructure.

   The Environmental Impact Bond model was recently used by the District of Columbia Water and Sewer Authority (DC Water) to finance the construction of green infrastructure to reduce stormwater pollution. If the green infrastructure projects perform as expected, DC Water pays investors a return near their normal market rate of borrowing. If stormwater pollution is reduced by an amount greater than anticipated, DC Water will pay a performance bonus to investors. If these projects are more effective than expected, the utility will therefore not have to invest in as many acres of green infrastructure going forward, resulting in significant capital expenditures savings. If, however, pollution is reduced by an amount less than anticipated, DC Water pays investors reduced amount of interest, which allows the utility to protect its budget and reallocate recouped funds toward future stormwater projects.

2. **Stormwater Utility / Stormwater Accelerator:** [3] A stormwater utility is a specialized entity responsible for managing stormwater runoff and associated water quality issues. Like other utilities that manage wastewater or drinking water, a stormwater utility would be empowered to assess user fees to fund the construction and maintenance of projects that reduce or eliminate water pollution resulting from stormwater runoff. In so doing, the stormwater utility generates a revenue stream that can be used to sustainably provide funding for stormwater projects or can be leveraged by issuing debt.

   The Stormwater Accelerator is an innovative financing program being developed by Rhode Island Infrastructure Bank with the goal of providing bridge loans that enable borrowers to more quickly complete green infrastructure projects. As with other infrastructure projects, stormwater projects require substantial upfront capital to complete. The Stormwater Accelerator enables entities to complete projects today and pledge stormwater utility fees or other funding sources to repay the bridge loan. Through the Stormwater Accelerator an entity can complete a project more quickly and more cheaply, meaning benefits will begin accruing sooner and costs that increase over time, due to inflation and other factors, can be avoided.

3. **Resilience Zone:** [4] A Resilience Zone would entail the creation of an overlay district or special district in an area vulnerable to the impacts of climate change coupled with a special assessment or voluntary fee paid by property owners within the district. Funds collected through a special assessment or fee would be used to complete resilience projects benefiting the properties located within the district. This approach has the benefit of creating a revenue stream and aligning incentives by ensuring that benefits flow directly to those paying for the completion of projects.

4. **Resilience Bond:** [5] A Resilience Bond is a proposed modification of the existing Catastrophe Bond model to utilize a portion of the bond proceeds to pay for resilience projects. Many entities have used Catastrophe Bonds to protect against large-scale disasters by partially shifting risk to private investors. When a Catastrophe Bond is issued, the proceeds of the bond are generally held by a trustee and are only released to the issuer if a predetermined triggering event (e.g., damages from a storm exceeding a certain amount) occurs during the term of the bond. If the triggering event occurs, the issuer gains access to the bond proceeds to cover the losses that were caused by the disaster. If the triggering event does not occur, the proceeds are used to repay investors along with interest.

Project site visit in Smithfield

Above: The berm protecting Warwick Wastewater Treatment Facility
Far above: Warren Wastewater Treatment Facility upgrade groundbreaking

A Resilience Bond would retain many of the characteristics of the Catastrophe Bond except that a portion of the bond proceeds would be used to invest in projects that reduce the likelihood of the triggering event occurring. For example, if a triggering event is the amount of losses resulting from flooding, then some of the bond proceeds would be used to pay for flood mitigation measures. This provides a benefit to both the bond issuer, who receives the flood mitigation projects, and the investors, who see a reduced risk of the triggering event occurring.

5. **Property Assessed Resilience:** [6] A conceptual financing model based on Property Assessed Clean Energy (PACE) programs now active in many states, Property Assessed Resilience (PAR) would enable private property owners to invest in resilience projects. The PACE model utilizes energy savings realized from energy efficiency and renewable energy projects to repay the loan used to finance the projects. Similarly, PAR would take advantage of anticipated reductions in insurance costs that would result from resilience upgrades to provide a revenue stream for repayment of the loan. As with the PACE program, PAR would utilize a municipal benefit assessment to act as security for the loan.

