# TOWN OF NANTUCKET
# PRE-DISASTER HAZARD MITIGATION PLAN

**MARCH 2007**
***Revised July 2007***

**MMI #2967-01-1**

*Prepared For:*

Town of Nantucket
16 Broad Street
Nantucket, Massachusetts 02554

*Prepared By:*

Milone & MacBroom, Inc.
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773

# TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

# TABLE OF CONTENTS (Continued)

## LIST OF FIGURES



## APPENDED TABLES



## APPENDICES

# *1.0 INTRODUCTION*

## *1.1 Background and Purpose*

The term *hazard* refers to an extreme natural event that poses a risk to people, infrastructure, or resources. In the context of disasters, hazard mitigation is commonly defined as any sustained action that reduces or eliminates long-term risk to people, property, and resources from hazards and their effects. Hazard mitigation can result in long-term, cost-effective, and environmentally-sound reduction of hazard vulnerability. In addition, hazard mitigation can protect critical community facilities, reduce exposure to risk, and minimize disruption to the community.

The primary purpose of a pre-disaster hazard mitigation plan is to identify natural hazards and risks, existing capabilities, and activities that can be undertaken by a community to prevent loss of life and reduce property damages associated with the identified hazards. The plan is relevant not only in emergency management situations, but also should be used within the community's land use, environmental, and capital improvement frameworks.

The Disaster Mitigation Act of 2000 (DMA), commonly known as the 2000 Stafford Act amendments, was approved by Congress and signed into law in October 2000, creating Public Law 106-390. The purpose of the DMA is to establish a national program for pre-disaster mitigation and streamline administration of disaster relief.

The Disaster DMA requires local communities to have a Federal Emergency Management Agency (FEMA)-approved mitigation plan in order to be eligible to receive post-disaster Hazard Mitigation Grant Program (HMGP) grants and Pre-Disaster Mitigation (PDM) program project grant funds. Once a jurisdiction has a FEMA-

approved hazard mitigation plan, the jurisdiction is then eligible to apply for PDM project funds for mitigation activities.

The subject pre-disaster hazard mitigation plan was developed to be consistent with the requirements of the HMGP, PDM, and Flood Management Assistance (FMA) programs. These programs are briefly described below.

***Pre-Disaster Mitigation (PDM) Program***

The Pre-Disaster Mitigation program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through pre-disaster mitigation planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of pre-disaster plans and projects is meant to reduce overall risks to populations and facilities. PDM funds should be used primarily to support mitigation activities that address natural hazards. In addition to providing a vehicle for funding, the PDM program provides an opportunity to raise risk awareness within communities.

***Hazard Mitigation Grant Program (HMGP)***

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to States and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities

to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.

***Flood Mitigation Assistance (FMA) Program***

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the National Flood Insurance Program (NFIP). FEMA provides FMA funds to assist States and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities. Three types of grants are available under FMA. These are Planning, Project, and Technical Assistance grants.

## *1.2 Hazard Mitigation Goals*

The primary goal of this Pre-Disaster Hazard Mitigation Plan (known informally herein as the "hazard mitigation plan") is to ***reduce the loss of or damage to life, property, infrastructure, and natural, cultural and economic resources from natural disasters.*** This includes the reduction of public and private damage costs. Limiting losses of and damage to life and property will also reduce the social, emotional, and economic disruption associated with a natural disaster.

Developing, adopting, and implementing this hazard mitigation plan is expected to:

- **Increase access to and awareness of funding sources for hazard mitigation projects.** Certain funding sources, such as the Pre-Disaster Mitigation Competitive Grant Program and the Hazard Mitigation Grant Program, will be available if the hazard mitigation plan is in place and approved.

- **Identify mitigation initiatives to be implemented if and when funding becomes available.** This HMP will identify a number of mitigation recommendations, which can then be prioritized and acted upon as funding allows.

- **Connect hazard mitigation planning to other community planning efforts.** This HMP can be used to guide community development through inter-departmental coordination.

- **Improve the mechanisms for pre- and post-disaster decision making efforts.** This plan emphasizes actions that can be taken now to reduce or prevent future disaster damages. If the actions identified in this plan are implemented, damage from future hazard events can be minimized, thereby easing recovery and reducing the cost of repairs and reconstruction.

- **Improve the ability to implement post-disaster recovery projects** through development of a list of mitigation alternatives ready to be implemented.

- **Enhance and preserve natural resource systems.** Natural resources, such as wetlands and coastal floodplains, provide protection against disasters such as floods and hurricanes. Proper planning for and protection of natural resources can provide hazard mitigation at substantially reduced costs.

- **Educate residents and policy makers about natural hazard risk and vulnerability.** Education is an important tool to ensure that people make informed decisions that complement Nantucket's ability to implement and maintain mitigation strategies.

- **Complement future Community Rating System efforts.** Implementation of certain mitigation measures may increase a community's rating, and thus the benefits that it derives from FEMA.

## *1.3 Identification of Hazards and Document Overview*

As stated in Section 1.1, the term *hazard* refers to an extreme natural event that poses a risk to people, infrastructure, or resources. The following have been identified as natural hazard events that can affect the Town of Nantucket:

- Inland and Coastal Flooding
- Sea Level Rise, Shoreline Change, and Erosion
- Summer and Winter Storms
- Wildfires
- Earthquakes

This document has been prepared with the understanding that a single *hazard effect* may be caused by multiple *hazard events*. For example, flooding may occur as a result of frequent heavy rains, a hurricane, or a winter storm. Despite the cause, flooding is persistent and demands high expenditures from the Town. Table 1-1 relates a variety of natural hazard effects to their causes.

To identify current vulnerabilities and potential mitigation strategies associated with hazard events, each hazard event has been individually discussed in a separate chapter. The exception is flooding. The hazard effects of inland and coastal flooding have been addressed individually in two separate chapters prior to the chapters dedicated to discussing their causes.

Insert Table 1-1

**Effects of Natural Hazards**

| | Causes | | | | | |
|---|---|---|---|---|---|---|
| **Effects:** | **Hurricanes and Tropical Storms** | **Sea Level Rise and Shoreline Change** | **Summer Storms and Tornadoes** | **Winter Storms** | **Wildfires** | **Earthquakes** |
| Inland Flooding | X | | X | | | |
| Flooding from Poor Drainage | X | X | X | | | |
| Coastal Flooding | X | X | | X | | |
| Storm Surge | X | | | X | | |
| Coastal Erosion | X | X | | X | | |
| Wind | X | | X | X | | |
| Falling Trees/Branches | X | | X | X | | |
| Lightning | X | | X | | | |
| Hail | | | X | | | |
| Snow | | | | X | | |
| Blizzard | | | | X | | |
| Ice | | | | X | | |
| Fire/Heat | | | | | X | |
| Smoke | | | | | X | |
| Shaking | | | | | | X |

It is important that the individual hazards addressed in this plan are consistent with those listed in the Nantucket Emergency Operations Plan (EOP). The Risk Analysis Summary of the EOP states the following:

*"Nantucket officials judge the town to be at high risk for blizzards and other types of severe winter storms that carry high winds, heavy precipitation and extreme temperatures, and also at high risk for the power outages which often accompany these storms. They assign a moderate risk rating to hurricanes and other types of severe warm weather storms. Like the rest of Massachusetts, Nantucket is at moderate risk for earthquake occurrence and impact. Because Nantucket encompasses significant land masses of wooded and/or undeveloped area, the risk for forest fire is moderate. Because of the density of buildings in many parts of the island there is a moderate risk for severe fires.... Nantucket's location in a general area of the state where tornado activity occurs periodically supports a moderate risk rating for tornado occurrence...."*

After the introductory chapter, this document continues with a general discussion of the Town of Nantucket's community profile, including the physical setting, demographics, development trends, governmental structure, and sheltering capacity. Next, each chapter of this Plan pertaining to a natural hazard is broken down into six or seven different parts. These are *Setting*; *Hazard Assessment*; *Historic Record*; *Existing Programs, Policies, and Mitigation Measures*; *Vulnerabilities and Risk Assessment*; *Potential Mitigation Measures, Strategies, and Alternatives*; and *Recommended Actions*. These are described below.

- ***Setting*** identifies the general areas of Nantucket that are at risk from the hazard.

- ***Hazard Assessment*** describes the specifics of a given hazard, including characteristics and associated effects. Associated return intervals, probability and risk, and relative magnitude are also discussed.

- ***Historic Record*** is a discussion of past occurrences of the hazard, and associated damages.

- ***Existing Programs, Policies, and Mitigation Measures*** gives an overview of the measures that the Town is currently undertaking to mitigate the given hazard. These may take the form of ordinances and codes, structural measures such as seawalls and jetties, or public outreach initiatives.

- ***Vulnerabilities and Risk Assessment*** focuses on the specific areas at risk to the hazard. Specific land uses in the given areas are identified. Critical buildings and infrastructure that would be affected by the hazard are also identified.

- ***Potential Mitigation Measures, Strategies, and Alternatives*** identifies mitigation alternatives.

- ***Recommended Actions*** is a list of the recommended mitigation measures that would be beneficial to protect against a given hazard, based on social, technical, administrative, political, legal, economic, and environmental factors (i.e. the "STAPLEE" method).

This document concludes with a strategy for implementation of the Hazard Management Plan, including a schedule, a program for monitoring and updating the plan, and a discussion of technical and financial resources.

## *1.4 Documentation of the Planning Process*

Mr. Robert Bates, Jr. of the Fire Department coordinated the development of this Hazard Mitigation Plan. The following individuals were also involved:

- Mr. Bernie Bartlett, Building Department
- Ms. Peggy Fantozzi, Technical Consultant to Conservation Commission
- Mr. David Fronzuto, Marine Resources Department
- Mr. Robert Gardner, Wannacomet Water Company
- Mr. Mark MacDougall, Fire Department & Emergency Management Services
- Ms. Tracy Murray, Selectman's Office
- Mr. Alfred Peterson, Nantucket Airport
- Mr. Nathan Porter, GIS Department
- Mr. Richard Ray, Health Department
- Mr. David Sylvia, Nantucket Airport
- Mr. Jeff Willett, Department of Public Works
- Ms. Leslie Woodson, AICP, Planning & Economic Development Department

An extensive data collection, evaluation, and outreach program was undertaken to compile information about existing hazards and mitigation in the Town of Nantucket, as well as to identify areas that should be prioritized for hazard mitigation. The following is a list of meetings that were held or attended to develop this Hazard Mitigation Plan:

- ***A project initiation meeting was held July 12, 2006.*** This meeting addressed the scope of services necessary to develop this HMP. Initial input was provided by the project team.

- ***Meetings with the above individuals were held on August 14 and 15, 2006.*** The hazards, areas of concern, existing mitigation, and potential solutions relevant to the jurisdiction of each Department were discussed.

- ***A meeting of the Massachusetts Coastal Hazards Commission was attended on September 11, 2006.*** The purpose of the meeting was for the commission to discuss its preliminary recommendations and the public comments received.

- ***An informational community meeting was held September 14, 2006 to address the concerns of citizens.*** Nantucket citizens were invited to comment on specific problems and potential solutions.

- ***An informational meeting with key project stakeholders was held October 5, 2006 to address the concerns of these organizations.*** Members of the Nantucket Land Council, Nantucket Land Bank, University of Massachusetts-Boston Nantucket Field Station, Sconset Beach Preservation Fund, and The Sconset Trust attended the meeting.

- ***A project meeting was held December 11, 2006.*** This meeting addressed the project status, and the advisory group discussed findings and conclusions.

- ***A project meeting was held February 22, 2007.*** A draft of the plan and recommendations were reviewed with the members of the project team.

Appendix A contains copies of meeting minutes and other records that document the development of this Hazard Mitigation Plan.

## *1.5 Massachusetts Coastal Hazards Commission*

The purpose of the Massachusetts Coastal Hazards Commission (CHC) is to review existing coastal hazards practices and policies, identify data and information gaps, and draft recommendations for administrative, regulatory, and statutory changes. The CHC will report its result to the Legislature in 2007. At the February 15, 2006, kickoff

meeting for the Massachusetts Coastal Hazards Commission, Governor Mitt Romney and Environmental Affairs Secretary Stephen Pritchard charged the Commission to:

- Generally characterize Massachusetts' vulnerability to coastal hazards (including coastal storms, erosion, sea level rise, storm surge, etc.);

- Evaluate the adequacy of coastal hazards data and tools, regulations, and best management practices for development in coastal flood or erosion prone areas;

- Evaluate management approaches to coastal hazards, including (1) existing seawall repair, removal, or replacement with alternatives; (2) beach nourishment, including an evaluation of offshore sand mining for such purpose; (3) coastal retreat, including infrastructure relocation and private property acquisition; (4) market-based influences and incentives/disincentives (insurance, etc.); and (5) hazard mitigation planning;

- Target the South Shore for an initial detailed coastal hazards assessment. This detailed assessment will specifically characterize coastal hazards practices; inventory public storm damage protection infrastructure and characterize as good, adequate, or failing; and identify and generally characterize significant/major areas of both public and private infrastructure. Additionally, the assessment will identify substandard infrastructure (seawalls, revetments, needed beach nourishment) and provide estimated capital and maintenance costs to address: (1) immediate conditions; and (2) out-year conditions with assumed constant rate of sea-level rise, with the objective of developing a 20-year Coastal Infrastructure and Protection Plan;

- Initiate 20-year Coastal Infrastructure and Protection Plans for the Cape and Islands, South Coast, Boston Harbor and North Shore regions. These Plans will be completed by November of 2007; and

- Make recommendations as deemed necessary and appropriate.

In May 2006, the Coastal Hazards Commission hosted a series of public forums to solicit input on local storm damage and erosion issues, concerns, and potential solutions. Draft recommendations were released on August 9, 2006, with public comments accepted through September 15, 2006. Final recommendations were published in May 2007.

Although the latter portion of the CHC process coincided with the development of the Nantucket HMP, the two projects resulted from unrelated political and regulatory programs. However, the timing of the recommendations of the CHC lends itself to a critical review and incorporation into the Nantucket HMP. CHC recommendations are presented in Section 6.6.

# 2.0 COMMUNITY PROFILE

## 2.1 Physical Setting

The Town of Nantucket is located off the coast of Massachusetts approximately 20 miles east of Martha's Vineyard and 25 miles south of Cape Cod. The Town of Nantucket is coincident with the County of Nantucket and includes the islands of Nantucket, Tuckernuck, and Muskeget. Refer to Figure 2-1 for a location plan of the Town, and Figure 2-2 for a more detailed map of the Town on a USGS topographic base.

Nantucket has an area of 48 square miles and approximately 88 miles of shoreline. Nantucket Sound is located north of the Town, and the open Atlantic Ocean is located to the east and south. Sheltered and semi-sheltered marine systems include Nantucket Harbor, connected to Nantucket Sound; Polpis Harbor, an embayment of Nantucket Harbor; and Madaket Harbor, at the west end of Nantucket Island toward Tuckernuck. Extensive sandy shoals are located east and west of Nantucket.

Key physical features of Nantucket Island include high bluffs at Sankaty Head and the Nantucket Cliffs, long systems of beaches and dunes (Great Point and Coatue) formed by longshore currents, several north-south trending elongated ponds that are typically cut off from the ocean by narrow beaches (such as Hummock Pond and Miacomet Pond), extensive moorlands, and numerous areas of tidal wetlands. Nantucket does not, however, have many non-tidal fresh watercourses, due to the sandy nature of the soil and the flat terrain. Exceptions include the stream known as Phillips Run and a tributary of Miacomet Pond.

Figure 2-1 Location Map

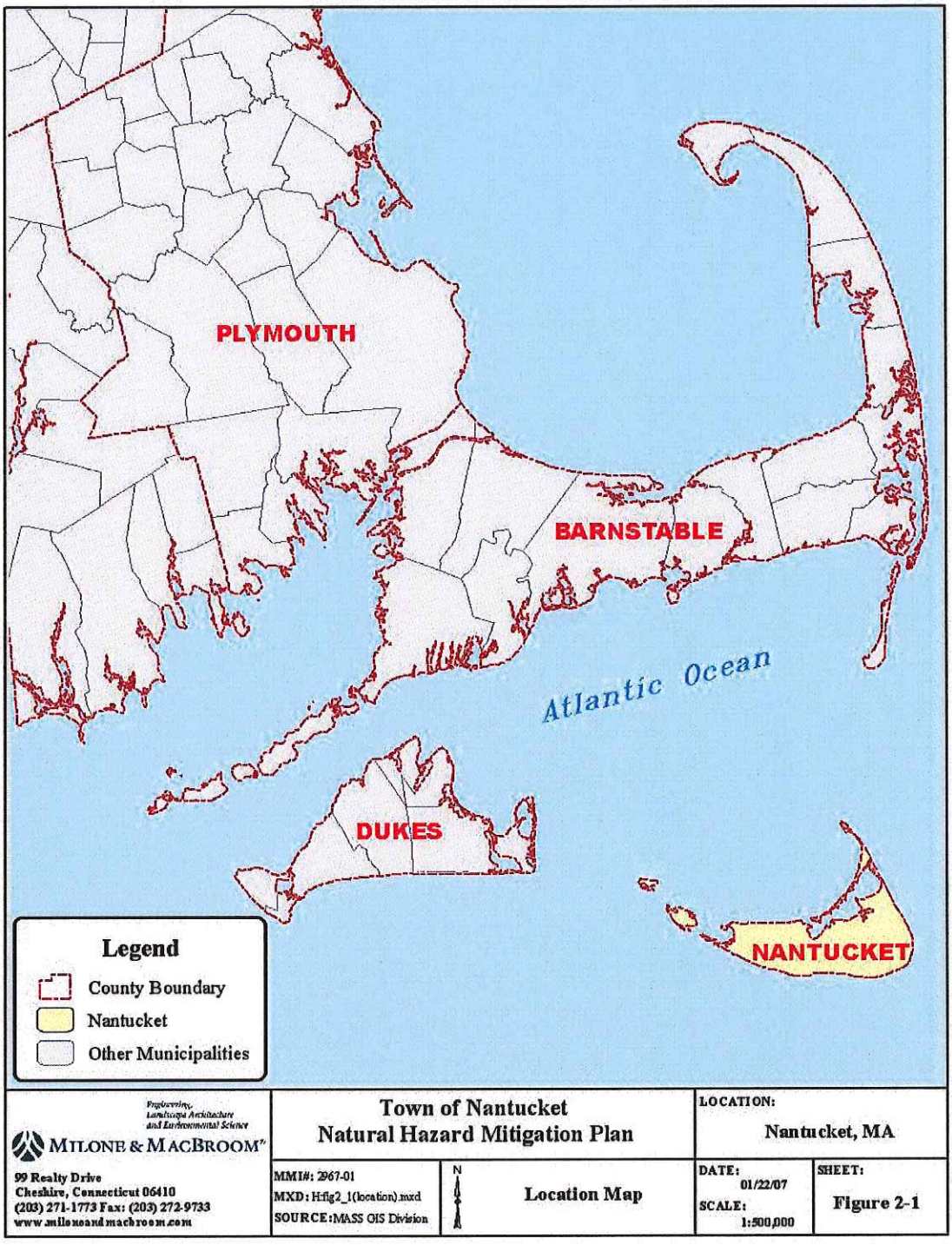
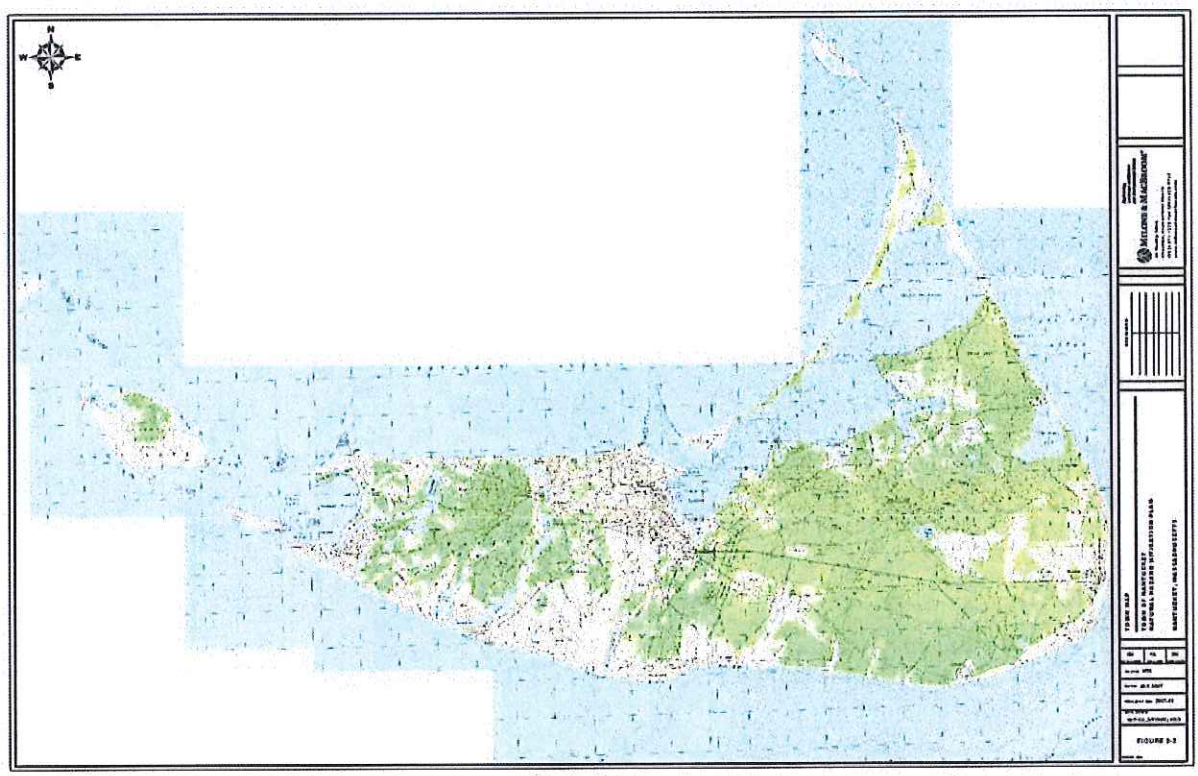


Figure 2-2 Town Map



## 2.2 *Geology*

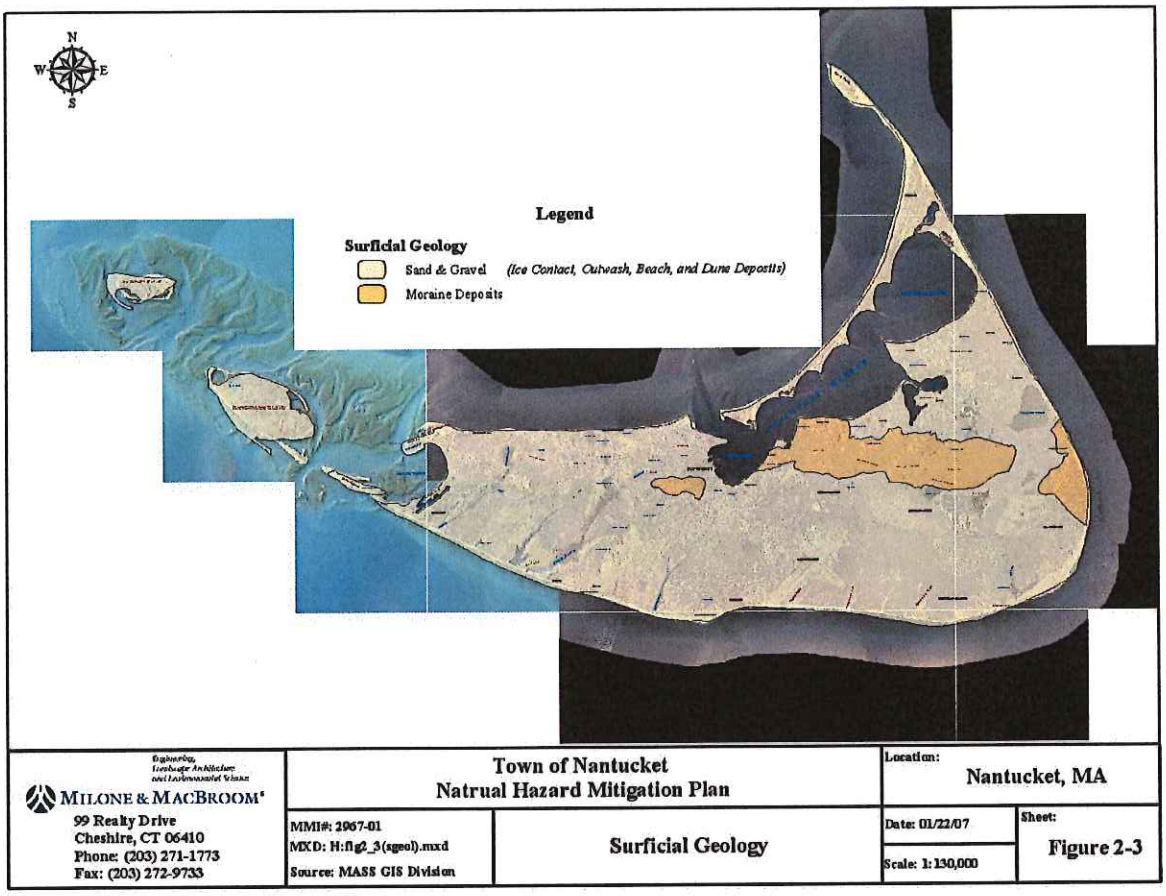
Geology is important to the occurrence and relative effects of natural hazards such as shoreline change, erosion, earthquakes, and flooding. Thus, it is important to understand the geologic setting and variation of geologic formations in Nantucket.

Nantucket is located in the Atlantic Coastal Plain, a broad belt along the eastern seaboard of the United States and the Gulf of Mexico, extending from the mouth of the Rio Grande to Cape Cod. The region is generally characterized by sedimentary rock formations and thick unconsolidated sediment deposits that extend to the continental shelf.

Nantucket was formed by the Laurentide continental ice sheet associated with the last North American glaciation, less than 25,000 years ago. Cape Cod, Martha's Vineyard, Block Island, and Long Island have similar origins. Sometime after 23,000 years ago, the glacier reached its maximum advance at a position marked by the islands of Nantucket and Martha's Vineyard. The terminal moraine of this glacier consists of unsorted glacial till (ranging from clay, silt, and sand to boulders) and extends from Nantucket Harbor to Siasconset ("Sconset"), including the Shawkemo Hills, Sauls Hills, Folger Hill, and the cliffs at Sankaty Head. Refer to Figure 2-3 for a depiction of surficial geology.

Other parts of the island are smoother and flatter, as they were formed as the outwash plain of the glacier. Outwash plains are made up of silt, sand, and gravel deposited by meltwater streams that flowed across the plain in a braided pattern. This resulted in a flat depositional surface that slopes gently away from the ice front. Outwash deposits can form an irregular morphology called kame and kettle terrain. A kame is a hill composed of outwash deposits, which originally filled a hole in the ice. When ice melted away, the deposits formed a hill. Kettles formed where outwash was deposited around and over an ice block. When the ice block melted, the outwash collapsed to form a hole.

Figure 2-3 Surficial Geology




| | | |
|---|---|---|
| Engineering, Landscape Architecture and Environmental Science<br>MILONE & MACBROOM<br>99 Realty Drive<br>Cheshire, CT 06410<br>Phone: (203) 271-1773<br>Fax: (203) 272-9733 | Town of Nantucket<br>Natrual Hazard Mitigation Plan | Location: Nantucket, MA |
| MMI#: 2067-01<br>MXD: H:\fig2_3(sgeol).mxd<br>Source: MASS GIS Division | Surficial Geology | Date: 01/22/07<br>Scale: 1:130,000<br>Sheet: Figure 2-3 |

By 18,000 years ago, the Laurentide ice sheet had retreated northward into the Gulf of Maine. By roughly 15,000 years ago, the ice had retreated from the Gulf of Maine and the remainder of New England.

Not all of the surficial materials of Nantucket were deposited directly by the glaciers or by glacial meltwater. Beach and dune deposits were laid down by waves and wind, respectively. Of course, these deposits were derived from the tills and outwash.

## *2.3 Climate*

Nantucket's island setting provides for moderate temperature variation characterized by distinct seasons. Average daily summer temperatures are in the low 70s and average daily winter temperatures are in the upper 20s and lower 30s Fahrenheit. Extreme conditions can raise summer temperatures to near 100 degrees and winter temperatures to below zero, although these occurrences are very infrequent. Mean precipitation is 37 inches, spread evenly over the course of a year with average precipitation of three to four inches per month. Snowfall ranges from 12 to 24 inches per year.

By comparison, average annual state-wide precipitation based on more than 100 years of record is higher, at 43 inches. However, average annual precipitation in Massachusetts has been increasing since the end of the 19$^{th}$ century. The National Climatic Data Center (2006) reports that the trend from 1895 through 2006 equates to an additional 1.18 inch of precipitation per decade. Likewise, total annual precipitation in Nantucket has increased over time. According to the Massachusetts Hazard Mitigation Plan (2004), precipitation in Massachusetts is predicted to increase by 10% in spring and summer, 15% in autumn, and 20 to 60% in winter. The continued increase in precipitation only heightens the need for hazard mitigation planning, as the occurrence of floods and snow hazards may change as a result of greater precipitation.

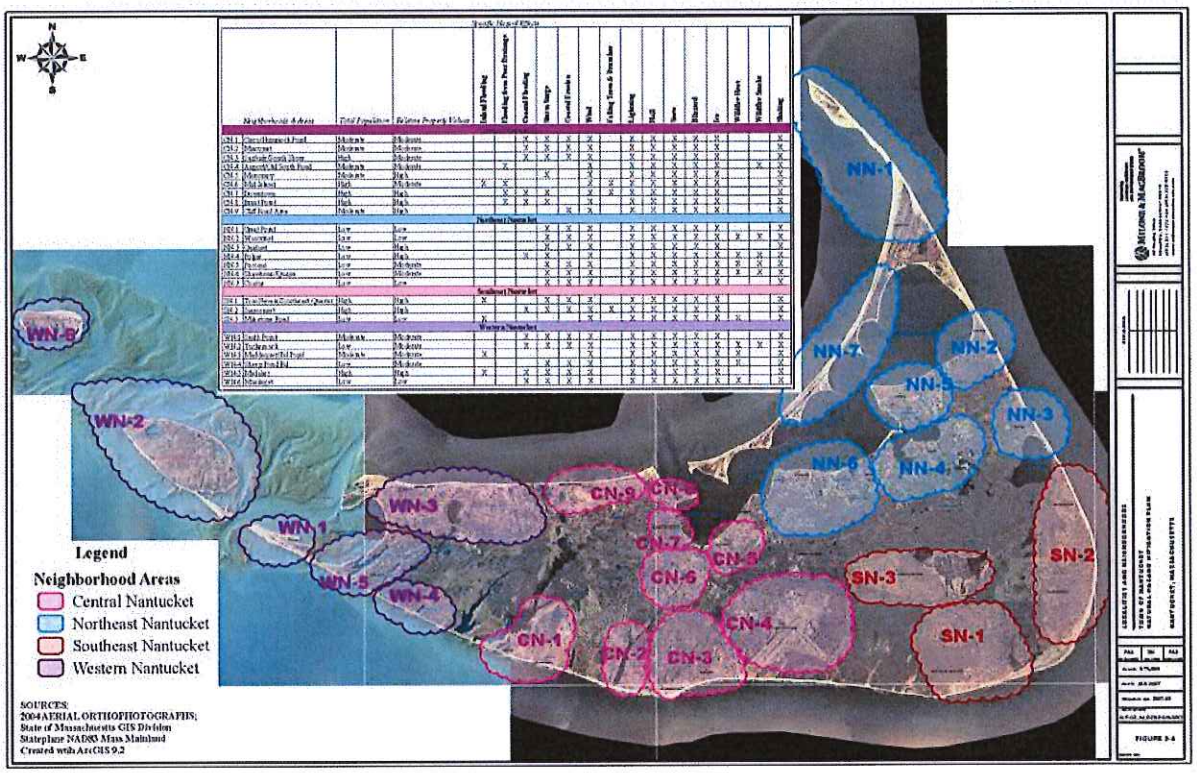
## 2.4 *History and Land Use*

Nantucket was discovered by Bartholomew Gosnold in 1602, but the first Englishmen to settle Nantucket arrived in 1659 when the land was owned by ten men. By 1670, the island was owned by only 27 men. After they laid out land for homesteads, approximately 60% of the island was set aside for sheep pasture. Owners of these sheep commons were known as "Proprietors of the Common and Undivided Lands of Nantucket." The expanses of common lands persisted until the 19th century when private ownership increased. By 1970, 92% of the island was privately-owned, yet still largely undeveloped.

Although Nantucket has only a few formally-named villages such as Madaket and Siasconset ("Sconset"), numerous neighborhoods are located throughout the Town. These are depicted on Figure 2-4 along with a cross-reference table of hazard effects. Many of these localities date back to the original pattern of settlement and land ownership on Nantucket. Unlike many cities and towns, Nantucket does not delineate boundaries between neighborhoods and localities. Thus, the patterns on Figure 2-4 are meant to be approximate and are intended to aid the discussions herein, and do not imply any formal demarcations.

Whaling began in the late 1600s but first came to prominence in Nantucket in the early 1700s. By the 1820s, Nantucket had become a wealthy city and the whaling capital of the world. This prominence continued until the 1840s, but as whaling ships increased in size, Nantucket Harbor was too shallow to accommodate them. Whaling moved to New Bedford, and in 1846 a large part of downtown Nantucket was destroyed by a fire. By the end of the decade, many residents had departed for gold exploration in California. The last whaling ship operated from Nantucket until 1869.

Figure 2-4 Localities and Neighborhoods



At the same time as the decline in whaling and the passing of the sheep pastures, agriculture also declined in Nantucket. By the 1870s, tourism was beginning to be viewed as a viable means of economic growth, although it did not take off until the 1890s. As recently as 1893, a railroad ran from downtown Nantucket to Surfside, turned at a right angle to the east running along the south shore, ending in Sconset. The railroad was abandoned in the 20th century in favor of other means of transportation.

Zoning ordinances did not exist on Nantucket for many years. The first historic districts were established in 1955, "Old and Historic Nantucket" and "Old and Historic Siasconset," to promote exterior design standards.

Current land use in Nantucket primarily consists of residential, commercial, institutional, and conservation lands. Some agricultural uses have remained as well. Refer to Figure 2-5 for a map of land use. Commercial uses are concentrated in the downtown and mid-island areas. Institutional uses such as schools, municipal buildings, and transportation centers are concentrated in the population centers of downtown, Sconset, and Madaket; and at the airport.

Approximately 16,419 acres of land in Nantucket are classified as conservation lands, owned by the Nantucket Conservation Foundation (NCF), Massachusetts Audubon Society, Madaket Land Trust, Sconset Trust, Nantucket Land Bank, Nantucket Land Council, The Nature Conservancy, the Trustees of Reservations, the Town of Nantucket, State and Federal governmental agencies, and other conservation groups. This is an increase of 24% above the 13,223 acres reported in 2001. Overall, the 16,419 acres make up 55% of the total land area of Nantucket. NCF owns 30% of Nantucket Island, and is the largest landowner in the Town. Refer to Figure 2-6 for a map of conservation lands.

Figure 2-5 Land Use Map

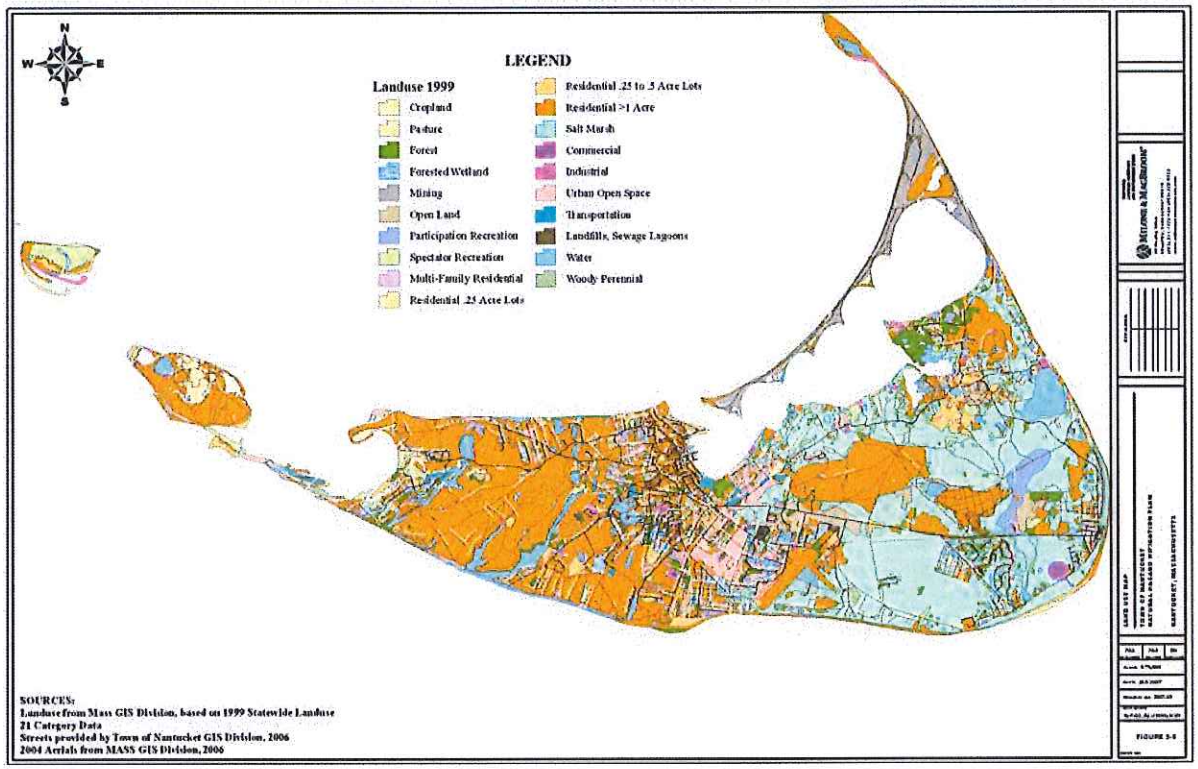
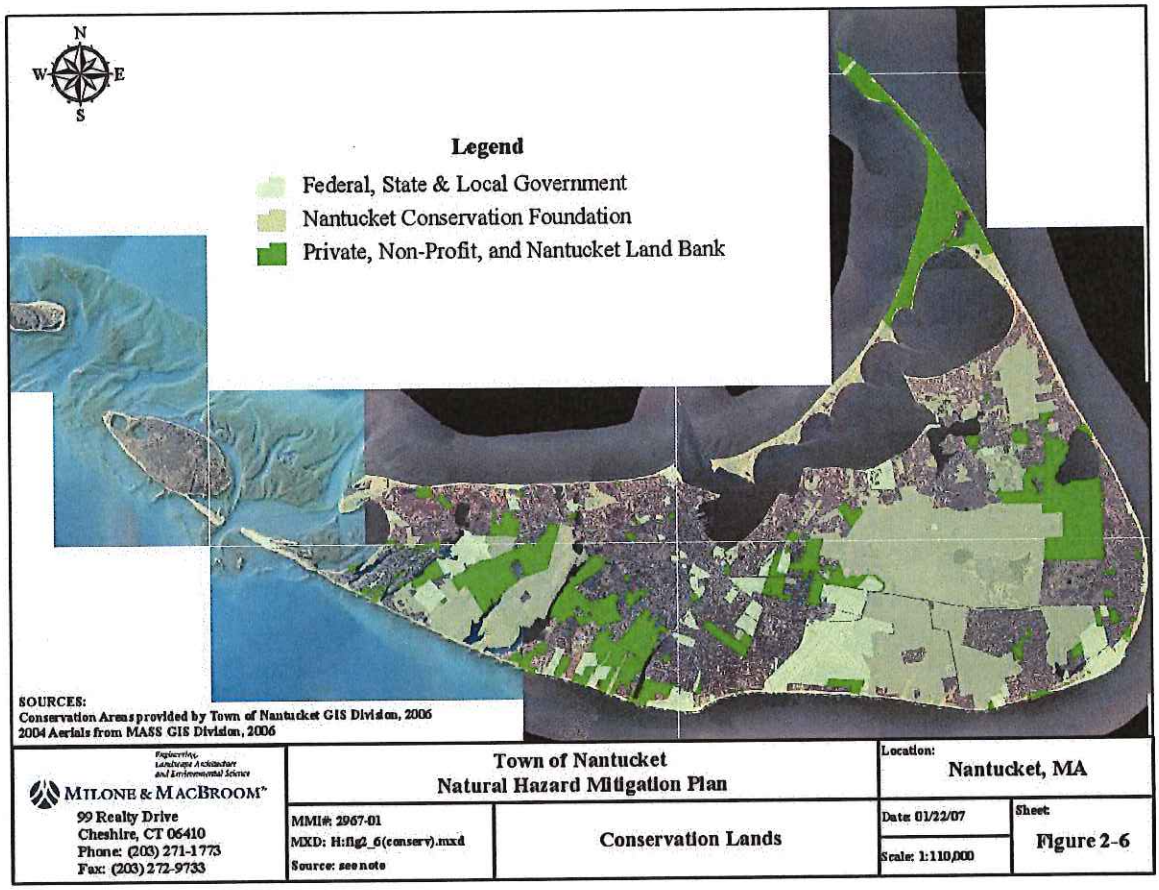


Figure 2-6 Conservation Lands



## 2.5 *Population and Demographic Setting*

Demographic trends for the Town of Nantucket are different than many other communities in Massachusetts and are closely tied to the island's economy. Nantucket was the third largest city in Massachusetts while its whaling economy was booming. At the end of its whaling heyday in the 1840s, Nantucket had a population of 9,712. By the 1870s, the town's population was only 4,000.

The suburbanization that characterized the U.S. after World War II from the late 1940s through the 1970s, with the construction of new roads and the enhanced availability of the automobile and federally funded housing programs, did not affect Nantucket. Instead, from the 1930s through the 1970s, the year-round population of Nantucket remained approximately 3,500. In the 1970s, the summer population was 16,000.

According to the 2000 U.S. Census, 9,520 people were residing in Nantucket. This represented an enormous population increase of 58% between 1990 and 2000. This growth was due in large part to the attractive setting and high quality of life, as well as the influence of tourism and the need for workers to support the tourism industry. The estimated population in 2005 was 10,168, a more stable 7% increase over the preceding five years, but still representing substantial growth as compared to trends for the State of Massachusetts. In 2000, 19% of the population of Nantucket was younger than 18 years of age, 70% was between the ages of 18 and 64, and only 11% was 65 years and older.

