UNDERSTANDING THE EFFECTS OF HURRICANE STORM SURGE IN FALMOUTH, MA

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CERTIFICATION STATEMENT

I hereby certify that this paper constitutes my own product, that where the language of other is set forth, quotation, marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed___ Glen Rogers________________________________________________________
ABSTRACT

The Falmouth, MA Fire Rescue Department (FFRD) did not have adequate knowledge of hurricane storm surge, storm surge impacts on the community and storm surge impacts on emergency services. The purpose of this study was to develop a body of knowledge on the effects of hurricane storm surge on the community of Falmouth, MA. Descriptive and historical research methods were used throughout the research to answer the following questions a) What are the historical impacts of hurricane storm surge on life and property in Falmouth, MA? b) What are the predicted impacts of storm surge on Falmouth, MA? c) What is the population within the hurricane storm surge zone in Falmouth, MA? d) How many dwellings are located in the hurricane storm surge zone? e) What critical infrastructures are located in the hurricane storm surge zone? f) Are the effected population and businesses within the storm surge zone aware of their location? g) Are Falmouth Fire Rescue personnel aware of Falmouth’s storm surge zones? h) Are Falmouth Fire Rescue personnel aware of the effects of storm surge on emergency operations during a hurricane? This study found that there is not adequate knowledge of hurricane storm surge zones and impacts of surge on emergency operations with the FFRD. Personnel believed they had experience with hurricane emergency operations however the rarity of even minor hurricanes leaves a gap in experience that can only be spanned through education and training. This study recommends the FFRD pursue a community risk assessment, educate emergency personnel and the community on the dangers of hurricane storm surge.
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INTRODUCTION

The Falmouth, MA Fire Rescue Department (FFRD) does not have any knowledge base about hurricane storm surge and hurricane storm surge impacts on the community and emergency services. This purpose of this research was to utilize descriptive and historical research methods to discover the impacts of hurricane storm surge on this coastal community and the emergency services in order to answer the following research questions a) what are the historical impacts of hurricane storm surge on life and property in Falmouth? b) what are the predicted impacts of hurricane storm surge on Falmouth? c) what is the population within the hurricane storm surge in Falmouth? d) how many dwellings are located in the hurricane storm surge zone in Falmouth? e) what critical infrastructures are located in the hurricane storm surge zone? f) Are the effected population and businesses within the storm surge zone aware of their location? g) are FFRD personnel aware of Falmouth’s storm surge zone? h) are FFRD personnel aware of the effects of storm surge on emergency operations during a hurricane?

BACKGROUND AND SIGNIFICANCE

The Falmouth Fire Rescue Department protects the citizens, visitors and structures in the Town of Falmouth. The town was incorporated in 1686 as part of the Plymouth Bay Colony formed by the Pilgrims who sailed from England. Falmouth is located on the peninsula of Cape Cod off the southeastern tip of Massachusetts. Cape Cod is essentially an island separated from the mainland by the Cape Cod Canal. Access to Cape Cod is limited to two highway bridges with four lanes each and one Railroad Bridge. The town comprises 44 square miles with a year round population of 33,451 and a summer population of 108,500. (Falmouth Chamber Commerce, 2010)
The median age of Falmouth is 45 thereby signifying a significant retirement community. There are 20,000 housing units grouped around several unique villages which provide the large town with a small town feel. A renowned scientific presence, the Woods Hole Oceanographic Institution and Marine Biological Laboratory, is clustered in the town’s Woods Hole village. The community has many 10 public and private schools, 10 nursing and assisted living facilities and a 95 bed hospital.

The town government is led by a town manager overseen by a five member board of selectmen. The community incorporates a biannual representative town meeting to approve the town budget and vote on major matters within the town. Taxes are raised primarily via property taxes, vehicle excise taxes and other assorted fees. (Falmouth Chamber Commerce, 2010)

The Falmouth Fire Department was established as a volunteer firefighting unit in 1897 utilizing 13 far flung stations with hand drawn hose reels and ladder carriages. The volunteers could only ‘run’ a mile or so with the wagon like apparatus and the water supply was limited hence the fire and life safety protection was minimal.