6. **Credit Trading Market:** A credit trading market involves the purchase and sale of credits that represent a specific type of investment and help entities to meet regulatory requirements in a way other than the direct completion of projects. For example, a stormwater credit trading market would enable property owners to complete projects that reduce stormwater pollution and receive credits based upon the amount of pollution avoided. These credits can then be sold to other property owners that must comply with regulatory or legal requirements to reduce stormwater pollution. This enables market participants to determine the most efficient way to complete stormwater projects. A similar model is used by the Regional Greenhouse Gas Initiative, a multi-state agreement which aims to reduce greenhouse gas emissions.

CHAPTER SIX

Overcoming Financing Barriers

The completion of climate resilience projects is a complex process which has been hindered by several barriers, most notably an inability to utilize traditional financing tools. As a result, many projects identified as essential for protecting Rhode Island from the impacts of climate change remain stalled. While some entities may take advantage of existing financing programs, others may require the adoption of new and emerging financing models. Fortunately, financial innovations may provide access to capital for these vital projects.

Rhode Island Infrastructure Bank stands ready to assist policymakers as they implement these new solutions to protect the state and its communities from climate change. As Rhode Island's central hub for local infrastructure investment, the Infrastructure Bank is ready, willing, and able to provide information, resources, and technical assistance on resilience financing.

A sign at the Warwick Wastewater Treatment Facility marking the impact of the Great Flood of 2010

RECOMMENDED CLIMATE RESILIENCE ACTIONS

- Support the passage and implementation of the 2018 Green Economy and Clean Water Bond. [7] The Bond includes $20.5 million for climate resilience focused investments throughout the state and aligns with priority actions identified in this Strategy.
- Develop, publish, and maintain a comprehensive list of climate resilience funding opportunities to increase awareness of federal, state, and local sources.

CHAPTER 6: REFERENCES

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5 *Shalini Vajjhala, "Financing infrastructure through resilience bonds," The Avenue - Brookings Institution, December 15, 2015, www.brookings.edu/blog/the-avenue/2015/12/16/financing-infrastructure-through-resilience-bonds/.*

6 *Rebecca A. French, Wayne W. Cobleigh, Jessica H. LeClair, and Yi Shi, "Financing Resilience in Connecticut: Current Programs, National Models, and New Opportunities," Sea Grant Law and Policy Journal 8, no. 1 (August 2017), http://nsglc.olemiss.edu/sglpj/vol8no1/3-french-et-al.pdf.*