Overall town population density using the 2005 population estimate is 212 people per square mile. However, taking the 16,419 acres of undeveloped and conservation land into account, the developed portions of the Town have a density of approximately 477 people per square mile. The downtown, Madaket, and Sconset neighborhoods are home to more residents than any other areas in the community. More than 1,000 commercial

and residential buildings are located downtown, and approximately 700 homes are located in Sconset.

According to the Massachusetts Institute for Social and Economic Research (MISER, 2003), the projected Town populations in 2010 and 2020 are 11,939 and 14,426, respectively. These projections are taken from the MISER "middle series" projection. The "high series" projections for 2010 and 2020 are 12,334 and 15,314, respectively, slightly higher than the middle series projections. In general, all of these projections estimate that continued population growth will occur. The anticipated locations of this growth are discussed in the following section.

## *2.6 Development Trends*

Unlike many coastal communities in the United States, residential development on Nantucket is not concentrated along the shoreline. This is mainly because many of these areas are substantially protected as conservation lands, and the remaining private land is already developed in accordance with previously accepted densities or more recent zoning.

Instead, residential development is projected to remain scattered among available parcels located in the central and eastern portions of the Town. The potential for large developments is believed to be low. Very little development is occurring in the northeast and western parts of the Town. The most common types of applications to the Planning Board are "ANRs" (approval not required) for infill and development of disperse lots. Overall, ANRs and new subdivisions create approximately 100 lots per year. This rate of residential development is generally consistent with the population projections described in Section 2.5.

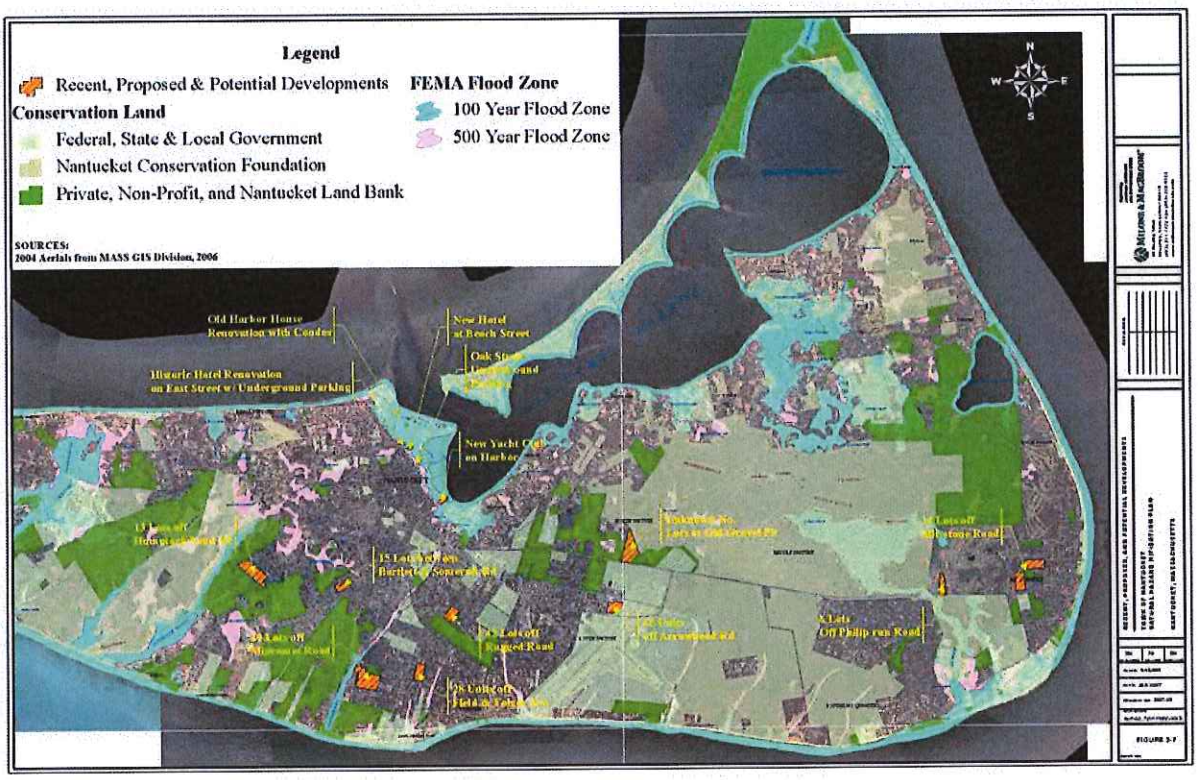
Approximately 15 residential developments have been constructed in the last year, are slated for construction in the near future, have pending approvals, or have been identified as possible developments during discussion with local officials. Some of these include:

- 42 lots (with eight affordable)
- 28 lots (with five affordable)
- 13 lots off Hummock Pond Road
- 15 lots between Bartlett Road and Somerset Road
- 19 lots off Miacomet Road
- 28 units along Field and Folger Avenues
- 42 units off Rugged Road
- 65 units off Arrowhead Road
- An unknown number of lots at an old gravel pit off Milestone Road
- 6 new lots off Philip Run Road
- 14 new lots north of Milestone Road and west of Burnell Street; and
- A few condominium units at the old Harbor House hotel site

Figure 2-7 identifies these recent, current, or future potential residential developments. Note that none of the recent and new residential developments are located in mapped floodplains.

Commercial developments are also identified on Figure 2-7. These include three inns and hotels in the downtown area (two renovations and one new construction) and the new Great Harbor Yacht Club on Nantucket Harbor in the location of an old pier. Underground parking with a flood gate is being developed downtown off Oak Street. Most of these projects are in mapped floodplains. Overall, most of these projects involve renovations and redevelopment, given the scarcity of vacant land in the downtown area.

Figure 2-7 Recent, Proposed, and Potential Developments



Although new development is regulated closely by various Town departments and commissions, developers do not always adhere to the highest possible level of storm damage prevention. For example, the developers of Great Harbor Yacht Club submitted a Letter of Map Revision to FEMA and were approved to change the flood zone from V to A (approval date January 6, 2006), essentially lowering the standard for construction relative to wave velocity damage prevention. While this process may be technically defensible, it has resulted in waterfront development with a lower standard for protection against storms.

## *2.7 Governmental Structure*

The Town of Nantucket is managed by a Board of Selectman. The Board of Selectmen oversees many of the municipal departments, commissions, and boards. According to the most recent report of the Nantucket Government Study Commission, local government has three broad components consisting of voters and the Town Meeting, elected officials and appointed committees, and administration.

Elected boards and officials include the selectmen, Town Clerk, Planning Board, Planning & Economic Development Commission, School Committee, Historic District Commission, and the Water Commission. Boards and Commissions appointed by the Selectmen include Airport, Conservation, Parks & Recreation, Zoning Board of Appeals, Finance, and Local Emergency Planning. The directors or chiefs of the Fire, Police, Public Works, Health, Building, and Marine Resources Departments report to the Town Administrator. In turn, the Town Administrator reports to the Board of Selectmen. An organizational chart is included as Figure 2-8.

Figure 2-8

Many municipal departments, commissions, and boards are involved with natural hazard pre-disaster mitigation. The following subsections describe general departmental responsibilities, and duties related to natural hazard pre-disaster mitigation. Where applicable, one or more of the six types of pre-disaster mitigation (*prevention, property protection, natural resource protection, structural projects, emergency services, and public education*) are identified as relevant for each department.

***Emergency Management Department***

The Emergency Management Department "seeks to maximize survival of persons and preservation of property in the County/Town of Nantucket in the event of a natural or man-made disaster by effective planning and coordinated use of all personnel, equipment, available shelter, and any other resources during an actual emergency." The Department is also responsible for mitigation and financial recovery from such incidents, and for formulating and exercising emergency plans for natural disasters and hazardous materials accidents which may occur at facilities and transportation routes within the County/Town.

According to the EOP, the Emergency Management Director's responsibilities relative to mitigation and preparedness include:

- Coordinates and carries out all Emergency Management activities in emergency and non- emergency time periods ensuring smooth running of the department and the EOC.
- Coordinates public emergency education/awareness.
- Develops and maintains the local Comprehensive Emergency Management Plan. Refer to the Resource Manual for suggested forms and lists to be used in the EOC.

- Develops EOC procedures to assure activation on short notice and adequate staffing and communications capabilities including maintaining lists of resources and personnel to be notified when emergency situation occurs.
- Oversees the planning and development of basic warning/notification functions.
- Trains public officials and EOC personnel regarding EOC operations.
- Ensures stocking and/or tracks availability of food, water, administrative supplies,
- Designates facilities to be used as EOC and alternate EOC. other essential supplies and equipment for emergency operations.
- Ensures that adequate resources are available at alternate EOC.
- Consults with coordinators of all individual emergency functions to ensure readiness for management of potential emergency/disasters.

The Emergency Management Department, through the Fire Department, coordinated and oversaw the development of this Pre-Disaster Hazard Mitigation Plan. In the future, this department will coordinate the update of the Pre-Disaster Hazard Mitigation Plan.

As a hybrid of the Fire and Police Departments, Emergency Management Department staff include the Police Chief/Emergency Management Director, the Fire Chief/Deputy Emergency Management Director, and the coordinator of Radio Amateur Civil Emergency Services (RACES) and Amateur Radio Emergency Service (ARES). The types of mitigation that are directly administered by the Emergency Management Department include mainly emergency services and public education. However, as the department responsible for emergency planning, all six types of natural hazard mitigation may be influenced by the actions of the department.

***Fire Department***

Day-to-day duties of the Fire Department include fire response, emergency medical response, fire prevention and safety education, ambulance response, and fire alarm plan

review. Duties related to natural hazard mitigation include those listed above, such as planning and coordination of personnel, equipment, shelters, and other resources necessary during an emergency. The types of mitigation that are directly administered by the Fire Department include mainly emergency services and public education. Communication and coordination with the Police Department (below) is critical before, during, and after natural hazard emergencies.

According to the EOP, the Fire Department's other responsibilities relative to mitigation and preparedness include:

- Provides fire code enforcement and fire prevention services including inspection public education.
- Maintains plans for providing resources and services needed during disaster/emergency periods.
- Maintains fire department resources.
- Provides training of primary and auxiliary fire personnel to utilize to the maximum degree resources during emergency/disaster periods.
- Ensures hazardous materials safeguards are in place.
- Maintains readiness of all fire service equipment, supplies, procedures, and mutual aid agreements needed in connection with emergency disaster response activities.

***Police Department***

Day-to-day duties of the Police Department include crime prevention, criminal investigations, traffic enforcement, motor vehicle accident investigations, beach patrol, and bicycle patrol. Duties related to natural hazard mitigation include planning and coordination of personnel, equipment, shelters, and other resources necessary during an emergency. The types of mitigation that are directly administered by the Police Department include mainly emergency services and public education. Communication

and coordination with the Fire Department (above) is critical before, during, and after natural hazard emergencies.

According to the EOP, the Police Department's other responsibilities relative to mitigation and preparedness include:

- Maintains plans for maintaining law and order and traffic and crowd control during disaster/emergency periods.
- Maintains law enforcement resources.
- Provides training of primary and auxiliary law enforcement personnel.
- Ensures that law enforcement mutual aid agreements are in place.

***Department of Public Works***

Day-to-day duties of the Department of Public Works (DPW) include engineering, wastewater collection and treatment at the Surfside and Sconset treatment plants, sewer maintenance, solid waste disposal and recycling, and roadway maintenance. The types of mitigation that may be administered by DPW include prevention, property protection, natural resource protection, and structural projects.

Specifically, with regard to pre-disaster mitigation, roadway/infrastructure maintenance and complaint logging/tracking are the two primary duties of the DPW. For example, DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. DPW also conducts snow removal and deicing on roads; tree and tree limb removal in right-of-ways; and maintains and upgrades storm drainage systems to prevent flooding caused by rainfall. Approximately 250 trees are pruned each year.

According to the EOP, the DPW's other responsibilities relative to mitigation and preparedness include:

- Maintains plans for provision of equipment and services needed during emergency/disaster period.
- Provides training as needed to DPW and other response personnel for optimal
- utilization of resources during emergency/disaster periods.
- Maintains DPW resources. Refer to Resource Manual for DPW inventory.
- Maintains roads, bridges, waterways, water and sewer systems and services.
- Maintains flood control systems.
- Provides engineering services and consultation.
- Provides snow and debris removal.
- Maintains readiness of all DPW equipment, supplies, and personnel needed in connection with emergency/disaster response activities.
- Ensures written agreements are in place with emergency response organizations for utilization of equipment.
- Provides fuel storage.

Because of the duties described above, DPW is often the de-facto first responder during emergencies. Disasters are extremely taxing on the resources of the Department, and the island setting of Nantucket precludes opportunities for mutual aid agreements with other municipalities, such as those enjoyed by mainland communities. Mutual aid memorandums of understanding are in place with local contractors, and these are used when necessary during large storms. Although DPW typically is supplied by the Town with needed equipment, staffing sometimes is not optimal to operate the equipment during emergencies. Even with these potential problems, DPW has succeeded in maintaining access for the Police and Fire Departments to respond to emergencies.

***Building Department***

The Building Department issues permits for building, electrical, plumbing, gas, and siding; issues zoning violations; and issues certificates of occupancy and certificates of inspection. Although other departments and commissions may review development plans and develop or revise regulations, many important types of pre-disaster mitigation are funneled through, and enforced by, the Building Department. For example, the Building Department enforces A and V-zone standards for flood-proof construction and building elevations, maintains elevation certificates, and enforces building codes that protect against wind and fire damage. Thus, the types of mitigation that are administered by the Building Department include prevention and property protection.

***Health Department***

The Health Department is responsible for licensing, inspections, regulation enforcement, water quality testing, and complaint investigations as related to sanitary issues. The Health Department coordinates much of the education and outreach that is necessary for successful pre-disaster mitigation. For example, a recent effort of the Health Department has been education of property owners, merchants, and residents in flood zones to move critical equipment and property off the first floor, above flood elevations. Thus, the types of mitigation that are administered by the Health Department include prevention, property protection, and public education.

***Marine and Coastal Resources Department***

The Marine and Coastal Resources Department has five primary areas of responsibility, as follows:

- Harbor Management – The department operates the Town's 100-slip marina, seasonal transient slips, and pump out facilities; permits and inspects 1,600 private moorings; negotiates and monitors the 125 rental mooring contract; performs search and rescue missions, fire fighting, and oil spill response throughout all waters of Nantucket; and deploys and maintains 78 navigational aids.

- Law Enforcement – Enforces state and local boating laws, safety regulations, boat registration, jet skis, and speeding; enforces fisheries (within the three mile limit) and shellfishing state and local laws; issues 1,800 non-commercial shellfish permits; patrols and regulates 100 commercial bay scallop boats for a five month season; and posts and patrols all areas open/closed to shellfishing.

- Water Quality – Maximizes the number of non-commercial and commercial shellfish beds open to the public; performs water sampling and analysis for all waters of Nantucket; maintains parameters outlined for the continuance of a Federal No-Discharge Zone with emphasis on education and enforcement; coordinates Title V sampling with the Health Department to reduce the number of septic sources of pollution; and monitors single source and ground water run off pollution points.

- Beach-Pond Management – Rescues individuals endangered while swimming and boating and provides first aid; coordinates marine-related missing person searches with other agencies; continuously checks barrier beaches for marine mammal stranding events and monitors areas for endangered species prior to pond opening and dredging activities; and issues beach stickers and provides educational materials to individuals driving on the authorized beaches.

- Support and Maintenance – Provides technical assistance to state and local agencies upon request in the development of recommendations for environmental issues; maintains department buildings, piers, boats and equipment on a year-round basis;

and develops bid specifications, coordinates grant awards, and monitors contract performance (for example, related to major repairs of department structures).

With regard to pre-disaster mitigation, the Department has many roles, reflecting all six mitigation types (prevention, property protection, natural resource protection, structural projects, emergency services, and public education). The Department's mission is to be extremely proactive when it comes to storms. Department staff post weather and surf advisories and conduct informal education of boaters regarding the potential for storm damage. Before storms, the Department first recommends that people leave Nantucket, and then assists remaining boaters with removal of boats from the harbor, and securing crafts that remain in the harbor. The Department is responsible for maintaining, repairing, and improving piers and boat ramps that are used to remove and secure boats. Finally, through its beach management duties, the Department helps protect natural resources that reduce hazard effects, such as dunes and barrier beaches.

***Conservation Commission***

The Massachusetts Wetlands Protection Act requires that no person shall remove, dredge, or alter any bank, freshwater or coastal wetlands, beach, dunes, flat, marsh, meadow or swamp bordering on any resource area as defined in the Act without filing written notice of the intention to perform such work with the Conservation Commission of the Town in which the land is located and receiving a permit from the Commission to perform the work. This mandated authority was reinforced by the 1963 Annual Town Meeting which authorized the establishment of a Conservation Commission for the Town.

The Conservation Commission is comprised of seven members appointed by the Board of Selectmen. The Commission function is to review, condition and permit activities within 100 feet of inland and coastal wetlands. The Town has a separate Wetlands By-law, Chapter 136, that increases protection over the State Wetlands Protection Act.

In February 1988, the Conservation Commission passed local regulations which provide for more strict controls in and around both inland and coastal wetlands than are provided by the State's enabling legislation and ensuing regulations. The Commission's protected interests of public and private groundwater protection, prevention of pollution, erosion control and storm damage prevention provide great benefit to the Town's seasonal and year-round economy.

***Planning Board***

The Planning Board regulates secondary dwelling permits, residential subdivisions, and special permits for major commercial development, Moorlands Management District developments, major residential developments, multi-family developments, and second curb cuts. The Board is elected separately than other municipal commissions. Planning Board staff administer subdivision regulations, amend zoning regulations and zones as needed, and coordinate planning studies and documents.

Recall that two important types of natural hazard mitigation are prevention and natural resource protection. Because the subdivision regulations, zoning regulations, and several master and area plans directly and/or indirectly address hazard mitigation, the Planning Board and staff have a unique opportunity to enforce and encourage pre-disaster mitigation, similar to the Conservation Commission.

***Nantucket Memorial Airport***

The Nantucket Memorial Airport is one of the two important transportation hubs serving the community. The Nantucket Memorial Airport is governed by the Town's Airport Commission. According to the Town of Nantucket web site, the airport has operated for

more than 60 years and is open seven days a week, year-round. The airport serves over 500,000 commercial passengers each year.

According to the airport web site, Nantucket Memorial Airport is responsible for operating and maintaining airport facilities; and ensuring that runways, taxiways and other facilities are in good working condition, meet FAA regulations, and are available for use. The FAA is responsible for managing Nantucket's airspace and for ensuring the safe and expeditious flow of traffic. This is accomplished through a coordinated effort between Nantucket Air Traffic Control Tower located at the Airport and Cape Terminal Radar Approach Control located at Otis Air Force Base on the Cape. Nantucket Air Traffic Control Tower is responsible for selecting the runway(s) in use at any particular time. With regard to pre-disaster mitigation, the Nantucket Memorial Airport is mainly involved with the element of emergency services.

***Wannacomet Water Company and Siasconset Water Company***

Wannacomet Water Company and Siasconset Water Company provide potable water and fire protection to their respective water service areas. Both water companies are municipal departments that are overseen by separate elected commissions.

The water companies provide support roles as related to natural disaster preparation and response. Water company equipment and personnel is available to assist the Emergency Management Department. Before storms, water tanks are filled and equipment is secured. Through careful preparation, fire protection and potable supply are available during and after natural disasters. Natural disasters specifically addressed in the water system emergency plans include hurricanes, fires, and earthquakes.

### *Selectman's Office*

The mission of the Board of Selectmen is to "serve the community by providing clear, concise goals and policies that ensure quality in the delivery of town services and improved efficiencies in operating town government." The Office of the Selectmen oversees administration of Town government, licensing, personnel administration, and administration of policies and procedures. Although the selectmen and the Town Administrator do not directly participate in hazard mitigation, they oversee most of the other departments described in this section, including Health, Building, Fire, Police, Public Works, and Marine and Coastal Resources; and appoint the Airport Commission, Conservation Commission, and Zoning Board of Appeals.

## 2.8 *Review of Existing Plans and Regulations*

The Town of Nantucket has a number of regulations on the books that fall within the categories of natural hazard mitigation formally known as "property protection," "natural resource protection," "emergency services," and "prevention." These regulations are incorporated into the zoning ordinance, the wetlands regulations, and the subdivision regulations. These three sets of regulations are presented below.

### *Zoning Regulations*

In Nantucket, the Planning Board is charged with administering zoning regulations. As explained in Section 2.7, the Planning Board is elected separately than other municipal commissions. The zoning ordinance is Chapter 139 of the Code of the Town of Nantucket.

*Flood Hazard Overlay Zone*

The zoning ordinance provides for a Flood Hazard overlay zone to ensure public safety through reducing the threats to life and injury, among other purposes. The corresponding regulations for this overlay zone stipulate limitations on construction of structures and other activity. According to Chapter 139, *"The Flood Hazard District is located and bounded on maps entitled, 'Flood Insurance Rate Map, Town of Nantucket, Massachusetts, Nantucket County' prepared by the Federal Emergency Management Agency dated November 6, 1996.... The Flood Hazard District shall be considered an overlay district to be superimposed on the Zoning Map of Nantucket."* The District includes all special flood hazard areas designated on the Nantucket Flood Insurance Rate Map (FIRM) as Zones A, AE, A1-30, AH, AO, V1-30, and VE, which indicate the one-hundred-year regulatory floodplain.

The cited purpose in Chapter 139 is directly tied to flood damage mitigation: *"The purposes of the Floodplain District are to ensure public safety through reducing the threats to life and personal injury; eliminate new hazards to emergency response officials; prevent the occurrence of public emergencies resulting from water quality, contamination, and pollution due to flooding; avoid the loss of utility services which if damaged by flooding would disrupt or shut down the utility network and impact regions of the community beyond the site of flooding; eliminate costs associated with the response and cleanup of flooding conditions; reduce damage to public and private property resulting from flooding waters."*

In addition to meeting the requirements of zoning districts in which a particular piece of land may lie, all development which lies within a boundary of the Flood Hazard District, including structural and nonstructural activities, alterations, additions, relocations and demolitions, must be in compliance with MGL c. 131, § 40, and the requirements of the

Massachusetts State Building Code pertaining to construction in floodplains (currently Section 2102) and the following additional requirements:

- V1-30 Zones: All new construction, except water-related structures such as piers, groins, and similar structures, shall be located landward of the reach of mean high tide. Man-made alteration of sand dunes which would increase potential flood damage is prohibited.

- AH and AO Zones: All new residential and commercial structures and substantial improvement to residential and commercial structures have adequate drainage paths around structures on slopes, to guide floodwaters around and away from proposed structures.

In addition, all development in the Flood Hazard District, including structural and nonstructural activities whether permitted by right, by site plan review, or by special permit, must be in compliance with the following:

- Section of the Massachusetts State Building Code that addresses floodplain and coastal high hazard areas (780 Code of Massachusetts Regulations [CMR] 3107.0, "Flood Resistant Construction");
- Wetlands Protection Regulations, Department of Environmental Protection (DEP) (310 CMR 10.00);
- Inland Wetlands Restriction, DEP (302 CMR 6.00);
- Coastal Wetlands Restriction, DEP (302 CMR 4.00);
- Minimum Requirements for Subsurface Disposal of Sanitary Sewage, DEP (310 CMR 15, Title 5);
- Any variances from the provisions and requirements of the above-referenced state regulations may only be granted in accordance with the required variance procedures of these state regulations; and

- All other applicable Nantucket regulations and bylaws.

*Open Space District*

A new Open Space (OS) district was proposed in 2006. This district is believed to be beneficial to natural hazard disaster mitigation because it will protect areas of Nantucket that have been purchased for, or designated as, open space. The Bylaw allows a variety of uses such as conservation, recreation, agriculture, cemeteries, small parking lots, and certain expansions of existing dwellings.

***Subdivision Regulations***

In Nantucket, the Planning Board is charged with administering subdivision regulations. Components of the regulations that address natural hazard mitigation are listed below:

- Section 2.0 of the subdivision regulations requires that a site analysis report answer the following questions relative to flood hazards: *"Has the layout of streets and lots fully reflected the need to protect life and property by properly locating building lots out of areas of Special Flood Hazard as delineated by the Federal Government? Will floodway easements be used to protect these areas from encroachment and advise lot purchasers of the nature of their prospective property? Has the proposed system of drainage taken severe storm damage into account?"*

- Section 3.04 of the subdivision regulations requires that subdivisions be designed to prevent loss of life and property due to flooding. Parts a, b, and c of Section 3.04 specify additional requirements for flood damage prevention as follows:

  - √ ...new structures will be able to be safely sited within areas of each lot so that the lowest floor (including basement) is elevated to above the 100-year flood;

- √ Designate flood hazard areas as common open space to be deeded fee simple to the Nantucket Conservation Commission, a homeowners association or a suitable conservation organization;
- √ Include conservation easements in the plan to accommodate flood hazard areas.

Section 3.04 further requires that all public utilities and facilities such as sewer, gas, electrical, and water systems shall be located, elevated, and constructed to minimize or eliminate flood damage. Special drainage measures shall be taken to reduce exposure of areas, both on and off-site, to flood damage.

- Section 3.08 of the subdivision regulations requires that "land subject to hazard to life, health, or property shall not be subdivided for residential purposes until such hazards have been eliminated or unless adequate safeguards against such hazards are provided."

- Section 4.07 of the subdivision regulations requires certain easements for providing underground electrical, cable, and telephone lines; and provision of easements along watercourses or channels to provide for the possibility of flood and protection of banks.

- Part (a) of Section 4.08 of the subdivision regulations requires that access be adequate to "ensure direct ingress and a rapid response time for emergency vehicles." Part (b) requires that electrical and telephone service be installed underground.

***Wetland Regulations***

The Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00) provide guidance to all local municipalities in the State relative to inland and coastal wetland and coastal resource protection. The regulations were revised in 2005 to provide greater

protection through review of activities in buffer areas, streamline some permit processes, and clarify other provisions of the law.

In Massachusetts, local Conservation Commissions are charged with administering wetland regulations. As explained in Section 2.7, the Nantucket Conservation Commission is comprised of seven members appointed by the Board of Selectmen. The Commission function is to review, condition and permit activities within 100 feet of inland and coastal wetlands.

The Town has a separate Wetlands Bylaw, Chapter 136 of the Code of the Town of Nantucket, that increases protection above the State Wetlands Protection Act. Flood and erosion hazard mitigation are important considerations set forth in the bylaws. Section 136-2 of the wetland regulations require that projects be reviewed in the context of not only impacts to wetlands, but *potential effects on flood control, erosion control, and storm damage prevention.* Section 136-3 of the wetland regulations prevents filling, altering, dredging, or construction on or within *100 feet of land subject to tidal action, coastal storm flowage, inland or coastal flooding or inundation, or within 100 feet of the 100-year storm line*, without a permit.

The Town of Nantucket Conservation Commission has published *Wetland Protection Regulations* (revised through May 18, 2005) to administer Bylaw Chapter 136. These regulations set forth certain performance standards for activities that are designed to protect the ability of resources to protect against flood damage and erosion, and prevent or limit construction near areas prone to flood damage and erosion. Examples of these performance standards include:

- For "Land Under the Ocean"

  - √ "No new bulkheads or coastal engineering structures shall be permitted to protect structures constructed or substantially improved after 8/78. Bulkheads may be rebuilt if the Commission determines that there is no environmentally better way to control the erosion problem, including in appropriate cases the moving of the threatened building. Other coastal engineering structures may be permitted only upon a clear showing that no other alternative exists to protect a structure built prior to 9/78, but not substantially improved, from imminent danger."
  - √ "Water dependent projects shall be designed and performed so as to cause no adverse effects on… erosion control… storm damage prevention, flood control…."

- For "Coastal Beaches"

  - √ "No new bulkheads or coastal engineering structures shall be permitted to protect structures constructed or substantially improved after 8/78…[same as above]."
  - √ "Clean fill of similar grain size may be used on a coastal beach nit not on a tidal flat, only if the Commissioner authorizes its use, and only if such fill is to be used for a beach or dune nourishment project."
  - √ "In areas of eroding shoreline, the distance from all buildings to the coastal beach shall be at least 20 times the average annual shoreline erosion or 100 feet, whichever is the lesser."

- For "Coastal Dunes"

  - √ "Fill may be used only if the Commissioner authorizes its use and only if such fill is to be used for a beach or dune nourishment project."

- √ "Any activity allowed on a coastal dune or within 100 feet of a dune shall be restricted to such activity that is determined by the Commissioner not to have any adverse effect on the dune… by causing any modification of the dune form or slope that would increase the potential for erosion, storm or flood damage…."

- For "Coastal Banks"

  - √ "No new bulkheads or coastal engineering structures shall be permitted to protect structures constructed or substantially improved after 8/78…[same as above]."
  - √ "In areas of eroding shoreline, the distance from all buildings to the coastal beach shall be at least 20 times the average annual shoreline erosion or 100 feet, whichever is the lesser."
  - √ "All permits issued for the construction of buildings under the Bylaw within 100 feet landward of the top of coastal bank shall contain the specific condition that no coastal engineering structure of any kind shall be permitted on an eroding bank in the future to protect the project allowed by this permit."

- For "Land Subject to Coastal Storm Flowage"

  - √ "The work shall not reduce the ability of the land to absorb and contain flood waters, or to buffer inland areas from flooding and wave damage."
  - √ "Building upon areas subject to coastal storm flowage in locations where such structure would be subject to storm damage may not be permitted. If permitted, all construction must be in compliance with state and local building code regulations for flood hazard areas."

- For "Vegetated Wetlands"

  - √ Proposed projects shall not use procedures that the Commission determines changes the flood protection function (leveling out of storm surges by storing and slowly releasing water) of vegetated wetlands by significantly changing the rate of water flow through the wetlands (by channelization or other means)."

- For "Land Subject to Flooding"

  - √ Projects on land subject to flooding shall be permitted only in connection with such procedures determined by the Commission as not having the effect of reducing the ability of the land to absorb and contain floodwaters."
  - √ "The Commission may require compensating or greater flood storage capacity in the same watershed if it permits any filling of land subject to flooding, and all filling of areas subject to flooding shall be strictly minimized."
  - √ Building upon areas subject to flooding shall be in compliance with appropriate state and local building code requirements."

***Municipal Plans***

The Town of Nantucket has an active planning process through several boards and commissions, the results of which are evident by the numerous plans and reports available to the public. The Comprehensive Community Plan (2001) was developed under the guidance of the Planning & Economic Development Commission to set forth goals, objectives, and recommendations for different municipal departments and commissions relative to quality of life and sustainable growth. In addition, the Town has prepared or authorized preparation of a build-out analysis, at least three special area plans (discussed below), and a variety of transportation plans.

Development of a new Comprehensive Plan is underway under the guidance of the Planning Board. The Town's mapping is impressive, indicating that competent GIS analysts are on hand to maintain and present a variety of geographic data. Zoning, historic district, beach, bus route, and other maps are readily available via the Town's web site.

***Comprehensive Community Plan***

The Comprehensive Community Plan organizes its recommendations into chapters about growth, housing, employment, environmental issues, transportation, infrastructure, and health. Many of the recommendations are quite relevant as they encompass elements of pre-disaster hazard mitigation relative to coastal hazards, fire safety, wind damage prevention, emergency services, and public safety:

- Carefully review new development in proximity to the shoreline, especially in areas of active coastal erosion;
- Support efforts to identify, implement, and thoroughly test new beach preservation technologies such as beach dewatering;
- Prepare a comprehensive assessment of long-term effects of shoreline erosion on existing infrastructure – both public and private, historic and recent – including an assessment of the relative costs of relocation versus the implementation of various beach-protection technologies.
- Encourage a zoning bylaw amendment… that would apply to new homes in relative proximity to the spring high water line within those parts of the Island Perimeter District that are especially prone to coastal erosion. The purpose would be to minimize public or private liability or loss. This provision is meant to complement the jurisdiction of the Conservation Commission over coastal resources.

- Urge the water companies to establish a program for the extension of the public water supply into areas within growth boundaries that require public water for fire protection.
- Urge the water companies to identify and upgrade those portions of the public water supply systems that are substandard from the standpoint of needed pressure and volume for fire-fighting purposes.
- Urge the water companies to continue to implement innovative solutions to fire protection where it is not feasible to extend a conventional water system.
- Study the feasibility and cost-effectiveness of central dispatching for all public safety providers to increase the effectiveness of response and better coordinate provision of emergency services.
- Evaluate the system of private roads to determine where essential improvements are necessary to provide adequate access for emergency vehicles; where certain roads are deemed essential… consider the dedication of those roads as public roads or the formal negotiation of either public or private maintenance agreements.
- Add additional boat ramps at all harbors for emergency preparedness purposes and backup storage sites for vessels hauled during emergencies.
- Utilize opportunities occasioned by other projects to place utilities underground.
- Continue the program of placing utilities underground in the historic districts of Nantucket and Siasconset and as opportunities arise, elsewhere throughout the island.
- Conduct a survey of the island's private roads to identify those to be acquired as public roads for safety of residents. These roads shall include:
  - √ private through roads that interconnect two or more public roads
  - √ major collector roads that are principal or exclusive access roads to neighborhoods with substantial populations
- Develop and adopt a policy governing the improvement of public roads that is based on the premise that the lowest acceptable road-improvement standard shall be utilized to provide public safety.

- Enforce existing private road maintenance agreements that are required by the Town of Nantucket.
- Continue to propose that new subdivisions with private roads have homeowners associations that provide maintenance adequate for public safety.

The Comprehensive Community Plan has a related Status Chart that summarizes the recommendations of this plan along with the status of these recommendations. The recommendations in the Status Chart are similar to, but more concise than those in the Plan:

- Support testing of beach-saving technology;
- Assess technology vs. relocation regarding beach erosion;
- Add zoning to Conservation Commission reviews to minimize losses near coastal erosion areas;
- Water companies to extend service for fire safety;
- Water companies to identify lines that are substandard for fire protection;
- Study central dispatching for fire and police services;
- Make private roads public for improved emergency access;
- Add boats ramps and storage areas for emergency response;
- Upgrade fire department facility;
- Place utilities underground;
- Seek more housing for seasonal police staff; and
- Evaluate fire and police departments relative to population growth.

Finally, an appendix to this Chart lists Comprehensive Community Plan accomplishments, including the following elements of hazard mitigation relative to coastal hazards, emergency services, and public safety:

- Community Preservation Act adopted, adding additional funding for open space;

- Program to acquire shoreline access;
- Special police hired to manage downtown traffic;
- Mid-Island plan promotes street interconnections;
- Central dispatch for fire and police being considered; and
- Upgrade of Fire Department facility.

***Sconset Area Plan***

The Sconset Area Plan (revised through March 2004) was developed to guide growth and conservation in the Sconset area. The plan was approved by the Nantucket Planning & Economic Development Commission but has not been adopted by the Town. Recommendations of the plan are divided into the categories Zoning and Preservation, Wastewater, Affordable Housing, Water, Traffic and Safety, Public Transportation, Peace and Quiet, Beach Preservation, Land Preservation, Emergency Preparedness, and Communications. Three categories include recommendations that are connected or related to pre-disaster hazard mitigation, as follows:

*Beach Preservation*

- Manage existing dewatering systems.
- Keep Sconset and Island community informed.
- Raise necessary funds.
- Design/propose additional systems in Sconset if new Lighthouse South system replicates Codfish Park accretion.
- Analyze causes/options if new system is ineffective.
- On an on-going basis, monitor research on innovative erosion control technologies.

*Land Preservation*

- Implement a greenbelt around the village, containing within it the areas of development and maintaining a clear demarcation of country outside the village.
- Conserve small areas within the village which might be preserved as open space.
- Encourage property owners and public entities to obtain Preservation Restrictions on their properties or portions of their property, or to obtain Conservation Restrictions on some of the beautiful historic gardens in Sconset.
- Work with the Sconset Trust and other non-profit conservation organizations on the island to obtain lands to keep them from development. This can be by purchase, by gift, or by some form of conservation restriction.
- Work with Sconset area property owners to encourage them to place restrictions on the development of their properties.

*Emergency Preparedness*

- Preparedness: Identify those things Sconset can do in advance to be prepared if a disaster should hit. This might include marking roads, training people in first aid, making sure you have a command center, make sure you have radios, etc.
- Response: Develop a plan to evacuate people from low areas, making sure your emergency forces know what to do in Sconset should a disaster hit the village.
- Recovery: Work with town departments such as DPW, to identify what needs to be organized for cleanup.
- In preparing a disaster plan for Sconset, develop a complete inventory of all hazards and possible situations.
- Conduct an Emergency Preparedness Seminar so that Sconset residents and those who will be involved in helping can be better prepared to anticipate a response to any emergency.

***Madaket Area Plan***

The Madaket Area Plan (revised through June 2006) was developed to guide growth and conservation in the Madaket area. The plan was approved by the Nantucket Planning & Economic Development Commission but has not been adopted by the Town. Recommendations of the plan are divided into the categories Land Use, Housing, Economic Development, Natural and Cultural Resources, Open Space and Recreation, Services and Facilities, and Circulation. Three categories include recommendations that are connected or related to pre-disaster hazard mitigation, as follows:

- Natural and Cultural Resources – Support the Nantucket Land Council campaign to purchase the development rights to the 270-acre Loring Property.

- Open Space – Open Space Zoning is the identification of parcels of land that are currently preserved as conservation areas or open space and rezoning them from a residential zone to open space zone so that the use of the site matches the zoning district. The Madaket Area Plan Work Group supports the concept of an Open Space Zoning District and suggests that the Planning Board study and develop documents needed to establish such a district.

- Circulation – An alternate access route to Madaket via Eel Point Road and Warren's Landing Road should be developed for emergency use.

***Mid-Island Area Plan***

The Mid-Island Area Plan (revised through February 2003 and adopted by the Town of Nantucket) was developed to guide growth in the central area of Nantucket, where the village character is lacking. Recognizing the good aspects of the adjacent Downtown area, the plan seeks to emulate the ideals that created the downtown. Recommendations

of the plan are divided into the categories Land Use, Housing, Traffic/Transportation, and Infrastructure. Two categories include recommendations that are connected or related to pre-disaster hazard mitigation, as follows:

*Traffic/Transportation*

- Objectives for all improvements in the Mid-Island Area should include enhancing traffic flow; reducing conflicts between motor vehicles, pedestrians, and bicyclists; increasing safety; enhancing emergency access; and making the Mid-Island Area more pedestrian-friendly.
- Reconstruct the Milestone Rotary as a modern roundabout.

*Infrastructure*

- Because the current fire station site is not large enough to provide for the future fire protection needs of the community, the Board of Selectmen should examine the need and feasibility of providing a replacement facility for the current Fire Station somewhere in the Mid-Island Area (not necessarily within the limits of the Area Plan study area).
- Inventory the extent and condition of water, sanitary sewer, and storm drainage facilities in the study area. Use this assessment as the basis for a short-range and long-range capital program of repair and / or replacement.
- Improve the storm drainage system on Pleasant Street near Tresses through a short-range capital program objective.
- Place utilities underground at a minimum along Pleasant Street in connection with streetscape improvements. If cost is prohibitive, at least install conduit, in anticipation of placing utilities underground in the future.

## 2.9 *Critical Facilities and Sheltering Capacity*

The Town of Nantucket considers that several categories of facilities are critical, for these are needed to ensure that emergencies are addressed while day-to-day management of the community continues:

- Emergency Services – Police, Fire, Coast Guard
- Municipal Facilities – Town Hall, Municipal Buildings, DPW
- Schools – Primarily for use as a Shelter
- Health Care – Hospital, Assisted Living
- Water Utilities – Tanks, Pumping Stations
- Wastewater Utilities – Pumping Stations, Treatment Plants
- Transportation – Steamship Dock, Airport, Transit Authority, Boat Ramps
- Fuel Storage and Power Generation – Tank Farms, Alternate Generating Facility
- Communications – Telephone Stations, Mobile Phone Towers

Upon comparison to other Massachusetts communities, Nantucket has a larger proportion of facilities that are considered critical. This is partly a reflection of the Town's isolation. For example, docks, boat ramps, and an airport may not be critical facilities for a community adjacent to another municipality with the same facilities, because one community could offer mutual aid services to another during a disaster. This arrangement is not possible for Nantucket. The inclusion of communications towers as critical facilities is another example. Due to its location 25 miles into the Atlantic Ocean, Nantucket must be able to rely on these facilities.

A list of critical facilities is provided in Table 2-1 on the next page. Figure 2-9 depicts locations of critical facilities. A few notable categories of critical facilities are discussed below.