In 1919, the town hired a young summer visitor from Worcester, MA, Ray D. Wells, to be the first full time Fire Chief. Over the next 10 years Chief Wells abolished the 13 hand drawn stations and established five stations in the significant villages of Woods Hole, Falmouth Center, East Falmouth, West Falmouth and North Falmouth. All stations were within one mile of the shoreline of town where the majority of the population lived. Each of these stations was outfitted with motorized apparatus and with at least one 24 hour a day person as a driver. (Todd, 1993)
Much has changed in the intervening years. The town’s population has grown from 3,500 to nearly 35,000 year round. The populated areas of town are denser and the sprawling of citizens has covered the entire town. Commercially the town currently houses a significant federal scientific and oceanographic community, several major and minor shopping malls and 10 nursing and assisted living facilities.

The Falmouth Fire Rescue Department (FFRD) of modern times is a full service emergency service providing five advanced life support ambulances, five fire engines, and one aerial ladder working within a $6 million municipal budget. The department also supports a three person fire prevention and life safety division providing fire inspection, code enforcement and fire education. Fire Suppression and Emergency Medical Services are provided by trained firefighter paramedics and emergency medical technicians. The department has four groups of 15 personnel (minimum of 10 personnel) from five stations. Each group is led by a shift Captain and Lieutenant. Command staff includes the Chief of Department, two Deputy Fire Chiefs, one Emergency Medical Supervisor, Fire Prevention Officer and two fire prevention inspectors. Civilian personnel include tow mechanics, one fire alarm supervisor and six dispatchers.

The FFRD responded to 6080 combined EMS and Fire incidents in calendar year 2010. Seventy five percent of those calls were for EMS related causes with the remaining 25% being fire alarms, miscellaneous assistance, and fires (FFRD, 2010). In calendar year 1989, the department responded to 3,296 incidents (FFRD, 1989). 1969 calendar year recorded 1127 incidents to the department (FFRD, 1969). Despite the obvious increase in incidents the department still operates from the same fire station locations. One fire station is staffed by a single firefighter. The same staffing that existed
90 years ago. Another station has 1 person 50% of the time. The interior of the town has no fire rescue station. This area is portioned out to the nearest station located towards the shoreline.

Falmouth’s charm, character and culture are derived from the sea. The community is surrounded on three sides by warm ocean waters. Buzzards Bay, on the western shore of Falmouth is an inverted “V” leading to the Cape Cod Canal. There are also several smaller bays and estuaries that are inverted “V” shapes. These land and water formations present many scenic opportunities for homeowners and visitors. These same inverted “V” embayments also present a potentially deadly hurricane surge zone.

The waters near Falmouth are fed by the Gulf Stream which is a warm water flow fed up the entire east coast of the United States. Warm water is a hurricane feeder hence the areas of the Gulf of Mexico and the eastern seaboard to Cape Cod are especially susceptible to tropical ocean disturbances. Falmouth is located on the southern and western sectors of Cape Cod facing southerly approaching weather such as tropical storms and hurricanes. The far eastern and northern sectors of Cape Cod harbor much colder waters fed from the North Atlantic and Gulf of Maine. These areas also face away from tropical flows therefore these areas are less susceptible to direct hurricane damage.

Hurricanes have been a frequent, albeit unwelcome, weather event throughout history. Since the advent of the FFRD in 1897 there have been 25 hurricanes that have impacted the community. Firefighters from the department have been the major rescuers and responders to emergencies during these weather events. FFRD records and living history have pointed out several significant hurricanes since the mid 1930’s. 1938, 1944, 1954(Carol, Edna, Hazel), 1985 (Gloria), 1991 (Bob) are years that are etched in the town records as significant recent hurricane events. (Book of Falmouth, 1986)
The author has been most impacted by the 1985 Hurricane Gloria, 1991 Hurricane Bob and a most recent “near miss”, for Falmouth at least, Hurricane Irene. As an emergency responder, the author has been directly involved in responding to or planning during the events. Each of these events presented a storm staffing increase at each of the fire stations however no “action plan” or “safety plan” ever emerged.