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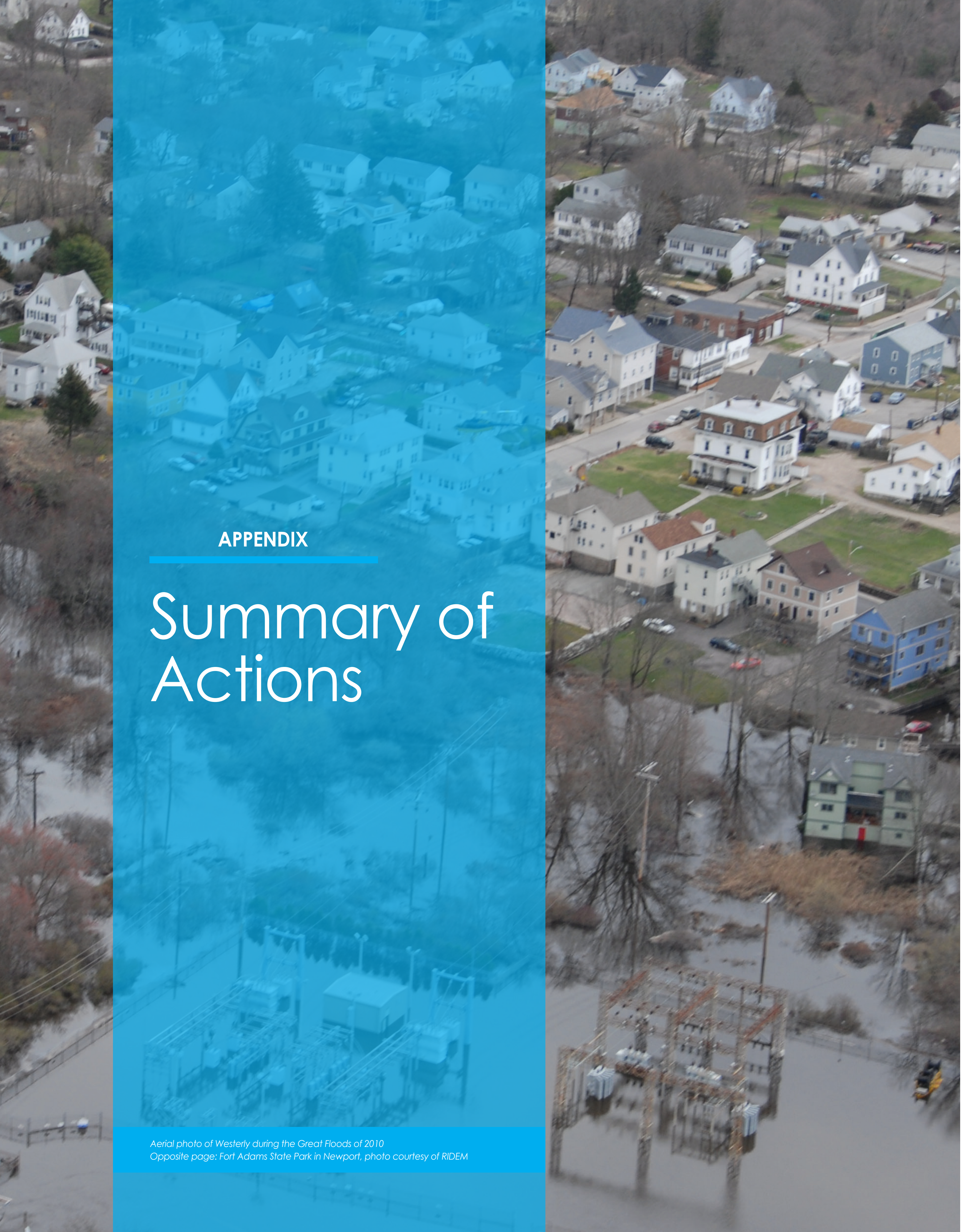


APPENDIX

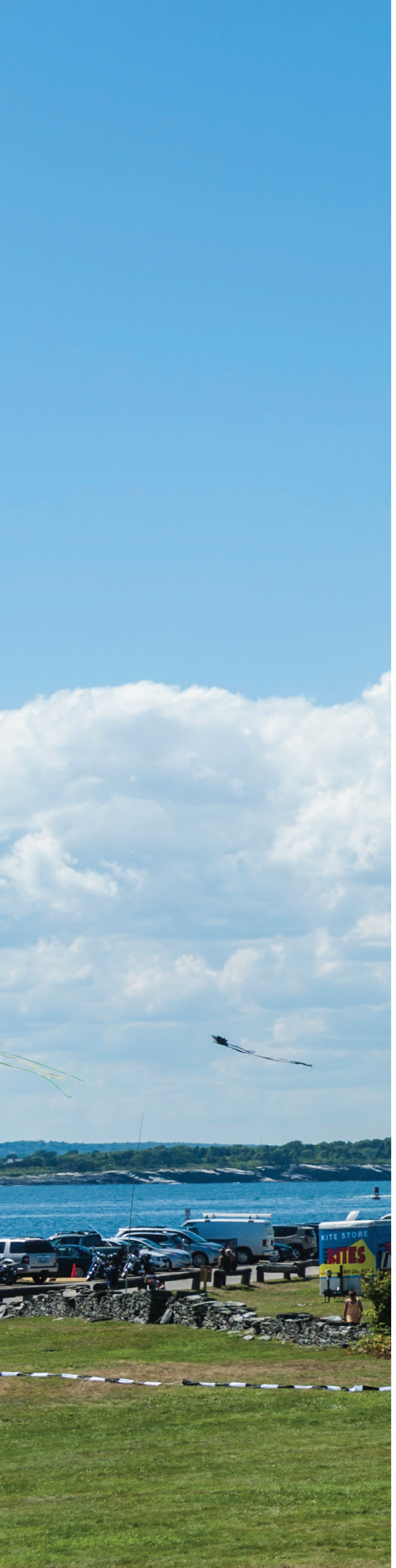
Summary of Actions

Aerial photo of Westerly during the Great Floods of 2010
Opposite page: Fort Adams State Park in Newport, photo courtesy of RIDEM