**Table 2-1**
**Critical Facilities**

| Facility | Address or Location | Emergency Power Supply? | Shelter? | In Floodplain or Coastal Flood Hazard Area? | Near Erosion Zone? |
|---|---|---|---|---|---|
| ***Emergency Services*** | | | | | |
| Police Station | S. Water St | Yes | No | Yes | No |
| Main Fire Station (Emergency Operations) | 131 Pleasant St | Yes | No | No | No |
| Madaket Fire Station | Madaket Rd | No | No | No[1] | No |
| Sconset Fire Station | W. Sankaty Rd | No | No | No[1] | No |
| Police & Coast Guard Barracks | Low Beach Rd | No | No | No[1] | Yes |
| ***Municipal Facilities*** | | | | | |
| Town Hall | 16 Broad St | No | No | Margin | No |
| Town Building | 22 Federal Rd | No | No | No | No |
| Town Building | 2 Fairgrounds Rd | Yes | Yes | No | No |
| Town Building | 37 Washington St | No | No | Yes | No |
| Marine Department | 34 Washington St | No | No | Yes | No |
| DPW Facility | 188 Madaket Rd | Yes (garage only) | No | No | No |
| ***Schools and Health Care Facilities*** | | | | | |
| High School | 10 Surfside Rd | Yes | Yes | No | No |
| Elementary School | 30 Surfside Rd | No | No | No | No |
| Nantucket Cottage Hospital | 57 Prospect St | Yes | No | No | No |
| Academy Hill Apartments | Westminster St | No | No | No | No |
| Our Island Home | 9 East Creek Rd | No | No | Margin[2] | No |
| Landmark House | 144 Orange St | No | No | Margin | No |
| Sherburn Common | Pleasant St | No | No | No | No |
| The Homestead | 115 Main St | No | No | No | No |

1. Not located in floodplain or coastal flood hazard area, but potentially cut off during a 100-year flood event
2. Located in a hurricane storm surge area

**Table 2-1 (Continued)**
**Critical Facilities**

| Facility | Address or Location | Emergency Power Supply? | Shelter? | In Floodplain or Coastal Flood Hazard Area? | Near Erosion Zone? |
|---|---|---|---|---|---|
| ***Water and Wastewater Utilities*** | | | | | |
| Water Pumping Sta. | 1 Milestone Rd | Yes | NA | No | No |
| Main Water Tank | Cliff Rd | NA | NA | No | No |
| Sconset Water Tank | Lincoln St | NA | NA | No[1] | No |
| Sewer Pumping Sta. | Sea Street | Yes | NA | Yes | No |
| Sconset WWTP | Low Beach Rd | Yes | NA | No[1] | Yes |
| Surfside WWTP | South Shore Rd | Yes | NA | No | Yes |
| ***Transportation Facilities*** | | | | | |
| Steamship Dock | Broad St | No | No | Yes | No |
| Nantucket Airport | Airport Rd | Yes | No | No | No |
| Airport Maintenance Building | New South Rd | Yes | No | No | No |
| Transit Authority Office | New South Rd | No | No | No | No |
| Transit Authority Garage | New South Rd | No | No | No | No |
| Town Boat Ramp | Washington St | NA | NA | Yes | No |
| Madaket Boat Ramp | F Street | NA | NA | Yes | No |
| Madaket Marine Boat Ramp | 20 N. Cambridge St | NA | NA | Yes | No |
| Great Harbor Yacht Club Boat Ramp | 1 S. Beach Street | NA | NA | Yes | No |

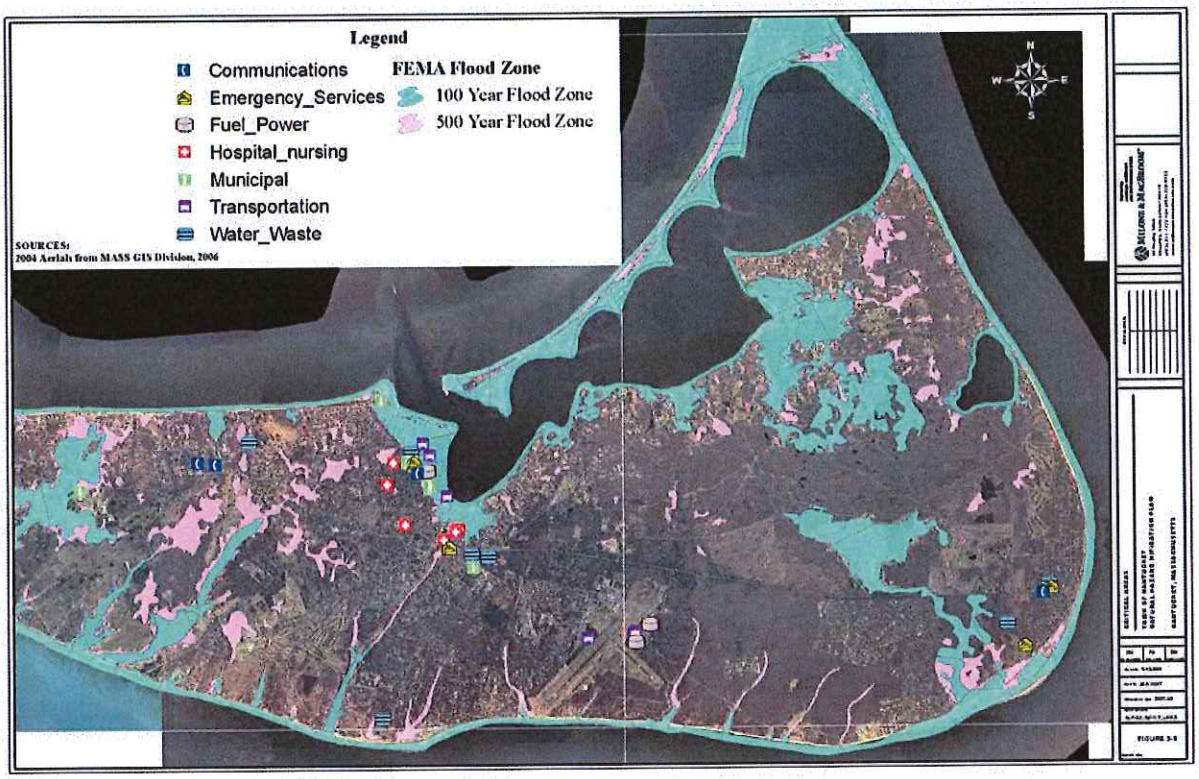
1. Not located in floodplain or coastal flood hazard area, but potentially cut off during a 100-year flood event

**Table 2-1 (Continued)**
**Critical Facilities**

| Facility | Address or Location | Emergency Power Supply? | Shelter? | In Floodplain or Coastal Flood Hazard Area? | Near Erosion Zone? |
|---|---|---|---|---|---|
| ***Fuel Storage and Power Generation*** | | | | | |
| Fuel Tank Farm | New Whale St | NA | NA | Yes | No |
| Propane Tank Farm | New South Rd | NA | NA | No | No |
| Alternate Generation Facilities | New South Rd | NA | NA | No | No |
| ***Communications*** | | | | | |
| Telephone/Microwave | Eel Point Rd | Yes | NA | No | No |
| Telephone Switching | Union St | Yes | NA | Margin | No |
| Telephone Switching | Bunker Hill Rd | Yes | NA | No[1] | No |
| Mobile Phone Tower | Madaket Rd | Yes | NA | No | No |
| Mobile Phone Tower | | Yes | NA | No | No |

1. Not located in floodplain or coastal flood hazard area, but potentially cut off during a 100-year flood event

Figure 2-9Critical Facilities



***Docks and Boat Ramps***

The Steamship Dock is the point of entry for almost all of the food, supplies, equipment, and resources that are used in Nantucket. It is also one of only two major passenger ferry terminals. An increase in truck traffic via the terminal has been realized over the past decade as population has increased. This has been accommodated, in part, by improving operational efficiencies. Two freight boats were also increased in capacity.

Many Nantucket residents consider the Steamship Dock to be the most important of all critical facilities. Keeping the dock open and operable before and after any natural disaster is paramount to the Town's ability to handle a disaster.

The Steamship dock is located in a 100-year coastal flood zone with wave velocity hazards. Although the dock is relatively elevated and could remain dry during certain storm surges, ships would not be expected to operate at such times. After subsidence of storm surges, rapid recovery of the dock area would be imperative.

Several 10,000-gallon fuel tanker trucks arrive via the Steamship Dock each week during the summer. It is important to maintain safe conditions for their arrival to avoid an accident or a fire, as a fuel-related incident could cut off the Steamship Dock (and hence, all of Nantucket) from the mainland. Similar to storm events, rapid recovery of the dock area after an accident or fire would be imperative.

The Town Boat Ramp is located at Nantucket Harbor and is available to all recreational boaters. Repairs to the facility were made as recently as fall 2006. The ramp was increased in width, pitch, depth. The repairs have made it easier for removal of two boats simultaneously. The Madaket Boat Ramp and Madaket Marine Boat Ramp offer boat ramp services to the western part of Nantucket. Madaket Marine also operates a large lift facility. All three boat ramps are located in 100-year coastal flood zones with wave

velocity hazards. The ramps would need to be used in advance of storms with any possibility of storm surge.

Gray Lady Marine was formerly the only large lift facility on Nantucket Harbor. Great Harbor Yacht Club now owns the property and maintains the facility and a boat ramp. Although there has been some question from residents that the facility will no longer be available to lift before storms or store boats with fixed masts/towers over 25 feet, Nantucket Planning Board permit conditions require that the facility remain available.

Several docks serve Tuckernuck Island, whereas Muskeget Island is not served by any facilities. DEP is reportedly in the process of removing two docks on Tuckernuck Island that were constructed without permits. However, the availability of an emergency access dock on Tuckernuck Island is important.

***Nantucket Airport***

Nantucket Airport as a whole is considered the most critical transit facility after the Steamship dock. The airport has its own emergency response personnel and they serve as the First Responders during emergency incidents, until the Nantucket Fire Department arrives. The airport has its own snow removal equipment. As with other areas in Nantucket, snow drifts are a problem and they need to be cleared frequently. Before wind storms of any kind, airplanes are moved to hangars and loose items are secured. They also maintain some emergency supplies for employees (cots, etc.) in order to remain operable. Fuel storage at the airport includes 50,000 gallons of aviation gasoline and 100,000 gallons jet fuel. The airport has its own generating facility. In summary, the airport can operate relatively autonomously, although it has a good relationship with the Town.

Although the airport is not located in a flood zone, erosion rates directly south of the airport are a concern. As explained in Section 6.0, the south shore of Nantucket is eroding at an average long-term rate of nine feet per year south of the airport. Eventually, significant portions of the airport will need to be relocated, including a runway, to retreat from the eroding coast. However, this will not occur for another 50 to 100 years.

***Fuel Tank Farm***

The fuel tank farm on New Whale Street in the harbor area is a considered a critical facility because fuels are stored at the site and distributed from the site. According to the Nantucket Pipeline and Bulk Fuel Storage assessment (VHB, 2005), the facility stores gasoline, heating oil, diesel fuel, and kerosene in 11 above-ground storage tanks ranging in capacity from 10,000 gallons to 200,000 gallons, for a total storage of one million gallons. The ages of the tanks range from the 1940s to the 1960s. Fuels are delivered to the tanks by tanker trucks arriving at the Steamship Dock and by barges that dock at the Nantucket Boat Basin Marina.

Nantucket residents are understandably concerned with potential accidents, fires, and explosions at and near the fuel tank farm. The most recent spill occurred in 2004. Although a fire has not occurred at the tank farm, a fire could be devastating to Nantucket because the densely-developed downtown area surrounds the tank farm. Accidents and fires could also occur near the tank farm as tanker trucks deliver fuels to and from the tank farm, and barges deliver fuels to the tank farm.

In the past few years, considerable discussion has occurred among various Nantucket officials about the relocation of bulk storage facilities to a location outside of downtown and closer to the airport, as the airport is a primary user of fuels delivered to Nantucket. As related to hazard mitigation in general, the primary benefit of this relocation would be

to remove a potential fire, explosion, and hazardous spill condition from the densely developed downtown area to a less-developed location. More specifically related to *natural* hazard mitigation, the primary benefits of a relocation would be to remove the tank farm from the harbor's coastal flood zone and site the facility in a location that is not only outside of a floodplain, but more accessible during natural hazard events such as floods and winter storms.

The Airport Commission authorized a feasibility study of locating a fuel terminal off the south shore of Nantucket, nearly three miles south of the airport. A pipeline would then be used to deliver fuels to the island in a location close to the airport. The estimated cost of such a project would be $50 million, according to the report. Permitting requirements would be extensive, given the necessary level of work in offshore and coastal zone areas.

***Wastewater Facilities***

The Town of Nantucket DPW operates two wastewater collection systems and treatment facilities. The larger system collects wastewater from the downtown and central areas. The Surfside treatment plant serves the larger system. The smaller system collects wastewater from the village of Sconset. The Sconset treatment plant serves the smaller system. The effluent beds at each wastewater treatment facility are located near the edges of the coastal dune/bluff, outside of mapped coastal flood zones but near eroding shorelines. It is understood that the beds will need to be relocated when the shoreline has eroded to within certain distances of each facility.

The Sea Street sewer pumping station is a critical facility because it is the heart of the larger sewer system that serves downtown and the central island. The pumping station sends up to nine million gallons per day (mgd) to the treatment plant using three 3-mgd pumps. Failure of the station would cause backups to most of the downtown customers and a major public health threat.

The pumping station is located within the 100-year coastal flood zone adjacent to Nantucket Harbor. The site of the pumping station was last flooded during the 1992 "No Name" storm. Sandbags were used to prevent water from entering the masonry pumping station building at doorways and other openings. Because sandbags work well to prevent flood damage, the Town has not moved forward with other means of flood control, such as dikes or flashboard gates.

Another problem that can occur during storms is infiltration of water to the wastewater system. It is believed that floodwaters can increase the demand to 14 mgd. During the 1992 No Name storm, the pumping station could barely keep up with the increased flow. DPW believes that ongoing infrastructure improvements will reduce the risk of floodwater infiltration, as all new manholes will have watertight seals.

The Sea Street sewer pumping station and the two treatment facilities are critical facilities that have dedicated emergency generators located on-site. All of the other sewer pumping stations have generators or can be fitted with portable generators during power outages. These include the Surfside, Kato Lane, Mizzenmast, Sherburne Commons, and Naushop pumping stations; and the two lift stations on Monomoy Road.

***Shelters***

Emergency shelters are considered to be an important subset of critical facilities, as they are needed most in emergency situations. According to the Nantucket EOP, "selection of mass care shelter should consider potential vulnerability to hazards such as flooding, and exposure to hurricane winds, and handicap accessibility, for example." As such, Town officials have designated the high school and the municipal building at 2 Fairgrounds Road as the primary and secondary shelters, respectively. The high school has a

sheltering capacity of 500 people. The capacity of the 2 Fairgrounds Road facility is pending, as redevelopment plans for the property are underway.

The shelters are reserved mainly for residents. During minor emergencies when people can not leave Nantucket, the shelters will not be opened to tourists until every hotel is full. During major emergencies, the shelters would be opened to everyone.

## *2.10 Evacuation*

According to the EOP, an emergency situation *"may require the evacuation of part of or all of the community. The characteristics and scope of the emergency will determine where evacuation occurs, the number of people affected, and the measures needed to ensure safety. The public will be advised to evacuate by public safety officials. The primary means of transportation during an evacuation is private automobile. Providing transportation to those without access to a vehicle or who require medical or other assistance is an important factor in the evacuation process."*

The discussion in the EOP pertains mainly to evacuation *within* portions of Nantucket. Evacuation of the community is not practical or feasible, and it is understood by Town officials that it could not be attempted. The population is too large, and transportation issues are too complex. For example, ferry service and/or airline service would be suspended during storms. Even if people could be brought to Hyannis, the Cape Cod Canal bridges are closed during major disasters. This underscores the importance of emergency preparedness, hazard mitigation planning, and ensuring adequate sheltering capacity. Although a reverse 911 system has been installed for Nantucket, it has not yet been implemented. This is a priority.

Informal evacuation routes are depicted on Figure 2-10. These are roadways that would be expected to be used by residents evacuating the neighborhoods discussed in Section 2.4. It is anticipated that evacuations from outlying areas would be directed toward the High School and the 2 Fairgrounds Road facility for those instances where evacuation from the island is not possible; and toward the airport and Steamship Dock in cases where sufficient time is available for leaving Nantucket. The Town intends to pursue a memorandum of understanding with tour bus companies to provide transport during emergencies.

Table 2-2 summarizes floodplain crossings for major roads such as arterials and collectors, and minor roads that serve a number of residents. For the downtown and Brant Point areas, numerous street segments are in floodplains, so not all streets are listed. Although the table shows that numerous crossings are present, most of these are 500-year flood zones. A small number of collector and arterial roadways do, however, cross 100-year floodplains. These include Polpis Road, Wauwinet Road, Milestone Road, Madaket Road, and Cambridge Road. Additional streets in the downtown and Brant Point areas are fully or partially within 100-year flood zones. Floodplains are described in more detail in Sections 3.0 and 4.0, covering inland and coastal flooding, respectively.

Figure 2-10Major Roadways and Evacuation Routes

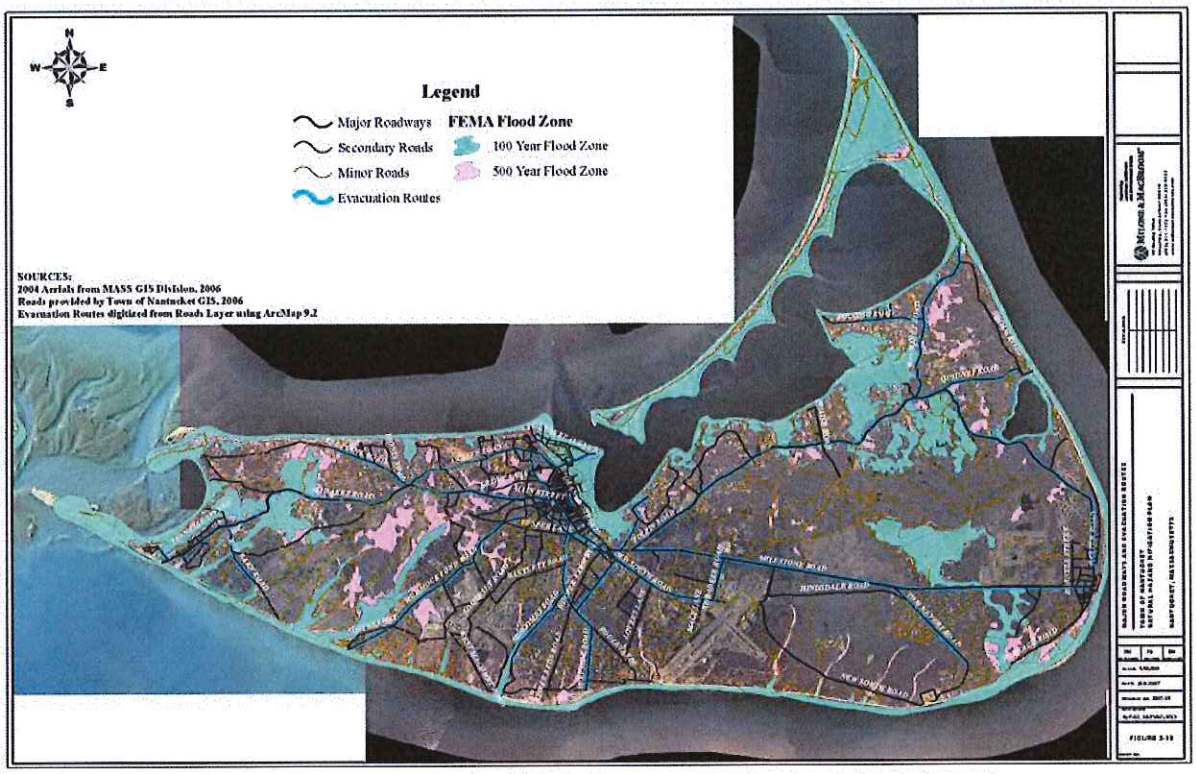


**Table 2-2**

**Floodplain Road Crossings**

| Road | Locality | Water Body or Watershed | Flood Zone | Base Flood Elevation |
|---|---|---|---|---|
| Wauwinet Rd | Wauwinet | Tidal creek | 100-yr AE | 8 feet |
| Wauwinet Rd | Pocomo | Near Polpis Harbor | 100-yr AE | 8 feet |
| Wauwinet Rd | Pocomo | Near Polpis Harbor | 500-yr X | Not mapped |
| Polpis Rd | Near Quidnet | Sesachacha Pond | 100 & 500-yr (road on line) | 8 feet |
| Polpis Rd | Polpis | Near Polpis Harbor | 500-yr X | Not mapped |
| Polpis Rd | Polpis | Near Polpis Harbor | 500-yr X | Not mapped |
| Polpis Rd | Quaise | Near Polpis Harbor | 500-yr X | Not mapped |
| Polpis Rd | Quaise | Fulling Mill Brook | 100-yr A5 | 8 feet |
| Milestone Rd | Milestone Rd | Phillips Run | 100-yr A | Not mapped |
| New South Rd | Airport | Coastal pond valley | 500-yr X | Not mapped |
| New South Rd | Airport | Coastal pond valley | 500-yr X | Not mapped |
| New South Rd | Airport | Coastal pond valley | 500-yr X | Not mapped |
| Orange St at Union Street | Downtown | Nantucket Harbor | 500-yr X | Not mapped |
| N. Beach St | Brant Point | Nantucket Harbor | 100-yr A | 8 feet |
| S. Beach St | Downtown | Nantucket Harbor | 100-yr A | 8 feet |
| Easton St | Brant Point | Nantucket Harbor | 100-yr A | 8 feet |
| Easy St | Downtown | Nantucket Harbor | 100-yr A | 8 feet |
| Washington St | Downtown | Nantucket Harbor | 100-yr A | 8-9 feet |
| Union St (southern part) | Downtown | Nantucket Harbor | 100-yr A | 8 feet |
| Atlantic Ave | Mid-Island | Miacomet valley | 500-yr X | Not mapped |
| W. Miacomet Rd | Miacomet | Miacomet Pond | 100 & 500-yr (road on line) | 8 feet |
| Eel Point Rd | Maddequet | Head of Long Pond | 500-yr X, B | Not mapped |
| Eel Point Rd | Maddequet | Head of Long Pond | 500-yr X, B | Not mapped |
| Eel Point Rd | Maddequet | Creek | 500-yr X, B | Not mapped |
| Madaket Rd | Madaket | Head of Long Pond | 100-yr AE | 8 feet |
| Madaket Rd | Madaket | Madaket Ditch | 100-yr AE | 8 feet |
| Madaket Rd | Madaket | Long Pond | 500-yr X | Not mapped |
| Cambridge Rd | Madaket | Hither Creek | 100-yr AE | 8 feet |
| Cambridge Rd | Madaket | Long Pond | 500-yr X | Not mapped |
| Cambridge Rd | Madaket | Long Pond | 100-yr AE | 7 feet |
| Tennessee Ave | Madaket | Hither Creek | 100 & 500-yr zones | 8 feet |
| Ames Street | Madaket | Hither Creek | 100-yr AE | 8 feet |

# 3.0 *INLAND FLOODING*

## 3.1 *Setting*

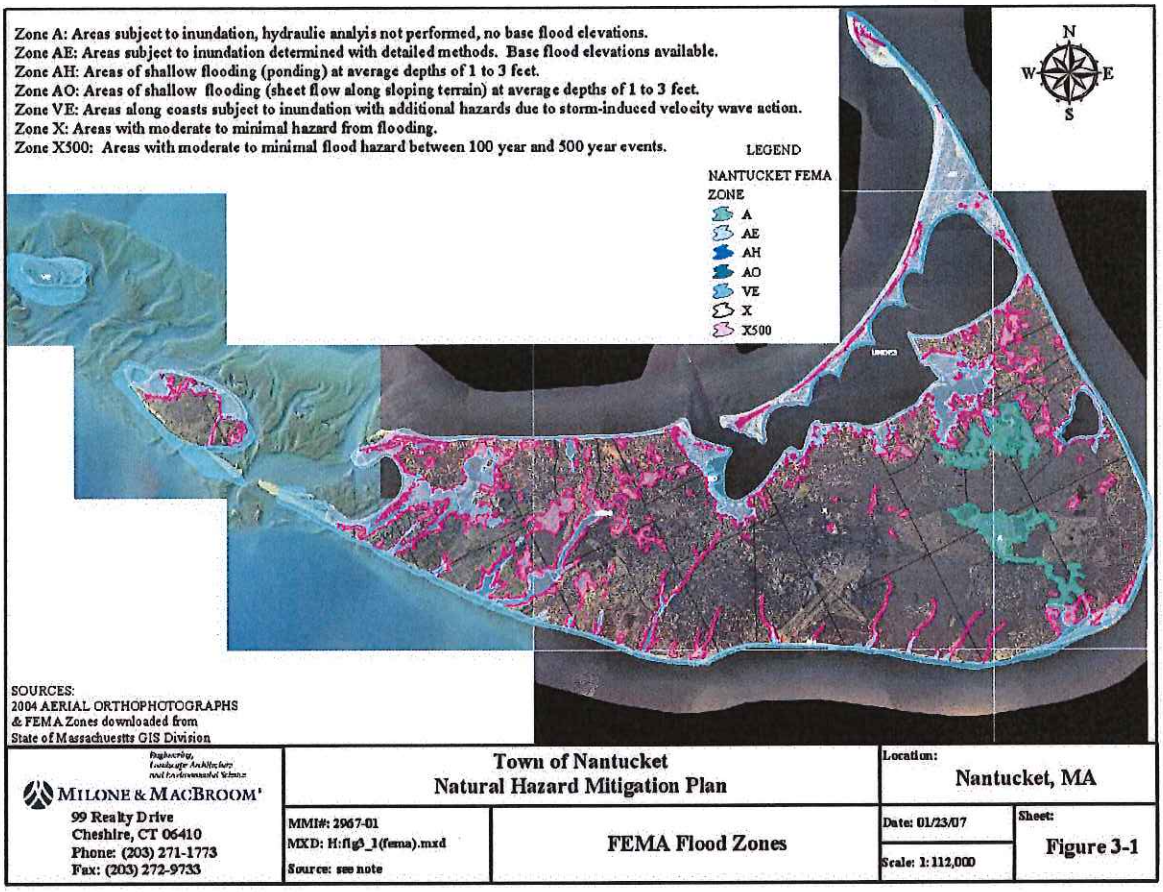
According to the Massachusetts Hazard Mitigation Plan, flooding in the State is often the direct result of weather events in Massachusetts including coastal storms such as nor'easters, heavy frontal rainstorms, tropical storms, and hurricanes. As a result of these events, Massachusetts is susceptible to the following:

- Riverine, or inland, flooding, including overflow from river channels, flash floods, ice-jams, and dam breaks;
- Coastal flooding associated with very high tides and storm surges. Massachusetts is exposed to coastal flooding along 1,500 miles of coastline, encompassing 78 communities.
- Stormwater flooding, urban flooding, or "nuisance flooding" due to poor or insufficient drainage and prevalence of impervious surfaces.

This section addresses the first and third items listed above, true inland flooding as well as nuisance flooding. Coastal flooding is discussed in Section 4.0.

Figure 3-1 depicts mapped inland and coastal floodplains of Nantucket. It is clear from the map that most of the flood zones are associated with coastal areas. As an island community with only a very few non-tidal watercourses, inland flooding is a relatively minor natural hazard that threatens Nantucket. Riverine or overbank flooding almost never occurs as a result of heavy rainfall and runoff. Instead, most riverine flooding actually occurs along tidal estuaries and ditches. Therefore, some of these areas are discussed in Section 4.0 as coastal flooding.

Figure 3-1


Zone A: Areas subject to inundation, hydraulic analyis not performed, no base flood elevations.
Zone AE: Areas subject to inundation determined with detailed methods. Base flood elevations available.
Zone AH: Areas of shallow flooding (ponding) at average depths of 1 to 3 feet.
Zone AO: Areas of shallow flooding (sheet flow along sloping terrain) at average depths of 1 to 3 feet.
Zone VE: Areas along coasts subject to inundation with additional hazards due to storm-induced velocity wave action.
Zone X: Areas with moderate to minimal hazard from flooding.
Zone X500: Areas with moderate to minimal flood hazard between 100 year and 500 year events.
LEGEND
NANTUCKET FEMA ZONE
A
AE
AH
AO
VE
X
X500
N
W
E
S
SOURCES:
2004 AERIAL ORTHOPHOTOGRAPHS
& FEMA Zones downloaded from
State of Massachusetts GIS Division
MILONE & MACBROOM
99 Realty Drive
Cheshire, CT 06410
Phone: (203) 271-1773
Fax: (203) 272-9733
Town of Nantucket
Natural Hazard Mitigation Plan
Location:
Nantucket, MA
MMI#: 2967-01
MXD: H:\fig3_1(fema).mxd
Source: see note
FEMA Flood Zones
Date: 01/23/07
Scale: 1:112,000
Sheet:
Figure 3-1

Nevertheless, non-tidal watercourses and floodplains that may experience minor, infrequent inland flooding include the following (some are listed on Table 2-2):

- Phillips Run, the stream connecting the cranberry bogs located north of Milestone Road to the ponds between Tom Nevers Road and Low Beach (100-year flood zone without mapped elevations);
- An area west of Sesachacha Pond (100-year flood zone without mapped elevations);
- Polpis Road along the southwest edge of at Sesachacha Pond (a 100-year floodplain with a velocity zone);
- The floodplain extending from the mid-island area south (downstream) to Miacomet Pond, the only freshwater pond on Nantucket (500-year and 100-year flood zones); and
- Other 500-year floodplains draining in southerly directions to coastal ponds.

Flooding caused by poor drainage, known from this point forward as *nuisance flooding*, is a more common type of inland flooding faced by Nantucket residents. Nuisance flooding is common in the following specific and general areas:

- Harbor Area / Easy Street (a 100-year coastal flood zone);
- Orange Street;
- Pleasant Street at Daves Street near the Post Office;
- Lovers Lane;
- Old South Road near Airport; and
- Area Between Madaket Road & Hummock Pond Road (including some 500-year flood zones).

Of course, nuisance flooding can occur in almost any developed area, even in communities such as Nantucket that are characterized by well-drained sandy soils. This is because most of the Town's drainage systems rely on infiltration and subsurface

leaching. These types of systems can be easily overwhelmed if undersized for any given storm.

Appended Table 1 identifies the relationships between various Nantucket localities and the natural hazards addressed in this plan. Note that the localities identified above are checked in the "inland flooding" and "flooding from poor drainage" columns. Appended Table 1 will be referenced again in subsequent chapters of this plan.

## *3.2 Hazard Assessment*

Nantucket lies in the zone of westerly prevailing winds and often experiences cyclonic disturbances that have crossed the country from the west or southwest. It is also exposed to coastal storms, some of tropical origin, that move up the Atlantic coast with heavy rainfall. In late summer and autumn these storms may attain hurricane intensity. Most inland flooding in Nantucket is caused by storms with heavy rainfall.

In order to provide a national standard without regional discrimination, the 100-year flood has been adopted by FEMA as the base flood for purposes of floodplain management. This flood has a 1% chance of being equaled or exceeded each year and is expected to be exceeded once on the average during any 100-year period. Similarly, a 500-year flood has a 0.2% chance of occurring in a given year. The 500-year floodplain indicates areas of moderate flood hazard.

While floodplains are lands along watercourses that are subject to periodic flooding, floodways are those areas within the floodplains that actually convey floodwaters. Floodways are subject to water being carried at relatively high velocities and forces. The floodway fringe are those areas of the floodplain outside the floodway which are subject to inundation but do not convey the floodwaters. Given its relative lack of non-tidal inland watercourses, floodways are not mapped on Nantucket.

FEMA maintains information to demonstrate areas within the Town of Nantucket that are vulnerable to flooding. These including Flood Insurance Rate Maps (FIRM) updated through 1996. It is important to note that individual letters of map amendment (LOMA) have been issued by FEMA for specific properties subsequent to the FIRM revision date. Table 3-1 describes the various zones depicted on the FIRM panels for Nantucket.

**Table 3-1**
**FIRM Zone Descriptions**

| Zone | Description |
|---|---|
| A | An area inundated by 100-year flooding, for which no base flood elevations (BFEs) have been determined. |
| AE | An area inundated by 100-year flooding, for which BFEs have been determined. |
| AH | An area inundated by 100-year flooding (usually an area of ponding), for which BFEs have been determined; flood depths range from 1 to 3 feet. |
| AO | An area inundated by 100-year flooding (usually sheet flow on sloping terrain), for which average depths have been determined; flood depths range from 1 to 3 feet. |
| V | An area inundated by 100-year flooding with velocity hazard (wave action); no BFEs have been determined. |
| VE | An area inundated by 100-year flooding with velocity hazard (wave action); BFEs have been determined. |
| Area Not Included | An area that is located within a community or county that is not mapped on any published FIRM. |
| X | An area that is determined to be outside the 100- and 500-year floodplains. |
| X500 | An area inundated by 500-year flooding; an area inundated by 100-year flooding with average depths of less than 1 foot or with drainage areas less than 1 square mile; or an area protected by levees from 100-year flooding. |

Nuisance flooding occurs from heavy rains with a much higher frequency than 100-year and 500-year events, and often in different areas than those depicted on the FIRM panels. These frequent flooding events occur in areas with insufficient drainage; where conditions may cause flashy, localized flooding; and where tidal influences may exacerbate drainage problems.

## 3.3 *Historic Record*

Of those non-tidal watercourses and floodplains that may experience rare, minor inland flooding, records of flooding are only available for two of the four as follows:

- The Phillips Run corridor is a 100-year flood zone, but occurrences of flooding are very rare and risk to residents is minimal due to the rural nature of the area and its near-entire occupation by designated conservation lands. The only risk from flooding of this corridor is the potential cutoff of the eastern part of Milestone Road and the village of Sconset.
- Likewise, a vast area west of Sesachacha Pond is a 100-year flood zone, but occurrences of flooding are very rare and risk to residents is minimal due to the rural nature of the area and the presence of designated conservation lands.
- Where Polpis Road runs along the southwest edge of Sesachacha Pond within a 100-year flood zone, high northeast winds reportedly cause water to flood the road. Also, if the pond is not drawn down in the spring as it normally is, the road floods during more moderate northeast winds.
- The floodplain extending from the mid-island area south (downstream) to Miacomet Pond consists of 500-year and 100-year flood zones, and nuisance flooding of residential properties occurs at least once every five years along the "valley" where the 500-year floodplain is mapped. Much of this flooding is due to encroachment into and within the floodplain. At the southern end of this area, Miacomet Pond rises due to heavy rainfall and comes very close to flooding the roads that are located on either side (Miacomet East and Miacomet West) at least once each year.
- Other 500-year floodplains draining in southerly directions to coastal ponds are rarely believed to flood.

As explained in Section 3.1, nuisance flooding is the more common type of inland flooding faced by Nantucket residents. Nuisance flooding is common in the following areas:

- Harbor Area / Easy Street (a 100-year flood zone) – Minor flooding can occur each month during the astronomical high tide when the base level of the drainage system (Nantucket Harbor) rises. More significantly, if Nantucket is experiencing rainfall at the same time as the high tide, stormwater can not drain and the area will flood. The following areas flood a couple times each year: Lower Broad Street, Easy Street, Washington Street, and Brant Point. Approximately $23 million will be spent in the next five to ten years as part of the Town's Stormwater Improvement Project to upgrade storm drainage problems. Check valves will be installed to prevent backups. The project will improve water quality as well. But when it rains, the new system might not drain as quickly as the current system, so the problem may not be entirely solved.
- Orange Street – A single drainage pipe currently handles the watershed above Orange Street, and it is frequently overwhelmed during storms. This pipe will be enlarged and the problem will likely be corrected during Phase I of the ongoing Stormwater Improvement Project. According to the National Climate Data Center (NCDC), Orange Street was recently closed during flooding that occurred due to a heavy rainstorm on June 7, 2006.
- Pleasant Street at Daves Street – The low area at the post office floods during many storms, as the drainage system was designed for a 20-year storm but additional development has occurred since that time.
- Lovers Lane – Nuisance flooding along the road will occur during many storms, but is only severe in a five-year storm and upward. Two residents have built dikes along their properties to mitigate for the flooding.
- Old South Road near Airport – The north side of this road is lower than the south side, and water drains down to residential properties during most heavy rainstorms.

- Area Between Madaket Road & Hummock Pond Road – This area includes some 500-year flood zones, but the problem is mainly related to drainage. Drainage from much of the Town was previously directed west and south to the coastal ponds. Private development has occurred where drainage ditches were located, and the Town has needed to make repairs, trying to get water to keep draining in the same direction.

## *3.4 Existing Programs, Policies, and Mitigation Measures*

According to the Nantucket EOP, the municipal responsibilities relative to flood mitigation and preparedness include:

- Identify areas in the community that are flood prone and define methods to minimize the risk. Review National Flood Insurance Maps.
- Disseminate emergency public information and instructions concerning flood preparedness and safety.
- Community leaders should ensure that Nantucket is enrolled in the National Flood Insurance Program.
- Strict adherence should be paid to land use and building codes (e.g. Wetlands Protection Act), and new construction should not be built in flood prone areas.
- Ensure that flood control works are in good operating condition at all times.
- Natural water storage areas should be preserved.
- Maintain plans for managing all flood emergency response activities including addressing potentially hazardous dams.
- Place EOC personnel on standby during stage of flood watch and monitor NWS/New England River Forecast Center reports.
- Ensure that public warning systems are working properly and broadcast any information that is needed.
- Review mutual aid agreements.
- Monitor levels of local bodies of water.

- Arrange for all evacuation and sheltering procedures to be ready for activation when needed.
- Carry out, or assist in carrying out, needed flood-proofing measures such as sand bag placement, etc.
- Regulate operation of flood control works such as flood gates.
- Notify all Emergency Management related groups that will assist with flood response activities to be ready in case of flood warning.

The Town of Nantucket has a number of measures in place to prevent inland and nuisance flood damage. These include regulations, codes, and ordinances; and a process for installing and maintaining storm drainage systems.

Regulations, codes and ordinances that apply to flood hazard mitigation include Chapter 136 of the Nantucket Code and the accompanying Wetland Regulations; Chapter 139 of the Nantucket Code and the provisions of the Flood Hazard Overlay Zone; and the Subdivision Regulations. The components of these regulations, codes, and ordinances that apply to floodplain development and flood damage prevention were listed in Section 2.8. The Conservation Commission, Planning Board, and Building Department are all charged with administering portions of these regulations.

With regard to outreach and education, a recent effort of the Health Department has been education of property owners, merchants, and residents in flood zones to move critical equipment and property off the first floor, above flood elevations. The Health Department can do this through education more successfully than other departments, targeting existing buildings, whereas the Conservation Commission and Building Department can only enforce these types of modifications during new or substantial construction.

The DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. With regard to roads, bridges, and culverts at creeks, the DPW regularly maintains Town-owned roads and facilities and upgrades/improves them as needed. However, DPW does not have sufficient equipment to barricade all roadways that could potentially flood.

With regard to installation and maintenance of drainage systems, the DPW regularly maintains Town-owned culverts, catch basins, leaching systems, and other drainage facilities. DPW is currently administering a major Stormwater Improvement Project with anticipated water quality benefits, but better drainage is also anticipated for certain areas. The program is described in the next section. Finally, DPW also maintains a database of drainage and flooding complaints, and addresses problems as they arise. This helps pinpoint potential locations of hazard effects.

In addition to existing mitigation at the municipal level, private mitigation measures have been implemented in Nantucket. Recall that two residents on Lovers Lane constructed low dikes along their property lines to prevent flooding from poor drainage on the roadway.

## *3.5 Vulnerabilities and Risk Assessment*

According to the Massachusetts Hazard Mitigation Plan, NFIP claims in Nantucket related to flooding exceeded $5 million between 1978 and 2002, placing it in the top seven municipalities in the State in terms of total claim value. Most of these claims were related to coastal flooding, although some were related to inland and nuisance flooding.

Also according to the Massachusetts Hazard Mitigation Plan, FEMA map revision priorities for Nantucket panels range from "lowest" for Tuckernuck and "low" for the

area between the airport and Tom Nevers, to "medium" for mid-island and Monomoy. Map revision priority is reportedly "high" for northwest and northeast Nantucket, and "very high" for downtown, Madaket and Sconset. The priority level is generally a reflection of FEMA's perception of risk and vulnerability, and in certain cases these are consistent with local knowledge and the observations discussed above.

This section discusses specific areas at risk to inland flooding and nuisance flooding within Nantucket. Critical facilities and evacuation routes are identified as applicable.

***Downtown, Brant Point, and Mid-Island***

The most populous area of nuisance flooding vulnerability is the region extending from Brant Point through downtown to the mid-island area, including adjacent areas to the west. According to DPW, The stormwater system includes a network of approximately 8.5 miles of pipes, 340 catch basins, infiltrators, grit chambers, and 21 outfall pipes. Many of the outfalls to Nantucket Harbor are undersized and impacted by backwater from tides, causing upstream flows to surcharge and deposit sediment in the systems, leading to nuisance flooding.

In short, minor flooding can occur each month along the harbor during the astronomical high tide when the base level of the drainage system rises. More significantly, if Nantucket is experiencing rainfall at the same time as the high tide, stormwater can not drain and the area will flood. Lower Broad Street, Easy Street, Washington Street, and Brant Point reportedly flood at shallow depths a few times each year. Critical facilities in this area include the Steamship Dock, the fuel tank farm, municipal buildings on Washington Street, the sewer pumping station, and a telephone switching station.

The ongoing Stormwater Improvement Project will upgrade the storm drainage system and is expected to improve water quality and reduce flooding by increasing outfall

capacities, combining outfalls, installing riprap and flap gates, installing structures to catch sediment, and calling for increased street sweeping and catch basin sump cleaning. However, it is possible that the new system might not drain as quickly as the current system, so the nuisance flooding problem may not be entirely solved.

Also near downtown, flooding occurs at Orange Street where a single drainage pipe currently handles the watershed above Orange Street, becoming overwhelmed during storms. Flooding in this area most recently occurred in June 2006, requiring the road to be closed. This pipe will be enlarged and the problem will likely be corrected during the Stormwater Improvement Project. Slightly west of downtown where Pleasant Street intersects with Daves Street, the low area at the post office floods during many storms, as the drainage system was designed for a 20-year storm but additional development has occurred since that time. Flooding on Orange Street and Pleasant Street does not directly affect critical facilities, but these are important roadways that would be used during storms or storm surge events if evacuation was necessary.

A broad region between Madaket Road and Hummock Pond Road includes some 500-year flood zones, but the problem in this area is mainly related to poor drainage. Drainage from much of the Town was previously directed west and south from this area to the coastal ponds. As development has occurred where drainage ditches were located, the Town has attempted to maintain drainage in the same direction. Critical facilities and roads are not affected. The flooding mainly causes problems for private property owners.

Finally, the floodplain extending from the mid-island area downstream to Miacomet Pond consists of 500-year and 100-year flood zones, and nuisance flooding of residential properties occurs at least once every five years along the "valley" where the 500-year floodplain is mapped. Much of this flooding is due to encroachment into and within the floodplain. Critical facilities and roads are not affected. The flooding mainly causes problems for private property owners.

Although nuisance flooding in the Brant Point/downtown/mid-island area is relatively frequent and reduces the quality of life for residents in these areas, this type of flooding is not life-threatening and does not result in significant flood damage to property. This is primarily because the flood depths are typically nominal. Streets often remain passable to vehicles with more clearance, and floodwaters drain within hours of their appearance.

***Sconset***

Sconset is not vulnerable to nuisance flooding, but is vulnerable to inland flooding because flooding can reduce access to and from Sconset via Milestone Road and Polpis Road. The Phillips Run corridor crosses Milestone Road as a 100-year flood zone, although occurrences of flooding are very rare. The risk from flooding of this corridor is the potential cutoff of the eastern part of Milestone Road. Likewise, where Polpis Road runs along the southwest edge of Sesachacha Pond within a 100-year flood zone, high northeast winds can cause water to flood the road, cutting off Sconset from this direction. If Milestone Road and Polpis Road were flooded simultaneously, Sconset residents would be isolated.

Critical facilities in Sconset include the Sconset Fire Station, the Police & Coast Guard Barracks, a water tank, and the Sconset sewage treatment plant. However, most of these facilities support Sconset residents and are not needed by the remainder of Nantucket, such that their isolation would not necessarily be a hardship.