Hurricane Bob of 1991 nearly cost the lives of six firefighters caught in a storm surge at the New Silver Beach area of North Falmouth. These firefighters responded to a call for a building collapse with a person trapped. The victim in peril was located in a structure 50 feet from Buzzard’s Bay at an elevation of two feet above high tide protected by a three foot seawall. The firefighters drove their large “Brush Breaker” to the scene instead of a smaller fire engine due to downed trees along the route. This vehicle is a tandem axle, six wheel drive, 1000 gallons water tank, overall height of nine feet and a vehicle weight of 45,000 pounds. Personnel did not drive through water to the building in questions. Their initial thoughts and experience were that the hurricane force winds of this Category 2 storm had caused the collapse. (R. Ferreira, Personal Communications March 13, 2012)

Minutes after their arrival they noticed water rising at a moderate pace. The pace was greater than rain could accumulate so they thought perhaps the water was ocean water. Very quickly the water rose to two feet in depth, the firefighters and the victim waded to higher ground. Upon reaching higher ground they looked back to a water level now at four feet and the apparatus was flooded thru the cab and bobbing in the water. They had been nearly caught in the major killer of hurricanes, the storm surge. (R. Ferreira, Personal Communication, March 13, 2012)
The fire personnel had no knowledge of hurricane storm surge. They were not provided with any information or plan to ensure their safety in a storm surge. They wore heavy firefighting protective gear. They had no access to personal floatation devices (PFD) or rescue rope. Flood maps, hurricane plans, PFD’s and rescue rope were available however not distributed to any personnel during this event.

The firefighters narrowly avoided drowning as was the tale of three members of the United States Coast Guard during the 1938 Hurricane. These three men lost their lives in an extreme storm surge in the Woods Hole area of Falmouth attempting to rescue civilians. The civilian perished as well. (Falmouth Enterprise, Sept. 23, 1938)

The 1938 hurricane inundated the Falmouth community, and many other northeastern seaboard communities, with no warning. Citizens were unprepared and did not evacuate. Technology did not exist to accurately forewarn the citizens. Without prior warning there would be no planning or evacuation of shorefront villages. Structures were built to minimum construction codes which did not adequately protect the inhabitants from hurricane winds or surge. Emergency responders were caught by surprise as well.

The 1991 hurricane, Bob, provided accurately forewarning. Flood maps had been developed and structures had been built to resist stronger forces. FEMA and local officials had been enforcing 100 year flood zone building restrictions. Advancements locally and nationally had been made from 1938 to 1991. Yet responders nearly perished through the direct result of lack of planning or preparation. The information did not get down to the level of the responder. One has to wonder whether the average citizen within a storm surge zone is aware of the dangers as well. Hopefully, advancements at all levels will enhance the safety of citizens and first responders 20 years after Hurricane Bob.
This author has attended the Executive Fire Officer Program course of study in Executive Analysis of Fire Service Operations in Emergency Management in December 2011 at United States National Fire Academy located in Emmitsburg, MD. This instruction in disaster management developed the students in such topics as Incident Command, Damage Assessment and Emergency Operations during floods, tornados, earthquakes and hurricanes.

The mission of United States Fire Administration (USFA, 2009) is to “provide national leadership to foster a solid foundation for our fire and emergency service stakeholders in prevention, preparedness and response.” (USFA, 2009) This research directly accomplishes the first three USFA goals of 1) reducing risk at the local level through prevention and mitigation, 2) improve local planning and preparedness and 3) improve the fire and emergency services’ capability for response to and recovery from all hazards (USFA, 2009).

LITERATURE REVIEW

This research project began on returning to the Falmouth Fire Rescue Department from the Executive Analysis of Fire Service Operations in Emergency Management course at the National Fire Academy with one simple question. That question was “Are Falmouth Fire Fighters prepared to operate safely during the next hurricane?” Prior to asking the question to the department personnel this researcher found it necessary to investigate storm surge and its effects on Falmouth.
The genesis of improving firefighter safety in any natural disaster is to gain a basic understanding of how the natural disaster is formed. Emergency responders facing a hurricane need to garner an understanding of the natural characteristics of hurricane development as well as the unique features of the force they are facing. This research work is not designed as an in depth scientific research on hurricanes however an understanding of the characteristics of hurricane activity is required in order to respond effectively.

The Weather Book comprehensively explains hurricanes as well as many other weather phenomena in a “layman’s” format melding science with graphic displays. The term Hurricane is used to describe a weather event involving a warm moist air mass usually originating off of a tropical land mass near the equator. Hurricanes are a weather system name for violent storms effecting North America while the same systems in Asia and South Pacific are called Typhoons and Cyclones. Since this research is directed at emergency personnel in the United States Eastern Seaboard community of Falmouth, MA the main emphasis will be on how hurricanes form and impact this area.