From Strategy to Implementation

The recommended climate resilience actions throughout Resilient Rhody provide guideposts in the process to better prepare Rhode Island for a changing climate and increased natural hazards. Moving from planning to action is challenging and requires sustained energy and resources from key strategy development stakeholders. The EC4 will provide continued leadership and staff resources to the implementation of this Strategy.

Implementation will begin immediately by refining each of the recommended actions to include a timeline for completion, agency ownership, and cost range. A system for tracking implementation progress and performance will also be developed to ensure accountability and identify gaps and trends. Some actions within Resilient Rhody have already progressed due to the strategy development process and highlights the opportunities from increased collaboration among the EC4.



CHAPTER TWO:
Critical Infrastructure and Utilities

WATER

Drinking Water Systems

- Assist water suppliers in developing local Emergency Interconnection Programs to address supply vulnerability among small systems throughout the state. Emergency Water System interconnections provide redundancy of supply and the ability to address water emergencies rapidly and efficiently across water supply districts.
- Assess the vulnerability of near coastal drinking water reservoirs to storm surge and sea level rise.
- Advance common goal setting and communication between water suppliers that manage reservoirs and downstream municipalities. Ensure downstream flood mitigation via proactive spillway management without adverse impacts on safe yield.
- Ensure that all major suppliers have current contingency contracts for the purchase of emergency supplies and have established emergency interconnection/distribution process.

Wastewater Treatment Facilities

- Accelerate treatment system and pumping station hardening projects identified in *Implications of Climate Change for RI Wastewater Collection & Treatment Infrastructure* to include the installation of submarine doors; elevated, watertight protections of motor control centers; waterproofing and elevated instrumentation, windows, hatches, and vents; and installation of standby power systems.
- Provide additional fuel-storage capacity at major wastewater systems where it is necessary to maintain self-sufficient standby power during times of long-term power grid outages.
- Expand flood modeling/mapping efforts within inland areas to enhance the recommendations in *Implications of Climate Change for RI Wastewater Collection & Treatment Infrastructure*. Data should include statewide precipitation projections that can be used for other sectors as well.

Dams

- Prioritize remediation actions and investments identified in RIDEM's 2017 dam hazard study to ensure compliance and downstream safety.
- Establish a notification system for dam safety to coordinate the actions of officials at the federal, state, and local levels. The system should use the process developed by the National Weather Service for severe weather, including a dam advisory, a dam watch, and a dam warning.

- Develop Emergency Action Plans (EAPs) for all statewide high hazard and significant hazard dams. Responding to an emergency at a dam without an EAP increases the risk to life and property yet many statewide dams do not have plans filed. RIDEM and RIEMA have been working to increase the number of filed EAPs but a more robust program is needed to ensure compliance.

Stormwater

- Work with local governments to establish sustainable revenue sources for the operation and maintenance of local stormwater management systems (e.g., applying asset management approaches commonly used with wastewater and drinking water systems) to ensure drainage systems are functioning as designed/intended and repaired/upgraded as needed.
- Encourage the use of green infrastructure to enhance the capacity of traditional stormwater systems to provide multiple community and ecosystems benefits to enhance water quality and provide multiple community benefits.
- Update the Stormwater Design and Installation Standards Manual/Rules to reflect changing precipitation patterns.
- Use Total Maximum Daily Loads (TMDLs) and other watershed plans to identify areas of existing impervious surface that can be removed and to prioritize retrofitting of existing drainage systems.
- Identify existing stormwater management structures that are subject to frequent coastal and riverine flooding and take steps to mitigate the impacts of this flooding on stormwater infrastructure and its performance.
- Update the state land use plan, Land Use 2025, to include climate change and resilience topics as well as stormwater water management needs, policies, and actions for stormwater utility districts.
- Develop a bridge loan at Rhode Island Infrastructure Bank to provide upfront capital to communities and organizations who are RIDOT and RIDEM reimbursement stormwater grant recipients.