***Outlying Areas***

At the southern end of the floodplain extending from the mid-island area to the south consisting of 500-year and 100-year flood zones, Miacomet Pond can rise due to heavy rainfall and comes very close to flooding the roads that are located on either side

(Miacomet East and Miacomet West) at least once each year. Critical facilities are not located in this area, and only the residents of Miacomet would be affected by the loss of access.

At Lovers Lane, Old South Road, and in many other parts of Nantucket, nuisance flooding along roadways will occur during many storms, but is typically only severe in a five-year storm and upward. Critical facilities are generally not located in these areas, and mainly the residents on the subject streets are affected by temporary poor access. In cases where stormwater may flow onto individual properties, property owners have utilized solutions such as building low dikes and walls. Overall, although Nantucket is vulnerable to this type of nuisance flooding, the problem areas are disparate and probably more effectively addressed on a case-by-case basis.

## *3.6 Potential Mitigation Measures, Strategies, and Alternatives*

A number of measures can be taken to reduce the impact of an inland or nuisance flood event. These include measures that prevent increases in flood losses by managing new development, measures that reduce the exposure of existing development to flood risk, and measures to preserve and restore natural resources. These are listed below under the categories of *prevention, property protection, structural projects, public education and awareness, natural resource protection,* and *emergency services.*

### *3.6.1 Prevention*

Prevention of damage from flood losses often takes the form of floodplain regulations and redevelopment policies. In most communities, these are usually administered by building, zoning, planning, and/or wetland bylaw and regulation enforcement. The following general guidelines are preventive tools that municipalities may have available:

- Planning and Zoning: Zoning ordinances should regulate development in flood hazard areas. Flood hazard areas should reflect a balance of development and natural areas.

- Floodplain Development Regulations: Development regulations encompass subdivision regulations, building codes, and floodplain ordinances. Site plan and new subdivision regulations should include the following:

  - √ Requirements that every lot have a buildable area above the flood level;
  - √ Construction and location standards for the infrastructure built by the developer, including roads, sidewalks, utility lines, storm sewers, and drainage ways; and
  - √ A requirement that developers dedicate open space and flood flow, drainage, and maintenance easements.

  Building codes should ensure that the foundation of structures will withstand flood forces and that all portions of the building subject to damage are above or otherwise protected from flooding. Floodplain ordinances should at minimum follow the requirements of the National Flood Insurance Program for subdivision and building codes. These could be included in the ordinances for zoning and building codes, or could be addressed in a separate ordinance.

- Stormwater Management Policies: Development and redevelopment policies to address the prevention of flood losses should include effective stormwater management policies. Developers should be required to build detention and retention facilities where appropriate. Infiltration can be enhanced to reduce runoff volume, including the use of swales, infiltration trenches, vegetative filter strips, and permeable paving blocks. Generally, post-development stormwater should not leave a site at a rate higher than under pre-development conditions.

In many communities, standard engineering practice is to avoid the use of detention measures if the project site is located in the lower one-third of a watershed. The effects of detention are least effective and even detrimental if used at such locations because of the delaying effect of the peak discharge from the site that typically results when detention measures are used. By detaining stormwater in close proximity to the stream in the lower reaches of the overall watershed, the peak discharge from the site will occur later in the storm event, which will more closely coincide with the peak discharge of the stream, thus adding more flow during the peak discharge during any given storm event. However, in Nantucket, the distinction is not considered to be important because of the lack of inland watercourses.

- Drainage System Maintenance: An effective drainage system should be continually maintained to ensure efficiency and functionality. Maintenance should include programs to clean out blockages caused by overgrowth and debris. Culverts should be monitored, and repaired and improved when necessary.

- Education and Awareness: Other prevention techniques include the promotion of awareness of natural hazards among citizens, property owners, developers, and local officials. Technical assistance for local officials, including workshops, can be helpful in preparation for dealing with the massive upheaval that can accompany a severe flooding event. Research efforts to improve knowledge, develop standards, and identify and map hazard areas will better prepare a community to identify relevant hazard mitigation efforts.

Recall that the Nantucket Conservation Commission administers the wetland regulations and the Nantucket Planning Board administers the subdivision regulations. The zoning regulations are not really used to regulate floodplain development; this mainly occurs as part of the Conservation Commission review. In general, the Conservation Commission deals with flooding more than the Planning Board. The Nantucket Building Department

is charged with ensuring that development meets the flood damage prevention codes. The Health Department provides the education and outreach that is often needed to reach owners of properties that are not subject to regulatory programs administered by the zoning, wetland, and subdivision regulations.

Based on the above guidelines and the existing roles of the Conservation Commission, Planning Board, Building Department, and Health Department, the following *preventive* mitigation measures are recommended:

- Increased cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department is necessary with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people. In particular:

  - √ The Conservation Commission should universally and fairly apply the flood damage prevention codes within the bylaws and regulations administered by the Commission;
  - √ The Planning Board should take a more active role in ensuring that the zoning ordinance and subdivision regulations are used to ensure that their own flood damage preventions codes are followed;
  - √ The Building Department should not be placed in a difficult position at the end of the process to enforce flood damage prevention codes when the Conservation Commission and/or Planning Board may have allowed for variances in building locations, structure elevations, etc.
  - √ The Health Department should be provided with the staff and funding to provide education with regard to flood mitigation of existing properties that are not subject to permitting programs of the Conservation Commission, Planning Board, Building Department.

- At the same time, to streamline the permitting process and ensure maximum education of a developer or applicant, a checklist should be developed that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project. This list could be provided to an applicant at any Town department.
- The Town should urge or petition FEMA to more critically evaluate LOMA applications that are received, with an eye toward the "no adverse impact" requirement cited by FEMA, such that redevelopments do not potentially cause increased flooding or wave velocities to other properties.

Finally, recall that Sesachacha Pond is drawn down twice each year to prevent high water levels. This should be continued as long as it protects Polpis Road from flooding.

### *3.6.2 Property Protection*

Steps should be taken to protect existing public and private properties. Non-structural measures for public property protection include acquisition and relocation of properties at risk for flooding; purchase of flood insurance; and relocating valuable belongings above flood levels to reduce the amount of damage caused during a flood event.

Structural flood protection techniques applicable to property protection include the construction of barriers, dry floodproofing, and wet floodproofing techniques. Barriers include levees, floodwalls, and berms, and are useful in areas subject to shallow flooding. Dry floodproofing refers to the act of making areas below the flood level water-tight. Walls may be coated with compound or plastic sheathing. Openings such as windows and vents should be either permanently closed or covered with removable shields. Flood protection should only be two to three feet above the top of the foundation because building walls and floors cannot withstand the pressure of deeper water.

Wet floodproofing should only be used as a last resort. Wet floodproofing refers to intentionally letting floodwater into a building to minimize pressures. Furniture and electrical appliances should be moved away from advancing floodwaters.

All of the above *property protection* mitigation measures may be useful for Nantucket residents to prevent damage from inland and nuisance flooding. The Health Department should continue its outreach and education in these areas.

### 3.6.3 *Emergency Services*

A natural hazard mitigation plan addresses actions that can be taken before a disaster event. In this context, emergency services that would be appropriate mitigation measures for inland flooding include:

- forecasting systems to provide information on the time of occurrence and magnitude of flooding;
- a system to issue flood warnings to the community and responsible officials; and
- emergency protective measures, such as evacuation and emergency flood-water control.

Based on the above guidelines, a number of specific proposals for improved *emergency services* are recommended to prevent damage from inland and nuisance flooding. These are common to all hazards in this plan, and are listed in Section 11.1.

### 3.6.4 *Public Education and Awareness*

The objective of public education is to provide an understanding of the nature of flood risk, and the means by which that risk can be mitigated on an individual basis. Public information materials should encourage individuals to be aware of flood mitigation

techniques, including discouraging the public from modifying channels and/or detention basins in their yards, and dumping in or otherwise altering watercourses and storage basins. Individuals should be made aware of drainage system maintenance programs and other methods of mitigation. The public should also be told what to expect when a hazard event occurs, and the procedures and time frames necessary for evacuation.

Based on the above guidelines, a number of specific proposals for improved *public education* are recommended to prevent damage from inland and nuisance flooding. These are common to all hazards in this plan, and are listed in Section 11.1.

### *3.6.5 Natural Resource Protection*

Floodplains can provide a number of natural resources and benefits, including storage of flood waters, open space and recreation, water quality protection, erosion control, and preservation of natural habitats. Retaining the natural resources and functions of floodplains can not only reduce the frequency and consequences of flooding, but also minimize stormwater management and nonpoint pollution problems. Through natural resource planning, these objectives can be achieved at substantially reduced overall costs.

Measures for preserving floodplain functions and resources typically include:

- adoption of floodplain regulations to control or prohibit development that will alter natural resources;
- development and redevelopment policies focused on resource protection;
- information and education for both community and individual decision-makers; and
- review of community programs to identify opportunities for floodplain preservation.

Measures for restoring diminished or destroyed resources and functions provide for re-establishment of an environment in which these functions can again operate. Measures

that involve improving the natural condition of areas or restoring them to their previous natural state include development of land reuse policies focused on resource restoration and review of community programs to identify opportunities for floodplain restoration.

Based on the above guidelines, the following specific *natural resource protection* mitigation measures are recommended to help prevent damage from inland and nuisance flooding:

- Selectively pursue conservation objectives listed in the Madaket Area Plan.
- Purchase the development rights to the 270-acre Loring Property in Madaket.
- Selectively pursue conservation objectives listed in the Sconset Area Plan.
- Adopt open space zoning.

### *3.6.6 Structural Projects*

Structural projects include the construction of new structures or modification of existing structures to lessen the impact of a flood event. Stormwater controls such as drainage systems, detention controls such as dams and reservoirs, and conveyance structures such as culverts and bridges can be employed to lessen the impact of floodwater runoff. On-site detention can provide temporary storage of stormwater runoff. Levees, floodwalls, and dikes physically control the hazard to protect certain areas from floodwaters. Channel alterations can be made to confine more water to the channel and accelerate flood flows. Care should be taken when using this technique to ensure that problems are not exacerbated in other areas of the watershed. Individuals can protect private property by constructing walls and levees around structures.

Based on the above guidelines, the following specific *structural* mitigation measures are recommended to prevent damage from inland and nuisance flooding:

- Conduct master drainage studies for problem areas, such as the broad area between Madaket Road and Hummock Pond Road, to ensure that individual repairs and upgrades fit seamlessly with upstream and downstream drainage systems.
- Improve the storm drainage system on Pleasant Street to reduce flooding.
- Complete the Orange Street drainage system upgrade to reduce flooding and allow better drainage of upstream areas.
- Ensure that the Milestone Road crossing of Phillips Run can convey the 100-year flood and make repairs if necessary to convey the 100-year flood.
- Increase the elevation of Polpis Road at Sesachacha Pond to the base flood (8') plus one foot freeboard.

## *3.7 Recommended Actions*

The proposed mitigation strategies for addressing inland and nuisance flooding are listed below.

- Increase cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people.
- Streamline the permitting process and ensure maximum education of a developer or applicant. Develop a checklist that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project. This list could be provided to an applicant at any Town department.
- Urge or petition FEMA to more critically evaluate LOMA applications that are received such that redevelopments do not potentially cause increased flooding or wave velocities to other properties.

- Continue to draw down Sesachacha Pond twice each year to prevent high water levels as long as it protects Polpis Road from flooding.
- Increase the elevation of Polpis Road at Sesachacha Pond to the base flood (8') plus one foot freeboard.
- Selectively pursue conservation objectives listed in the Madaket Area Plan.
- Purchase the development rights to the 270-acre Loring Property in Madaket.
- Selectively pursue conservation objectives listed in the Sconset Area Plan.
- Adopt open space zoning.
- Conduct master drainage studies for problem areas, such as the broad area between Madaket Road and Hummock Pond Road, to ensure that individual repairs and upgrades fit seamlessly with upstream and downstream drainage systems.
- Improve the storm drainage system on Pleasant Street to reduce flooding.
- Complete the Orange Street drainage system upgrade to reduce flooding and allow better drainage of upstream areas.
- Ensure that the Milestone Road crossing of Phillips Run can convey the 100-year flood and make repairs if necessary to convey the 100-year flood.

Recommendations for emergency services and public education are provided in Section 11.1 because they are common to all hazards.

# 4.0 COASTAL FLOODING

## 4.1 Setting

Coastal flooding is a well-documented natural hazard that threatens the Town of Nantucket far more frequently, and in many more locations, than inland flooding. A review of the flood zone map (Figure 3-1) reveals that the perimeter of Nantucket consists of A (100-year) and V (100-year flood zones with wave velocity hazards) zones. The FEMA mapping implies complete inundation for areas such as Brant Point, Smith Point, Muskeget Island, and Coatue/Great Point, during 100-year coastal flood events; and partial inundation of the population centers in Madaket Village and downtown Nantucket. Many of Nantucket's localities are checked in the "coastal flooding" column of Appended Table 1.

In addition to the areas described above, flooding at tidal creeks and ponds can occur in the 100-year coastal flood zones that extend inland from the shoreline, not necessarily affecting structures but potentially cutting off access via roadways. The most notable examples include Polpis Road at Fulling Mill Brook, Wauwinet Road at Polpis Harbor, Madaket Road at the Head of Long Pond, and Madaket Road at Madaket Ditch.

## 4.2 Hazard Assessment

Refer to Figure 3-1 for the areas of Nantucket susceptible to coastal flooding based on FEMA flood zones. These flood zones are based on the 100- and 500-year flood events. As explained in Section 3.0, a 100-year flood event has a 1% chance of occurring in any given year. A 500-year flood has a 0.2% chance of occurring in any given year. Unlike inland flooding, coastal flooding is typically due to hurricanes, nor'easters, or other events that are discussed in subsequent sections of this plan.

Smaller magnitude flood events occur on a more frequent basis. For example, coastal areas and low-lying areas proximal to waters under tidal influence may be susceptible to frequent flooding.

Coastal flooding can occur as a result of astronomical high tides acting alone or concurrent with storms; as a result of nor'easters, hurricanes and tropical storms; or simply as a result of persistent strong winds. These causes will be discussed in Sections 5.0 and 8.0. In additional, it is believed that coastal flooding will increase in frequency as sea level rises, as discussed in Section 6.0.

## *4.3 Historic Record*

Most non-nuisance, widespread flooding in Nantucket is caused by coastal storms such as nor'easters and tropical storms and hurricanes, which are frequently accompanied by low pressures and strong winds that cause tidal flooding. Detailed discussions of hurricanes and nor'easters are provided in Sections 5.0 and 8.0, respectively. A general record of significant coastal flooding in southeastern Massachusetts is presented below. This information was taken from USGS Water-Supply Paper 2375, *Massachusetts Flood and Droughts* (1989) and the NCDC storm event database. Other references are cited in Sections 5.3 and 8.3.

- September 1938 – The Great New England Hurricane of 1938 caused strong hurricane storm surge flooding of 18 to 25 feet in southeastern Massachusetts including the Cape Cod area.
- September 1944 – The Great Atlantic Hurricane of 1944 caused strong hurricane storm surge flooding in Cape Cod, Nantucket, and Martha's Vineyard.
- August 1954 – Hurricane Carol caused strong hurricane storm surge flooding of 10 to 15 feet in the Cape Cod area.
- September 1954 – Hurricane Edna caused hurricane storm surge flooding of six feet in southeastern Massachusetts, including the Cape Cod area.

- February 1978 – Record tidal flooding occurred in the Cape Cod area.
- August 1991 – Hurricane Bob caused strong hurricane storm surge flooding of 12 to 15 feet in Southeastern Massachusetts and the Cape Cod area.
- December 1992 – The "No-Name Storm" of 1992 is the most recent record of *severe* and *widespread* coastal flooding on Nantucket. This nor'easter caused significant coastal flooding along Nantucket Harbor in the downtown (with inundation up to Sea Street) and Brant Point areas, and caused significant erosion along many ocean-facing beaches such as Codfish Park in Sconset. During this storm, the Fire Department had trouble reaching some homes in Madaket to rescue residents.
- December 1995 – A strong nor'easter caused coastal flooding in Nantucket and other southeastern Massachusetts communities.
- April 1997 – A strong storm with 50 to 90 mph winds on Nantucket caused flooding and erosion in Codfish Park.
- February 1998 – A strong nor'easter caused coastal flooding in Nantucket and other southeastern Massachusetts communities. In addition, 12 to 20 feet of erosion occurred in eastern Nantucket.
- October 2005 – A strong fall nor'easter entrained with remnants of tropical storm Wilma caused coastal flooding in Nantucket and other southeastern Massachusetts communities.
- February 2006 – A strong nor'easter caused coastal flooding in Nantucket and other southeastern Massachusetts communities.
- April 16-17, 2007 – A very strong nor'easter caused coastal flooding and severe erosion in Nantucket and other southeastern Massachusetts communities.

Even during lesser storm events, coastal flooding has the potential to occur. Consider the following locations that have been identified by Nantucket town officials:

- Polpis Road at Fulling Mill Brook – The road has come within six inches of flooding as water levels in the tidal brook increase landward as a result of high winds;

- Wauwinet Road at Polpis Harbor – The road has flooded in the past when water levels in the harbor increase as a result of high winds;
- Madaket Road at the Head of Long Pond and Madaket Road at Madaket Ditch – Although these road crossings did not flood during the No Name storm in 1992, they have come close to flooding. High water has been known to come within one foot of the road during significant storms. The previous six and eight-inch culverts were replaced with larger culverts.

## 4.4 *Existing Programs, Policies, and Mitigation Measures*

According to the Nantucket EOP, the municipal responsibilities relative to flood mitigation and preparedness include:

- Identify areas in the community that are flood prone and define methods to minimize the risk. Review National Flood Insurance Maps.
- Disseminate emergency public information and instructions concerning flood preparedness and safety.
- Community leaders should ensure that Nantucket is enrolled in the National Flood Insurance Program.
- Strict adherence should be paid to land use and building codes (e.g. Wetlands Protection Act), and new construction should not be built in flood prone areas.
- Ensure that flood control works are in good operating condition at all times.
- Natural water storage areas should be preserved.
- Maintain plans for managing all flood emergency response activities including addressing potentially hazardous dams.
- Place EOC personnel on standby during stage of flood watch and monitor NWS/New England River Forecast Center reports.
- Ensure that public warning systems are working properly and broadcast any information that is needed.
- Review mutual aid agreements.

- Monitor levels of local bodies of water.
- Arrange for all evacuation and sheltering procedures to be ready for activation when needed.
- Carry out, or assist in carrying out, needed flood-proofing measures such as sand bag placement, etc.
- Regulate operation of flood control works such as flood gates.
- Notify all Emergency Management related groups that will assist with flood response activities to be ready in case of flood warning.

The Town of Nantucket has in place a number of measures to prevent coastal flood damage. These include regulations, codes, and ordinances; a process for maintaining roads, bridges, and culverts at tidal creeks; a variety of structural flood control features in coastal areas of Nantucket; elevation of structures; and the use of warning systems.

Regulations, codes and ordinances that apply to flood hazard mitigation include Chapter 136 of the Nantucket Code and the accompanying Wetland Regulations; Chapter 139 of the Nantucket Code and the provisions of the Flood Hazard Overlay Zone; and the Subdivision Regulations. The pertinent components of these regulations, codes, and ordinances were listed in Section 2.8. The Conservation Commission, Planning Board, and Building Department are all charged with administering portions of these regulations during new or substantial construction. Through non-regulatory outreach programs, the Health Department educated property owners, merchants, and residents in flood zones to move critical equipment and property off the first floor, above flood elevations.

DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. With regard to roads, bridges, and culverts at tidal creeks, the DPW regularly maintains Town-owned roads and facilities and upgrades/improves them as needed. For example, the Madaket Road crossings at the Head of Long Pond and Madaket Ditch were

replaced with larger culverts under the direction of DPW. However, DPW does not have sufficient equipment to barricade roadways that could potentially flood.

With regard to preexisting structures that were constructed (in part) to reduce coastal flood damage, examples include the jetties at the mouth of Nantucket Harbor and seawalls that exceed coastal base flood elevations. Bulkheads are common in the harbor area and a variety of other projects have been conducted in oceanside areas to combat erosion, but these are meant for shoreline stabilization and erosion control rather than coastal flood control.

Only a few structures in coastal flood zones have been elevated above the base flood level. A striking example is visible south of the Ames Avenue bridge in Madaket. Because many beachfront dwellings are located on bluffs, they do not need to be elevated. In the downtown area, the predominance of older structures and the existing of height restrictions explains the lack of elevation above the base flood level.

## *4.5 Vulnerabilities and Risk Assessment*

According to the Massachusetts Hazard Mitigation Plan, NFIP claims in Nantucket related to flooding exceeded $5 million between 1978 and 2002, placing it in the top seven municipalities in the State in terms of total claim value. Most of these claims were related to coastal flooding. Repetitive-claim properties are located in Sconset, Madaket, along the southwest shore, and in the downtown and Brant Point area.

FEMA map revision priorities for Nantucket panels range from "lowest" for Tuckernuck and "low" for the area between the airport and Tom Nevers, to "medium" for mid-island and Monomoy. Map revision priority is reportedly "high" for northwest and northeast Nantucket, and "very high" for downtown, Madaket and Sconset. The priority level is generally a reflection of FEMA's perception of risk and vulnerability, and in certain cases

these are consistent with local knowledge and observations.

The Nantucket Harbor area (including downtown and Brant Point) and Madaket Village are considered to be the most vulnerable populations with regard to coastal flooding. The prevalence of low-lying coastal land and the high building and population densities creates a dangerous potential for repeated flood damage, even with the protections provided by the sheltered harbors.

Several critical facilities are located in coastal flood zones and are therefore vulnerable to flooding. These include the municipal buildings 16 Broad Street, 34 Washington Street, and 37 Washington Street; the Police Station; Our Island Home and Landmark House; the sewer pumping station on Sea Street; the Steamship Dock, all four boat ramps listed in Table 2-1, and the fuel tank farm.

A close review of the FEMA Flood Insurance Rate Maps for the Town of Nantucket provides an interesting glimpse into the close relationship between these communities and their coastlines. The FIRM for the harbor area depicts a highly developed area with a complex array of A zones and V zones with different elevations, due to the encroachment of structures into the harbor. The FIRM for the Madaket section of Nantucket depicts neighborhoods where streets pass through A zones, B zones, and non-flooding areas all within two blocks. Approximately 140 dwellings in Madaket and 950 buildings in the downtown and Brant Point areas are located within 100-year and 500-year flood zones, with the majority of these numbers concentrated in the 100-year zones.

Madaket residents are potentially affected by flooding in another important way. Madaket Road is the only available means of evacuation from Madaket Village to central Nantucket during a flood event. Anyone using the road must cross the Head of Long Pond and Madaket Ditch, both of which are 100-year flood zones. Although these crossings did not flood during the No Name storm in 1992 when portions of Madaket Village flooded, a more significant storm could flood the crossings at a time when the

road is most needed. Similarly, the bridge connecting Smith Point residents to Madaket has the potential to flood, although less frequently as the bridge currently has eight to ten feet of freeboard.

Residents of Polpis and Wauwinet are similarly potentially effected by flooding that can occur where Polpis Road crosses Fulling Mill Brook, and where Wauwinet Road passes in close proximity to Polpis Harbor. During a severe storm, these residents may find that their primary means of evacuation are not available.

Residents of Nantucket's other population centers are less likely to be affected by coastal flooding. In Sconset, most dwellings and commercial establishments are located on the bluff, far above the flood zone and at risk for erosion but not chronic flooding. The exception in Sconset is the Codfish Park neighborhood, where 61 cottages, dwellings, garages, and outbuildings are located outside the mapped 100-year coastal floodplain, but near the edge of the 100-year flood zone with wave velocity hazard. This area did indeed experience flooding and erosion during the 1992 No Name storm, with several structures lost to the ocean. Damage to structures also occurred in the April 1997 storm.

In summary, the Madaket, Brant Point, and downtown areas are most vulnerable to *inundation* caused by coastal flooding. Efforts to mitigation for coastal flooding should be concentrated in these areas, or along evacuation routes from these areas.

## *4.6 Potential Mitigation Measures, Strategies, and Alternatives*

Many potential mitigation strategies for coastal flooding are essentially the same as those for inland flooding, and are not restated in this section under the headings for prevention, property protection, structural projects, emergency services, public education, and natural resource protection. Potential strategies that are more applicable to coastal flooding than inland flooding are presented below.

***V-Zone Standards and Freeboard Standards***

In recognition of increased flood losses in coastal environments, often due to increased development, the Association of State Floodplain Managers (ASFPM) has adopted a No Adverse Impact (NAI) floodplain management philosophy. These policies focus on individual- or community- level responsibility and mitigation of flood risk. NAI should be viewed as a set of principles to follow when designing or evaluating development activities. Implementation of NAI principles can be accomplished through planning initiatives, regulatory programs, individual- or community-based projects, and public education and outreach.

The NFIP and the accompanying locally adopted floodplain management ordinances set forth specific design requirements aimed at minimizing damage to buildings in mapped V zones caused by waves and storm induced erosion. These requirements state that new, substantially damaged, or substantially improved structures that are built in V zones must, among other requirements, be elevated on piers, piles, or other open foundation type, with the lowest horizontal structural component elevated to or above the flood elevation. The area below the flood elevation is to be kept free of obstructions, used only for building access, parking, or storage. The intent of this requirement is to allow floodwaters and damaging waves to pass beneath a building without transferring any additional loads onto its foundational components.

One of the best mitigation options available, as identified by the ASFPM NAI principles, is to exceed the minimum NFIP requirements by constructing (or retrofitting) buildings located in sections of coastal A-zones to meet V-zone standards. Exceeding minimum regulatory requirements may increase costs for initial construction and maintenance, but these costs could more than be offset by long-term benefits.

Application of freeboard standards to coastal flood zone elevations is typically viewed as more effective than applying freeboard standards to inland flood zones. Freeboard

standards require structures to be elevated higher than the level that FEMA requires. When used alone, freeboard standards provide additional certainty that flood levels will not damage a structure. When use in combination with V-zone standards, freeboard standards can provide an additional level of flood damage prevention.

***Hard and Soft Structural Projects***

Physical structures that are capable of lessening the impacts of coastal flooding typically include seawalls, levees, and bulkheads. Because new hard structures are not allowed in the Town of Nantucket, soft solutions such as beach nourishment must be pursued as the only available structural projects to mitigate for coastal flooding. A discussion of beach nourishment is presented in Section 6.6.

## 4.7 *Recommended Actions*

The proposed mitigation strategies for addressing coastal flooding are listed below. Some of these are repeated from Section 3.7, given their applicability to coastal flood mitigation.

- Increase cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people.
- Streamline the permitting process and ensure maximum education of a developer or applicant. Develop a checklist that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project. This list could be provided to an applicant at any Town department.

- Urge or petition FEMA to more critically evaluate LOMA applications that are received such that redevelopments do not potentially cause increased flooding or wave velocities to other properties.
- Adopt freeboard standards (two feet for dwellings and one foot for roadways) when regulating the elevation of development in flood zones.
- Adopt V zone construction standards for coastal A zones.
- Encourage elevation of homes in the Codfish Park beach residential area to the base flood (9') plus two feet.
- Encourage elevation of homes in Madaket flood zones to the base flood (8') plus two feet.
- Offer to assist in the application for FEMA funds to relocate waterfront homes if owners agree to cease utilization of hard solutions.
- Increase the elevation of Wauwinet Road at Polpis Harbor to the base flood (8') plus one foot.
- Increase the elevation of Polpis Road at Fulling Mill Brook to the base flood (8') plus one foot.
- Increase the elevation of Madaket Road at Head of Long Pond to the base flood (8') plus one foot.
- Increase the elevation of Madaket Road at Madaket Ditch to the base flood (8') plus one foot.
- Ensure that pre-disaster natural hazard mitigation is a primary consideration and major factor in any analysis of bulk fuel storage and delivery alternatives, including those alternatives that remove the tank farm from the downtown area and move fuel delivery away from the harbor.
- If the above-referenced analyses find that the downtown tank farm should remain in place, the tank farm floodproofing should be inspected and upgraded to withstand not only waves and water velocities but also storm debris, and freeboard standards should be applied to increase the elevation of floodproofing by an additional two feet above the base flood.

- If the above-referenced analyses find that the downtown tank farm should be relocated, it should be relocated to an area outside flood and hurricane storm surge zones, and to an area that is accessible during natural disasters.
- Continue to make sandbags available to protect the downtown sewer pumping station
- Support privately-funded beach nourishment projects that are believed to have minimal environmental impacts.
- Develop a list of potential Town-funded and/or FEMA-funded beach nourishment demonstration projects and apply for funding to pursue these projects.
- Urge State regulators and the scientific community to make a determination relative to beach dewatering effectiveness.
- Revise the setback clause of the Wetland Regulations (20 times the erosion rate or 100 feet) to be more stringent.
- Focus open space and conservation acquisitions on coastal properties.
- Selectively pursue conservation objectives listed in the Madaket Area Plan if coastal properties are targeted.
- Purchase the development rights to the 270-acre Loring Property in Madaket.
- Selectively pursue conservation objectives listed in the Sconset Area Plan if coastal properties are targeted.
- Adopt open space zoning.

In addition, important recommendations that apply to all hazards are listed in Section 11.1.

# 5.0 *HURRICANES*

## 5.1 *Setting*

Hazards associated with tropical storms and hurricanes include winds, heavy rains, and flooding. As explained in Section 4.1 in the context of coastal flooding, Nantucket is an island community with significant coastal resources. While the coastline is susceptible to hurricane damage such as storm surge and flooding, wind damage can occur throughout the community. All of Nantucket's localities are checked in the "wind" column of Appended Table 1. Hurricanes therefore have the potential to affect any portion of Nantucket.

## 5.2 *Hazard Assessment*

Hurricanes are a class of tropical cyclones which are defined by the National Weather Service as non-frontal, low pressure large scale systems that develop over tropical or subtropical water and have definite organized circulations. Tropical cyclones are categorized based on the speed of the sustained (1-minute average) surface wind near the center of the storm. These categories are: Tropical Depression (winds less than 39 mph), Tropical Storm (winds 39-74 mph, inclusive) and Hurricanes (winds at least 74 mph).

The geographical areas affected by tropical cyclones are called tropical cyclone basins. The Atlantic tropical cyclone basin is one of six in the world and includes much of the North Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The official Atlantic hurricane season begins on June 1 and extends through November 30 of each year, although occasionally hurricanes occur outside this period.

## ***Storm Surge***

Abnormal high water levels along ocean coasts and interior shorelines are commonly caused by storm events. These higher than expected water levels, known as storm surges, are generally the result of regional scale meteorological disturbances. Storm surge is defined as the difference between the observed water level and the normal astronomical tide. Extratropical storms such as nor'easters have produced some of the highest storm surges and resultant damages on record. However, hurricanes have the potential to produce much higher storm surges because of the vast amount of energy released by these storm systems over relatively short duration.

A number of factors contribute to the generation of storm surges, but the fundamental forcing mechanism is wind and the resultant frictional stress it imposes on the water surface. The magnitude of storm surge within a coastal basin is governed by both the meteorological parameters of the hurricane and the physical characteristics of the basin. The meteorological aspects include the hurricane's size, measured by the radius of maximum winds; the intensity, measured by sea level pressure and maximum surface wind speeds at the storm center; the path, or forward track of the storm; and the storm's forward speed.

## ***The Saffir / Simpson Scale***

The Saffir / Simpson Hurricane Scale, which has been adopted by the National Hurricane Center, categorizes hurricanes based upon their intensity, and relates this intensity to damage potential. The scale uses the sustained surface winds (1-minute average) near the center of the system to classify hurricanes into one of five categories. The Saffir / Simpson scale is provided below.

- **Category 1:** Winds 74-95 mph (64-82 kt or 119-153 km/hr). Storm surge generally 4-5 feet above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage. Hurricanes Allison of 1995 and Danny of 1997 were Category 1 hurricanes at their peak intensities.

- **Category 2:** Winds 96-110 mph (83-95 kt or 154-177 km/hr). Storm surge generally 6-8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubbery and trees with some trees blown down. Considerable damage to mobile homes, poorly constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings. Hurricane Bonnie of 1998 was a Category 2 hurricane when it hit the North Carolina coast, and Hurricane Georges of 1998 was a Category 2 Hurricane when it hit the Florida Keys and the Mississippi Gulf Coast.

- **Category 3:** Winds 111-130 mph (96-113 kt or 178-209 km/hr). Storm surge generally 9-12 feet above normal. Some structural damage to small residences and utility buildings with a minor amount of curtainwall failures. Damage to shrubbery and trees with foliage blown off trees and large trees blown down. Mobile homes and poorly constructed signs are destroyed. Low-lying escape routes are cut off by rising water 3-5 hours before arrival of the center of the hurricane. Flooding near the coast destroys smaller structures with larger structures damaged by battering from floating debris. Terrain continuously lower than five feet above mean sea level may be flooded inland eight miles (13 km) or more. Evacuation of low-lying residences within several blocks of the shoreline may be required. Hurricanes Roxanne of 1995 and Fran of 1996 were Category 3 hurricanes at landfall on the Yucatan Peninsula of Mexico and in North Carolina, respectively.

- **Category 4:** Winds 131-155 mph (114-135 kt or 210-249 km/hr). Storm surge generally 13-18 feet above normal. More extensive curtainwall failures with some complete roof structure failures on small residences. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut off by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 feet above sea level may be flooded requiring massive evacuation of residential areas as far inland as six miles (10 km). Hurricane Luis of 1995 was a Category 4 hurricane while moving over the Leeward Islands. Hurricanes Felix and Opal of 1995 also reached Category 4 status at peak intensity.

- **Category 5:** Winds greater than 155 mph (135 kt or 249 km/hr). Storm surge generally greater than 18 feet above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut off by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of all structures located less than 15 feet above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within five to ten miles (8-16 km) of the shoreline may be required. Hurricane Mitch of 1998 was a Category 5 hurricane at peak intensity over the western Caribbean. Hurricane Gilbert of 1988 was a Category 5 hurricane at its peak intensity and is one of the strongest Atlantic tropical cyclones of record.

Table 5-1 lists the hurricane characteristics mentioned above as a function of category, as well as the expected central pressure.

**Table 5-1**
**Hurricane Characteristics**

| Category | CENTRAL PRESSURE | | WIND SPEED | | SURGE Feet | Damage Potential |
|---|---|---|---|---|---|---|
| | Millibars | Inches | MPH | Knots | | |
| 1 | >980 | >28.9 | 74-95 | 64-83 | 4-5 | Minimal |
| 2 | 965-979 | 28.5-28.9 | 96-110 | 84-96 | 6-8 | Moderate |
| 3 | 945-964 | 27.9-28.5 | 111-130 | 97-113 | 9-12 | Extensive |
| 4 | 920-644 | 27.2-27.9 | 131-155 | 114-135 | 13-18 | Extreme |
| 5 | <920 | <27.2 | >155 | >135 | >18 | Catastrophic |

The Saffir / Simpson Hurricane Scale assumes an average, uniform coastline for the continental United States and was intended as a general guide for use by public safety officials during hurricane emergencies. It does not reflect the effects of varying localized bathymetry, coastline configuration, astronomical tides, barriers or other factors that may locally modify surge heights during a single hurricane event.

## *5.3 Historic Record*

Through research efforts by the National Climatic Data Center in cooperation with the National Hurricane Center, records of tropical cyclone occurrences within the Atlantic Cyclone Basin have been compiled dating from 1871. Since 1886, detailed computer files of Atlantic tropical cyclones have been maintained by the National Hurricane Center. During this period of record, 29 hurricanes and 67 tropical storms have passed within a 150 mile radius of Newport, Rhode Island.

Since 1900, 12 storms have directly struck New England, including four Category 3 storms (in 1938, 1944, and two in 1954). Up to 47 storms have impacted the region with wind and/or heavy rain, according to the National Weather Service in Taunton, Massachusetts.

The Massachusetts Natural Hazard Mitigation Plan provides a good summary of storms that directly struck Massachusetts. According to the plan, Massachusetts has experienced approximately 32 tropical storms, nine Category 1 hurricanes, five Category 2 hurricanes, and one Category 3 hurricane between 1858 and 2000. This includes the destructive hurricane of 1938 and four other major hurricanes that struck the Massachusetts coast in 1954, 1955, 1985, and 1991.

To date, Massachusetts has not experienced a Category 4 or 5 hurricane. The last hurricane to reach landfall in New England was Hurricane Bob, a weak Category 2 hurricane, in August 1991.

According to various NOAA sources, notable New England hurricanes are as follows:

- 1635 (8/25) - Great Colonial Hurricane
- 1638 (8/3)
- 1675 (9/7) - Second Great Colonial Hurricane
- 1683 (8/23) - Hurricane and Flood of 1683
- 1713 (8/30)
- 1727 (9/27)
- 1743 (11/2) - Ben Franklin's Eclipse Hurricane
- 1749 (10/19)
- 1761 (10/23-24) - Winthrop's Hurricane
- 1770 (10/20) Stile's Hurricane
- 1778 (8/12-13) - The French Storm
- 1788 (8/19) - Western New England Hurricane
- 1815 (9/23) - The Great September Gale
- 1821 (9/3) - Redfield's Hurricane (arrived at low tide)
- 1841 (10/3) - The October Gale
- 1856 (8/21) - Charter Oak Storm

- 1869 (9/8) - September Gale of '69
- 1878 (10/23-24)
- 1879 (8/18-19) - Cape Cod Hurricane of '79
- 1893 (8/24)
- 1893 (8/29) - passed well-inland
- 1896 (10/12-13) - offshore hurricane
- 1916 (7/21) - excessive rain
- 1924 (8/26) - Off-shore Hurricane of '24
- 1933 (9/17-18) - 13.27 inches rain at Provincetown
- 1936 (9/18-19) - 7.79 inches rain at Provincetown
- 1938 (9/21) - Great New England Hurricane
- 1944 (9/14-15) - Great Atlantic Hurricane
- 1950 (9/11-12) - Hurricane Dog
- 1954 (8/31) - Carol
- 1954 (9/11) - Edna
- 1954 (9/11) - Hazel
- 1955 (8/17-19) – Connie and Diane; extreme floods
- 1960 (9/12) - Donna
- 1985 (9/27) - Gloria
- 1991 (8/19) - Bob

***Significant Storms***

The most devastating hurricane to strike New England, dubbed the "Long Island Express of September 21, 1938," was believed to be a Category 3 hurricane. The "Great Atlantic Hurricane" struck New England in September 1944. Hurricanes Carol and Edna struck in 1954, and back-to-back hurricanes Connie and Diane struck in 1955. In September of 1985, hurricane Gloria passed over New England. Descriptions of the four major 20th Century hurricanes affecting Nantucket are provided below. Portions of the descriptions

are taken from the publication *Southern New England Tropical Storms and Hurricanes, A Ninety-eight Year Summary 1909-1997*, by David R. Vallee and Michael R. Dion of the National Weather Service in Taunton, Massachusetts.

*The Great New England Hurricane of 1938 ("Long Island Express of 1938")*

The Great New England Hurricane of 1938 remains one of the most destructive storms ever to strike New England. The hurricane, believed to be a Category 3, was one of the powerful "Cape Verde" hurricanes that developed in the far eastern Atlantic, near the Cape Verde Islands. The storm did not weaken on its way toward New England, due to its rapid speed and its track over the warm waters of the Gulf Stream. The storm made landfall on September 21, 1938 on Long Island, New York, crossing Long Island Sound, and then again at Milford, Connecticut. The lowest pressure at the time of landfall (27.94 inches) occurred on the south side of Long Island.

Sustained hurricane force winds occurred throughout most of southern New England. The strongest winds ever recorded in New England occurred at the Blue Hill Observatory with sustained winds of 121 mph and a peak gust of 186 mph. Sustained winds of 91 mph with a gust to 121 mph was reported on Block Island. Extensive damage occurred to roofs and trees, and widespread power outages occurred. Rainfall from the hurricane resulted in severe river flooding across sections of Massachusetts. Three to six inches fell across much of western Massachusetts, although considerably less rain occurred to the east across the remainder of Massachusetts.

The eye made landfall at the time of astronomical high tide. The hurricane produced storm tides of 18 to 25 feet from New London, Connecticut east to Cape Cod. A storm surge of 12 to 15 feet in Narragansett Bay destroyed coastal homes, marinas and yacht clubs, and downtown Providence was submerged under a storm tide of nearly 20 feet.

Sections of Falmouth and New Bedford, Massachusetts were submerged under as much as eight feet of water.

The hurricane caused 564 deaths and approximately 1,700 injuries in Southern New England. Damage to fishing fleets in southern New England was catastrophic, with a total of 2,605 vessels destroyed and 3,369 damaged.

*Hurricane Carol, 1954*

Hurricane Carol was the most destructive hurricane to strike southern New England since the Great New England Hurricane of 1938. Carol developed in the Bahamas but did not accelerate until passing east of Cape Hatteras, North Carolina. Carol made landfall on eastern Long Island and southeastern Connecticut, moving over 35 mph.

Sustained winds of 80 to 100 mph were measured in the eastern half of Connecticut, all of Rhode Island, and most of eastern Massachusetts. Trees and power lines were blown down. The strongest wind ever recorded on Block Island, Rhode Island occurred during Carol, at 135 mph. The National Weather Service in Warwick, Rhode Island recorded sustained winds of 90 mph, with a peak gust of 105 mph. Lowest recorded pressure was 28.36 inches on the south shore of Long Island. Rainfall amounts ranged from two to five inches across most of the area. The heaviest amounts, up to six inches, occurred in Connecticut and across extreme north central Massachusetts.

Hurricane Carol made landfall just after high tide, causing coastal flooding. Storm surge levels ranged from 10 to 15 feet from the New London area eastward. Narragansett Bay and New Bedford harbor received the largest surge heights of over 14 feet in the upper reaches of both water bodies. Coastal communities from central Connecticut eastward were devastated. Entire coastal communities were nearly wiped out in New London,

Groton, and Mystic, Connecticut, as well as from Westerly to Narragansett, Rhode Island. As in 1938, downtown Providence was flooded under 12 feet of water.

Hurricane Carol destroyed nearly 4,000 homes, along with 3,500 automobiles and over 3,000 boats. Most of Rhode Island, much of eastern Connecticut, and much of eastern Massachusetts lost electrical power.