Upper level warm easterly winds drive a moist air mass over the warm waters of a deep tropical ocean waters essentially vacuuming up water from the ocean into the clouds. The ocean water must be 80 degrees Fahrenheit or above to breed the storm and ocean waters throughout the event must be warm as well or the storm will diminish. Seventy degrees Fahrenheit water temperature is the breaking point for storm continuation as a hurricane.

Since ocean water temperatures are required to be warm hurricanes by nature are seasonal events occurring during the months of June thru November. The primary months for hurricanes in the northeastern United States are July, August and September. The
primary warm water ocean current that supplies Atlantic Hurricanes is the Gulf Stream. The Gulf Stream is an ocean current of warm, 70-80 Fahrenheit water streaming up from the Gulf of Mexico around Florida then directly north along the eastern shore of the United States to the southern shore of Cape Cod whereupon the current veers northwesterly into the North Atlantic Ocean.

This warm water vacuum is built, spun and steered by unidirectional upper level winds. The presence of upper level cross winds or cool winds will tend to shear the storm and destroy formation of a hurricane. Glancing upper level winds of the Jet Stream, flowing primarily west to east, will tend to affect storm movement as will the size and location of a high pressure weather zone.

As this weather system moves easterly across the tropical portion of the Atlantic Ocean it builds a large wind zone. Tropical and Extra tropical weather systems, as they are called before they become hurricanes, have winds of between 35 and 74 mile per hour. These winds circulate the storm into a counter clockwise pinwheel shape. Once winds become 74 mile per hour or greater the storm will form a definable “eye” or clear space in the center of the system then a full-fledged hurricane is formed. This hurricane becomes powerful enough to actually “lift” a spinning dome of water from the ocean upward toward the center eye. This dome of seawater creates an area of intense “ripples” of raging seawater around the storm. Once this dome of water reacts with shallower water its intensity increases until it finally contacts a land mass and the force pushes the water inland as a “hurricane storm surge”. This water level is increased as it flows into bays and inlets that form inverted ‘V’ or ‘U’ shapes. These shapes compress the water
volume into a smaller area increase the water pressure and volume. This increases the
damage to property and shorelines as well as increased risk of injury or death danger.

The combination of the 75 MPH counterclockwise winds, the storms forward
motion, intense inner moisture and a moving dome of water are all elements that make
this weather event a grave danger to lives and property near the coast. The winds rip apart
trees and structures while the pounding ocean waves break apart anything near the coast
and the dome of water or “storm surge” floods the coastal areas. These effects are
primarily on the eastern or right side of the eye. The upper right quadrant of the storm is
the most dangerous due centrifugal force. The western, or left side, of the storm can be
equally dangerous as this area dumps huge amount of rain. The wind will rip anywhere in
the storm while the right side floods with ocean water and the left side floods with rain
water.

Prior to the mid 1940’s forecasting and predicting hurricanes was nonexistent.
Astute weather observers would note weather condition and barometric changes when the
storm was occurring around them. No method existed to warn or communicate a warning
to the population effected. Large losses of life were a common occurrence without pre-
warning. With the advent of World War II in the mid 1940’s, weather forecasting and
prediction improved. Loss of life lessened greatly with the advanced warning provided by
weather forecasters and improved communication.

A method was devised to “scale” or “rate” a hurricane to provide increased
guidance to people and building engineers in 1973. The Saffir-Simpson Hurricane Scale
was developed by Herbert Saffir and Robert Simpson. The scale categorizes hurricanes
into 5 levels depending on barometric pressure, wind speeds and storm surge.
1. Category 1  minimal 28.94 mm/hg or greater 74-95 mph winds  4-5 ft. surge

2. Category 2 moderate 28-59-28.91 mm/hg 96-110 mph winds  6-8ft  surge

3. Category 3 extensive  27.91-28.47 mm/hg 111-130 mph winds  9-12ft surge

4. Category 4 extreme  27.17-27.88 mm/hg 131-155 mph wind  13-18ft.surge

5. Category 5 catastrophic less 27.17 mm/hg 155 + mph wind  18+ ft. surge

The term “storm surge” must be understood as thoroughly as the term “hurricane”. The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) is the arm of the federal government that is tasked with researching and predicting weather in the United States. This agency has a dedicated section of weather professionals under the National Hurricane Center (NHC). The NHC website provides in depth understanding of the effects of hurricane storm surge. Storm surge itself is the abnormal rise of ocean water due to the hurricanes forward motion and the pressure. This rise of water varies greatly from storm system to storm system. The depth and shape of the ocean bottom, land geography and distance from the storm’s eye are all factors that forecasters use to develop a computer model of storm surge.