Ports

- Strengthen storm resilience and post-storm recovery at the ports through strategic partnerships and planning. Shipping lines will turn to ports that rapidly resume normal operations after hurricanes. Rhode Island and cities like Providence and East Providence should approach storm resilience and climate change as a business opportunity through inclusion of resilience planning. For example, state agencies should support the ports in developing pre-contracts for debris removal after hurricanes or businesses could implement data backup mechanisms to help the ports resume operations more quickly after a storm.
- Establish a new collaborative partnership between the state and port community to understand the economic implications of severe weather events and benefits of storm resilience planning.

POWER

Electric Grids

- Design and implement a comprehensive, targeted strategy addressing energy security vulnerabilities at the municipal or facility level, based on findings of the *Energy Assurance Plan*. This strategy should address risks specific to discrete critical infrastructure assets, including hospitals, police and fire stations, water and sewage treatment plants, senior centers and nursing homes, shelters, correctional facilities, fueling stations, and grocery stores. Smart energy security investments at these locations and energy resilience solutions could alleviate the impacts of power outages and fuel supply disruptions in energy emergencies. Examples of such solutions are backup generation, fuel reserves, distributed generation, combined heat and power, energy storage, and microgrids.
- Act on the policy recommendations outlined in the OER report, *Resilient Microgrids for Rhode Island Critical Services*, and remove market barriers to implementing microgrids at critical facilities.
- Modernize the grid and complementary efforts through the Power Sector Transformation initiative currently under review at the PUC, as recommended by the state energy plan and the House Energy Security Resolution Report. The initiative includes recommendations for the utility business model, grid connectivity and meter functionality, distribution system planning, and beneficial electrification. These facets will help accelerate the integration of non-conventional resources and support the development of a more resilient, reliable, efficiency, and flexible electric grid.
- Reduce the number and extent of power outages as described in *Division Docket No. D-17-45: Review of National Grid Storm Preparedness and Restoration Efforts Related to the Storm of October 29-30, 2017*, including:
  - Supplement weather forecasting services with additional tools to achieve more accurate storm forecasts.
  - Develop a mechanism to rapidly adjust weather classifications based on actual, current impacts and review classification system, planned resources, and staging locations based on classifications. A utility's emergency response plan should incorporate methods to rapidly adjust when storm impacts are more severe than anticipated.
  - Consider enhancements to existing vegetation management programs. Strategic tree removal, for example, can mitigate power outages due to tree-related downed power lines.
  - Enhance communications systems to respond quickly to changes in storm severity from what was predicted. Better communication systems and protocol are needed to properly convey changes in urgency and actions both internally and to the public.
  - Improve guidelines and contracts for mutual aid to allow for more appropriate magnitude and timing of crew additions in the state.

Fuel Supply

- Ensure fuel terminals have undertaken all appropriate hardening and resilience measures to protect their facilities from future storms and have made provisions to restore operations after storms. This includes continuing strategic long-term planning for improving the resilience of marine terminals.
- Develop a Petroleum Set-Aside Program, as recommended by the *Energy Assurance Plan*, to ensure essential public needs are met during a severe fuel shortage. This program should specify best practices to ensure fuel delivery to priority end-users, such as hospitals, police and fire stations, water and sewage treatment plants, senior centers and nursing homes, shelters, correctional facilities, fueling stations, and grocery stores. This program should also define best practices and prioritize critical infrastructure assets.

TRANSPORTATION

Roads, Bridges, and Culverts

- Develop a *Transportation Asset Management Plan* for RIDOT assets that integrates future climate risks into a comprehensive asset management approach for transportation assets to ensure adequate investment and a state of good repair.
- Align the *Transportation Improvement Program and Transportation Asset Management Plan* processes to ensure asset management and risked-based planning for infrastructure maintenance and new projects.
- Update the state land use plan, Land Use 2025, to include climate change and resilience actions for transportation infrastructure and updated goals and priorities set by the Long-Range Transportation Plan.