*Hurricane Edna, 1954*

Hurricane Edna struck New England only 11 days after Hurricane Carol. Edna followed a track up the East Coast that was slightly east of Carol's track, moving toward southern New England at over 45 mph, but about 100 miles further east. Edna passed over Martha's Vineyard and Nantucket, then across the eastern tip of Cape Cod, becoming one of the only tropical systems to directly pass over Nantucket.

Winds of 75 to 95 mph were measured in eastern Massachusetts and coastal Rhode Island. Peak wind gusts included 120 mph on Martha's Vineyard, 110 mph on Block Island, and 100 mph at Hyannis, Massachusetts. The winds knocked out electrical power across sections of Rhode Island, eastern Massachusetts, and nearly all of Cape Cod, Martha's Vineyard, and Nantucket. The lowest recorded pressure was 28.02 inches at Edgartown on Martha's Vineyard.

Edna arrived during a rising tide and resulted in severe flooding across Martha's Vineyard, Nantucket and Cape Cod, where storm surges of over six feet were measured. Damage to the boating community was severe across Cape Cod, but was much less across the remainder of Massachusetts and Rhode Island. Most of the damage occurred in areas that were left weakened by Carol.

Edna's track across the extreme eastern part of the region resulted in heavy rainfall and inland flooding. Rainfall amounts of three to six inches were common, with over seven inches in northeastern Massachusetts. The total combined rainfall for Carol and Edna ranged from five to seven inches along and west of the Connecticut River and over Cape Cod, to as much as 11 inches from southeast Connecticut, across most of Rhode Island, to northeast Massachusetts. Considerable urban and small stream flooding occurred. Edna caused 21 deaths in New England.

*Hurricane Bob, 1991*

Hurricane Bob was the most recent hurricane to strike New England, although several tropical storms have struck since Bob's landfall in August 19, 1991. Hurricane Bob developed in the Bahamas and moved north-northeastward, paralleling the U.S. east coast. The eye of Hurricane Bob passed over Block Island and made landfall over Newport, Rhode Island.

Hurricane Bob brought sustained hurricane force winds to the coastal communities of Rhode Island and southeast Massachusetts. Coastal communities experienced sustained winds between 75 to 100 mph. Peak wind gusts to 125 mph were recorded on Cape Cod in the towns of Brewster and North Truro. The highest sustained wind of 100 mph was recorded in North Truro. Block Island reported sustained winds of 90 mph, with gusts in excess of 105 mph. Additionally, four tornadoes were reported as Hurricane Bob made landfall. Wind damage to trees and utility poles was widespread and resulted in numerous power outages. Over 60% of residents in southeast Rhode Island and southeast Massachusetts lost power. The lowest barometric pressure was recorded at 28.47 inches.

Hurricane Bob caused a storm surge of 10 to 15 feet in Buzzards Bay. The Buzzards Bay shore east to Cape Cod was hardest hit by the surge. The highest surges of 12 to 15 feet, were observed in Onset, Bourne, Mashpee and Wareham, at the head of Buzzards

Bay. Extensive beach erosion occurred along the shore from Westerly, Rhode Island eastward. Some south-facing beach locations on Martha's Vineyard and Nantucket Islands reportedly lost up to 50 feet of beach to erosion.

Bob was responsible for six deaths in New England, with all of these Connecticut. Total damage in southern New England was approximately $680 million, including about $70 million in Massachusetts.

***Recent Tropical Storms***

The most recent tropical storm to pass over Nantucket was Beryl in 2006. Beryl did not cause any significant damage due to its weakened status. According to various news reports, the storm hit Nantucket at 3:00 AM and had maximum sustained winds of 50 mph with a steady rainfall.

## *5.4 Existing Programs, Policies, and Mitigation Measures*

***Flood Damage Prevention***

Existing mitigation measures appropriate for both inland and coastal flooding have been discussed in previous sections. These include the ordinances, codes, and regulations cited in Section 2.8 that have been enacted to minimize storm damage.

DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. With regard to roads, bridges, and culverts at tidal creeks, the DPW regularly maintains Town-owned roads and facilities and upgrades/improves them as needed. However, DPW does not have sufficient equipment to barricade all roadways that could potentially flood.

***Harbor Damage Prevention***

The Marine and Coastal Resources Department has a very proactive approach to pre-disaster mitigation when it comes to tropical storms and hurricanes, as well as other storms. The emphasis is removing people and boats from harm's way before a storm strikes. With 71 sinkings during Hurricane Bob and 63 during the No Name Storm, inspections by the Marine and Coastal Resources Department have increased sharply. All moorings are inspected on a three-year cycle. Weather is monitored on three web sites and posted at the harbor. The Department recommends that people leave the vicinity of the island before storms strike. If they can not leave, the Department can offer 125 rental moorings and a 100-slip marina. Two boats ramps are available in Madaket.

The Department tries to remove as many vessels as possible before storms. This is a difficult feat because more than 3,000 boats can be in and near the harbor on a warm, sunny summer day. In advance of Hurricane Edward (Labor Day 1996), 1,000 boats were hauled in 36 hours. Before Tropical Storm Beryl (2006), 250 boats were hauled. The Department has reduced property damage and water pollution by removing boats. The Department will place removed vessels wherever possible, including ball fields. The Department sometimes identifies everyone in the mooring field with medical problems before a storm, in order to understand who may need additional assistance during a storm.

The main town pier was constructed in 1976. The floating add-on was installed in 2001. A firefighting cart is located on the pier. The pier area also has a closed-circuit TV and lights that can be viewed on the internet.

Boat ramp repairs at the harbor were made as recently as fall 2006. The ramp was increased in width, pitch, depth. The repairs have made it easier for removal of two boats simultaneously. The Department coordinates its own seawall and jetty repairs, including permitting, and works well with the Conservation Commission. FEMA helped fund a

recent bulkhead repair after it was damaged. The new bulkhead is not fastened to the pier; this allows a give-and-take with the waves that large boats need. A wave barrier is also incorporated. It was constructed winter 2005-2006 with a State and FEMA assistance.

It is important to understand that the Coast Guard has only limited shallow-water capabilities, so the Town handles these areas around Nantucket. The relationship between the Town and the Coast Guard is good.

***Wind Damage***

Wind loading requirements are addressed through the Building Department's administration of building codes. The current enforceable building code is believed to be antiquated. The new building code was supposed to take effect in September 2006, and is meant to be enforceable by March 2007. The wind design codes will change from 90 mph to 120 mph, providing a much higher standard of protection against wind damage.

DPW responds to damage from tropical storm and hurricane winds. Prior to forecast tropical storms and hurricanes, DPW will dispatch equipment and personnel to outlying areas of Nantucket such as Sconset and Madaket. However, roughly half of the roads on Nantucket are private. These are normally not maintained by DPW, nor are trees maintained by the Town. Public education for these areas is important. As an example, 30 to 40 pine trees along Russell's Way were blown down two years ago. A resident was trapped for several days. Ultimately, the Town assisted with cleanup.

***Coastal Damage Prevention***

With regard to preexisting structures that were constructed to reduce coastal storm damage, examples include the jetties at the mouth of Nantucket Harbor and seawalls that

exceed coastal base flood elevations. Numerous concrete, steel, and wood bulkheads in the harbor area have been erected and maintained over the years to stabilize the shoreline and stop erosion.

A variety of other projects have been conducted in other areas to combat erosion, such as beach nourishment; installation and operation of a beach dewatering system at two Sconset beaches; and riprap, bulkheads, seawalls, and related structures that pre-date the regulations that no longer allow their construction. These will be discussed further in Section 6.4.

***Emergency Services***

According to the Nantucket EOP, the municipal responsibilities relative to hurricane mitigation and preparedness include:

- Develop and disseminate emergency public information and instructions concerning hurricane preparedness and safety.
- Community leaders should ensure that Nantucket is enrolled in the National Flood Insurance Program.
- Develop and enforce local building codes to enhance structural resistance to high winds and flooding. Limit new construction to areas that are not vulnerable to direct hurricane effects.
- Make informed decisions concerning protecting natural attributes such as beaches and dunes with breakwaters and sea walls. Review National Flood Insurance Rate Maps and Hurricane Evacuation Maps for possible impact on the community.
- Maintain plans for managing all hurricane emergency response activities.
- Ensure that warning/notification systems and equipment is ready for use at the hurricane warning stage.
- Review mutual aid agreements.

- Designate suitable wind and flood resistant shelters in the community and make their locations known to the public.
- Prepare for coordination of evacuation from potentially impacted areas including alternate transportation systems and locations of special needs facilities.

The Water Companies have active roles in pre-disaster mitigation. Before storms, water tanks are filled and equipment is secured. Through careful preparation, fire protection and potable supply are available during and after natural disasters. Generators are located at the wellfields and pumping stations. Hurricanes are specifically addressed in the water system emergency plan. This is important, for example, because a tree was once blown over during a hurricane/tropical storm and broke a water main.

The Massachusetts Property Insurance Underwriting Association also participates in hurricane mitigation by distributing a flyer to its policyholders. The hurricane preparedness flyer includes tips for protecting the homeowner family and the home, organized in the categories "preparing ahead of a storm," "when a hurricane watch is issued," "when a hurricane warning is issued," and "after a hurricane." The flyer also includes a hurricane disaster supply kit checklist and tips for developing a family communication plan.

## 5.5 *Vulnerabilities and Risk Assessment*

Nantucket is particularly vulnerable to hurricanes despite moderate hurricane occurrences when compared with other areas within the Atlantic Tropical Cyclone basin. The location of Nantucket at the extreme southeast corner of the New England region, protruding into the Atlantic Ocean toward the north-northeast path taken by many tropical systems, places it in the potential path of many tropical storms and hurricanes. The coastline geometry; bathymetry; and hurricane direction, intensity, and forward speed are influential parameters that affect resulting hazards to Nantucket.

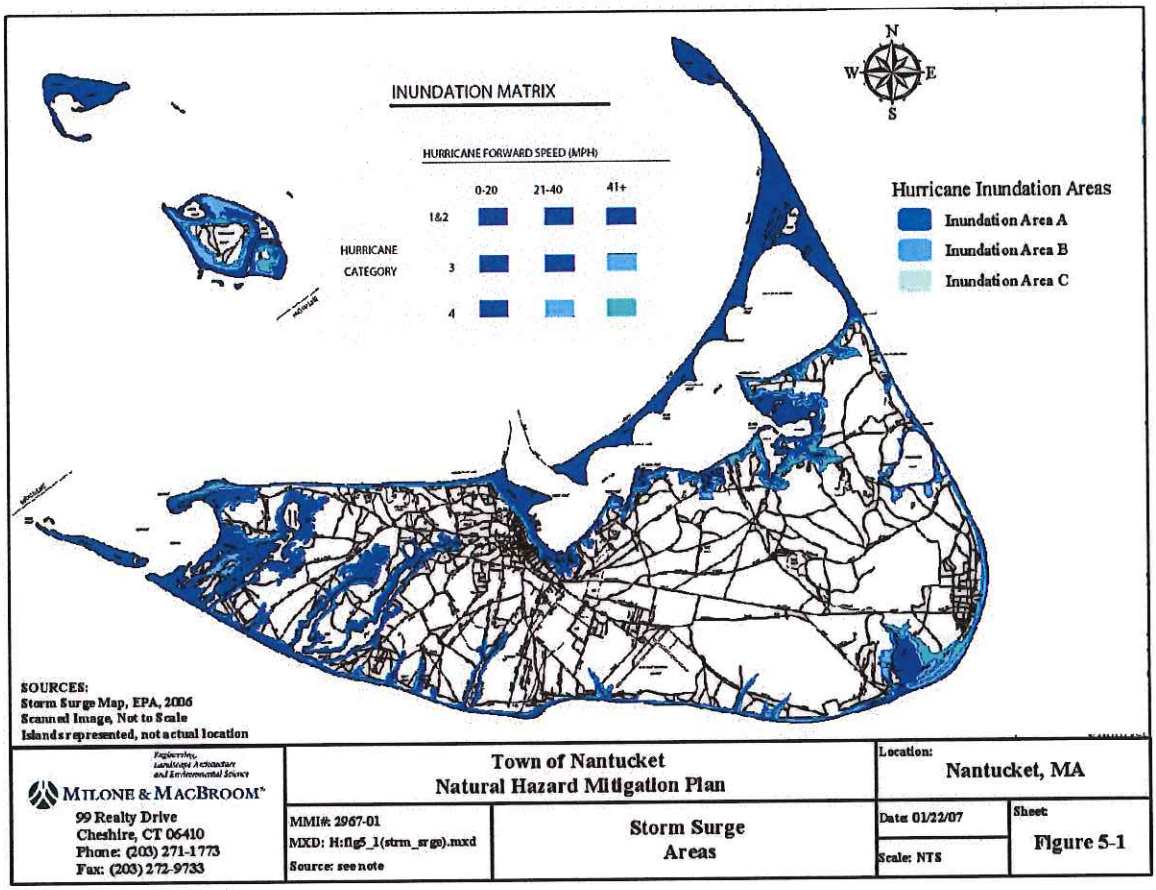
According to the Massachusetts Hazard Mitigation Plan, New England is considered to be long overdue for another major hurricane strike. Based on past hurricane and tropical storm landfalls, the frequency of hurricanes to hit the Massachusetts coastline is an average of once out of every six years. Nantucket's position southeast of New England places it in the path of more tropical storms and hurricanes than central New England. For example, tropical storm Beryl in 2006 passed closer to Nantucket than any other New England community.

According to the presentation "Fundamentals of Catastrophe Modeling" by AIR Worldwide Corporation, June 30, 2006, each year Massachusetts has a 1% probability of a $5 billion loss. Factoring in development and growth of property values, the probability of a $5 billion loss in the next ten years is 15%. Furthermore, Nantucket, Martha's Vineyard, Cape Cod, and the Buzzards Bay towns have the highest risk for residential property loss in Massachusetts, should a hurricane occur.

This section provides information on areas that would be at risk due to hurricane storm surge. It does not address issues such as flooding that may be associated with heavy rains that often accompany hurricane type storms. Flooding is addressed in both the Inland Flooding and Coastal flooding sections of this plan.

The areas impacted by hurricane storm surge are shown on Figures 5-1. This map was digitized from the *Southern Massachusetts Hurricane Evacuation Study Technical Data Report Inundation Map*, dated May 1997. This figure shows the potential surge areas for Category 1 and 2, Category 3, and Category 4 hurricanes, respectively. Inundation areas reflect "worst case" combinations of hurricane direction, forward speed, landfall point, and high astronomical tide.

Figure 5-1


INUNDATION MATRIX
HURRICANE FORWARD SPEED (MPH)
0-20
21-40
41+
HURRICANE CATEGORY
1&2
3
4
N
W
E
S
Hurricane Inundation Areas
Inundation Area A
Inundation Area B
Inundation Area C
SOURCES:
Storm Surge Map, EPA, 2006
Scanned Image, Not to Scale
Islands represented, not actual location
Engineering, Landscape Architecture and Environmental Science
MILONE & MACBROOM
99 Realty Drive
Cheshire, CT 06410
Phone: (203) 271-1773
Fax: (203) 272-9733
Town of Nantucket
Natural Hazard Mitigation Plan
Location:
Nantucket, MA
MMI#: 2967-01
MXD: H:\fig5_1(strm_srge).mxd
Source: see note
Storm Surge Areas
Date: 01/22/07
Scale: NTS
Sheet:
Figure 5-1

Inundation areas were derived from application of the National Hurricane Center's "SLOSH" model. The SLOSH model was developed by the National Weather Service and first used for real-time forecasting of surges from hurricanes within selected Gulf of Mexico and Atlantic coastal basins. SLOSH's success in surge forecasting has lead to utilization of the model for hurricane preparedness planning. The model calculates storm surge heights for the open ocean and coastal regions affected by a given hurricane. The model also calculates surge heights for bays, estuaries, coastal rivers, and adjacent upland areas susceptible to inundation from the storm surge.

Significant man-made or natural barriers (i.e., dunes, islands, etc.) are represented by the model and their effects are simulated in the calculation of surge heights. The model does not provide predictions based on rainfall amounts or interior freshwater flooding. It is assumed that Flood Insurance Rate Maps will be used to plan for evacuation of non-tidal areas. A detailed description of the SLOSH model is given in the *Southern Massachusetts Hurricane Evacuation Study Technical Data Report.*

Based on the model, storm surge from Category 4 hurricanes will cause flooding beyond what would be expected from a 100- or 500-year flood event. Specific areas of note where storm surge areas extend beyond the FEMA 100-year and 500-year flood zones include parts of Madaket and downtown that are on the margins of the mapped flood zones. For example, the critical facility Our Island Home is believed to be in a surge area, but not a mapped flood zone.

Other critical facilities in surge areas include the municipal buildings 16 Broad Street, 34 Washington Street, and 37 Washington Street; the Police Station; Landmark House; the sewer pumping station; the Steamship Dock, all four boat ramps listed in Table 2-1, and the fuel tank farm. In addition, Madaket and some of the localities along Polpis Road and Wauwinet Road are vulnerable to isolation during storm surge events by sea level rise.

Vulnerability is increasing because the Atlantic Basin has likely entered another active period of hurricane activity. The last period to occur, from the 1930s to the 1950s, included the four Category 3 hurricanes that have struck New England. The current period, which began in the 1990s, is expected to continue.

***Public Shelter Demand and Capacity***

The vulnerable Nantucket populations during "weak" and "severe" hurricane scenarios are 1,630 permanent residents and 9,890 seasonal residents, according to the *Southern Massachusetts Hurricane Evacuation Study Technical Data Report*. These numbers were based on population counts from the early 1990s. As discussed in Section 2.0, population increased by 58% between 1990 and 2000. Thus, these numbers are likely to have increased as well.

The *Southern Massachusetts Hurricane Evacuation Study Technical Data Report* further reports that shelter utilization during a severe hurricane would include 800 individuals in surge areas and 330 individuals in non-surge areas. Based on this analysis, the Town of Nantucket has lower than adequate facilities to handle the evacuation and sheltering needs based on hurricane analysis. Recall from Section 2.9 that the available sheltering capacity at the high school is approximately 500. However, plans are underway to include sheltering in the 2 Fairgrounds Road facility. Furthermore, recall from Section 2.9 that non-residents would be asked to take shelter in hotels and inns before using the public shelters.

## 5.6 *Potential Mitigation Measures, Strategies, and Alternatives*

Many potential mitigation measures for hurricanes include those appropriate for inland and coastal flooding. These were presented in Sections 3.6 and 4.6. However, hurricane mitigation measures must also address the effects of heavy winds and rain that are

inherently caused by hurricanes. Mitigation for wind damage is therefore emphasized in the subsections below.

### 5.6.1 *Prevention*

Although hurricanes and tropical storms can not be prevented, a number of methods are available to continue preventing damage from the storms, and perhaps to increase damage prevention. The Comprehensive Community Plan and Status Chart recommend the following types of prevention for hazard mitigation:

- Add additional boat ramps at all harbors for emergency preparedness purposes and backup storage sites for vessels hauled during emergencies.
- Add boats ramps and storage areas for emergency response.
- Utilize opportunities to place utilities underground.
- Continue the program of placing utilities underground in the historic districts of Nantucket and Siasconset and as opportunities arise, elsewhere throughout the island.

### 5.6.2 *Property Protection*

Potential mitigation measures for property protection during hurricanes include designs for hazard-resistant construction and retrofitting techniques. These may take the form of increased wind and flood resistance, as well as the use of storm shutters over exposed glass and the inclusion of hurricane straps to hold roofs to buildings. In addition, living and working areas can be elevated to allow a storm surge to pass safely underneath.

The Building Department should make literature available to developers during the permitting process regarding these design standards. The Health Department should continue its outreach and education for retrofitting of existing structures.

### 5.6.3 *Public Education and Awareness*

The public, especially those individuals living within hurricane storm surge evacuation zones, should be made aware of evacuation routes and available shelters. A number of specific proposals for improved *public education* are recommended to prevent damage and loss of life during hurricanes. These are common to all hazards in this plan, and are listed in Section 11.1.

### 5.6.4 *Emergency Services*

A natural hazard mitigation plan addresses actions that can be taken before a disaster event. In this context, emergency services that would be appropriate mitigation measures for hurricanes include diligent use of forecasting, implementation of warning systems such as Reverse 911 to provide information on the time of occurrence and magnitude of a storm, and early evacuation of neighborhoods and localities. Although evacuation of Nantucket as a whole may not be feasible, the long lead time before a predicted hurricane strike may provide for significant off-island evacuations.

Based on the above guidelines, a number of specific proposals for improved *emergency services* are recommended to prevent damage from inland and nuisance flooding. These are common to all hazards in this plan, and are listed in Section 11.1.

### 5.6.5 *Structural Projects*

Structural mitigation for hurricane storm surges is generally focused on constructing seawalls, which provide better protection than bulkheads. The Town of Nantucket is not in a position to construct new seawalls, as they are not permitted. However, previous recommendations for coastal flood mitigation provided in Section 4.6 will provide

mitigation for coastal flooding caused by hurricanes. Structural projects for wind damage mitigation are not possible.

## 5.7 ***Recommended Actions***

Recommendations for mitigation of hurricane and tropical storm winds include the following:

- Increase tree limb maintenance and inspections, especially in the downtown and Sconset areas.
- Continue to require that utilities be placed underground in new developments and pursue funding to place them underground in existing developed areas.
- Provide funding for additional Marine Department staff to assist with boat removal before storms.
- Designate official sites on land for boat storage during storm events.

Recommendations for mitigation of hurricane and tropical storm rains include the following:

- Conduct master drainage studies for problem areas, such as the broad area between Madaket Road and Hummock Pond Road, to ensure that individual repairs and upgrades fit seamlessly with upstream and downstream drainage systems.
- Improve the storm drainage system on Pleasant Street to reduce flooding.
- Complete the Orange Street drainage system upgrade to reduce flooding and allow better drainage of upstream areas.
- Sesachacha Pond is drawn down twice each year to prevent high water levels. This should be continued as long as it protects Polpis Road from flooding.

In addition, many of the recommendations in Sections 4.7 for mitigating coastal flooding are suitable for mitigation of storm surges. These are repeated below:

- Adopt freeboard standards (two feet for dwellings and one foot for roadways).
- Adopt V zone construction standards and coastal A zones.
- Encourage elevation of homes in the Codfish Park beach residential area to the base flood (9') plus two feet.
- Encourage elevation of homes in Madaket flood zones to the base flood (8') plus two feet.
- Offer to assist in the application for FEMA funds to relocate waterfront homes if owners agree to cease utilization of hard solutions.
- Increase the elevation of Wauwinet Road at Polpis Harbor to the base flood (8') plus one foot.
- Increase the elevation of Polpis Road at Fulling Mill Brook to the base flood (8') plus one foot.
- Increase the elevation of Madaket Road at Head of Long Pond to the base flood (8') plus one foot.
- Increase the elevation of Madaket Road at Madaket Ditch to the base flood (8') plus one foot.
- Ensure that pre-disaster natural hazard mitigation is a primary consideration and major factor in any analysis of bulk fuel storage and delivery alternatives, including those alternatives that remove the tank farm from the downtown area and move fuel delivery away from the harbor.
- If the above-referenced analyses find that the downtown tank farm should remain in place, the tank farm floodproofing should be inspected and upgraded to withstand not only waves and water velocities but also storm debris, and freeboard standards should be applied to increase the elevation of floodproofing by an additional two feet above the base flood.

- If the above-referenced analyses find that the downtown tank farm should be relocated, it should be relocated to an area outside flood and hurricane storm surge zones, and to an area that is accessible during natural disasters.
- Continue to make sandbags available to protect the downtown sewer pumping station.
- Support privately-funded beach nourishment projects that are believed to have minimal environmental impacts.
- Develop a list of potential Town-funded and/or FEMA-funded beach nourishment demonstration projects and apply for funding to pursue these projects.
- Urge State regulators and the scientific community to make a determination relative to beach dewatering effectiveness.
- Revise the setback clause of the Wetland Regulations (20 times the erosion rate or 100 feet) to be more stringent.
- Increase cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people.
- Streamline the permitting process and ensure maximum education of a developer or applicant, a checklist should be developed that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project.
- Urge or petition FEMA to more critically evaluate LOMA applications that are received such that redevelopments do not potentially cause increased flooding or wave velocities to other properties.
- Focus open space and conservation acquisitions on coastal properties.
- Selectively pursue conservation objectives listed in the Madaket Area Plan if coastal properties are targeted.
- Purchase the development rights to the 270-acre Loring Property in Madaket.

- Selectively pursue conservation objectives listed in the Sconset Area Plan if coastal properties are targeted.
- Adopt open space zoning.

In addition, important recommendations that apply to all hazards are listed in Section 11.1.

# 6.0 *SEA LEVEL RISE, SHORELINE CHANGE, AND EROSION*

## 6.1 *Setting*

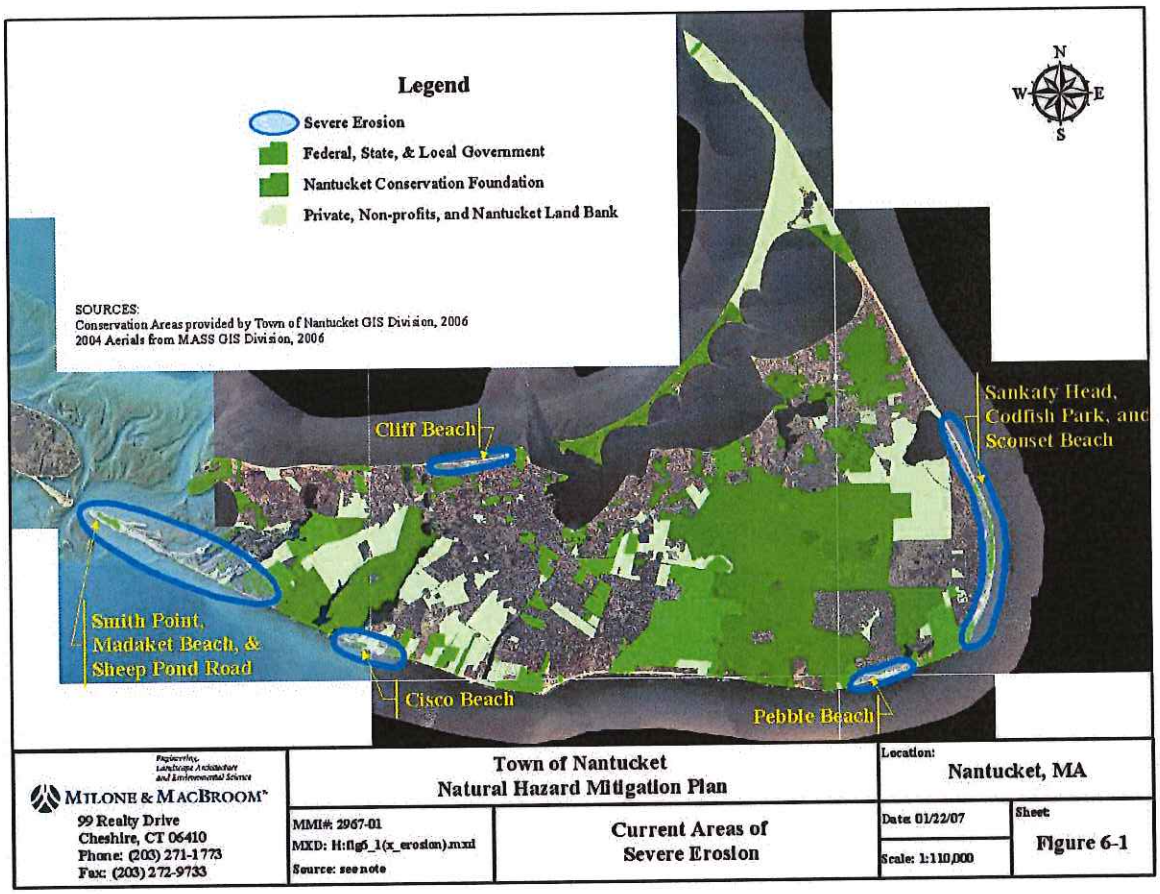
Sea level rise is a phenomenon that affects coastal and tidal areas, and land areas with elevations close to sea level. As such, the entire community of Nantucket is vulnerable to sea level rise, although the timing of the impacts from this phenomenon will vary with distance from the shoreline.

Likewise, coastal erosion and shoreline change will one day affect the entire island of Nantucket, even as the more immediate concerns are focused on the shoreline. Although the entire perimeter of the island (along with Muskeget and Tuckernuck) is vulnerable, the areas of Nantucket that currently or have recently suffered from severe erosion and shoreline change include those listed below and depicted on Figure 6-1:

- Codfish Park in Sconset
- Sconset Beach in Sconset
- Low Beach in Sconset
- Pebble Beach along the south shore
- Cisco Beach along the south shore
- Sheep Pond Road along the south shore toward Madaket
- Madaket Beach in Madaket
- Smith Point in Madaket
- Cliff Beach along the north shore

These localities are checked in the "coastal flooding" and "coastal erosion" columns of Appended Table 1.

Figure 6-1 – Areas of Severe Erosion



## 6.2 *Hazard Assessment*

Although erosion and shoreline change have long been recognized as coastal hazards, it is only recently that the chronic problem of sea level rise has been closely connected to the acute threats erosion and shoreline change. Indeed, sea level rise will increase the incidence, severity, and adverse effects of erosion and shoreline change.

### *Sea Level Rise*

Sea levels are currently rising along the Atlantic Coast as a result of climate change, which may be attributable to greenhouse gases. Rising sea levels will inundate low areas, increase erosion of beaches and bluffs, increase the incidence of flooding from storm surges, and enable saltwater to advance upstream and intrude further into aquifers.

Rising sea level affects both the natural and the human-made environments. Future sea level rise could result in the disappearance of a large percentage of Nantucket's coastal wetlands, unless they can advance as quickly as the rising level. Saltwater advancing upstream along estuaries can alter the point at which flocculation leads to sedimentation and the creation of shoals.

As sea level rises, storm surges from hurricanes and nor'easters will reach further inland as they are starting from a higher base level. By the end of the 21$^{st}$ century, it is possible that a Category 1 hurricane storm surge will be similar to what is now a Category 3 hurricane storm surge.

FEMA coastal base flood elevations, which are currently at 8 to 9 feet (NGVD) depending on the location, will progressively rise. This means that the 100-year and 500-year flood levels will affect lands that are currently at unaffected elevations. This will exacerbate the problem of coastal and near-coastal inland flooding within Nantucket.

As sea level rises, drainage systems become less effective. Rainstorms will have the potential to cause greater flooding. Nantucket already experiences problems with inadequate storm drainage in areas such as Brant Point and downtown. As sea level rises, these areas will likely experience increased flooding.

Between 1990 and 2000, the population of Nantucket increased by 58%. As coastal population densities increase, greater numbers of people and assets are at risk. For example, increased storm surges due to rising sea levels has the potential to flood important low-lying arterial roadways that currently flood only infrequently.

***Erosion and Shoreline Change***

Nantucket Island continues along the path that started 12,000 years ago after the last glaciation, slowly giving way to the advancing Atlantic Ocean. This net loss of land is due partly to active erosion of bluffs, dunes, beaches, etc.; and partly to passive submergence caused by a the natural component of relative sea level rise. The erosion and passive submergence together cause a net loss of land resulting in shoreline change.

As stated in the Massachusetts Hazard Mitigation Plan, coastal erosion and shoreline change can result in significant economic loss through the destruction of buildings, roads, infrastructure, natural resources and wildlife habitats. Damage often results from the combination of an episodic event with severe storm waves and dune or bluff erosion.

The Massachusetts Coastal Zone Management (CZM) program provides a good description of erosion and shoreline change processes on its web site. Erosion, transport, and the accretion that results are continuous and interrelated processes. Each day wind, waves, and currents move sand, pebbles, and other small materials along the shore or out to sea. Shorelines also change seasonally, tending to accrete slowly during the summer

months when sediments are deposited by relatively low energy waves and erode dramatically during the winter when sediments are moved offshore by high energy storm waves, such as those generated by nor'easters.

The source of the sand that created and continues to feed the beaches, dunes, and barrier beaches in Massachusetts comes primarily from the erosion of coastal landforms. For example, the material eroded from the Atlantic-facing coastal bluffs of the Cape Cod National Seashore supplies sand to downdrift (i.e., down current) beaches of the Cape.

While erosion is necessary and natural, is has the potential to damage coastal property and infrastructure. According to CZM, erosion can expose septic systems and sewer pipes, contaminating shellfish beds and other resources; release oil, gasoline, and other toxins to the marine environment; and sweep construction materials and other debris out to sea. Public safety is jeopardized when buildings collapse or water supplies are contaminated.

According to USGS, four possible erosional outcomes can occur during a storm and storm surge event. "Swash" occurs when the maximum elevation of wave runup is higher than the beach but still lower than the base of the dune or bluff. This results in the erosion of the beach. "Collision" occurs when the maximum elevation of wave runup is higher than the base of the dune or bluff, but lower than the top of the dune or bluff. Collision results in severe erosion of the dune or bluff. "Overwash" occurs when the maximum elevation of wave runup is higher than the top of the dune or bluff. Overwash can result in damage to structures behind the dune. Finally, "inundation" occurs when the base tide and surge level is higher than the beach and dune. This is the most dangerous of the four outcomes with regard to flood damage.

CZM notes that shoreline change can result in significant "economic and emotional loss" in the current land use system of fixed property lines and ownership. However,

attempting to halt the natural process of erosion with seawalls and other hard structures can shift the problem, subjecting other property owners to similar losses. Also, without the sediment load associated with erosion, beaches and dunes can be threatened and may slowly disappear as the sand sources that sustain them are eliminated. The challenge is to site coastal development in a manner that allows natural physical coastal processes such as erosion to continue.

## 6.3 *Historic Record*

### *Sea Level Rise*

The Intergovernmental Panel on Climate Change (IPCC) concludes that there has been a global mean rise in sea level between 10 and 25 cm (approximately 4 to 10 inches) over the last 100 years (Neumann et. al., 2000). Relative sea level rise at Boston and Woods Hole gauges over the same time period is estimated at 26 cm (10 inches), according to USGS.

In its landmark 2001 report, the IPCC estimated that global sea level will rise 9 to 88 centimeters during the 21st century. According to the much-publicized February 2007 report by IPCC, these predictions have been somewhat refined using six models to predict a more narrow range of sea level rise of 28 to 43 cm (11 to 16.9 inches) in the 21st century.

The rate of sea level rise in Massachusetts will remain slightly higher than the global projections, due to the effects of regional subsidence. Overall, sea level is likely to rise more than one foot along most of the Atlantic Coast by the end of the current century.

## ***Erosion and Shoreline Change***

### *Historical Maps*

The earliest records of shoreline change for Nantucket are available from a review of historical topographic maps and nautical charts. These maps have documented striking changes in the southwestern portion of Nantucket from Madaket to Muskeget Island. The Nantucket Shoals Nautical Chart from 1791 depicts a barrier island between Muskeget and Tuckernuck that disappeared the next century. This barrier island was aligned with the southern shore of Nantucket Island at Madaket, whereas Muskeget and Tuckernuck were located behind (north) of the barrier island and the shoreline alignment.

The topographic map from 1893 shows that the barrier island was gone by then, with a long barrier beach extending from Madaket (where Smith Point is currently located) to a position southwest of Tuckernuck. The barrier beach and Tuckernuck were separated by a very narrow strait. The 1903 Nantucket Shoals Nautical Chart shows a continuation of this northward erosional progression, with the southern shore of Tuckernuck finally merged with the barrier beach and aligned with the southern shore of Nantucket at Madaket. The maps from 1791 through 1903 also show a progressive shrinking of Muskeget Island.

By 1944, topographic maps show the disappearance of the barrier beach west of Madaket and a wide expanse of water between Tuckernuck Island and Smith Point (the western extent of the Madaket barrier beach system).

The aforementioned maps document a significant northward shift of the southern shoreline. For example, Hummock Pond was a U-shaped pond in 1893. By 1945, the beach south of the pond had advanced northward far enough that it decreased the width of water connecting the two arms of the U. Hummock Pond is now two separate ponds,

with the beach advancing so far to the north that it merged with the peninsula between the two arms. Likewise, several north-south ponds along the southern shoreline have disappeared over the same time frame, including Nobadeer Pond, Madequecham Pond, and most of Sheep Pond.

It is more difficult to detect changes in the shoreline in the Sconset area based on a review of the historical maps. However, the topographic maps from 1945 and 1951 depict many more homes in the Codfish Park area as compared to the same area today. Specifically, homes on the east side of Codfish Park Road are clearly visible in the historical topographic maps, whereas the area east of the road is currently occupied by the beach and the ocean.

*"Selected Resources of the Island of Nantucket"*

A detailed record of erosion and shoreline change from 1896 through 1962 is available from the University of Massachusetts Cooperative Extension Service publication "Selected Resources of the Island of Nantucket" (1966). Table 6-1 lists the incidents reported in the publication. This list is not meant to be exhaustive or inclusive of all major shoreline change and erosion events.

**Table 6-1**
**Notable Storm Damage, 1896-1962**

| Date | Description |
|---|---|
| 12/15/1896 | Ocean broke through at Haulover (head of harbor). |
| 1/25/1905 | Harbor level 7.5 feet above normal low water. |
| 1/18/1908 | Bluff erosion up to 25 feet in Surfside area. |
| 1/10/1914 | Ocean broke through at Great Point; severe erosion. |
| 1/16/1915 | Sound broke through Coatue; erosion of Nantucket Cliffs. |
| 8/16/1925 | Bluff erosion at Surfside and Madaket; flooding of all south shore ponds. |
| 1/26-29/1933 | Ocean broke through at Haulover; bluff erosion at Squam and Nantucket Cliffs; flooding of Miacomet and Hummock Ponds. |

**Table 6-1 (Continued)**
**Notable Storm Damage, 1896-1962**

| Date | Description |
|---|---|
| 9/21/1938 | Hurricane of '38: Bluff erosion along entire south shore; ocean broke through at Broad Creek (this area is no longer a creek; instead it comprises the southern curve of Madaket Harbor). |
| 3/2/1947 | Heavy surf and flooding at Madaket; washover of ocean to Hummock Pond and Sheep Pond; bluff erosion at Cisco. |
| 8/31/1954 | Hurricane Carol: Smith's Point cut off from Nantucket. |
| 9/11/1954 | Hurricane Edna: Bluff erosion along entire south shore; Nobadeer Valley flooded (southeast of airport); washover of ocean to Hummock Pond. |
| 1/7/1958 | Ocean washover at Broad Creek. |
| 9/20/1961 | Hurricane Ester: Ocean washover at Broad Creek; heavy surf with 20' waves at Madaket. |
| 10/20-24/1961 | Heavy surf with 20' waves along south shore; Madaket ocean side erodes 40'; harbor water level 5' above normal. |
| 11/14-15/1962 | Harbor water level 6.5' above normal. |

*Massachusetts Shoreline Change Project*

The Massachusetts CZM Shoreline Change Project is available to help educate residents and property owners about erosion and shoreline change. In the previous phase of the Shoreline Change Project, CZM completed a statistical analysis from the mid-1800s to 1978 for ocean-facing coastlines and produced maps depicting several historic shorelines to demonstrate long-term shoreline change. CZM distributed these maps to coastal conservation commissions in 1997, helping local decision makers identify coastlines that are prone to storm damage and significant erosion and to assess erosion potential.

CZM recently completed an update of the Shoreline Change Project, using 1994 NOAA aerial photographs of the Massachusetts shoreline. CZM established an agreement with the USGS, the Woods Hole Oceanographic Institute (WHOI) Sea Grant Program, and Cape Cod Cooperative Extension to produce a 1994 shoreline, add it to the previous

project, and update the statistics and calculate erosion rates. The new maps and statistical analysis of shoreline change now cover the time period from the mid-1800s to 1994.

Overall, these studies demonstrated that the Massachusetts shore is eroding at approximately one-half foot per year. Of the communities mapped, 72% are showing an overall long-term erosion trend, while 28% are showing long-term accretion. Nantucket, West Tisbury, and Chilmark reportedly have the highest erosion rates in the State of Massachusetts, at over two feet per year. Nantucket's southwest shore reportedly has the highest long-term average annual rate of erosion, at slightly more than 12 feet per year. Indeed, WHOI (1998) reports that the erosion rates in southwest Nantucket are highest in Massachusetts.

In the Low Beach area, the study demonstrated that the shoreline is very unstable. Between 1846 and 1887, the beach reportedly accreted 238 feet; from 1887-1955 it eroded 32 feet; and from 1955-1978, this same beach eroded 204 feet. Despite the apparent long-term net stability of the beach, any buildings constructed here when the beach was accreting would have subsequently been destroyed when it eroded.

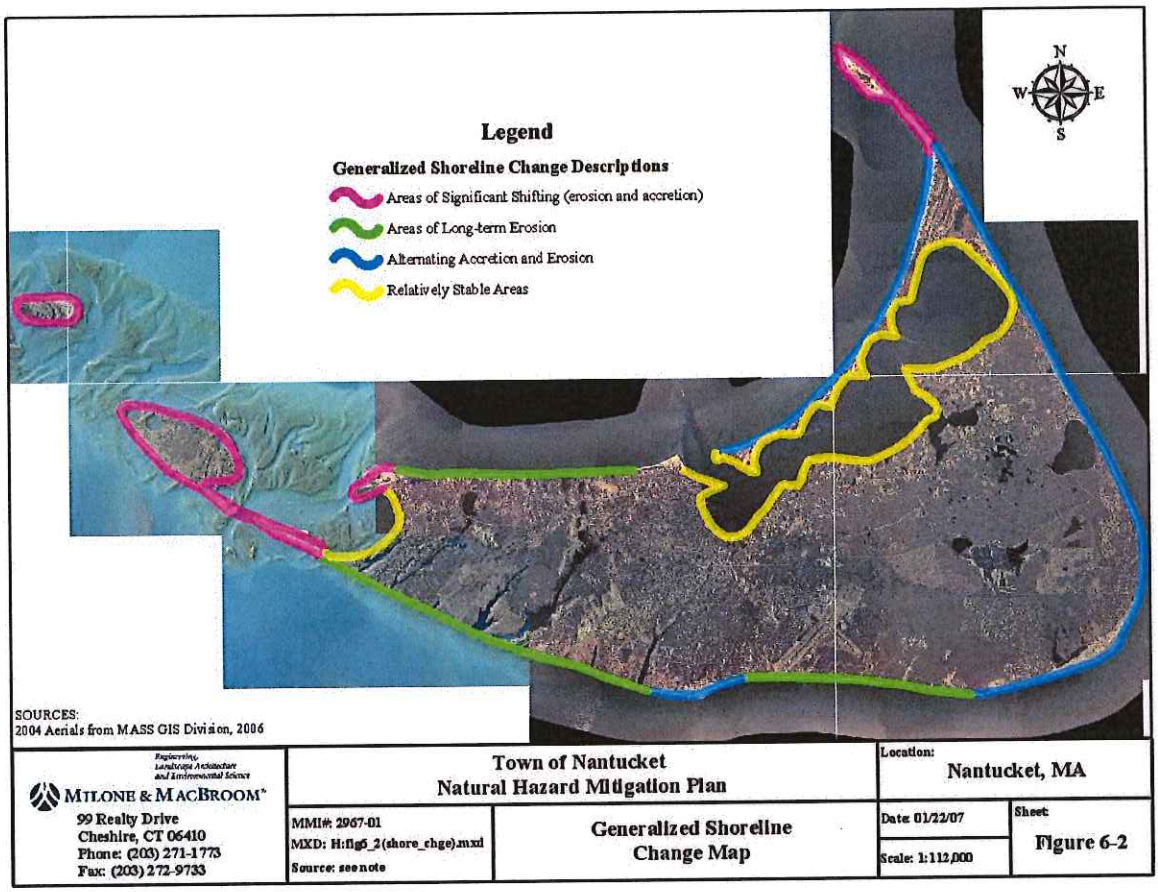
Table 6-1 lists erosion and accretion data for a selection of transects around the perimeter of Nantucket Island located near critical facilities and other points of interest. This information was taken from an independent review of the CZM Shoreline Change Project maps conducted for this natural hazard mitigation plan.