The website also defines several important terms that aid in the understanding of storm surge. The first term to understand is “mean sea level’. Ocean water is constantly moving due to winds, weather pressure systems. The vertical rise and fall of the ocean due to the gravitational relationship between the earth and the moon is called a “tide”. “Normal” high and low tides are constant factors to oceanfront communities. There can also be extremes of tides depending on the proximity of the moon.
“Mean Sea Level” (MSL) is a land measurement delineating the average level of
the ocean water between average low and average high tides. Although MSL is an
average vertical location of the tide meeting the land, NOAA has a few methods of
marking this location. The current global warming phenomena are causing a Sea Level
Rise (SLR) causing a MSL moving target. The National Geodetic Vertical Datum of 1929
(NGVD1929) and North American Vertical datum of 1988 (NAVD1988) are often
scientific survey points used on maps and in mapping of flood and storm surge zones.

Storm surge is forecast from MSL determined from the factors of the intensity of
the hurricane. A hurricane forecast will typically predict a number such as a “five foot
storm surge”. This is five feet above MSL. The important item to factor is the timing of
landfall comparative to the timing of high tide. “Storm Tide” is the most important term
to understand and is often confused with storm surge. Storm tide is the total of the actual
normal tide height for a land area and the storm surge. A storm surge of five feet added to
a two foot high tide above MSL would equate to a seven foot storm tide. However a five
foot surge with a two foot low tide, below MSL, would equate to a three foot storm tide.
The worst case scenario is any storm surge that comes on top of an astronomical high
tide. (APPENDIX A)

Jeffrey Masters, Ph.D. explains storm surge basics in the Weather Underground’s
website. Storm surge is described as the most destructive force of a hurricane not only in
lives lost but in property as well. Moving water from a storm surge can move an
automobile with one foot of rise and six inch rise can sweep a person away. Debris is
often a part of a storm surges moving water causing additional damage and injury.
This article points out that there are three mechanisms of a storm surge. First is the action of winds piling up the water against the shoreline. This action comprises 85% of the surge. A shallow and sloping ocean floor will cause a greater surge than a steep and deep condition. 5-10% of the surge is waves pushing water inland faster than water can drain off. The action of the low pressure within the storm’s eye actually “sucking up” the water accounts for another 5-10%. (Appendix B)

Wind is also a significant factor in hurricane storm surge damage. The pounding action of wind driven waves causes significant additional damage and life loss. Waves increase in height and intensity when their velocity contacts shallow ocean waters such a barrier beach or sandbar.

This research by others provided an understanding of hurricanes and hurricane storm surge and how these natural events develop and impact coastal communities. Significant science has been developed by government and private organizations to enhance hurricane preparedness and save lives.

NOAA National Weather Forecast Office website on New England Hurricane Climatology provides a historical summary of storm events. Certainly hurricanes have been occurring throughout the region for millennia. Native Americans and early European settlers in North America often have referred to “Great Storms” in diaries, lore and ships logs. This NWS report states that from 1900-1997 there were 25 hurricanes to threaten New England. The decade of the 1950’s was the most active with seven hurricanes, three striking in 1954 alone. The1960’s next with six such storms. From 1977 to 1984 there were no storms striking the area.
The months of August and September are the most active months for southern New England hurricanes. Storm Surge history shows that the Hurricane of September 1938 and Hurricane Carol of August 1954 both brought 14 foot storm tides to the Falmouth area.

NOAA Table 10 also produced a document showing the incidence of direct hits on the United States mainland by state and month from 1900-2000. Of importance to Falmouth are direct hits on states to the west of Cape Cod being Rhode Island, Connecticut and New York. This table shows that September is the most active month with New York having four strikes, Connecticut and Rhode Island having two each. August strikes involved only one strike on each state in those years. The region does get hit by hurricanes however on the lower end of the scale.