Public Transportation

- Ensure continuity of RIPTA operations following extreme weather events through implementation of backup power generation at key facilities.
- Develop a *Transportation Asset Management Plan* for RIPTA assets that integrates a comprehensive asset management approach to ensure a state of good repair and investments that consider all future climate risks.

All Critical Infrastructure

- Ensure that data are consistent across agencies and municipalities. This is critical to maximizing limited resources and capacity. Updating, coordinating, and standardizing foundational resilience data including GIS layers (e.g., STORMTOOLS, critical infrastructure, precipitation projections) and related metadata should be centralized. Hosting coordinated data will provide

support for municipal/agency decision-making on infrastructure/public facility investments.

- Develop a tracking system for implementation of identified actions to measure progress and demonstrate alignment with EC4 climate resilience goals.
- Build relationships and learn from climate adaption efforts in neighboring states to accelerate technical assistance to municipalities for local implementation. Rhode Island should look to the region for examples of how to model municipal and nonprofit partnerships that move from planning to prioritized project identification and funding.

CHAPTER THREE: Natural Systems

COASTAL

Coastal Wetlands

- Continue monitoring and assessment of coastal wetland habitats and management practices to evaluate and prioritize future actions. Statewide models, such as the Sea Level Affecting Marshes Model (SLAMM), should be updated to identify opportunities for restoration and assist in planning for future marsh migration. To minimize loss and preserve the benefits of coastal wetland habitats, conservation and management must be approached at multiple scales and timeframes.
- Identify opportunities for retreat and infrastructure removal on state-owned properties, which can serve as demonstration sites for shoreline adaptation. State agencies and their partners should continue to work with municipalities to identify opportunities for retreat, removal of derelict infrastructure, and enhancement of natural shoreline areas. Where possible, retreat rather than fortification should be emphasized as a coastal adaptation strategy. Implemented restoration projects should continue to be monitored to evaluate the effectiveness of different restoration practices.

Beaches and Barriers

- Preserve the dynamic nature of beaches and barriers in future management of these critical natural systems. Differentiation between developed and undeveloped systems is necessary when considering management approaches. New development should be minimized in undeveloped beach and dune areas and retreat incentivized as a coastal adaptation strategy where possible.
- Develop initiatives for coastal resilience activities, such as monitoring existing pilot projects, developing offshore sand sources suitable for beach replenishment, prioritizing beaches to be re-nourished, and creating beach and barrier migration pathways through property acquisition and relocation of structures.

INLAND

Forests

- Encourage protection of significant portions of the remaining intact forest cover in Rhode Island and conserve the landscape values of larger, unbroken tracts of land. This will require considerable collaboration with private landowners, who own about 72% of the forested land area in the state, as well as creative sustainable investment ideas.
- Incentivize the creation of Forest Stewardship Plans to help protect soil and water quality, fish and wildlife habitat, timber and other wood products, and outdoor recreation. Landowners with completed/updated Forest Stewardship Plans can take advantage of the Farm, Forest, and Open Space Act, which can provide significant reductions in property taxes.
- Support municipalities in developing urban tree inventories and implementing urban forest master plans with a goal toward mitigating increased urban heat.

Water Resources

- Identify and assess inland riparian buffer conditions statewide (e.g., using aerial photos and field reconnaissance). Identifying and mapping small headwater streams and their riparian buffers should be a high priority. These areas can be more effectively protected by state and local land use policies/regulations once they are identified. The assessment can also be used to develop priority areas for buffer restoration and protection.
- Develop a comprehensive environmental monitoring strategy, prioritize gaps, and continue to strengthen coordination of upland water resource monitoring activities. Monitoring programs should be aligned with regional data collection strategies relating to climate change, aquatic ecosystems, and water quality.

CHAPTER FOUR: Emergency Preparedness

Evacuation Shelters and Routes

- Prioritize protection of the local fuel supply along evacuation routes during climate-related disasters. During Hurricane Irma (2017) in Florida, the large number of residents attempting to evacuate at the same time created a burden on the fuel supply and many evacuees were stranded without fuel, stalling their evacuation, and increasing calls for assistance from emergency services personnel.
- Inform residents of evacuation routes and shelter locations in the event of severe weather necessitating an evacuation. Some evacuation routes within the state have been altered, changed, and revised since the last update.