**Table 6-2**
**Erosion and Accretion Rates in Selected Nantucket Coastal Areas**

| Transect | Location | 1846-1887 | 1887-1955 | 1955-1978 | 1978-1994 | Overall ft/year |
|---|---|---|---|---|---|---|
| 27759 | Warren Ldg. Madaket Harbor | 29 | 52 | 6 | -8 | 1 |
| 27978 | Cliff Rd north of Water Tank | -184 | -161 | 10 | -41 | -2 |
| 28028 | At Jetties Beach | -67 | 611 | 274 | -45 | 6 |
| 28053 | North side of Brant Point | 147 | 49 | -29 | -85 | 1 |
| 28201 | At UMass Field Station | -63 | -5 | -43 | 0 | -1 |
| 29306 | Sankaty Head Lighthouse | 257 | -82 | -80 | -71 | 0 |
| 29314 | Along Baxter Road | 272 | 15 | -84 | -116 | 1 |
| 29351 | At Codfish Park cottages | 351 | 155 | -177 | -133 | 1 |
| 29392 | Near Sconset WWTP Beds | 102 | 185 | 15 | 353 | 4 |
| 29399 | Near Sconset WWTP Beds | -373 | 643 | -457 | 259 | 1 |
| 29461 | End of Tom Nevers Road | 338 | -214 | -116 | -98 | -1 |
| 29552 | South of Propane Storage & Airport Maint. Facility | -393 | -704 | -113 | -141 | -9 |
| 29590 | South of Airport | -487 | -602 | -198 | -75 | -9 |
| 29676 | South of Main WWTP | 952 | -369 | 91 | -36 | 3 |
| 29784 | End of Hummock Pond Road | -232 | -528 | -239 | -141 | -8 |
| 29858 | Along Sheep Pond Road | -270 | -896 | -256 | -184 | -11 |
| 29913 | Along Madaket Beach | -507 | -927 | -282 | -64 | -13 |
| 29949 | Smith Point | -760 | -679 | -303 | -120 | -12 |

Figure 6-2 depicts areas of shifting, long-term erosion, alternating accretion and erosion, and relatively stable areas from 1846 through 1994. It is important to note that this figure provides only a very generalized depiction of trends. The Massachusetts Shoreline Change maps should be reviewed for details.

Figure 6-2


Legend
Generalized Shoreline Change Descriptions
Areas of Significant Shifting (erosion and accretion)
Areas of Long-term Erosion
Alternating Accretion and Erosion
Relatively Stable Areas
N
W
E
S
SOURCES:
2004 Aerials from MASS GIS Division, 2006
Engineering, Landscape Architecture and Environmental Science
MILONE & MACBROOM
99 Realty Drive
Cheshire, CT 06410
Phone: (203) 271-1773
Fax: (203) 272-9733
Town of Nantucket
Natural Hazard Mitigation Plan
Location:
Nantucket, MA
MMI#: 2967-01
MXD: H:\fig5_2(shore_chge).mxd
Source: see note
Generalized Shoreline Change Map
Date: 01/22/07
Scale: 1:112,000
Sheet:
Figure 6-2

*Other Sources of Information*

It is understood that much of the severe erosion facing Nantucket occurs during discrete storm events. As stated in the Massachusetts Hazard Mitigation Plan, four large events in the early 1990s had major impacts on the Massachusetts coastline, state-wide. These were Hurricane Bob, the October 1991 Nor'easter, the December 1992 Nor'easter (Nantucket's No Name Storm) and the March 1993 storm; as well as the most recent coastal storms in the winters of 2001 and 2003, and spring 2004.

The NCDC further reports that Nantucket suffered erosion during the 1992 No Name Storm, a December 1993 storm, an April 1997 storm, a January 1998 storm, and a February 1998 storm. During the 1992 No Name Storm, several homes were washed out to sea in Codfish Park and the beach suffered severe erosion. During the April 1997 storm, the homes in Codfish Park were evacuated and a portion of one home was lost. During the January 1998 storm, the Pebble Beach parking lot was lost to erosion and had to be relocated. The next month during the February 1998 storm, 12 to 15 feet of bluff was lost in Sconset.

A group of consecutive storms can have a significant impact. According to the article "Tempering the Wrath of Mother Nature" (The Nantucket Independent, August 24, 2005), the storms of winter 2004-2005 took an average of 15 feet of bluff along Baxter Road in Sconset.

The most recent severe erosion event occurred during the spring nor'easter of April 16-17, 2007. During this storm, southeast wind gusts of 64 mph and 18 to 20-foot waves re-severed Esther Island from Smith Point and undermined one of the homes on Sheep Pond Road, causing it to fall onto Madaket Beach. Erosion controls along Baxter Road in Sconset were destroyed.

## 6.4 *Existing Programs, Policies, and Mitigation Measures*

The CZM Shoreline Change Project is available to help educate residents and property owners about erosion and shoreline change. To help make informed and responsible decisions, CZM states that coastal managers, shorefront landowners, and potential property buyers need information on both current and historical shoreline trends, including reliable measurements of erosion and accretion rates in non-stable areas. The goal of the Shoreline Change Project is to develop and distribute scientific data that will help inform local land use decisions.

The Shoreline Change Project presents long-term and short-term shoreline change rates at 40-meter intervals along the entire Massachusetts coast. In a broad sense, this information may provide useful insight into the erosional forces at work along the Massachusetts coast. But CZM cautions users of this tool when applying this information to specific property or local sections of coastline, and advises that one should consult with a professional when attempting to use the Shoreline Change Project data for planning purposes.

Although Nantucket does not currently have a comprehensive plan to address sea level rise, important pieces are indeed in place, in the form of the ordinances, codes, and regulations cited in Section 2.8 that have been enacted to minimize storm, erosion, and flood damage.

Recall from Sections 3.4 and 4.4 that DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. At the Sconset WWTP, the Town must plan a new location for the effluent beds if the bluff at Low Beach erodes to within 100 feet of a permanent marker. The marker is 300 feet from the ocean and 100 feet from the beds. At the Surfside WWTP, bathymetric mapping has indicated that erosion

and accretion will occur, and the shoreline will be stable for 20 to 25 years. Funding for the plant takes the life span of the plant and effluent beds into account.

With regard to pre-existing structures that were constructed to reduce erosion and stabilize shorelines, examples include the jetties at the mouth of Nantucket Harbor and numerous concrete, steel, and wood bulkheads in the harbor area.

A variety of other projects have been conducted in other areas to combat erosion, such as beach nourishment; installation and operation of a beach dewatering system at two Sconset beaches; and riprap, bulkheads, seawalls, and related structures that pre-date the regulations that no longer allow their construction. Beach nourishment and beach dewatering are described in Section 6.6.

Homes and the Sankaty Lighthouse are being moved back (retreating from the shoreline) in the eastern part of Nantucket. Private funds were raised for the lighthouse project, and private funds are typically used for home relocation.

## *6.5 Vulnerabilities and Risk Assessment*

### *Sea Level Rise*

According to the USGS publication "National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast," the ***coastal vulnerability index*** of the Nantucket shoreline as related to sea level rise varies from "moderate" to "very high," depending on the location. The "moderate" score has an associated relative sea level rise projection of 2.5 to 2.95 mm/year, the "high" score translates to 2.95 to 3.16 mm/year, and the "very high" score translates to greater than 3.16 mm/year. "Very low" and "low" coastal vulnerability indices were not assigned to Nantucket. These are reserved for rocky shores such as those found in Maine.

Transportation infrastructure in Nantucket at risk to adverse affects from sea-level rise includes portions of the roads listed in Table 2-2, such as Broad Street, Washington Street, North Beach Street, South Beach Street, Easton Street, Polpis Road, Wauwinet Road, Madaket Road, Cambridge Street, Tennessee Avenue, and Codfish Park Road. Without improvements, many of these roads will have more difficulty draining due to rising base level, and will flood more frequently due to winds or even small storm surges.

Port facilities on the water's edge are particularly vulnerable to sea level rise. Docks, piers, boat ramps, jetties, and other facilities are deliberately set at an optimal elevation relative to the water level, and therefore a rise in sea level leaves them at a less optimal elevation. However, unlike roads, these facilities tend to be rebuilt relatively frequently as compared with the time it takes for a substantial rise in sea level.

Commercial, industrial, and residential properties along the coastline are also vulnerable to sea level rise. In general, these are the same areas that were identified in Sections 4.0 and 5.0 in the context of coastal flooding and hurricanes, respectively. The most vulnerable areas are those where topography is relatively flat, such as Brant Point, and areas adjacent to Nantucket harbor and tidal creeks and waterways.

All of the critical facilities in coastal flood zones and storm surge areas are vulnerable to sea level rise. These include the municipal buildings 16 Broad Street, 34 Washington Street, and 37 Washington Street; the Police Station; Our Island Home and Landmark House; the sewer pumping station; the Steamship Dock, all four boat ramps listed in Table 2-1, and the fuel tank farm. In addition, Madaket is vulnerable to isolation caused by sea level rise, although the speed of sea level rise allows for transportation improvements to remedy this situation.

***Erosion and Shoreline Change***

The entire community of Nantucket is vulnerable to erosion and shoreline change in the long term. In the short term, coastal erosion and shoreline change vulnerabilities are greatest in the following areas:

- Codfish Park in Sconset – This area has suffered repeatedly and significant erosion has occurred most during the 1992 No Name Storm, a December 1993 storm, an April 1997 storm, and a February 1998 storm. Since then, the beach has accreted somewhat and the erosion problem is temporarily on hold. However, it is believed that erosion will again threaten this area. Although critical facilities are not immediately affected, more than 50 homes are located on the beach *below* the bluff, and these homes are extremely vulnerable to erosion and subsequent loss.

- Sankaty Head and Sconset Beach – Severe erosion has recently plagued these areas, with Sankaty Head Lighthouse scheduled for a coordinated retreat from the shoreline. Homes along Baxter Road have been moved back as well, and a number of erosion control projects are underway along this area, including terracing of the bluff and beach dewatering. The storms listed above (1992, 1993, 1997, and 1998) also affected this area, but the difference between Sconset Beach and Codfish Park at present is that the Baxter Road and Sankaty Head portions of Sconset Beach are undergoing severe erosion now.

- Low Beach in Sconset – Although Low Beach is not currently eroding, it has accreted and eroded over a very wide range in the last 100 years. If the bluff erodes to within 100 feet of a permanent marker, the Town must plan a new location for the effluent beds at the Sconset WWTP, which is one of the designated critical facilities. The marker is 300 feet from the ocean and 100 feet from the beds.

- Pebble Beach along the south shore – Portions of Tom Nevers Road have been lost to erosion, but homes have not yet been lost. The bluff in this area has undergone some striking erosion. A parking lot was lost during a January 1998 storm. However, critical facilities are not affected.

- Surfside – Bathymetric mapping has indicated that erosion and accretion will continue to occur, and the shoreline will be relatively stable for 20 to 25 years. However, this area is densely developed with homes and is also the site of the Surfside WWTP, one of the designated critical facilities.

- Nobadeer Beach along the south shore – Similar to other south shore areas, this is near the portion of Nantucket that is eroding most rapidly. One very critical facility – the airport – is located north of this stretch of beach.

- Cisco Beach along the south shore – Similar to Tom Nevers Road, the road has been lost but no homes have been cut off. The bluff in this area has undergone some striking erosion, and this is near the portion of Nantucket that is eroding most rapidly.

- Sheep Pond Road along the south shore toward Madaket – Sheep Pond Road was once lost to erosion, and the Town rebuilt the road (it is unpaved) to maintain access for the small number of homes in this area. This is the portion of Nantucket that is eroding second most rapidly based on the rates listed in Table 6-1. Three homes were in imminent danger of loss as of the date of this plan when it was submitted to FEMA for review in March 2007, and the owners had placed massive sandbags in front of their homes to try and prolong the lives of their homes. Subsequently, one of the homes was lost in the April 16-17, 2007 nor'easter. However, critical facilities of Nantucket are not affected.

- Madaket Beach in Madaket – In this area of rapid erosion, at least one home is in imminent danger of loss and a few others are essentially on the beach without protection from a bluff (as of the date of this plan). However, critical facilities are not affected.

- Smith Point in Madaket – The area with highest erosion rates, Smith Point is no longer home to many dwellings. Heavy surf from the April 16-17, 2007 nor'easter re-severed the end of Smith Point, known as Esther Island. The three cottages on Esther Island will be accessed by boat until the point of breakthrough is naturally reconnected. Critical facilities are not affected in this area.

- Cliff Beach along the north shore – Although the south shore is known for the most rapid erosion rates, portions of the north shore are subject to erosion as well. Homeowners along Cliff Beach are investigating beach nourishment as a means of extending the life span of their properties. However, critical facilities are not affected.

## 6.6 *Potential Mitigation Measures, Strategies, and Alternatives*

Land use planning in coastal areas must take into account the phenomenon of sea level rise. Three fundamental long-term responses to sea level rise are typically reported in the literature. These are *retreat*, *accommodation*, and *protection*. These three responses are applicable to erosion and shoreline change, as well.

### *Retreat*

*Retreat* refers to the eventual abandonment of the coastal zone, allowing nature to take its course. This allows for existing coastal ecosystems to shift landward. Retreat may be motivated by excessive economic or environmental impacts of hard or soft measures of

protection. Retreat may be implemented through anticipatory land use planning, regulation, and building codes, or could be motivated through economic incentives.

As a general rule, retreat is feasible in parts of Nantucket, and has been used with moderate success in some cases (Sankaty Head Lighthouse) and less success in others (some private homes). Retreat will continue to be practiced in Nantucket, but is not feasible in the most densely developed areas such as downtown.

***Accommodation***

*Accommodation* allows for the continued use of land at risk, but does not prevent the land from flooding. Measures associated with accommodation may take the form of elevating buildings on piles, and establishing other means of flood hazard mitigation. Accommodation may evolve without any governmental action, but could be assisted by strengthening flood preparation and flood insurance programs. Protective measures are implemented by authorities currently responsible for water resource and coastal protection. Policies should be developed with the ultimate goal to protect coastal property values, or they will be at risk of not being accepted by the community.

Accommodation is feasible only in the limited parts of Nantucket where flooding from storm surges is more problematic than erosion, and where height restrictions for historic buildings may be in place. As such, it has been used in a limited number of cases (elevated homes in Madaket). Overall, accommodation may continue to be practiced in Nantucket, but is not feasible in the most densely developed areas such as downtown.

***Protection***

*Protection* is the construction of structures meant to protect land from inundation and flooding. These may be hard structures such as dikes and sea walls, or soft solutions

including beach nourishment. Of the hard structures, three main structures are utilized to hold back the sea. These are seawalls, bulkheads, and revetments. Seawalls are designed to withstand the full force of waves, and are used if significant wave impact at the project site is expected to be greater than three feet. Bulkheads are designed to retain fill and generally are not exposed to severe wave action. Revetments are designed to protect shorelines against erosion by currents and light wave action. Beach nourishment is discussed in a separate subsection below.

Hard structures are not permitted in Nantucket. Therefore, beach nourishment is the primary means of protection available to Nantucket. It is still a relatively unused solution in Nantucket and in Massachusetts, in general. It is believed that beach nourishment projects will increase as retreat, accommodation, and hard solutions become more difficult, costly, or unlawful to use.

As a general proposition, holding back the sea with structures results in large-scale elimination of wetlands, beaches, mudflats, and other coastal habitat. As shoreline erosion advances toward the structure, if sediment is not replaced at an adequate rate, the coastal fringe will eventually disappear under the water surface. This is why beaches in front of bulkheads and seawalls tend to disappear over time.

***Elevation of Roads and Land***

Elevation of land and infrastructure is another form of protection from sea level rise. Elevation has the important advantage that many types of drainage systems will continue to work properly, as the same or greater head gradient will exist between the drainage system and sea level. Elevation of road surfaces can be achieved in connection with repaving or re-grading of roads. In some communities, continued elevation of roads parallel to water bodies can create a diking effect, protecting areas landward of the road.

In these cases, care must be taken that road elevation does not cause excessive runoff and flooding problems in other areas that become diked by the elevated roadways.

Nantucket has a few roads that are parallel to, located within, or located at the edge of coastal flood zones. A few are located downtown, one (Tennessee Avenue) is located in Madaket, and a few are located in Sconset. In addition, Polpis Road runs along the coastal flood zone of Nantucket Harbor in several locations.

***Freeboard Standards and Application of V Zone Codes in A Zones***

Although many reports about sea level rise have publication dates as far back as the 1990s or even the late 1980s, States and local communities were slow to address sea level rise until the beginning of the 21st century. For example, the State of Maryland recently developed a comprehensive sea level response strategy for county governments to use for addressing coastal hazards in the context of sea level rise. Some of the recommendations include basing set-backs for new development on erosion rates, and applying freeboard standards to coastal flood zone elevations such that structures would be elevated higher than FEMA requires. In other States, application of V zone building codes (that protect structures from wave and velocity damage) has been considered for coastal A zones (where regulations merely protect structures from inundation).

Milone & MacBroom, Inc. has incorporated some of these recommendations into our hazard mitigation plans for coastal communities. In some cases, such as the City of New Haven, local officials have responded well to the recommendations, and plan to utilize these recommendations to eventually modify ordinances. In other cases, such as with the City of Bridgeport and the Town of Fairfield, Connecticut, municipal officials believe that the more innovative recommendations are too restrictive and may be impossible to incorporate into existing regulations.

***Beach Nourishment***

Beach nourishment is the process of replacing sand on and along eroded beaches. Sand may be obtained from offshore areas or from onshore sources. Because beach nourishment does not stop erosion and shoreline change, it must be repeated as necessary to slow the progress of erosion and shoreline change. In many parts of the United States where hard solutions are not feasible or prudent, beach nourishment is the only means available for slowing the retreat of the shoreline.

Beach nourishment is common in Florida and has been used in New York and New Jersey, and has been used in a few Massachusetts communities. According to WHOI (1998), three major beach nourishment projects in Massachusetts are considered successful in that they met their cost-benefit objectives and longevity predictions. In addition to these major projects, at least 80 smaller beach nourishment projects have been completed in Massachusetts (SBPF, 2006). According to the Nantucket Conservation Commission, several Nantucket beach nourishment projects are in the planning and permitting stages, including one for the north shore (the Cliff Beach area).

The largest proposed beach nourishment project in Nantucket history is currently being coordinated and funded by the Siasconset Beach Preservation Fund (SBPF). SBPF was founded in 1992 by Sconset property owners concerned with the eroding bluffs and beaches of Sconset and nearby environs. Over the last ten years, SBPF has implemented a number of smaller piecemeal solutions for erosion control including dune guard fencing, planting of beach grass, placement of mats at the toe of the bluff, and operation of beach dewatering systems in two locations. Results have been mixed.

The two beach dewatering systems, in particular, are believed to have worked to some extent, but did not achieve their design objectives. Beach dewatering is a seldom-used technology that creates a negative pore fluid pressure beneath the beach by removing

ground water from the beach. As waves carry sand onto the beach front, the negative pore fluid pressure captures the sand (interpreted from WHOI, 2002) and is believed to lead to accretion.

Beach dewatering is believed to consume a significant amount of energy and requires ongoing maintenance. According to WHOI (1998), preliminary monitoring results from the Codfish Park beach dewatering system installed in 1994 indicated that the project was not meeting its design objectives due to intermittent operation and repeated damage to the discharge piping as caused by storms.

SBPF's current proposal is to nourish 2.5 miles of beach from Sesachacha Pond to Sconset Village using 2.5 million cubic yards of sand removed from a bank located three miles east of Nantucket. The beach width will be increased to 200-250 feet, and the beach elevation will be increased by ten feet. The total estimated cost of the project is $23 million, inclusive of planning, permitting, and execution. Funding will consist entirely of private donations. Future re-nourishments would be funded with or without possible State and Federal assistance.

The proposed project also includes two small dune rebuilding projects proposed for Codfish Park and an area further south at the sewer beds; renovations to the two beach dewatering systems in the area of the project (known as Codfish Park and LHS-S); and bank stabilization that utilizes terraces constructed of fabric bags and vegetation.

The beach nourishment portion of the project features two distinct components, a design beach profile to be maintained to consistently provide protection against a major storm, and an advanced nourishment profile beach. The advanced nourishment profile is considered sacrificial, eroding over time in response to natural coastal processes, while preventing loss of the design beach. As it erodes, the advanced nourishment profile will

provide sediment to the littoral system at a rate somewhat in excess of that provided naturally over the past decade.

According to the Environmental Impact Report, the reported public benefits of the project include:

- Preservation of the Sconset shoreline and village, including a portion of the coast owned by the Town;
- Protection of Codfish Park Road and its utilities (water and electrical);
- Protection of the Sconset sewer beds;
- Protection of 45 to 50% of the Town's tax base;
- Creation of 40 acres of endangered bird habitat;
- Protection of the Sconset bluff walk (a public accessway); and
- Demonstration of beach nourishment as a potential solution to use elsewhere.

According to the Town of Nantucket web site, SBPF submitted a Draft Environmental Impact Report on June 15, 2006. On August 16, 2006 the Massachusetts Secretary of Environmental Affairs determined that the Draft Environmental Impact Report/Notice of Project Change (DEIR/NPC) adequately and properly complied with the Massachusetts Environmental Policy Act and its implementing regulations. Subsequently, SBPF submitted a Full Environmental Impact Report to the Massachusetts Environmental Policy Office in December 2006. A review is pending.

***Massachusetts Coastal Hazards Commission***

As explained in Section 1.5, final recommendations were released by the Coastal Hazards Commission (CHC) in May 2007. Of the numerous recommendations, the following have been selected as recommendations that may be applicable to, or possible to implement for, the Town of Nantucket:

- The Commonwealth needs to evaluate the distribution of regional coastal hazards and emergency management information to coastal communities before and during storm events. This should include ways to ensure that the public is kept informed with up to date and accurate hazard information and actions government officials are requesting the public to take. It could include use of various electronic mediums (broadcast media, emergency alert system, websites/portals, highway signs/radio, etc.), public outreach forums, distributed literature, and targeted high risk populations/locations.
- The Community Preservation Coalition should educate communities about their abilities to acquire storm damaged properties using the Community Preservation Act or other available sources of funding. Encourage towns to adopt the Community Preservation Act to fund acquisition of storm prone properties.
- The Board of Building Regulations and Standards should update the State Building Code requirements for coastal construction, and also encourage collaboration between Building Inspectors and Conservation Commissions.
- Coastal towns should explore informal coordination processes or the modification of their bylaws to provide for the coordination of permitting and approval by local departments. This coordination should promote more complete and comprehensive understanding of a project and any related permits.
- Evaluate the feasibility of a guidance document or revisions to the Wetland Protection Act regulations to develop best management practices or performance standards for "Land Subject to Coastal Storm Flowage."
- Identify existing culverts and tide gates associated with transportation crossings that are priorities for replacement due to flood hazards or environmental resource concerns; and address flooding, wetlands hydrology, and maintenance in the early stages of design and implementation of new or replacement transportation projects that cross coastal wetlands and waterways.

- The Commonwealth, through its policies, regulations, and activities, should implement a program of regional sand management that promotes nourishment as the preferred alternative for coastal hazard protection.

All of the above recommendations of the CHC have been incorporated into the recommendations of this Plan, with the language appropriately changed to be specific to local geography, issues, concerns, and the regulatory process.

***Other Potential Mitigation Options***

The Comprehensive Community Plan, Comprehensive Community Plan Status Chart, Madaket Area Plan, and Sconset Area Plan include a number of recommendations that are related to erosion and shoreline change hazard mitigation. These include:

- Carefully review new development in proximity to the shoreline, especially in areas of active coastal erosion.
- Support efforts to identify, implement, and thoroughly test new beach preservation technologies such as beach dewatering.
- Prepare a comprehensive assessment of long-term effects of shoreline erosion on existing infrastructure – both public and private, historic and recent – including an assessment of the relative costs of relocation versus the implementation of various beach-protection technologies.
- Encourage a zoning bylaw amendment that would apply to new homes in relative proximity to the spring high water line that are especially prone to coastal erosion. The purpose would be to minimize public or private liability or loss. This provision is meant to complement the jurisdiction of the Conservation Commission over coastal resources.
- Support testing of beach-saving technology.
- Assess technology vs. relocation regarding beach erosion.

- Add zoning to Conservation Commission reviews to minimize losses near coastal erosion areas.
- Manage existing beach dewatering systems.
- Keep the Sconset and Nantucket Island communities informed about the dewatering systems.
- Raise necessary funds [for maintaining the dewatering systems].
- Propose additional dewatering systems in Sconset if the new Lighthouse South system replicates the Codfish Park accretion.
- Analyze causes/options if new dewatering system is ineffective.
- On an on-going basis, monitor research on innovative erosion control technologies.

Some of these recommendations may or may not be advisable, in light of the discussions in this section.

## *6.7 Recommended Actions*

Many of the recommendations for mitigating coastal flooding and hurricane storm surges in Sections 4.7 and 5.7 are suitable for mitigation of erosion, shoreline change, and rising sea level. These are repeated below, with emphasis added (*italics*) for recommendations that will address rising sea level in the long term:

- *Adopt freeboard standards (two feet for dwellings and one foot for roadways).*
- *Adopt V zone construction standards and coastal A zones.*
- *Encourage elevation of homes in the Codfish Park beach residential area to the base flood (9') plus two feet.*
- *Encourage elevation of homes in Madaket flood zones to the base flood (8') plus two feet.*
- Offer to assist in the application for FEMA funds to relocate waterfront homes if owners agree to cease utilization of hard solutions.

- *Increase the elevation of Wauwinet Road at Polpis Harbor to the base flood (8') plus one foot.*
- *Increase the elevation of Polpis Road at Fulling Mill Brook to the base flood (8') plus one foot.*
- *Increase the elevation of Madaket Road at Head of Long Pond to the base flood (8') plus one foot.*
- *Increase the elevation of Madaket Road at Madaket Ditch to the base flood (8') plus one foot.*
- *Ensure that pre-disaster natural hazard mitigation is a primary consideration and major factor in any analysis of bulk fuel storage and delivery alternatives, including those alternatives that remove the tank farm from the downtown area and move fuel delivery away from the harbor.*
- *If the above-referenced analyses find that the downtown tank farm should remain in place, the tank farm floodproofing should be inspected and upgraded to withstand not only waves and water velocities water but also storm debris, and freeboard standards should be applied to increase the elevation of floodproofing by an additional two feet above the base flood.*
- If the above-referenced analyses find that the downtown tank farm should be relocated, it should be relocated to an area outside flood and hurricane storm surge zones, and to an area that is accessible during natural disasters.
- Continue to make sandbags available to protect the downtown sewer pumping station.
- *Support privately-funded beach nourishment projects that are believed to have minimal environmental impacts.*
- *Develop a list of potential Town-funded and/or FEMA-funded beach nourishment demonstration projects and apply for funding to pursue these projects.*
- Urge State regulators and the science community to make a determination relative to beach dewatering effectiveness.
- *Revise the setback clause of the Wetland Regulations (20 times the erosion rate or 100 feet) to be more stringent.*

- *Increase cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people.*
- *Streamline the permitting process and ensure maximum education of a developer or applicant, a checklist should be developed that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project.*
- *Urge or petition FEMA to more critically evaluate LOMA applications that are received such that redevelopments do not potentially cause increased flooding or wave velocities to other properties.*
- Continue to draw down Sesachacha Pond twice each year to prevent high water levels as long as it protects Polpis Road from flooding.
- *Focus open space and conservation acquisitions on coastal properties*
- *Selectively pursue conservation objectives listed in the Madaket Area Plan if coastal properties are targeted.*
- *Purchase the development rights to the 270-acre Loring Property in Madaket.*
- *Selectively pursue conservation objectives listed in the Sconset Area Plan if coastal properties are targeted.*
- Adopt open space zoning.

In addition, important recommendations that apply to all hazards are listed in Section 11.1.

# 7.0 SUMMER STORMS & TORNADOES

## 7.1 Setting

Like hurricanes and winter storms, summer storms and tornadoes have the potential to affect any area within the Town of Nantucket. Furthermore, because these types of storms and the hazards that result (wind, hail, and lightning) might have limited geographic extent, it is possible for a summer storm to harm one area within the Town without harming another. The entire Town of Nantucket is therefore susceptible to summer storms and tornadoes. Refer to the "wind," "lightning," and "hail" columns of Appended Table 1.

## 7.2 Hazard Assessment

Heavy wind including tornadoes and downbursts; lightning; heavy rain or hail; and flash floods are the primary hazards associated with summer storms. Inland flooding was covered in Section 3.0, and will not be discussed in detail here.

### Tornadoes

Tornadoes are spawned by certain thunderstorms. The Fujita scale was accepted as the official classification system for tornado damage for many years following its publication in 1971. The Fujita scale rated the intensity of a tornado by examining the damage caused by the tornado after it has passed over a man-made structure. The scale ranked tornadoes using the now-familiar notation of F0 through F5, increasing with wind speed and intensity. The following graphic of the Fujita scale is provided by FEMA. A description of the scale follows in Table 7-1.

## Fujita Tornado Scale

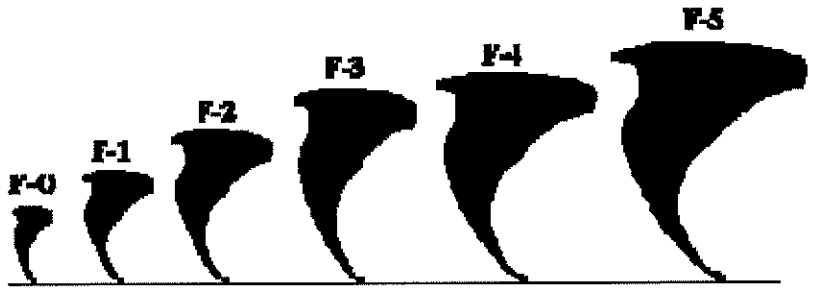



**Table 7-1**
**Fujita Scale**

| F-Scale Number | Intensity | Wind Speed | Type of Damage Done |
|---|---|---|---|
| F0 | Gale tornado | 40-72 mph | Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards. |
| F1 | Moderate tornado | 73-112 mph | The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed. |
| F2 | Significant tornado | 113-157 mph | Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated. |
| F3 | Severe tornado | 158-206 mph | Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted. |
| F4 | Devastating tornado | 207-260 mph | Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated. |
| F5 | Incredible tornado | 261-318 mph | Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged. |

The Enhanced Fujita Scale was released by NOAA for implementation on February 1, 2007. According to the NOAA web site, the Enhanced Fujita Scale was developed in response to a number of weaknesses to the Fujita Scale that were apparent over the years, including the subjectivity of the original scale based on damage, the use of the worst damage to classify the tornado, the fact that structures have different construction depending on location within the United States, and an overestimation of wind speeds for F3 and greater. The Enhanced F-scale is still a set of wind estimates based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of eight levels of damage to 28 specific indicators. Table 7-2 relates the Fujita and enhanced Fujita scales.

**Table 7-2**
**Enhanced Fujita Scale**

| **Fujita Scale** | | | **Derived EF Scale** | | **Operational EF Scale** | |
|---|---|---|---|---|---|---|
| *F Number* | *Fastest 1/4-mile (mph)* | *3 Second Gust (mph)* | *EF Number* | *3 Second Gust (mph)* | *EF Number* | *3 Second Gust (mph)* |
| 0 | 40-72 | 45-78 | 0 | 65-85 | 0 | 65-85 |
| 1 | 73-112 | 79-117 | 1 | 86-109 | 1 | 86-110 |
| 2 | 113-157 | 118-161 | 2 | 110-137 | 2 | 111-135 |
| 3 | 158-207 | 162-209 | 3 | 138-167 | 3 | 136-165 |
| 4 | 208-260 | 210-261 | 4 | 168-199 | 4 | 166-200 |
| 5 | 261-318 | 262-317 | 5 | 200-234 | 5 | Over 200 |

The historic record of tornadoes is discussed in Section 7.3. The pattern of occurrence in Massachusetts is expected to remain unchanged. According to the Massachusetts Natural Hazard Mitigation Plan, the highest relative risk for tornadoes in the state will continue to be from central to northeast Massachusetts. Although the potential for a strike in Nantucket is always present, Nantucket has not been struck by a tornado since record keeping began in the middle of the 20th century. Overall, the risk to the Town of Nantucket is believed to be low for any given year.

Waterspouts are weak tornadoes that form over warm water and are most common along the Gulf Coast and southeastern states, but they have occurred along the Massachusetts coastline. Waterspouts occasionally move inland, becoming tornadoes and causing damage and injuries. In the western United States, they occur with cold late fall or late winter storms, during a time when you least expect tornado development. In the northeast, it appears that waterspouts, like tornadoes, may occur at any time with the correct conditions. Overall, the risk to the Town of Nantucket is believed to be low to moderate for any given year.

***Lightning***

Lightning is a circuit of electricity that occurs between the positive and negative charges within the atmosphere or between the atmosphere and the ground. In the initial stages of development, air acts as an insulator between the positive and negative charges. However, when the potential between the positive and negative charges becomes too great, a discharge of electricity (lightning) occurs.

In-cloud lightning occurs between the positive charges near the top of the cloud and the negative charges near the bottom. Cloud to cloud lightning occurs between the positive charges near the top of the cloud and the negative charges near the bottom of a second cloud. Cloud to ground lightning is the most dangerous. In summertime, most cloud to ground lightning occurs between the negative charges near the bottom of the cloud and positive charges on the ground.

Lightning reportedly kills an average of 87 people per year in the United States, in addition to an average of 300 lightning injuries per year. Most lightning deaths and injuries occur outdoors, with 45% of lightning casualties occurring in open fields and ballparks, 23% under trees, and 14% involving water activities.

Although lightning is usually associated with thunderstorms, it can occur on almost any day. The likelihood of lightning strikes in Nantucket is very high during any given thunderstorm. In addition, several notable areas of Nantucket are more susceptible than others due to high elevations at Sankaty Head, Sconset, and the Cliff Road area.

***Downbursts***

A downburst is a severe localized wind blasting down from a thunderstorm. They are more common than tornadoes in New England. These "straight line" winds are distinguishable from tornadic activity by the pattern of destruction and debris. Depending on the size and location of these events, the destruction to property may be significant. Downbursts may be categorized as microbursts (affecting an area less than 2.5 miles in diameter) or macrobursts (affecting an area at least 2.5 miles in diameter).

It is difficult to find statistical data regarding frequency of downburst activity. However, downburst activity is, on occasion, mistaken for tornado activity in Massachusetts, indicating that it is a relatively uncommon yet persistent hazard. The risk to the Town of Nantucket is believed to be low to moderate for any given year.

***Hail***

Hailstones are chunks of ice that grow as updrafts in thunderstorms keep them in the atmosphere. Most hailstones are smaller in diameter than a dime, but stones weighing more than a pound have been recorded. While crops are the major victims of hail, it is also a hazard to vehicles and property.

Hailstorms typically occur in at least one part of Massachusetts each year during a severe thunderstorm. Overall, the risk of at least one hailstorm occurring in the Town of Nantucket is low to moderate in any given year.

## 7.3 *Historic Record*

Convective thunderstorms are less common on Nantucket than on mainland Massachusetts. This is due to ocean waters mitigating the temperature differentials that can occur throughout the course of a day. Nevertheless, frontal storms can and do occur on Nantucket, causing heavy rain and wind numerous times each year. For example, a quick perusal of the NCDC database lists a severe thunderstorm with wind gusts of 60 mph recorded at Nantucket Airport on April 9, 2000.

Worcester County and areas just to its west have been dubbed the "tornado alley" of Massachusetts, as the majority of significant tornadoes in Massachusetts weather history have occurred in that region. According to the Massachusetts Hazard Mitigation Plan, the most destructive tornado in New England history was the Worcester tornado of June 9, 1953. The tornado hit at about 3:30 p.m. and passed through Barre, Rutland, Holden, Worcester, Shrewsbury, Westborough, Southborough and Fayville. It killed 94 people and left almost 1,300 people injured. With wind speeds between 200 to 260 mph, the force of the tornado carried debris miles away and into the Atlantic Ocean. Based on the extent of destruction, it was believed that this tornado may have been an F5.

Two other deadly tornadoes occurred subsequently in Massachusetts: the May 29, 1995 Great Barrington tornado, an F4, which claimed three lives and injured 24; and the August 28, 1973 West Stockbridge tornado, a F4, which killed four and injured 36.

According to the Massachusetts Hazard Mitigation Plan, six waterspouts were observed in Massachusetts between 1995 and 2004, with the most recent having been seen in Rockport in May 2000. However, since that time, a waterspout was reported off Cape Cod during a nor'easter that became a severe short-term winter storm on December 9, 2005.

The NCDC does not list any tornado, funnel cloud, or waterspout activity for Nantucket for the period of record (1950-present). Although the NCDC database is heavily subjective as it relies on local reports in addition to National Weather Service information, it appears that tornado, funnel cloud, or waterspout activity is rare for Nantucket.

Between 1950 and 2006, hail was recorded only once for Nantucket, with a report of 0.75-inch hailstones on April 6, 1982. It is likely that additional hail events have struck Nantucket, but they can be very localized and underreported.

## 7.4 *Existing Programs, Policies, and Mitigation Measures*

Warning is the primary method of existing mitigation for tornadoes and thunderstorm-related hazards. A *severe thunderstorm watch* is issued by the National Weather Service when the weather conditions are such that a severe thunderstorm (damaging winds 58 miles per hour or more, or hail three-fourths of an inch in diameter or greater) is likely to develop. A *severe thunderstorm warning* is issued when a severe thunderstorm has been sighted or indicated by weather radar. Tables 7-3 and 7-4 list the NOAA Watches and Warnings, respectively, as pertaining to summer storms and tornadoes observed in the EOP:

**Table 7-3**
**NOAA Weather Watches**

| Weather Condition | Meaning | Actions |
|---|---|---|
| Severe Thunderstorm | Severe thunderstorms are possible in your area. | Notify your personnel, and watch for severe weather. |
| Tornado | Tornadoes are possible in your area. | Notify your personnel, and be prepared to move quickly if a warning is issued. |
| Flash Flood | It is possible that rains will cause flash flooding in your area. | Notify your personnel to watch for street or river flooding. |

**Table 7-4**
**NOAA Weather Warnings**

| Weather Condition | Meaning | Actions |
|---|---|---|
| Severe Thunderstorm | Severe thunderstorms are occurring or are imminent in your area. | Notify your personnel and watch for severe conditions or damage (i.e. downed power lines and trees. Take appropriate actions listed in department and City EOP. |
| Tornado | Tornadoes are occurring or are imminent in your area. | Notify your personnel, watch for severe weather and insure personnel and equipment are protected. Take appropriate actions listed in department and City emergency plans. |
| Flash Flood | Flash flooding is occurring or imminent in your area. | Notify personnel to watch local rivers and streams. Be prepared to evacuate low-lying areas. Take appropriate actions listed in department and City emergency plans. |

Aside from warnings, several other methods of mitigation for wind damage are employed in Nantucket. Continued location of utilities underground is an important method of reducing wind damage to utilities and the resulting loss of services. The Nantucket DPW conducts tree and tree limb removal in public right-of-ways. Prior to forecast summer storms, DPW will dispatch equipment and personnel to outlying areas of Nantucket such as Sconset and Madaket. But in general, half of the roads on Nantucket are private. These are normally not maintained by DPW, nor are trees maintained by the Town. Public education for these areas is important. As an example, 30 to 40 pine trees along Russell's Way were blown down two years ago. A resident was trapped for several days. Ultimately, the Town assisted with cleanup.

As explained in Section 5.4, wind loading requirements are addressed through the Building Department's administration of building codes. The current enforceable

building code is believed to be antiquated. The new building code was supposed to take effect in September 2006, and is meant to be enforceable by March 2007. The wind design codes will change from 90 mph to 120 mph, providing a much higher standard of protection against wind damage.

The detailed responsibilities of the Marine and Coastal Resources Department described in Section 5.4 are applicable to summer storms with high winds as well, although it is understood that summer storm intensity is more difficult to predict than tropical storms and hurricanes.

According to the Nantucket EOP, the municipal responsibilities relative to tornado mitigation and preparedness include:

- Develop and disseminate emergency public information and instructions concerning tornado safety, especially guidance regarding in-home protection and evacuation procedures, and locations of public shelters.
- Strict adherence should be paid to building code regulations for all new construction.
- Maintain plans for managing tornado response activities. Refer to the non-institutionalized, special needs and transportation resources listed in the Resource Manual.
- Designate appropriate shelter space in the community that could potentially withstand tornado impact.
- Periodically test and exercise tornado response plans.
- Put emergency Management on standby at tornado 'watch' stage.

## *7.5 Vulnerabilities and Risk Assessment*

The central and southern United States are at higher risk for lightning and thunderstorms than the northeast. However, more deaths from lightning occur on the East Coast than

elsewhere, according to FEMA. Most thunderstorm damage is caused by straight-line winds exceeding 100 mph. Straight-line winds occur as the first gust of a thunderstorm or from the downburst from a thunderstorm, and have no associated rotation.