NOAA’s website also provides an online display of Historical Hurricane Tracks. This site is searchable by location, year and ocean basin with adjustable distance makers. The search for areas within 65 miles west of Falmouth shows a significant history. From 1851 to 2008 there were 16 hurricanes of varying intensity. (APPENDIX C)

The Hurricane of 1938 describes the impact of this unannounced storm on Falmouth. Eyewitness accounts in this text all state they had no knowledge of an impending storm and therefore no time to escape the wrath of this category three storm. The late afternoon of September 21, 1938 brought along a 14 foot storm tide to the Falmouth area. This surge was 11 1/2 feet above the predicted high tide of 2 1/2 feet. “Like Narragansett bay (Rhode Island), Buzzards Bay captured and funneled the storm tides pushing up from the south, and the hurricane struck near high tide.” (Goudsouzian, 2004 p. 30) Two sections of Falmouth sustained loss of life. Five people, including three
rescuers of the United States Coast Guard perished in swift moving storm surges in Woods Hole. Three civilians perished as their home was crushed by waves in the New Silver Beach area of North Falmouth.

The storm’s eye passed over central Long Island, New York. This track placed Falmouth on the outer end of the east or right side of the hurricane. Tides were high at the time of landfall as well. This condition placed Falmouth in the danger zone for high storm surge.

The Town Officers’ Annual report for the town of Falmouth 1938 has “Remarks by the Chief” on the 1938 storm. The Fire Chief states that the storm became apparent around 2 p.m. and that by 3 p.m. all off duty personnel were recalled to duty. One hundred and thirty nine civilians were rescued by firefighters from the storm waters and nine lives were lost.

Falmouth Enterprise of the day recalls local impacts of the storm. The hurricane arrived around 3p.m. just prior to the predicted high tide at 6 p.m. This combined surge and incoming tide increased the hurricane storm surge to 14 feet. Eight lives were lost. One victim was in a stalled vehicle on a barrier beach along the south shore of town. The surge washed the car violently into a nearby pond according to witnesses. Two local estate caretakers were washed out to sea along with three United States Coast Guardsmen during a rescue attempt on a low lying roadway in the Woods Hole portion of Falmouth. Two older civilians were last seen clinging atop the roof of their home in the New Silver Beach area of North Falmouth.

Carol at 50: Remembering Her Fury recalls the August 31, 1954 storm that struck Falmouth with a Category 3 level intensity. This storm was forecast fairly well for the
era. The public was aware that a dangerous storm was approaching however the timing of landfall was off by four hours in some locations. The Falmouth region was in the dangerous right quadrant of this powerful storm. Luckily the storm struck around 8 a.m. on a rising tide. Woods Hole storm surge was 10.1 feet. The funnel shaped Buzzards Bay saw a 14 foot surge. New Silver Beach area of Falmouth saw significant damage.

The text also chronicles the September 11, 1954 storm called “Edna”. The folks of Falmouth were only 10 days into recovery when this storm approached. Landfall came to Martha’s Vineyard with the eye of the storm passing over the Falmouth area. Position of this storm to the center and east of Falmouth and the timing at low tide caused little damage to the community.

Town Officers Annual Report for the Town of Falmouth 1954 documents the actions of the public safety departments of the community. Fire Chief Ray D. Wells recalls in his report that the storm arrived at around 7 a.m. on the morning of August 31, 1954. Five lives were lost, one hundred thirty seven persons were rescued, five fire apparatus were submerged and five firefighters sustained minor injuries. He goes on to note that the community was hit with a lesser storm on September 11 with high winds but no surge. October 15 brought another hurricane threat which positioned Falmouth on the western side of the storm sustaining some high winds and rain. (Falmouth Annual Report, 1954)

Civil Defense Director Victor Friar reported that the “Carol” arrived four hours prior to forecasts. Public Safety personnel who were tasked initially with warning residents to evacuate were instead caught in the storms fury.
Falmouth Enterprise of September 3, 1954 provides a comprehensive reporting of the storms effects on the community. Five civilians perished in the storm surge along the southern barrier beach area of Falmouth. Two women and three children under the age of seven were washed into a nearby estuary by the storm surge. Eyewitness civilians were in the process of forming a “human chain” to reach the group as they made their way through rushing waters from their beachfront home. The rushing waters washed the victims to their deaths before the rescuers could reach them. The victims were all summer visitors unfamiliar with the dangers of a hurricane.

This newspaper also describes infrastructure losses along the shore. Public water supply pipes. Roadway bed and bridges were undermined along the shore.