- Conduct a statewide reassessment of evacuation routes and the associated signage. Implementing a public outreach initiative to inform citizens about evacuation routes and shelter locations through homeowner associations, nonprofit organizations, and state and local governments will help citizens become more resilient to the impacts of a changing climate.

Building Design and Construction

- Improve predictions of facility-level impacts of approaching storms. Predictions days before a storm makes landfall will assist facilities in their preparedness efforts. By developing a more resilient facility, the cascading effects to other facilities and services can be eliminated, resulting in a more resilient community that is better able to provide services to its residents before, during, and after major storms.
- Complete in-depth vulnerability assessments and three-dimensional visualizations of storm impacts for Rhode Island's critical facilities under any storm conditions, including unprecedented events, like Hurricane Harvey or Irma (2017).
- Develop more realistic storm preparedness training for facility managers and emergency managers. Traditionally, FEMA storm training simulations make trainees respond to impacts without considering when the impact would be triggered by a storm. Determining the exact storm force that causes an impact will allow training simulations to input impacts in the same chronological order as a real storm.

Emergency Services

- Incorporate emergency service providers as essential stakeholders in municipal and statewide resilience planning efforts. This will ensure the challenges facing emergency services during disaster events are addressed in preparedness and recovery plans.
- Develop preparedness and resilience guidelines and best practices for emergency services. Such guidelines may include preparedness and resilience trainings and exercises, self-assessments of emergency response departments, and suggested changes to develop stronger, more resilient response capacity during natural or man-made disasters.
- Create standard impacts and response procedures for critical facilities and services. For example, fire, ambulance, and police department personnel cannot respond to emergencies when winds exceed 60 mph. Identify and establish best response and preparedness practices for critical facilities and emergency services.
- Provide state support to municipal emergency services to incentivize disaster preparedness and resilience building activities, such as hosting trainings on ensuring continuity in the operations planning of emergency response, providing grants to departments for the development of resilience strategies, and officially recognizing departments that are proactively engaging in disaster and resilience planning.

CHAPTER FIVE: Community Health and Resilience

- Develop technical assistance and statewide support for bottom-up, community-led groups to carry out planning and action to make their communities more climate resilient.
- Increase outreach to current and prospective homeowners and renters about property-related climate risks and how to reduce them. This could include incorporating climate resilience opportunities into existing social services outreach programs, strengthening real estate disclosure requirements to incorporate additional information related to climate risks, and increasing outreach through homebuyer education programs, which are mandatory for Rhode Island housing loans.
- Support existing proposals to make infrastructure upgrades to school buildings and recommend that resilience improvements be encouraged in projects that would be funded by the proposed $250 million bond proposed in Governor Raimondo's budget.
- Recommend that RIDE identify opportunities to integrate climate resilience into the school construction process, including actions to address storm and flooding vulnerabilities. The state should also identify school buildings located in flood zones and offer guidance on ways to increase resilience as part of local and state planning efforts.
- Expand K-12 education on environmental literacy, including climate-related emergency preparedness, by developing resources for school use and identifying how these concepts can be incorporated into existing state standards.
- Expand the Rhode Island Low Income Home Assistance Program (LIHEAP) to include cooling assistance for eligible low-income residents (e.g., air conditioning units, help with summer utility bills, emergency assistance to avoid shut-offs) and incentivize retrofits and weatherization for home and business property owners.
- Encourage all governmental entities involved in disaster recovery to draft appropriate restoration tools.

CHAPTER SIX: Financing Climate Resilience Projects

- Support the passage and implementation of the 2018 Green Economy and Clean Water Bond. The Bond includes $20.5 million for climate resilience focused investments throughout the state and aligns with priority actions identified in this Strategy.
- Develop, publish, and maintain a comprehensive list of climate resilience funding opportunities to increase awareness of federal, state, and local sources.

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