Although most of Nantucket is shrubby, two areas of the Town are particularly susceptible to damage from high winds due to heavily treed landscapes and high residential densities. These are Sconset and downtown Nantucket, where 150-foot elm trees are common. Tree limbs may not be suited to withstand high winds. If trees fall in these areas, the proximity of structures puts them at risk for damage.

Although it was neither a summer storm or a winter storm, the spring nor'easter of April 16-17, 2007 caused the most notable tree damage of the last few years. During the storm, a 75-year old elm tree on Broad Street fell and damaged the historic Jared Coffin House inn. Winds from the storm also caused about $4,200 in damage to municipal facilities throughout the Town, including damage to fencing, roof shingles, siding, and windows.

Likewise, the downtown and Sconset areas are more vulnerable to lightning due to the presence of tall structures, and in the case of Sconset and the Cliff Road area, structures at higher elevations.

## *7.6 Potential Mitigation Measures, Strategies, and Alternatives*

Both the FEMA and the NOAA websites contain valuable information regarding preparing for a protecting oneself during a tornado, as well as information on a number of other natural hazards. This information is available at:

*FEMA*
http://www.fema.gov/library/prepandprev.shtm.

*NOAA*

http://www.nssl.noaa.gov/NWSTornado/

Available information from FEMA includes:

- Design and construction guidance for community shelters.
- Recommendations to better protect from tornado damage for your business, community, and home. This includes construction and design guidelines for business and homes, as well as guidelines for creating and identifying shelters.
- Ways to better protect property from wind damage.
- Ways to protect property from flooding damage.
- Construction of safe rooms within homes.

NOAA information includes a discussion of family preparedness procedures and the best physical locations during a storm event.

Specific mitigation steps that can be taken to prevent property damage and protect property are given below.

***Prevention***

- Continue or increase the Town-wide tree limb inspection program to ensure that the potential for downed power lines is minimized.
- Place utilities underground. The Comprehensive Community Plan and Mid-Island Area Plan, in particular, discuss the need for underground utilities.

***Property protection***

- Encourage, or consider requiring, the use of storm shutters along the coastline.

- Provide for the Building Department to make literature available during the permitting process regarding appropriate design standards.

## 7.7 ***Recommended Actions***

The following actions are recommended to mitigate for winds, hail, tornadoes, and downbursts:

- Increase tree limb maintenance and inspections, especially in the downtown and Sconset areas.
- Continue to require that utilities be placed underground in new developments and pursue funding to place them underground in existing developed areas.

The following actions, taken from Section 3.7, are recommended to mitigate for heavy rains and flash flooding caused by thunderstorms:

- Sesachacha Pond is drawn down twice each year to prevent high water levels. This should be continued as long as it protects Polpis Road from flooding.
- Conduct master drainage studies for problem areas, such as the broad area between Madaket Road and Hummock Pond Road, to ensure that individual repairs and upgrades fit seamlessly with upstream and downstream drainage systems.
- Improve the storm drainage system on Pleasant Street to reduce flooding.
- Complete the Orange Street drainage system upgrade to reduce flooding and allow better drainage of upstream areas.

In addition, important recommendations that apply to all hazards are listed in Section 11.1.

## *8.0 WINTER STORMS*

### *8.1 Setting*

Similar to summer storms and tornadoes, winter storms have the potential to affect any part of the Town of Nantucket. However, unlike summer storms, winter events and the hazards that result (wind, snow, and ice) have more widespread geographic extent. The entire Town of Nantucket is therefore susceptible to winter storms. One need only refer to the "coastal flooding," "wind," "falling trees & branches," "snow," "blizzard," and "ice" columns of Appended Table 1 to understand the widespread effects of winter storms.

A particularly troublesome problem in Nantucket is that of drifting snow, because it can renders roads impassable only hours after plowing. Drifting snow is most problematic at the following nine locations, due to their positions downwind from clear areas without windbreaks.

- Milestone Road along Conservation land
- Polpis Road at Golf Course
- Polpis Road near Pinelands
- Cliff Road west of Gosnold Road
- Eel Point Road
- Red Barn Road
- Bartlett Farm Road
- West Miacomet Road at Golf Course
- Hummock Pond Road at Cemetery

## 8.2 *Hazard Assessment*

This section focuses on those effects commonly associated with winter storms, including those from blizzards, ice storms, heavy snow, freezing rain and extreme cold. Most deaths from winter storms are indirectly related to the storm, such as from traffic accidents on icy roads and hypothermia from prolonged exposure to cold. Damage to trees and tree limbs and the resultant downing of utility cables are a common effect of these types of events. Secondary effects include loss of power and heat.

According to the National Weather Service, approximately 70% of winter deaths related to snow and ice occur in automobiles, and approximately 25% of deaths occur from people being caught in the cold. In relation to deaths from exposure to cold, 50% are people over 60 years old, 75% are male, and 20% occur in the home.

The classic winter storm in New England is the nor'easter, which is caused by a warm moist, low pressure system moving up from the south colliding with a cold, dry high pressure system moving down from the north. Wind driven waves can batter the coastline, causing flooding and severe beach erosion. Coupled with a high tide, the low pressure of a nor'easter can have an effect similar to a storm surge from a hurricane.

Severe winter storms can produce an array of hazardous weather conditions, including heavy snow, blizzards, freezing rain and ice pellets and extreme cold. The National Weather Service defines a blizzard as winds over 35 mph with snow and blowing snow reducing visibility to near zero.

Massachusetts experiences at least one severe winter storm every five years, although a variety of small and medium snow and ice storms occur nearly every winter. The likelihood of a nor'easter occurring in any given winter is therefore considered high, and the likelihood of other winter storms occurring in any given winter is very high.

## 8.3 *Historic Record*

According to the Massachusetts Hazard Mitigation Plan, the last three Presidential disaster declarations in Massachusetts (April 2004, December 2003, and February 2003) were the result of winter nor'easters. Winter weather disaster declarations and emergency declarations involving Nantucket County in the last 30 years are listed below along with the FEMA disaster identification numbers:

- Blizzard of 1978, February 1978 – FEMA-546 – Counties of Barnstable, Bristol, Dukes, Essex, Nantucket, Norfolk, Plymouth, and Suffolk;
- December Blizzard, December 1992 – FEMA-975 – Counties of Barnstable, Dukes, Essex, Plymouth, and Suffolk are listed; Nantucket County is not listed but was heavily damaged;
- March Blizzard, March 1993 – FEMA-3103 – All 14 Counties;
- January Blizzard, January 1996 – FEMA-1090 – All 14 Counties;
- March Blizzard, March 2001 – FEMA-3165 – Counties of Berkshire, Essex, Franklin, Hampshire, Middlesex, Norfolk, and Worcester;
- February Snowstorm, February 17-18, 2003 – FEMA-3175-EM – All 14 Counties;
- December Snowstorm, Dec. 5-6, 2003 – FEMA-3191-EM – Counties of Barnstable, Berkshire, Bristol, Essex, Franklin, Hampden, Hampshire, Middlesex, Norfolk, Plymouth, Suffolk, and Worcester
- Snowstorm, January 22-23, 2005 – FEMA-3201 – All 14 Counties.

The NCDC includes documentation of other severe winter storms that were not necessarily disaster declarations. These include nor'easters in December 1993, December 1995, January and February 1998, and February 2006, with the latter coincident with a severe blizzard.

According to the Town of Nantucket Annual Report for fiscal year 2004-2005, a major Christmas nor'easter dumped 30 inches of snow on Nantucket and winds gusted to 110 mph. Power outages in some parts of the Town lasted four days. The main shelter was opened and 90 people sought shelter. The Landmark House was evacuated due to a loss of heat. Nantucket applied for and received a FEMA reimbursement for $123,000 toward qualified expenses.

Some winter storms can strengthen quickly with little warning. A recent example is a nor'easter that became a severe short-term winter storm on December 9, 2005, causing an unusual combination of hurricane-force winds, blizzard conditions, thunder and lightning, and even a reported waterspout off Cape Cod. This storm has subsequently been called a "blizzcane." Winds of 64 mph and 94 mph were measured at Nantucket Airport and Nantucket Harbor, respectively. An excerpt from the National Weather Service statement is provided below:

*"An 8-hour Southern New England Nor'easter became a severe short-term winter storm for Rhode Island and Eastern Massachusetts Friday afternoon, December 9th, 2005. The extreme rapid intensification of low pressure as it moved through Buzzards and Cape Cod Bays between 1:00 PM and 3:00 PM... then out to sea... created a short-term near blizzard scene mid-afternoon unlike no other in recent memory with damaging wind, whiteout conditions and about an hour of thunderstorms for many within and just east of the Interstate 95 corridor. The storm brought a general 7 to 17-inch snowfall over most of Southern New England except much less over the far southeast coastal plain.... near blizzard conditions and sharply falling temperatures struck the Cape and Islands mostly between 2:45 PM and 4:45 PM."*

## 8.4 *Existing Programs, Policies, and Mitigation Measures*

### *Flood Damage Prevention*

Existing programs applicable to coastal flooding and storm surges are the same as those discussed in Sections 4.4 and 5.4. For example, the Town of Nantucket has in place a number of measures to prevent coastal flood damage including regulations, codes, and ordinances; a process for maintaining roads, bridges, and culverts at tidal creeks; a variety of structural flood control features in coastal areas of Nantucket; elevation of structures; and the use of warning systems.

Regulations, codes and ordinances that apply to flood hazard mitigation include Chapter 136 of the Nantucket Code and the accompanying Wetland Regulations; Chapter 139 of the Nantucket Code and the provisions of the Flood Hazard Overlay Zone; and the Subdivision Regulations. The pertinent components of these regulations, codes, and ordinances were listed in Section 2.8. The Conservation Commission, Planning Board, and Building Department are all charged with administering portions of these regulations during new or substantial construction. Through non-regulatory outreach programs, the Health Department educated property owners, merchants, and residents in flood zones to move critical equipment and property off the first floor, above flood elevations.

DPW tracks, plans, prepares for, and responds to flooding, inundation, and/or erosion of roads and infrastructure such as the sewer pumping station and the wastewater treatment plants. With regard to roads, bridges, and culverts at tidal creeks, the DPW regularly maintains Town-owned roads and facilities and upgrades/improves them as needed. For example, the Madaket Road crossings at the Head of Long Pond and Madaket Ditch were replaced with larger culverts under the direction of DPW. However, DPW does not have sufficient equipment to barricade all roadways that could potentially flood.

With regard to preexisting structures that were constructed (in part) to reduce coastal flood damage, examples include the jetties at the mouth of Nantucket Harbor and seawalls that exceed coastal base flood elevations. Bulkheads are common in the harbor area and a variety of other projects have been conducted in oceanside areas to combat erosion, but these are meant for shoreline stabilization and erosion control rather than coastal flood control.

Only a few structures in coastal flood zones have been elevated above the base flood level. Because many beachfront dwellings are located on bluffs, they do not need to be elevated.

***Harbor Damage Prevention***

The responsibilities of the Marine and Coastal Resources Department described in Section 5.4 are applicable to winter storms with high winds as well, although it is understood that fewer boaters utilize the waters of Nantucket during the winter. Thus, it is easier to prepare for nor'easters than tropical storms and hurricanes with regard to sending boaters back to the mainland, or removing vessels and then locating removed vessels on the island.

***Snow and Ice Removal***

Programs that are specific to winter storms are generally those related to preparing plows, sand and salt trucks, and other associated snow removal and response preparations. Nantucket DPW conducts snow removal and deicing on roads; and tree and tree limb removal in right-of-ways. During a significant winter storm a few years ago, DPW expenses for snow removal were approximately $300,000. Prior to forecast winter storms, DPW will dispatch equipment and personnel to outlying areas of Nantucket such as Sconset and Madaket.

In general, half of the roads on Nantucket are private. These are normally not plowed by the DPW, nor are trees maintained by the Town. Public education for these areas is important. As an example, 30 to 40 pine trees along Russell's Way were blown down two years ago. A resident was trapped for several days. Ultimately, the Town assisted with cleanup.

***Wind Damage Prevention***

As explained in Sections 5.4 and 7.4, wind loading requirements are addressed through the Building Department's administration of building codes. The current enforceable building code is believed to be antiquated. The new building code was supposed to take effect in September 2006, and is meant to be enforceable by March 2007. The wind design codes will change from 90 mph to 120 mph, providing a much higher standard of protection against wind damage.

***Emergency Services***

The Water Companies have active roles in pre-disaster mitigation. Before storms, water tanks are filled and equipment is secured. Through careful preparation, fire protection and potable supply are available during and after natural disasters. Generators are located at the wellfields and pumping stations.

According to the Nantucket EOP, the municipal responsibilities relative to winter storm mitigation and preparedness include:

- Develop and disseminate emergency public information concerning winter storms, especially material which instructs individuals and families how to stock their homes, prepare their vehicles, and take care of themselves during a severe winter storm.

- As it is almost guaranteed that winter storms will occur annually in Massachusetts, local government bodies should give special consideration to budgeting fiscal resources with snow management in mind.
- Maintain plans for managing all winter storm emergency response activities.
- Ensure that warning/notification and communications systems are in Readiness.
- Ensure that appropriate equipment and supplies, especially snow removal equipment, are in place and in good working order.
- Review mutual aid agreements.
- Designate suitable shelters throughout the community and make their locations known to the public.
- Implement public information procedures during storm 'warning' stage.
- Prepare for possible evacuation and sheltering of some populations impacted by the storm (especially the elderly and special needs).

## 8.5 *Vulnerabilities and Risk Assessment*

As mentioned for summer storms, the treed landscapes of downtown and Sconset, where 150-foot elm trees are commonly in close proximity to densely populated residential areas, poses problems in relation to blizzard and ice condition damage. Tree limbs may not be suited to withstand high wind and snow or ice loads. If trees fall in these areas, the proximity of structures puts them at risk for damage.

For example, although it was neither a summer storm or a winter storm, the spring nor'easter of April 16-17, 2007 caused the most notable tree damage of the last few years. During the storm, a 75-year old elm tree on Broad Street fell and damaged the historic Jared Coffin House inn. Winds from the storm also caused about $4,200 in damage to municipal facilities throughout the Town, including damage to fencing, roof shingles, siding, and windows.

As noted in Section 8.1, drifting snow is a significant problem in nine specific areas, although it can occur anywhere:

- Milestone Road along conservation lands – Drifting snow is a major problem on Milestone Road caused, in part, by the re-creation of 1,100 acres of cleared pasture conditions has in vast conservation lands on the north side of the road. Snow drifts from 10 to 12 feet high occur. The drifting cuts off important emergency access. According to several Nantucket officials, a snow plow was buried by a drift on Milestone Road and completely lost during one 30-inch snowstorm a few years ago. It took two days to get it out of a drift. In 2005-2006, two rows of snow fencing were used and these helped, but bigger storms are more difficult to control. Even a 6-inch snowfall will cause bad drifts along Milestone Road. Because Milestone Road is one of only two routes available for Sconset residents to reach the central part of the Nantucket, it is critical that is remain passable.
- Polpis Road at Golf Course – Similar to Milestone Road, drifts can affect access along Polpis Road downwind of the golf course, northwest of Sconset. With Polpis Road subject to drifting along with Milestone Road, Sconset can become completely isolated.
- Polpis Road near Pinelands
- Cliff Road west of Gosnold Road
- Eel Point Road – Damage from winter storms is particularly troublesome along Eel Point Road because electrical power to Madaket runs is along Eel Point Road instead of Madaket Road. When drifting occurs and the private section of the road can not be traversed, power outages can become difficult to fix. A recent winter storm caused a three-day loss of power in Madaket.
- Red Barn Road – Drifts in this location can block the only route for Sheep Pond Road residents to evacuate during winter storms.
- Bartlett Farm Road – Drifts in this location affect main a farm, such that overall vulnerability is low.

- West Miacomet Road at Golf Course
- Hummock Pond Road at Cemetery – This is an area where alternate routes are available for evacuation, should drifting occur. Nevertheless, the drifting snow problem is common, and this is typically DWP's third plowing priority after Milestone Road and Polpis Road.

Even without drifts, winter storms present some potentially unique transportation vulnerabilities. There is a high propensity for traffic accidents during heavy snow and even light icing events. Roads may become impassable, inhibiting the ability of emergency equipment to reach trouble spots, as well as the accessibility to medical and shelter facilities. Stranded motorists, especially senior and/or handicapped citizens, are at a particularly high risk during a blizzard.

Navigation hazards can occur during winter storms and cold periods. The Nantucket Harbor channel needs to be kept clear because it is the only way in and out of the harbor. One problem that is unique to Nantucket is that winter storms with prolonged cold and wind can push ice into the harbor or freeze the harbor, cutting off access to many supplies, goods, and labor that come from the mainland, such as food. For example, the harbor froze and access was severely impacted a few years ago. Additionally, as explained in Section 2.9, fuels are delivered to the tank farm by tanker trucks arriving at the Steamship Dock and by barges that dock at the Nantucket Boat Basin Marina. Freezing of the harbor or channel can therefore stop fuel delivery to Nantucket.

Indirect effects from channel and harbor freezing can also occur. For example, ice can move channel markers. Buoys must be very secure during these conditions. Docks can become hazards during storms if they break free.

With regard to coastal flooding, the same vulnerable populations discussed in Section 4.5 and 6.5 are vulnerable to flooding caused by nor'easters. Further "flood" damage could be caused by flooding from frozen water pipes.

## *8.6 Potential Mitigation Measures, Strategies, and Alternatives*

Potential mitigation measures for storm surges and flooding caused by nor'easters include those appropriate for flooding. These were presented in Sections 3.6 and 4.6 and are not repeated herein. However, winter storm mitigation measures must also address wind, blizzard, snow, and ice hazards. These are emphasized in the following subsections. Note that natural resource protection and structural projects are generally not applicable categories of hazard mitigation for wind, blizzard, snow, and ice hazards.

### *8.6.1 Prevention*

Cold air, snow, and ice can not be prevented from impacting any particular area. Thus, mitigation should be focused on property protection, infrastructure protection, emergency services (discussed below), and prevention of damage to structures and utilities as caused by breakage of tree limbs.

Previous recommendations for tree limb inspections and maintenance in Sections 5.0 and 7.0 are thus applicable to winter storm hazards, as well. As recommended in the Comprehensive Community Plan and Status Chart and the Mid-Island Area Plan, utilities in Nantucket should be placed underground where possible. This could occur in connection with new development, and in connection with redevelopment or streetscape work in the downtown, mid-island, and Sconset areas. If utilities are underground, then heavy snow, ice, and winter winds can not damage or destroy them.

Of all the areas with drifting snow, it is most important to address the problem of drifting snow on Milestone Road, because access between the mid-island and Sconset must be maintained. Conservation groups should be urged to partially restore windbreaks along Milestone Road. Furthermore, two (or more) parallel sequences of snow fencing should be placed along Milestone Road.

Preventing damage to boats, and to structures from boats that have become free, is important during nor'easters just as it would be during hurricanes and tropical storms. While it is understood that significantly fewer boats are present in the waters of Nantucket in the winter as compared to the summer, their prompt removal before storms is recommended to maximize mitigation. Thus, the Town should provide funding for additional Marine Department staff to assist with boat removal before storms, and designate official sites on land for boat storage during storm events.

Finally, it is of utmost importance to keep Nantucket Harbor open and available to the Steamship Authority and Coast Guard during long cold spells. If the harbor freezes, the Town can become cut off from its supply of food, fuels, and labor. Thus, the Town should utilize available technology and warning systems to ensure that adequate equipment is available to keep the harbor open before deep cold spells occur.

### *8.6.2 Property Protection*

Property can be protected during winter storms through the use of shutters, storm doors, storm windows, weather stripping, and other means of keeping cold air outdoors and heat indoors. Where flat roofs are used on structures, snow removal is important as the heavy load from collecting snow may exceed the bearing capacity of the structure. Heating coils may be used to remove snow from flat roofs. Pipes should be adequately insulated to protect against freezing and bursting. All of these recommendations apply to new construction, although they may also be applied to existing buildings during renovations.

### 8.6.3 *Public Education and Awareness*

The public is typically more aware of the hazardous effects of snow, ice, and cold weather than they are with regard to other hazards discussed in this plan. Nevertheless, people are still stranded in automobiles, get caught outside their homes in adverse weather conditions, and suffer heart failure while shoveling during each winter in Connecticut. Public education should therefore focus on safety tips and reminders to individuals about how to prepare for cold weather.

### 8.6.4 *Emergency Services*

Plowing the access to and from critical facilities, such as hospitals and the shelters that were listed on Table 2-1, should be prioritized. It is recognized that this may not be a priority to all residents, as people typically expect their own roads to be cleared as soon as possible.

Of all the areas with drifting snow, it is most important to address the problem of drifting snow on Milestone Road, because access between the mid-island and Sconset must be maintained. Plowing should be as frequent as necessary to reduce drifting.

## 8.7 *Recommended Actions*

Most of the recommendations in Sections 4.7, 5.7, and 6.7 for mitigating coastal flooding and hurricane storm surges are suitable for mitigation of coastal flooding caused by nor'easters. These are not repeated in this subsection. The following recommendations are applicable to other aspects of winter storms such as winds, snow, and ice:

- Increase plowing of Milestone Road in snow drift areas.

- Urge conservation groups to restore windbreaks along Milestone Road.
- Continue to use two rows of snow fencing along Milestone Road.
- Increase tree limb maintenance and inspections, especially in the downtown and Sconset areas.
- Continue to require that utilities be placed underground in new developments and pursue funding to place them underground in existing developed areas.
- Provide funding for additional Marine Department staff to assist with boat removal before storms.
- Designate official sites on land for boat storage during storm events.
- Utilize available technology and warning systems to ensure that adequate icebreaking equipment is available to keep Harbor open.

Two recommendations for increased public safety in outlying vulnerable areas are as follows:

- Mobilize emergency equipment and personnel to Madaket village in advance of predicted nor'easters.
- Mobilize emergency equipment and personnel to Sconset village in advance of predicted nor'easters.

In addition, important recommendations that apply to all hazards are listed in Section 11.1.

# 9.0 *WILDFIRES*

## 9.1 *Setting*

The ensuing discussion about wildfires is focused on the undeveloped wooded, shrubby, or grassland areas of Nantucket, and low-density suburban type development found at the margins of these areas known as the wildland interface. Structural fires in high-density "urban" village centers such as downtown and Sconset are not covered. As a result, only some of Nantucket's localities are checked in the two wildfire columns of Appended Table 1.

## 9.2 *Hazard Assessment*

The Massachusetts Hazard Mitigation Plan defines "wildfire" as a highly destructive, uncontrollable fire. Although the term brings to mind images of tall trees engulfed in flames, wildfires can occur as brush and shrub fires, especially under dry conditions. Wildfires as also known as "wildland fires."

Nationwide, humans have caused approximately 90% of all wildfires in the last decade. Accidental and negligent acts include unattended campfires, sparks, burning debris, and irresponsibly discarded cigarettes. The remaining 10% of fires are caused mostly by lightning. Nevertheless, wildfires are also a natural process, and their suppression is now recognized to have created a larger fire hazard, as live and dead vegetation accumulates in areas where fire has been prevented. In addition, the absence of fire has altered or disrupted the cycle of natural plant succession and wildlife habitat in many areas. Consequently, federal, state and local agencies are committed to finding ways, such as prescribed burning to reintroduce fire into natural ecosystems, while recognizing that fire fighting and suppression are still important.

Massachusetts has particular vulnerability to fire hazards where urban development and wildland areas are in close proximity. The "wildland/urban interface" is where many fires are fought. The wildland areas are subject to fires because of weather conditions and fuel supply. An isolated wildland fires may not be a threat, but the combined effect of having residences, businesses, and lifelines near a wildland area causes increased risk to life and property. Thus, a fire that might have been allowed to burn itself out with a minimum of fire fighting or containment in the past, must now be fought to prevent fire damage to surrounding homes and commercial areas, as well as smoke threats to health and safety in these areas.

According to the Cape Cod Emergency Preparedness Handbook, wildfire season in New England typically begins in March and ends in November. Most wildfires occur in April and May when the majority of vegetation is less green than it is after May and June.

## *9.3 Historic Record*

According to the Massachusetts Hazard Mitigation Plan, wildfires have historically been a problem in the State. Approximately 3,000 wildfires burned more than 2,600 acres in Massachusetts during calendar year 2002. In calendar year 2003, nearly 2,000 wildfires burned over 1,600 acres.

According to the Cape Cod Emergency Preparedness Handbook, large wildfires in the Cape Cod and Islands region occurred in 1907 (the great forest fire of the Bourne-Sandwich area), 1964 (a large brush fire in South Sandwich), and 1965 (a forest fire that jumped Route 6 in Sandwich). The 1964 and 1965 fires occurred during the 1960s drought.

Although formal records of large fires on Nantucket are not available, brush fires have occurred on the island. Landfill fires can be particularly problematic. A large fire at the landfill burned for several days in 2004.

The most recent large fire on Nantucket occurred on April 1, 2007. According to the Nantucket Inquirer and Mirror, the brush fire was caused by a prescribed burn that became uncontrollable, lasting from 10 AM until 9 PM. The total area of burn was 75 acres in the middle moors near Altar Rock, on Nantucket Conservation Foundation land (45 acres larger than the 30 planned acres of prescribed burn). The Nantucket Airport navigational beacon was in danger, but was protected by firefighters. Other critical facilities were not in danger during the wildfire.

To fight the fire, equipment was brought in from the main fire station, the Sconset and Madaket stations, and the Nantucket Airport. Additionally, for the first time in recent history, equipment was brought in from off-island (the Hyannis, Cotuit, Osterville-Centerville, and Yarmouth fire departments), although it arrived too late to help battle most of the fire.

## 9.4 ***Existing Programs, Policies, and Mitigation Measures***

Existing mitigation for wildland fire control is typically focused on Fire Department training and maintaining an adequate supply of equipment. For example, in fiscal year 2004-2005, the Nantucket Fire Department received funding for a new wildland engine for Siasconset and a new wildland tender for the central fire station. Both will be useful for fighting wildland and structural fires on Nantucket. The Fire Department also received grants in fiscal year 2004-2005 for a new pumper, a new thermal imaging camera, education, and training.

Unlike wildfires on the west coast of the United States where the fires are allowed to burn toward development and then stopped, the Nantucket Fire Department goes to the fires on the island. This proactive approach is believed to be effective for controlling wildfires.

Education is also an important element of existing mitigation. Several informational pamphlets and books are available at the front desk of the Fire Department, including "Is Your Home Protected From Wildfire Disaster? – A Homeowner's Guide to Wildfire Retrofit." This booklet includes tips for residents to minimize risk from wildfires and escape from wildfires.

The Water Companies clearly have active roles in wildfire mitigation. Through careful preparation, fire protection and potable supply are available during and after natural disasters. The Fire Department has some of its own water storage, but relies on the water systems. All water service areas have fire protection. Fires are specifically addressed in the water system emergency plan. A forest management system is in place to protect system components. If a wildfire occurs, the pump house at Lovers Lane is soaked to prevent damage to the facility.

Finally, the Building Department has a role in fire mitigation as well. Fireproof roof shingles are required in Sconset, downtown, and mid-island areas. Although this requirement is directed primarily at preventing structural fires, it reduced wildfire potential at wildland interfaces.

## 9.5 *Vulnerabilities and Risk Assessment*

Overall risk of wildfires, brush fires, and the like is considered low as compared to arid, semi-arid, and mountainous regions of the United States. However, according to the Massachusetts Hazard Mitigation Plan, particular areas of the State at risk to wildfire include "the Southeastern area of Plymouth County, Cape Cod, and the Islands, where

forested areas pose wildland fire and urban interface fire hazards" and "These areas include rural areas where personnel and specialized equipment to handle major fires are scarce, as well as the wildland/urban interface areas around open spaces such as federal and state parks."

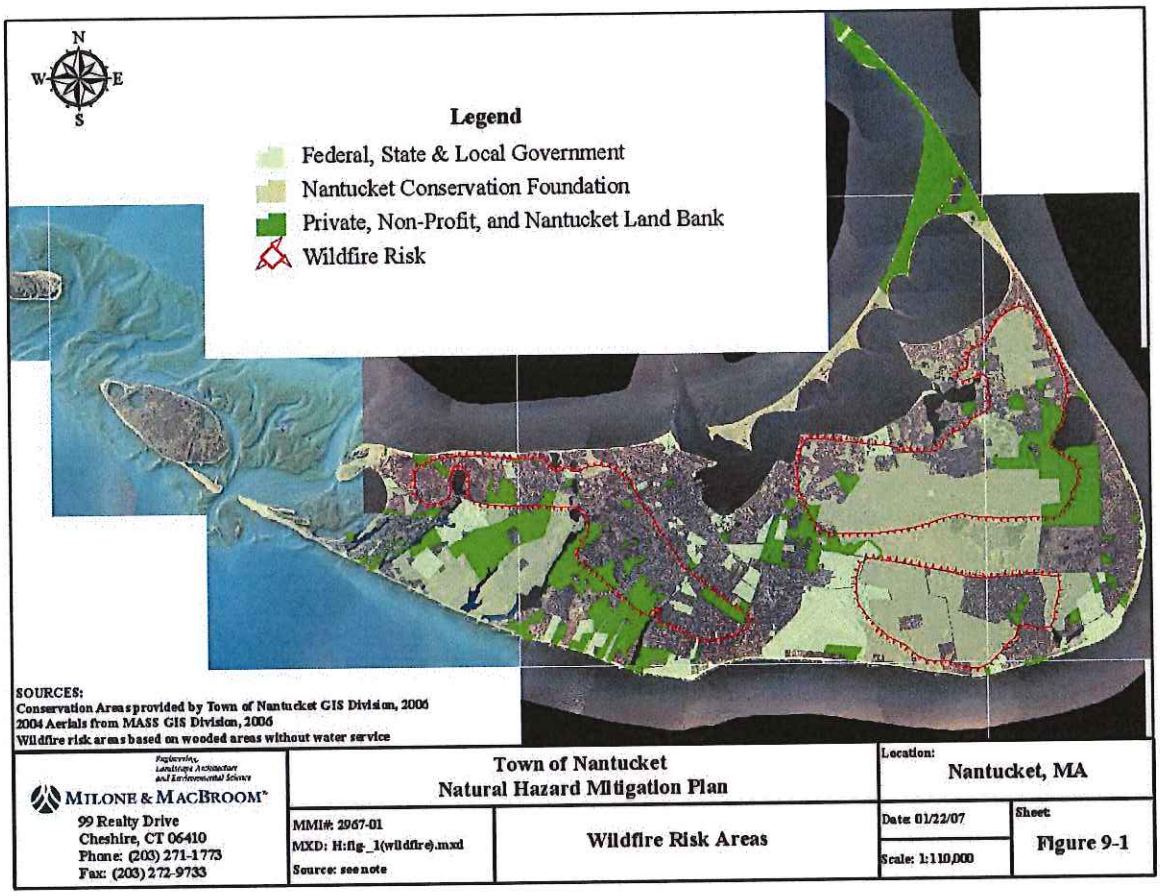
Although it may not be entirely accurate to portray Cape Cod and the Islands as particularly "at risk," given that most of the wildfires in Massachusetts have occurred elsewhere, Nantucket does has a few areas that have moderate risk of wildfires. Indeed, fires have occurred in the past, and as recently as April 1, 2007. In general, areas that are at most risk for wildfires have the following characteristics:

- History of fires
- Steep terrain
- Wooded areas within 100 feet of homes
- Individual trees within 30 feet of homes
- Public water system with hydrants is not available
- Limited access for firefighting vehicles and equipment

Three general areas of wildfire risk on Nantucket have been identified on Figure 9-1. Golf courses, cleared land, shrubby or grassy land, and areas of public water supply with fire protection are considered at low risk.

Not all areas at risk for fires are highly vulnerable, due to lack of affected populations and infrastructure. The most vulnerable populations and critical facilities are those that are considered to be at the wildland interface. For example, some of the more modest homes in Nantucket have brush growing right up to the edges of the houses, creating an unsafe situation, whereas the larger, more landscaped homes do not have this problem because of expansive lawn areas that surround the homes.

Figure 9-1


N
W
E
S
Legend
Federal, State & Local Government
Nantucket Conservation Foundation
Private, Non-Profit, and Nantucket Land Bank
Wildfire Risk
SOURCES:
Conservation Areas provided by Town of Nantucket GIS Division, 2006
2004 Aerials from MASS GIS Division, 2006
Wildfire risk areas based on wooded areas without water service
MILONE & MACBROOM
99 Realty Drive
Cheshire, CT 06410
Phone: (203) 271-1773
Fax: (203) 272-9733
Town of Nantucket
Natural Hazard Mitigation Plan
Location:
Nantucket, MA
MMI#: 2967-01
MXD: H:\fig_1(wildfire).mxd
Source: see note
Wildfire Risk Areas
Date: 01/22/07
Scale: 1:110,000
Sheet:
Figure 9-1

The following localities and population centers are considered to be relatively vulnerable to wildfires:

- Maddequet/Eel Point Road;
- Margins of the Mid-Island Area;
- Shawkemo/Quaise;
- Inland parts of Polpis, Wauwinet, and Quidnet; and
- Margins of Tom Nevers/Southeast Quarter.

Few of the critical facilities are considered to be vulnerable. Many of the critical facilities are in areas of public water supply with fire protection, minimizing vulnerability. The transit and fuel facilities along New South Road near the airport are located in an area that is considered at risk, but the firefighting capabilities of the Town and Airport minimize the overall vulnerability. The telephone/microwave station off Eel Point Road is in an area of moderate risk, but access to the site by firefighting vehicles and equipment is adequate. Finally, the airport's navigational tower is considered to be at risk, based on the April 1, 2007 fire.

## 9.6 *Potential Mitigation Measures, Strategies, and Alternatives*

Potential mitigation measures for wildfires include a mixture of prevention, education, and emergency planning. Although educational materials are available at the Fire Department building, they should be made available at the Building Department and Health Department offices as well. Education of homeowners on methods of protecting their homes is far more effective than trying to steer growth away from potential wildfire areas, especially given that the available land that is environmentally appropriate for development may be forested and located within inland areas.

Water system improvements are an important class of potential mitigation for wildfires. Several recommendations of the Comprehensive Community Plan and Status Chart refer to water system improvements. The following are based on the previously-published recommendation:

- Water companies should extend the public water supply systems into areas within growth boundaries that require water for fire protection.
- Water companies should identify and upgrade those portions of the public water supply systems that are substandard from the standpoint of adequate pressure and volume for fire-fighting purposes.
- Innovative solutions to fire protection should be explored where it is not feasible to extend a conventional water system. The Comprehensive Community Plan tasked the water companies with this recommendation, although it is better suited for the DPW and other departments. For example, as a result of the landfill fires adjacent to the DPW facility, DPW plans to secure future fire flows from a nearby pond. This type of approach could be pursued elsewhere.

The NCF, Nantucket Land Council, Nantucket Land Bank, and Massachusetts Audubon Society administer a prescribed burn program on Nantucket Island. Therefore, their collective staff have significant training in the handling of fires. The Nantucket Fire Department may be able to obtain assistance from these groups during brush fires or wildfires. The Fire Department should explore the possibility of formalizing a mutual aid relationship with the NCF, Nantucket Land Council, Nantucket Land Bank, and/or Massachusetts Audubon Society. This is especially pertinent after the April 1, 2007 blaze was caused by a prescribed burn program.

Finally, as recommended in the Comprehensive Community Plan and Status Chart and the Mid-Island Area Plan, utilities should be placed underground where possible. This could occur in connection with new development, and in connection with redevelopment

or streetscape work in the downtown, mid-island, and Sconset areas. If utilities are underground, then fires can not damage or destroy them.

## 9.7 ***Recommended Actions***

The following specific recommendations for wildfire mitigation should be pursued:

- Distribute copies of the booklet "Is Your Home Protected From Wildfire Disaster? – A Homeowner's Guide to Wildfire Retrofit" when developers and homeowners pick up or drop off applications in the Building Department and Health Department.
- Extend the public water supply systems into areas within reasonable growth boundaries that may benefit from water for fire protection.
- Identify and upgrade those portions of the public water supply systems that are substandard from the standpoint of adequate pressure and volume for fire-fighting purposes.
- Explore alternate solutions to fire protection where it is not feasible to extend a conventional water system.
- Develop fire ponds in vulnerable areas without public water systems.
- Develop a mutual aid relationship with the NCF, Nantucket Land Council, Nantucket Land Bank, and/or Massachusetts Audubon Society for firefighting assistance.
- Locate utilities underground wherever it is feasible.

In addition, specific recommendations that apply to all hazards are listed in Section 11.1.

# *10.0 EARTHQUAKES*

## *10.1 Setting*

The entire Town of Nantucket is susceptible to earthquakes. As a result, all of Nantucket's localities are checked in the "shaking" column of Appended Table 1. However, even though earthquakes have the potential to occur anywhere in the Town of Nantucket, the effects may be felt differently in some areas based on the type of geology.

## *10.2 Hazard Assessment*

An earthquake is a sudden rapid shaking of the earth caused by the breaking and shifting of rock beneath the earth's surface. Earthquakes can cause buildings and bridges to collapse, disrupt gas, electric and phone lines, and often cause landslides, flash floods, fires, avalanches, and tsunamis. Earthquakes can occur at any time without warning.

The underground point of origin of an earthquake is called its focus; the point on the surface directly above the focus is the epicenter. The magnitude and intensity of an earthquake is determined by the use of the Richter scale and the Mercalli scale, respectively.

The Richter scale defines the magnitude of an earthquake. Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the amplitude of earthquake waves recorded on instruments that have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value recorded by a seismograph, which records the varying amplitude of ground oscillations.

The magnitude of an earthquake is determined from the logarithm of the amplitude of recorded waves. Being logarithmic, each whole number increase in magnitude represents a tenfold increase in measured strength. Earthquakes with a magnitude of about 2.0 or less are usually called micro-earthquakes, and are generally only recorded locally. Earthquakes with magnitudes of 4.5 or greater are strong enough to be recorded by seismographs all over the world.

The effect of an earthquake on the Earth's surface is called the intensity. The Modified Mercalli Intensity Scale consists of a series of key responses such as people awakening, movement of furniture, damage to chimneys, and total destruction. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It is an arbitrary ranking based on observed effects.

The following is an abbreviated description of the 12 levels of Modified Mercalli intensity from the United States Geologic Survey:

I. Not felt except by a very few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rail bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are destroyed. Object thrown in the air.

Some earthquakes in Massachusetts are not associated with specific known faults, as opposed to seismic activity in California. Many earthquakes with epicenters in Massachusetts are referred to as intra-plate activity. Bedrock in Massachusetts, and New England in general, is highly capable of transmitting seismic energy; thus, the area impacted by an earthquake in Massachusetts can be four to 40 times greater than that of California.

Some earthquakes in Massachusetts occur at fault intersections along northwest-trending faults (Barosh, 1990). A zone of northwest-trending faults across New Hampshire extends offshore east of Boston through the epicenter of the 1755 Cape Ann earthquake.

Such faults are believed to be related to the transform faults in the North Atlantic Basin and apparently are due to its continued expansion. The Cape Ann quake had an apparent Intensity of VIII, an estimated magnitude of 5.8, and is the largest recorded for the northeastern U.S. (Woodhouse and Barosh, 1991).

Liquefaction is defined as the transformation of water-saturated granular material from the solid state to a liquid state. Earthquake-induced ground motion can cause the ground to flow and/or lose its strength. Fill material has a much higher potential for liquefaction as compared to other surficial materials.

## *10.3 Historic Record*

According to the USGS Earthquake Hazards Program, Massachusetts is a region of very minor seismic activity. This assessment is based on lack of historical and instrumental reports of strong earthquakes. However, earthquakes do occur in this region, and Connecticut, Rhode Island, Massachusetts, and New Hampshire regularly register seismic events.

According to the Massachusetts Natural Hazard Mitigation Plan, of the 4,738 earthquakes recorded in the Northeast Earthquake Catalog through 1989, 1,215 occurred within the boundaries of the six New England States, and 316 earthquakes were recorded in Massachusetts between 1627 and 1989. Between 1924 and 1989, there have been 96 earthquakes in the Northeast with a magnitude of 4.5 or greater on the Richter scale. Out of these 96 earthquakes, eight were within the six New England States and the other 88 within New York State or the Province of Quebec. Many of these earthquakes were so strong that they were felt throughout New England.

A good accounting of Massachusetts earthquakes is provided in the Earthquake Information Bulletin (1973, von Hake). The initial settlers of the early 17$^{th}$ century

compiled the extensive historical accounts that are now available. Strong earthquakes in the St. Lawrence Valley in 1638, 1661, 1663, and 1732 were felt in Massachusetts. The 1638 and 1663 shocks damaged chimneys at Plymouth, Salem, and Lynn. On June 11, 1643, Newbury, Massachusetts, was strongly shaken. In 1727 an earthquake described as "tremendous" in one report and "violent" in another caused much damage at Newbury. The shock was felt from the Keenebec River to the Delaware River and from ships at sea to the extreme western settlements. Several strong aftershocks were reported through the next year.

Eastern Massachusetts was shaken moderately on February 17, 1737, and June 24, 1741. Then on June 14, 1744, large numbers of bricks were shaken from tops of chimneys at Boston and other towns and stone walls were shaken down. The earthquake was reportedly felt at Falmouth, Maine.

On November 18, 1755, one of the most significant earthquakes in the northeastern region occurred off Cape Ann. At Boston, walls and chimneys were thrown down and stone fences were knocked down (intensity VIII, Modified Mercalli scale). Some descriptions mentioned violent movement of the ground, like waves of the sea, making it necessary to cling to something to prevent being thrown to the ground. At Pembroke and Scituate, small chasms opened in the earth through which fine sand reached the surface. Large numbers of fish were killed and many people on vessels felt shocks as if the ships were striking bottom. This earthquake was felt from Lake George, New York, to a point at sea 200 miles east of Cape Ann, and from Chesapeake Bay to the Annapolis River, Nova Scotia, about 300,000 square miles.

Little information is known about an earthquake that occurred on October 5, 1817. Walls were reported thrown down at Woburn, but additional details are lacking. Moderate earthquakes in 1847, 1852, 1854, 1876, 1880, 1903, 1907, 1925, 1940, and 1963 were felt over limited areas of eastern Massachusetts. The epicenter of the 1925 shock was

located off Cape Ann; the quake was reportedly felt from Providence to Kennebunk, Maine.

And last, but most relevant to this plan, the residents of Nantucket were jolted by a moderate earthquake on October 24, 1965. Very slight damage was reported. Doors, windows, and dishes rattled, and house timbers creaked.

## *10.4 Existing Programs, Policies, and Mitigation Measures*

According to the Nantucket EOP, the municipal responsibilities relative to earthquake mitigation and preparedness include:

- Community leaders in cooperation with Emergency Management Personnel should obtain local geological information and identify and assess structures and land areas that are especially vulnerable to earthquake impact and define methods to minimize the risk.
- Strict adherence should be paid to land use and earthquake resistant building codes for all new construction.
- Periodic evaluation, repair, and/or improvement should be made to older public structures.
- Emergency earthquake public information and instructions should be developed and disseminated.
- Earthquake drills should be held in schools, businesses, special care facilities, and other public gathering places.
- Earthquake response plans should be maintained and ready for immediate use.
- All equipment, supplies and facilities that would be needed for management of an earthquake occurrence should be maintained for readiness.
- Emergency Management personnel should receive periodic training in earthquake response.

- If the designated EOC is in a building that would probably not withstand earthquake impact, another building should be chosen for an earthquake EOC.
- Mass Care shelters for earthquake victims should be pre-designated in structures that would be most likely to withstand earthquake impact see the Resource Manual for Mass Care Shelters.
- It is assumed that all special needs facilities could be impacted to some extent by earthquake effects therefore preparedness measures should be in place to address the needs of all special needs facilities listed in the resource manual section of this plan.
- Most likely the entire population of the community will be affected by a seismic event. Estimate the maximum peak population affected, considering peak tourism, special event populations and work hours.

Structural requirements for earthquake damage mitigation are addressed through the Building Department's administration of building codes. The current enforceable building code is believed to be antiquated. The new building code was supposed to take effect in September 2006, and is meant to be enforceable by March 2007.

Earthquakes are specifically addressed in the Water Company's water system emergency plans. The main Wannacomet water system storage tank is designed to withstand earthquakes. A new tank for the Wannacomet system is planned. The Sconset tank is being replaced soon.

## *10.5 Vulnerabilities and Risk Assessment*

According to the Massachusetts Hazard Mitigation Plan, Nantucket is within the area of lowest risk for earthquakes in the State. The highest risk lies in northeast Massachusetts. The potential for a damaging earthquake to occur in Nantucket in any given year is low.

Surficial earth materials behave differently in response to seismic activity. Unconsolidated materials such as sand and artificial fill can amplify the shaking associated with an earthquake. In addition, artificial fill material has the potential for liquefaction. Increased shaking and liquefaction can cause greater damage to buildings and structures, and a greater loss of life.

Figure 2-5 depicts surficial geology of Nantucket. All of Nantucket is underlain by glacial silts, sand, and gravel. Bedrock is more than 1,000 feet below the surface. The areas of outwash deposits are slightly more susceptible to shaking than moraines. Nevertheless, according to the Massachusetts Hazard Mitigation Plan, the peak ground acceleration on Nantucket that could occur with a 2% probability in 50 years is on the order of 0.06 g (force of gravity), among the lowest in the State. Additionally, because none of the Town is built on fill material, structures are not at increased risk due to amplification of seismic energy and liquefaction.

Another factor that limits the vulnerability of Nantucket structures to earthquakes is that wood frame construction is preferred to masonry. Although some historic buildings in the downtown area are masonry, most of the structures in Nantucket are not. Interestingly, of all the critical facilities, the Fire Station, Police Station, and the municipal building at 16 Broad Street are most vulnerable due to their masonry construction. However, the low likelihood of earthquake occurrence and the anticipated low intensity reduce any cause for alarm that these facilities would not be available after an earthquake event.

## *10.6 Potential Mitigation Measures, Strategies, and Alternatives*

Because earthquakes can not be predicted and can affect the entire Town of Nantucket, potential mitigation can only include adherence to building codes, education of residents,

and adequate planning. The following potential mitigation measures have been identified:

- Continue to promote wood construction.
- Require adherence to the amended, updated Massachusetts Building Code.
- Ensure that employees of the Fire Department, Police Department, and 16 Broad Street building know how to evacuate in case of an earthquake.
- Ensure that municipal departments that are housed in masonry buildings have adequate backup facilities to utilize if damage occurs.

## *10.7 Recommended Actions*

The small number of possible mitigation measures listed above are recommended with equal importance. In addition, important recommendations that apply to all hazards are listed in Section 11.1.

# *11.0 SUMMARY OF RECOMMENDATIONS*

## *11.1 Additional Recommendations*

Recommendations that are applicable to two, three, or four hazards were discussed in the applicable subsections of Sections 3.0 through 10.0. For example, placing utilities underground is a recommendation for hurricane, summer storm, winter storm, and wildfire mitigation. As a result, it was listed in Sections 5.6, 7.6, 8.6, and 9.6, respectively.

A remaining class of recommendations is applicable to all hazards, because it includes recommendations for improving public safety and planning for emergency response. Instead of repeating these recommendations in section after section of this Plan, these are listed below. Many of these are based on recommendations in the Comprehensive Community Plan & Status Chart. A few are based on recommendations in the Madaket, Sconset, and Mid-Island Area Plans.

- Move forward with plans to develop the 2 Fairgrounds Road property such that it will include a combined Fire/Police facility with an emergency operations center (thus removing the Police facility from the coastal flood zone and providing additional space for the Fire Department).
- Move forward with plans to develop the 2 Fairgrounds Road property such that it will include a fully-equipped secondary shelter as a backup to the High School.
- While the improvements at the 2 Fairgrounds Road property are pending, study the feasibility and cost-effectiveness of central dispatching for fire and police services to increase the effectiveness of response and better coordinate provision of emergency services.
- Establish central dispatching if found to be feasible and cost-effective.

- Evaluate the equipment, training, and personnel needs of the Fire and Police Departments as Townwide population increases.
- Seek more housing for seasonal police staff.
- Evaluate private roads to determine where essential improvements are necessary to provide adequate access for emergency services.
- Formalize agreements for roadway maintenance with private road owners.
- Consider the dedication of some private roads as public roads or the formal negotiation of either public or private maintenance agreements.
- Identify private roads to be acquired as public roads for safety of residents. These roads shall include private through roads that interconnect two or more public roads, and major collector roads that are principal or exclusive access roads to neighborhoods with substantial populations.
- Develop and adopt a minimum standard of road improvement to be utilized for public safety. This may be paved or unpaved depending on other objectives related to drainage and infiltration, but design should be consistent.
- Enforce existing private road maintenance agreements that were required by the Town.
- Ensure that new subdivisions with private roads have designated homeowners associations to provide maintenance that is adequate for public safety.
- Identify actions that Sconset and Madaket residents can take in advance to be prepared if a disaster should hit that would isolate either village. This may include training residents in first aid, ensuring that a local command center is designated, and proving for reliable communications.
- Develop village evacuation plans for Sconset, Madaket, and the downtown/Brant Point areas.
- Conduct Emergency Preparedness Seminars for Sconset and Madaket residents.
- Develop an alternate access route to Madaket via Eel Point Road and Warren's Landing Road for emergency use.

- Improvements in the Mid-Island Area should include enhancing traffic flow, increasing safety, and enhancing emergency access.
- Reconstruct the Milestone Rotary as a modern roundabout.
- Purchase additional portable emergency generators for use at any critical facilities.

## *11.2 Priority Recommendations*

To prioritize recommended mitigation measures, it is necessary to determine how effective each measure will be in reducing or preventing damage. A set of criteria commonly used by public administration officials and planners was applied to each proposed strategy. The method, called STAPLEE, stands for the "Social, Technical, Administrative, Political, Legal, Economic and Environmental" criteria for making planning decisions. The following questions were asked about the proposed mitigation strategies:

- **Social**: Is the proposed strategy socially acceptable to the community? Are there equity issues involved that would mean that one segment of the community is treated unfairly?
- **Technical**: Will the proposed strategy work? Will it create more problems than it will solve?
- **Administrative**: Can the community implement the strategy? Is there someone to coordinate and lead the effort?
- **Political**: Is the strategy politically acceptable? Is there public support both to implement and maintain the project?
- **Legal**: Is the community authorized to implement the proposed strategy? Is there a clear legal basis or precedent for this activity?
- **Economic**: What are the costs and benefits of this strategy? Does the cost seem reasonable for the size of the problem and the likely benefits?

- **Environmental:** How will the strategy impact the environment? Will the strategy need environmental regulatory approvals?

Each proposed mitigation strategy was evaluated and assigned a score (Good = 3, Average = 2, Poor = 1) based on the above criteria. An evaluation matrix with the total scores from each strategy can be found as Appended Table 4. After each strategy was evaluated using the STAPLEE method, it was then possible to prioritize the strategies according to the final score. The highest scoring was determined to be of more importance, economically, socially, environmentally and politically and, hence, prioritized over those with lower scoring.

In consideration of the STAPLEE ranking results and the risks and vulnerabilities described in this plan, the following recommendations were identified by the Town of Nantucket project team as the highest priority projects and/or policies.

***Emergency Services and Public Education***

- Move forward with plans to develop the 2 Fairgrounds Road property such that it will include a combined Fire/Police facility with an emergency operations center (thus removing the Police facility from the coastal flood zone and providing additional space for the Fire Department).
- Move forward with plans to develop the 2 Fairgrounds Road property such that it will include a fully-equipped secondary shelter as a backup to the High School.
- Evaluate private roads to determine where essential improvements are necessary to provide adequate access for emergency services.
- Consider the dedication of some private roads as public roads or the formal negotiation of either public or private maintenance agreements.
- Develop village evacuation plans for Sconset, Madaket, and the downtown/Brant Point areas.

- Conduct Emergency Preparedness Seminars for Sconset and Madaket residents.
- Mobilize emergency equipment and personnel to Madaket village in advance of predicted nor'easters.
- Mobilize emergency equipment and personnel to Sconset village in advance of predicted nor'easters.
- Provide funding for additional Marine Department staff to assist with boat removal before storms.
- Designate official sites on land for boat storage during storm events.
- Utilize available technology and warning systems to ensure that adequate icebreaking equipment is available to keep Harbor open.
- Distribute copies of the booklet "Is Your Home Protected From Wildfire Disaster? – A Homeowner's Guide to Wildfire Retrofit" when developers and homeowners pick up or drop off applications in the Building Department and Health Department.
- Develop a mutual aid relationship with the NCF, Nantucket Land Council, Nantucket Land Bank, and/or Massachusetts Audubon Society for firefighting assistance.

***Prevention, Property Protection, and Structural Projects***

- Increase cooperation between the Nantucket Conservation Commission, Planning Board, Building Department, and Health Department with regard to controlling growth and development in inland flood zones. This will provide a system of checks and balances to ensure that development leads to flood-resistant structures and reduces risk to people.
- Streamline the permitting process and ensure maximum education of a developer or applicant. Develop a checklist that cross-references the bylaws, regulations, and codes related to flood damage prevention that may be applicable to the proposed project. This list could be provided to an applicant at any Town department.
- Revise the setback clause of the Wetland Regulations (20 times the erosion rate or 100 feet) to be more stringent.

- Adopt freeboard standards (two feet for dwellings and one foot for roadways) when regulating the elevation of development in flood zones.
- Adopt V zone construction standards for coastal A zones.
- Encourage elevation of homes in the Codfish Park beach residential area to the base flood (9') plus two feet.
- Encourage elevation of homes in Madaket flood zones to the base flood (8') plus two feet.
- Offer to assist in the application for FEMA funds to relocate waterfront homes if owners agree to cease utilization of hard solutions.
- Conduct master drainage studies for problem areas, such as the broad area between Madaket Road and Hummock Pond Road, to ensure that individual repairs and upgrades fit seamlessly with upstream and downstream drainage systems.
- Improve the storm drainage system on Pleasant Street to reduce flooding.
- Complete the Orange Street drainage system upgrade to reduce flooding and allow better drainage of upstream areas.
- Increase the elevation of Polpis Road at Sesachacha Pond to the base flood (8') plus one foot freeboard.
- Continue to make sandbags available to protect the downtown sewer pumping station
- Ensure that pre-disaster natural hazard mitigation is a primary consideration and major factor in any analysis of bulk fuel storage and delivery alternatives, including those alternatives that remove the tank farm from the downtown area and move fuel delivery away from the harbor.
- If the above-referenced analyses find that the downtown tank farm should remain in place, the tank farm floodproofing should be inspected and upgraded to withstand not only waves and water velocities but also storm debris, and freeboard standards should be applied to increase the elevation of floodproofing by an additional two feet above the base flood.

- If the above-referenced analyses find that the downtown tank farm should be relocated, it should be relocated to an area outside flood and hurricane storm surge zones, and to an area that is accessible during natural disasters.
- Continue to require that utilities be placed underground in new developments and pursue funding to place them underground in existing developed areas.
- Increase plowing of Milestone Road in snow drift areas.
- Urge conservation groups to restore windbreaks along Milestone Road.
- Extend the public water supply systems into areas within reasonable growth boundaries that may benefit from water for fire protection.
- Explore alternate solutions to fire protection where it is not feasible to extend a conventional water system.

***Natural Resources Protection***

- Support privately-funded beach nourishment projects that are believed to have minimal environmental impacts.
- Develop a list of potential Town-funded and/or FEMA-funded beach nourishment demonstration projects and apply for funding to pursue these projects.
- Urge State regulators and the scientific community to make a determination relative to beach dewatering effectiveness.
- Focus open space and conservation acquisitions on coastal properties.

## *11.3 Specific Sources of Funding*

The following sources of funding and technical assistance may be available for the priority projects listed above. Funding requirements and contact information are provided in Section 12.0.

***Beach Replenishment and Erosion Control***

- U. S. Army Corps of Engineers – *funding for beach nourishment.*
- U.S. Department of Agriculture – *technical assistance for erosion control.*
- U.S. Fish and Wildlife National Coastal Wetlands Conservation Grant Program - *matching funds at the State level for projects that conserve, restore, and protect coastal wetlands. Nationally competitive.*
- North American Wetlands Conservation Act Grants Program – *funding for projects that support long term wetlands acquisition, restoration, and/or enhancement. Requires a 1-to-1 funds match.*

***Flood Mitigation***

- FEMA Flood Mitigation Assistance Program (FMA) – *grants for pre-disaster flood hazard mitigation planning and projects such as property acquisition, relocation of residents, and flood retrofitting.*
- U.S. Army Corps of Engineers – *50/50 match funding for floodproofing and flood preparedness projects.*
- U.S. Department of Agriculture – *financial assistance to reduce flood damage in small watersheds and to improve water quality.*

***Hurricane Mitigation***

- FEMA State Hurricane Program - *financial and technical assistance to local governments to support mitigation of hurricanes and coastal storms.*
- FEMA Hurricane Program Property Protection – *grants to hurricane prone states to implement hurricane mitigation projects.*

***Wildfire Mitigation***

- Assistance to Firefighters Grant Program – *pre-disaster grants to organizations such as fire departments that are recognized for expertise is fire prevention and safety programs.*

***General Hazard Mitigation***

- FEMA Hazard Mitigation Grant Program (HMGP) – *funding for hazard mitigation projects following a presidentially-declared disaster.*
- FEMA Pre-Disaster Mitigation Grant Program (PDM) – *funding for hazard mitigation projects on a nationally competitive basis.*
- Massachusetts Land Acquisition & Conservation Program – *funding for open space acquisition.*
- Americorps – *teams may be available to assist with landscaping projects such as surveying, tree planting, restoration, construction, and environmental education.*

# 12.0 PLAN IMPLEMENTATION

## 12.1 Implementation Strategy and Schedule

The Nantucket Emergency Management Department is authorized to update this pre-disaster hazard mitigation plan as needed, coordinate its adoption by the Town of Nantucket, and guide it through the FEMA approval process.

As individual recommendations of the hazard mitigation plan are implemented, they must be implemented by the Town departments that oversee these activities. The Department of Public Works, Building Department, Health Department, Planning Department, Conservation Commission, Selectman's Office, Marine & Coastal Resources Department, Wannacomet Water Company, and the Nantucket Airport will primarily be responsible for implementing selected projects and studies. Appended Table 4 incorporates an implementation strategy and schedule, detailing the responsible department and anticipated time frame for the specific recommendations listed throughout this document.

## 12.2 Progress Monitoring and Public Participation

The Emergency Management Department will coordinate an annual meeting for review of the plan. Participants in this review will include officials or staff of the Department of Public Works, Building Department, Health Department, Planning Department, Conservation Commission, Selectman's Office, Marine & Coastal Resources Department, Wannacomet Water Company, and the Nantucket Airport. Attendance by additional Fire and/or Police Department representatives will be optional, as the Emergency Management Department covers the functions of both in the context of natural hazard pre-disaster mitigation.

Matters to be evaluated at the annual meeting will include a review of the goals and objectives of the original plan, a review of hazard events or disasters that occurred during the preceding year, a review of the mitigation activities that have been accomplished to date, a discussion of why any implementation may be behind schedule, and recommendations for new projects and revised activities. The meeting will be conducted in November or December, at least two months before the annual application cycle for pre-disaster grants (applications are typically due in February of any given year). This will enable a list of possible projects to be circulated for Town Departments to review, with sufficient time for developing an application.

The Town of Nantucket web site (http://www.nantucket-ma.gov/) includes a page for the Nantucket Planning & Economic Development Commission devoted to a list of links to various plans and studies. The Pre-Disaster Hazard Mitigation Plan will be posted in this location. An item will be added to this page by the end of 2007, indicating the availability of this hazard mitigation plan, advising residents of the annual schedule for updates, and instructing residents to provide comments and recommendations to the Emergency Management Department in connection with the annual update.

## *12.3 Updating the Plan*

The Emergency Management Department will update the pre-disaster hazard mitigation plan if a consensus to do so is reached at any of the annual meetings, but not less frequently than every five years. Updates may include deleting recommendations as projects are completed, adding recommendations as new hazard effects arise, or modifying hazard vulnerabilities as development patterns change. In addition, the list of shelters and critical facilities should be updated as necessary, or at least every three years.

## 12.4 *Technical and Financial Resources*

This subsection is comprised of a list of resources to be considered for technical assistance and potentially financial assistance for completion of the actions outlined in this plan. This list is not all-inclusive and is intended to be updated as necessary.

### *Federal Resources*

Federal Emergency Management Agency
Region I
99 High Street, 6th floor
Boston, MA 02110-2320
(877) 336-2734

*Mitigation Division*

Administers all of FEMA's hazard mitigation programs, including: National Flood Insurance Program and Community Rating System; prepares and revises flood insurance studies and maps; information on past and current acquisition, relocation, and retrofitting programs; expertise in other natural and technological hazards, including hurricanes, earthquakes and hazardous materials. Financial assistance includes Hazard Mitigation Grant program (post-disaster); Flood Mitigation Assistance Program (pre-and post-flood), Pre-Disaster Mitigation (PDM) grant program; training for local officials at Emergency Management Institute in Emmitsburg, Maryland.

- ***Earthquake Hazards Reduction Assistant Program***: As part of the National Earthquake Hazards Reduction Program (NRHRP), the purpose of the FEMA's State Earthquake Hazards Reduction Program is to provide funds for the development of comprehensive risk reduction programs at the State level and risk reduction measures at the local level to reduce future earthquake damages and losses. The fundamental goal of the program is to reduce earthquake impacts and the subsequent loss of lives, property damages, and economic losses. To accomplish these goals, technical assistance from State programs to local governments in the areas of structural and non-structural mitigation, building codes, and land-use planning ordinances is necessary.

- ***State Hurricane Program***: This program is concerned with reducing the impacts of hurricanes and coastal storms on coastal areas of the United States and its territories

as well as reducing the extent of subsequent losses. FEMA provides financial and technical assistance to State and local governments to support their efforts to mitigate the damaging effects of hurricane and coastal storms. State Hurricane Program funds are to be used for mitigation and preparedness activities related to hurricane hazards. Each participating State receives a Local Assistance allocation of $5,000 in addition to the State Assistance Grant.

- ***Hurricane Program Property Protection - Mitigation Grants***: This element of the Hurricane Program provides grants to hurricane-prone States to implement mitigation projects. Each FEMA Region with States participating in the Hurricane Program receives funds for this activity. The Regional offices solicit the States to undertake projects that reduce the risk of loss of life or injury from damaged structures and reduce the overall cost of hurricane disasters due to property damage. This program is administered by the CT OEM.

- ***Multi-State Groups***: There are three multi-state (regional) consortia that FEMA funds: the Western States Seismic Policy Council (WSSPC), the New England States Emergency Consortium (NESEC), and the Central United States Earthquake Consortium (CUSEC). The mission of all three consortia is to support the National Earthquake Hazard Program (Reduction) funded State earthquake programs. They provide support in areas such as coordination between the States in a region and public awareness and education, and they also reinforce interactions between all levels of government, academia, non-profit associations, and the private section.

- ***Technical Assistance Contracts***: The Mitigation Directorate has in place several Technical Assistance Contracts (TAC) that support FEMA, States, territories, and local governments with activities to enhance the effectiveness of natural hazard reduction program efforts. The TACs support FEMA's responsibilities and legislative authorities for implementing the earthquake, hurricane, dam safety, and floodplain management programs. The range of technical assistance services provided through the TACs varies based on the needs of the eligible contract users and the natural hazard programs. Contracts and services include:

  - *The Hazard Mitigation Technical Assistance Program (HMTAP) Contract*-supporting post-disaster program needs in cases of large, unusual, or complex projects; situations where resources are not available; or where outside technical assistance is determined to be needed. Services include environmental and biological assessments, benefit/cost analyses, historic preservation assessments, hazard identification, community planning, training, and more.

  - *The Wind and Water Technical Assistance Contract (WAWTAC)*-supporting wind and flood hazards reduction program needs. Projects include recommending

mitigation measures to reduce potential losses to post-FIRM structures, providing mitigation policy and practices expertise to States, incorporating mitigation into local hurricane program outreach materials, developing a Hurricane Mitigation and Recovery exercise, and assessing the hazard vulnerability of a hospital.

- *The National Earthquake Technical Assistance Contract (NETAC)* – supporting earthquake program needs. Projects include economic impact analyses of various earthquakes, vulnerability analyses of hospitals and schools, identification of and training on non-structural mitigation measures, and evaluating the performance of seismically rehabilitated structures, post-earthquake.

- ***Hazard Mitigation Grant Program (HMGP)*:** HMGP is a post-disaster mitigation program that provides funding for hazard mitigation projects in affected counties following presidentially declared disasters. Available funds are based on a percentage of the total damages caused by the particular disaster. Grants from this program are limited to state and local governments and certain non-profit organizations. There is a need to demonstrate a positive cost/benefit analysis and a cost-share requirement of 25% to match the federal funds provided. Grants are competitive within the affected area. This program is administered by the state of Massachusetts, Massachusetts Emergency Management Agency (MEMA).

- ***Flood Mitigation Assistance Program (FMA)*:** FMA is a pre-disaster mitigation program created by the National Flood Insurance Reform Act of 1994. This program provides both project and planning grants annually for flood hazard mitigation planning and projects with direct demonstrable benefits to the NFIP insurance fund. Administratively, this program is very similar to the HMGP described above.

- ***Pre-Disaster Mitigation Grant Program (PDM)*:** PDM is a pre-disaster mitigation program that provides funding for hazard mitigation projects on a nationally-competitive basis. Projects are submitted by states and communities and rated by a national panel. Yearly funding for this grant is in the millions of dollars. There is a need to demonstrate a positive cost/benefit analysis and a cost-share requirement of 25% to match the federal funds provided. This program is administered by the state of Massachusetts, Massachusetts Emergency Management Agency (MEMA).

<u>*Response & Recovery Division*</u>

Information on dollar amounts of past disaster assistance including Public Assistance, Individual Assistance, and Temporary Housing; information on retrofitting and acquisition/relocation initiatives. Coordinates federal disaster assistance programs, including 75% grants for mitigation projects to protect eligible damaged public and

private non-profit facilities from future damage through the Public Assistance Program, and 100% "minimization" grants through the Individuals and Family Grant Program.

Computer Sciences Corporation
New England Headquarters,
140 Wood Road, Suite 200,
Braintree, MA 02184
(617) 848-1908

A private company contracted by the Federal Insurance Administration as the National Flood Insurance Program Bureau and Statistical Agent, CSC provides information and assistance on flood insurance, including handling policy and claims questions, and providing workshops to leaders, insurance agents, and communities.

Small Business Administration
360 Rainbow Boulevard South, 3rd Floor
Niagara Falls, NY 14303
Disaster Program Director: Win Allred
(716) 282-4612 or 800-659-2955

SBA has the authority to "declare" disaster areas following disasters that affect a significant number of homes and businesses, but that would not need additional assistance through FEMA. (SBA is triggered by a FEMA declaration, however.) SBA can provide additional low-interest funds ( up to 20% above what an eligible applicant would "normally" qualify for) to install mitigation measures. They can also loan the cost of bringing a damaged property up to state or local code requirements. Can be used in combination with the new "mitigation insurance" under the NFIP, or in lieu of that coverage.

Environmental Protection Agency
Region I - JFK Federal Building, Government Center,
Boston, MA 02203
(617) 565-3400

- ***Capitalization Grants for State Revolving Funds:*** Low interest loans to governments to repair, replace, or relocate wastewater treatment plans damaged in floods. Does not apply to drinking water or other utilities.
- ***Clean Water Act Section 319 Grants:*** Cost-share grants to state agencies that can be used for funding watershed resource restoration activities, including wetlands and other aquatic habitat (riparian zones). Only those activities that control non-point pollution are eligible. Grants are administered through the CT DEP, Bureau of Water Management, Planning and Standards Division.

U.S. Dept. of Housing and Urban Development
Thomas P. O'Neill, Jr. Federal Building
10 Causeway Street, 3rd Floor
Boston, MA 02222-1092
(617) 994-8200

- ***Community Development Block Grants (CDBG):*** Communities with populations greater than 50,000 contact HUD directly regarding CDGB. One program objective is to improve housing conditions for low and moderate income families. Projects can include acquiring flood prone homes or protecting them from flood damage. Funding is a 100% grant; can be used as a source of local matching funds for other funding programs, such as FEMA's "404" Hazard Mitigation Grant Program. Funds can also be applied toward "blighted" conditions, which is often the post-flood condition. A separate set of funds exists for conditions that create an "imminent threat." The funds have been used in the past to replace (and redesign) bridges where flood damage eliminates police and fire access to the other side of the waterway.

U.S. Army Corps of Engineers
Special Studies Branch
424 Trapelo Road
Waltham, MA 02254
(617) 647-8505

Provide 100% funding for floodplain management planning and technical assistance under the Floodplain Management Services Program (FPMS). Various flood protection measures such as beach re-nourishment, stream clearance and snagging projects, floodproofing, and flood preparedness funded on a 50/50 matching basis by Section 22 planning Assistance to States program. They are authorized to relocate homes out of the floodplain if it proves to be more cost effective than a structural flood control measure.

U.S. Department of Commerce
*National Weather Service*
445 Myles Standish Blvd.
Taunton, MA 02780
(508) 823-2266

Prepares and issues flood, severe weather, and coastal storm warnings. Staff hydrologists can work with communities on flood warning issues and can give technical assistance in preparing flood warning plans.

U.S. Department of the Interior
*National Park Service*
Rivers and Rails Conservation Program
Regional Office, 15 State Street
Boston, MA 02109
(617) 223-5203

Technical Assistance with open space preservation planning; can help facilitate meetings and identify non-structural options for floodplain development.

U.S. Fish and Wildlife Service
New England Field Office
22 Bridge Street, Unit #1
Concord, NH 03301

Can provide technical and financial assistance to restore wetlands and riparian habitats through the North American Wetland Conservation Fund and partners for Wildlife programs. Also administers the

- ***National Coastal Wetlands Conservation Grant Program:*** A nationally competitive fund matching program to preserve, restore, and protect coastal wetlands. Funds are administered at the State level.
- ***North American Wetlands Conservation Act Grants Program:*** Provides matching grants to organizations and individuals who have developed partnerships to carry out wetlands projects in the United States, Canada, and Mexico. Funds are available for projects focusing on protecting, restoring, and/or enhancing critical habitat. Projects must support long-term wetlands acquisition, restoration, and/or enhancement, and require a 1-to-1 match. The program includes both Standard Grants (grant requests between $50,001 and $1,000,000) and Small Grants (funds not to exceed $50,000).

  Contacts: *Standard Grants proposals*: David Buie (david_buie@fws.gov), (301) 497-5870; *Small Grants Program proposals*: Keith Morehouse (keith_morehouse@fws.gov), (703) 358-1888. *General office number*: (703) 358-1784.

U.S. Department of Agriculture
*Natural Resources Conservation Service* (formerly SCS)
West Wareham Service Center
15 Cranberry Highway
West Wareham MA, 02576
(508) 295-5151

Technical assistance to individual land owners, groups of landowners, communities, and soil and water conservation districts on land-use and conservation planning, resource development, stormwater management, flood prevention, erosion control and sediment reduction, detailed soil surveys, watershed/river basin planning and recreation, fish and wildlife management. Financial assistance is available to reduce flood damage in small watersheds and to improve water quality. Financial assistance is available under the Emergency Watershed Protection Program; the Cooperative River Basin Program; and the Small Watershed Protection Program.

***State Resources***

Massachusetts Emergency Management Agency (MEMA)
400 Worcester Road
Framingham, MA 01702-5399
(508) 820-2000

The Massachusetts Emergency Management Agency (MEMA) is the state agency responsible for coordinating federal, state, local, voluntary and private resources during emergencies and disasters in the Commonwealth of Massachusetts. MEMA provides leadership to develop plans for effective response to all hazards, disasters or threats; train emergency personnel to protect the public; provide information to the citizenry; and assist individuals, families, businesses and communities to mitigate against, prepare for, and respond to and recover from emergencies, both natural and man made. MEMA administers FEMA's FMA, HMGP, and PDM programs with DCR.

Massachusetts Department of Conservation & Recreation (DCR)
251 Causeway Street
Boston, MA 02114
(617) 626-1250

- ***Flood Management Grants*** – DCR's Department of Flood Hazard Management, in coordination with the Massachusetts Emergency Management Agency, offers two grant programs to local government in order to reduce the risks and costs of natural disasters, especially floods, on homeowners and community infrastructure. These programs include pre-disaster grants through the annual Flood Hazard Mitigation Grant Program (FMA) and post-disaster grants through the Hazard Mitigation Grant Program (HMGP).
- ***Rivers and Harbors Grant Program*** – A statewide program of matching grants from DCR's Office of Waterways to towns and municipalities for design and construction to address problems on coastal and inland waterways, lakes and great ponds.

As of 2007, pertinent contact information for MEMA and DCR officials in the State Hazard Mitigation Team is as follows:

Richard Zingarelli
Acting State Hazard Mitigation
Officer/NFIP Coordinator
DCR/ Floodplain Management
251 Causeway St. Suite 800
Boston, MA 02114-2104
617-626-1407
Richard.Zingarelli@state.ma.us

Mike Gildesgame
DCR/Water Supply Protection
251 Causeway St. Suite 800
Boston, MA 02114-2104
617-626-1371
Mike.Gildesgame@state.ma.us

Christopher Penney
Regional Planner
DCR/Floodplain Management
251 Causeway St. Suite 800
Boston, MA 02114-2104
617-626-1352
Christopher.Penney@state.ma.us

Shirletta Leung
Disaster Recovery Admin.
MA Emergency Management
400 Worcester Rd.
Framingham, MA 01702
508-820-1436
Shirletta.Leung@state.ma.us

John Tommaney
Response & Recovery Branch Chief
MA Emergency Management
400 Worcester Rd.
Framingham, MA 01702
508-820-2016
John.Tommaney@state.ma.us

Elizabeth McDonald
Disaster Recovery Manager
MA Emergency Management
400 Worcester Rd.
Framingham, MA 01702
508-820-2067
Elizabeth.Mcdonald@state.ma.us

Paul Morey
Regional Planner
DCR/Floodplain Management
251 Causeway St. Suite 800
Boston, MA 02114-2104
617-626-1359
Paul.Morey@state.ma.us

Scott MacLeod
Mitigation Grants Manager
MA Emergency Management
400 Worcester Rd.
Framingham, MA 01702
508-820-1445
Scott.MacLeod@state.ma.us

Sarah Zingarelli
Hazard Mitigation Planner
MA Emergency Management
251 Causeway St. Suite800
Boston, MA 02114-2104
(Boston) 617-626-1386
(Framingham) 508-820-1435
Sarah.Zingarelli@state.ma.us

Eric Carlson
Environmental Engineer
DCR/Floodplain Management
251 Causeway St. Suite 800
Boston, MA 02114-2104
617-626-1362
Eric.Carlson@state.ma.us

Massachusetts Office of Coastal Zone Management
251 Causeway Street, Suite 800
Boston, MA 02114-2138
(617 626-1200

The Massachusetts Office of Coastal Zone Management (CZM) is a part of the Executive Office of Environmental Affairs (EOEA). Its mission is to balance the impacts of human activity with the protection of coastal and marine resources. As a networked program, CZM was specifically established to work with other state agencies, federal agencies, local governments, academic institutions, nonprofit groups, and the general public to promote sound management of the Massachusetts coast. CZM is funded primarily through the Commonwealth of Massachusetts, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Environmental Protection Agency (EPA). CZM administers a number of grant and technical assistance programs aimed at wetland restoration.

MA Department of Public Safety
One Ashburton Place, Room 1301
Boston, MA 02108
(617) 727-3200

DPS is the lead agency responsible for emergency management. Specific responsibilities include emergency preparedness, response & recovery, homeland security, oversight of MEMA, and oversight of the Board of Building Regulations and Standards.

***Private and Other Resources***

The Association of State Floodplain Managers (ASFPM)
4233 W. Belittling Highway
Madison, WI 53711
(608) 274-0123

Professional association of state employees that assist communities with the NFIP with a membership of over 1,000. ASFMP has developed a series of technical and topical research papers, and a series of Proceedings from their annual conferences. Many "mitigation success stories" have been documented through these resources, and provide a good starting point for planning.

Natural Hazards Center
(303) 492-6818

Includes the Floodplain Management Resource Center, a free library and referral service of the ASFPM for floodplain management publications. The Natural Hazards Center is located at the University of Colorado in Boulder, staff can use keywords to identify useful publications from the more than 900 documents in the library.

New England Flood and Stormwater Managers Association, Inc. (NEFSMA)
c/o MA DEM
100 Cambridge Street
Boston, MA 02202

NEFSMA is a non-profit organization made up of state agency staff, local officials, private consultants and citizens from across New England. NEFSMA sponsors seminars and workshops and publishes the NEFSMA News, three times per year to bring the latest flood and stormwater management information from around the region to its members.

National Center for Earthquake Engineering and Research
(716) 645-3391

A source for earthquake statistics, research, engineering and planning advice.

National Emergency Managers Association (NEMA)
c/o Council of State Governments
3650 Iron Works Pike, P.O. Box 11910
Lexington, Kentucky 4057-1910
606-244-8000

A national association of state emergency management directors and other emergency management officials. The NEMA Mitigation Committee is a strong voice to FEMA in shaping all-hazard mitigation policy in the nation. NEMA is also an excellent source of technical assistance.

New England States Emergency Consortium (NESEC)
(800) 445-6332

A clearinghouse for mitigation and preparedness information with cooperation from all of the New England states. NESED presents a unique, non-governmental approach to aid. This agency could secure access to private sources of monetary and logistics support.

Insurance Institute for Property Loss Reduction (IIPLR)
73 Tremont Street, Suite 510
Boston, MA 012109-3910
(617) 722-0200

A non-profit organization put together by the insurance industry to research ways of lessening the impact of natural hazard. IIPLR advocates the development and implementation of building codes and standards nationwide and may be a good source of model code language.

Volunteer Organizations
Volunteer organizations, such as the American Red Cross, the Salvation Army, Habitat for Humanity, Interfaith, and the Mennonite Disaster Service are often available to help after disasters. Service Organizations, such as the Lions, Elks, and VFW are also. Habitat for Humanity and the Mennonite Disaster Service Provide skilled labor to help rebuild damaged buildings incorporating mitigation or floodproofing concepts. The office of individual organizations can be contacted directly, or the FEMA Regional Office may be able to assist.

Americorps
Americorps is the recently installed National Community Service Organization. Teams of works can assist with landscaping projects such as surveying, tree planting, restoration, construction and environmental education. Some states have trained Americorps members to help during flood-fight situations, such as filling and placing sandbags.

## *13.0 REFERENCES*


AIR Worldwide Corporation, 2006, "Fundamentals of Catastrophe Modeling," presented to the Massachusetts Coastal Hazards Commission on June 30, 2006.

Brace, Peter B., 2005, "Tempering the Wrath of Mother Nature," in The Nantucket Independent, August 24, 2005.

Cape Cod Commission, 2004, *Natural Hazards Pre-Disaster Mitigation Plan,* Barnstable County, Cape Cod, Massachusetts.

Cape Cod Commission, 2004, Cape Cod Emergency Preparedness Handbook.

Connecticut Department of Environmental Protection, 2004, *Natural Hazard Mitigation Plan for 2004-2007.*

Earthquake Information Bulletin, 1973, Volume 5, Number 5, September-October 1973, by Carl Von Hake, http://earthquake.usgs.gov/regional/states/massachusetts/history.php

Eastham's Local Multiple Hazard Community Planning Team, with assistance from the Cape Cod Commission, 2004, *Pre-Disaster Mitigation (PDM) Plan,* Eastham, Massachusetts.

Federal Emergency Management Agency, Hazards, *Backgrounder: Tornadoes,* http://www.fema.gov/hazards/tornadoes/tornado.shtm

___, Library. Federally Declared Disasters by Calendar Year. http://www.fema.gov/library/drcys.shtm

___, Library. *Preparation and Prevention.* http://www.fema.gov/library/prepandprev.shtm

___, *Mitigation Division,* http://www.fema.gov/fima/

___, *National Hurricane Program,* http://www.fema.gov/hazards/hurricanes/nhp.shtm

___, 1987, *Reducing Losses in High Risk Flood Hazard Areas: A Guidebook for Local Officials,* The Association of State Floodplain Managers.

Godschalk, D.R., T. Beatley, P. Berke, D.J. Brower, and E.J. Kaiser, 1999, *Natural Hazard Mitigation: Recasting Disaster Policy and Planning*, Island Press: Washington, D.C.

Institute for Business and Home Safety, undated, "Is Your Home Protected From Wildfire Disaster? – A Homeowner's Guide to Wildfire Retrofit."

Kafka, Alan L., 2004, *Why Does the Earth Quake in New England? The Science of Unexpected Earthquakes*, Boston College, Weston Observatory, Department of Geology and Geophysics, http://www2.bc.edu/~kafka/Why_Quakes/why_quakes.html

Massachusetts Institute for Social and Economic Research, 2003, "MISER" population projections for Massachusetts.

Massachusetts Office of Coastal Zone Management, 2002, *Massachusetts Shifting Shorelines – New Data on Shoreline Change.*

National Oceanic and Atmospheric Administration, Atlantic Oceanographic and Meteorological Laboratory, Hurricane Research Division, *Hurricane Histograms.* http://www.aoml.noaa.gov/hrd/tcfaq/counties/CT.html

___, National Climatic Data Center (NCDC), *Extreme Weather and Climate Events.* http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

___, National Climatic Data Center (NCDC), 2006, *Massachusetts Climate Summary.* http://www.ncdc.noaa.gov/oa/climate/research/cag3/ma.html.

___, National Weather Service, National Hurricane Center Tropical Prediction Center. *NHC/TPC Archive of Past Hurricane Seasons.* http://www.nhc.noaa.gov/pastall.shtml

___, National Weather Service, 2006, "Examining the Southeast New England Threat," presented to the Massachusetts Coastal Hazards Commission on June 12, 2006.

___, National Weather Service. 2005. Statement for December 9, 2005 storm.

Neumann, J.E., G. Yohe, R. Nicholls, M. Manion, 2000, *Sea-level Rise and Global Climate Change, A Review of Impacts to the U.S. Coasts*, Prepared for the Pew Center on Global Climate Change.

New Hampshire Office of Emergency Management, 2000, *State of New Hampshire Natural Hazards Mitigation Plan.* Concord, New Hampshire.

Siasconset Beach Preservation Fund, 2006, *Erosion Happens. What Are we Going to Do About It?*

___, 2006, information from web site.

Town of Bourne, Massachusetts, 2004, *Pre-Disaster Hazard Mitigation Plan.*

Town of Nantucket, 2006, *Emergency Operations Plan.*

Town of Nantucket, 2006, Annual Report, July 1, 2004-June 30, 2005.

Town of Nantucket, 2005, Subdivision Regulations.

Town of Nantucket, 2005, Wetland Regulations.

Town of Nantucket, 2006, Town of Nantucket Code, Chapters 136 and 139.

Town of Wellfleet, Massachusetts, 2004, *Pre-Disaster Mitigation Plan.*

Town of Nantucket Planning & Economic Development Commission, 2001, The Nantucket Comprehensive Community Plan.

Tornado Project Online, http://www.tornadoproject.com/

United States Army Corps of Engineers, 1997, *Southern Massachusetts Hurricane Evacuation Study Technical Data Report.*

United States Department of Transportation, 2002, *The Potential Impacts of Climate Change on Transportation*, The DOT Center for Climate Change and Environmental Forecasting. Workshop, October 1-2, 2002, Summary and Discussion Papers.

United States Geological Survey, Earthquake Hazards Program, *Earthquake Information for Connecticut*, http://neic.usgs.gov/neis/states/connecticut/connecticut_history.html

___, 2006, "Potential Impacts of Sea-Level Rise on the Coast," presented to the Massachusetts Coastal Hazards Commission, May 8, 2006.

___, 1989, Water-Supply Paper 2375, Massachusetts Flood and Droughts.

___, 1999, *National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast*, U.S. Geological Survey Open-File Report 99-593.

___, Professional Paper 1693, Coastal Bluffs of New England.

___, *The Severity of an Earthquake*. http://pubs.usgs.gov/gip/earthq4/severitygip.html

University of Massachusetts Cooperative Extension Service, 1966, Selected Resources of the Island of Nantucket, An Inventory and Interpretation.

VHB, Inc., 2005, Nantucket Pipeline and Bulk Fuel Storage Feasibility Study, prepared for Nantucket Airport Commission.

Woods Hole Oceanographic Institute, 2002, *Stabilizing Dunes and Coastal Banks using Vegetation and Bioengineering: Proceedings of a Workshop Held at the Woods Hole Oceanographic Institution, Woods Hole, MA.*

___, 1998, *Coastal Landform Management in Massachusetts: Proceedings of a Workshop Held at the Woods Hole Oceanographic Institution, Woods Hole, MA.*

# APPENDIX B
# RECORD OF ADOPTION BY TOWN OF NANTUCKET

# APPENDIX A
# DOCUMENTATION OF PLAN DEVELOPMENT