Hurricane Bob August 16-August 20, 1991 A Brief History chronicles the development, path and destruction of this Category 2 storm along a path up the eastern seaboard of the United States. The storm made landfall around Newport, Rhode Island around 6 p.m. on August 19, 1991 placing Falmouth within 50 miles of the eye on the eastern portion of the system. “Initial survey results and “visual” estimates of high water marks suggest the highest storm surge values occurred in Massachusetts on the east side of the hurricane track, where wind funneled into Buzzards Bay” (Minsinger & Orloff, 1992 p.10) Several measurements plot a surge of nine feet in the western shore of Falmouth and five and three quarters feet in Woods Hole. High tide coincided with the storm’s arrival causing extensive flooding.

Infrastructure damage from the surge was reported to aids to navigation, road beds, bridge protection structures and sewer facilities.
Annual Reports Falmouth Massachusetts 1992 cites multiple reports from town public safety and public works agencies regarding Hurricane Bob. Fire Chief George Packish writes in his report “The rescue of one person from the Tea Room at Silver Beach was conducted at the height of the storm resulting in extreme danger to the rescue crew.” (Falmouth, 1992 p.99) The Chief goes on to report a serious head injury to a firefighter clearing debris after the storm. No lives were lost in the hurricane. Two thousand citizens were sheltered due to evacuation of low lying areas and local waterfront hotels.

Boldt, et.al in Marine Geology (2010) delves into historical storms in the region. The article also graphically displayed the storm surge from Hurricane Bob. The scientific presentation depicts a graphic analysis depicts a 2.5 meter (8-1/4 foot) storm surge and waves in Buzzards Bay region adjacent to North Falmouth area. A one meter (3-1/3 feet) storm surge occurred along the southern shore of Falmouth. (APPENDIX D)

The latest predicted hurricane to potentially impact Falmouth was Hurricane Irene on August 27, 2011 according the website of the National Hurricane Center. This storm was predicted to have enormous impacts on the Falmouth region due to astronomical high tides coinciding with the storms landfall within 50-75 miles to the west of Falmouth. This combination would have had great impacts. The storm however veered greatly to the west, inland, and increased its speed thereby sparing the area. A storm surge of three feet was seen. The overall storm tide affects were minimal as the surge occurred at mid tide, a point relative to mean sea level. Winds were tropical storm force from 35 mph with gusts to 56 mph (hardly the parameters for a hurricane).

The historical perspectives of hurricane storm surge impacts on Falmouth are vital to insuring the safety of the citizens and firefighters. The research and documentation of
others allow the author and readers to understand that these events have occurred and will occur with comparable impacts. Knowing the location and intensity of the impacts from previous experience are key to improving safety. These events are rare and experience among rescue personnel is limited.

The National Oceanic and Atmospheric Administration’s National Hurricane Center has developed several computerized hurricane storm surge models. The NHC website NHC.NOAA.gov describes the Sea, Lake, and Overland Surge from Hurricanes (SLOSH), Maximum Envelopes of Water (MEOW) and Maximum of MEOWs (MOM) as computerized programs that assist in predicting storm surge intensity for coastal locations.

SLOSH estimates storm surge heights and winds for predicted, past and hypothetical hurricanes. The United States coastline has been divided into grids of overlapping “basins” from which computer models are developed using different combinations of hurricane pressure, size, forward speed, track and winds. The models utilize the Geodetic Vertical Datum (NGVD) as a reference to produce storm surge inundation maps in a color coded, full motion computer graphic display.

The maps have a plus or minus 20 percent accuracy due to the unpredictability of natural forces. They also do not include wind driven wave calculations which are programmed separately.
SLOSH models have been created for historical storms i.e. Hurricane of 1938 as well as hypothetical storms to develop predictions of storm surge flood zones. These multiple models of SLOSH in a worst case scenario bring together a MEOW. The NHC has developed MEOW’s for each basin, each storm category, storm direction, forward speed and tide level. The maximum water level for any point of land for all level of hurricanes is the MOM. The models are developed for high tide and MSL for each storm category. These maps are planning tools and are accurate, as models, within two days prior to a hurricane. Within the 48 hour pre-storm window new SLOSH, MEOW and MOMs are developed for actual hurricane factors.

The Federal Emergency Management Agency (FEMA) is agency within the United States Government that is tasked with assisting citizens, first responders; local and state governments prepare, respond and recover from disasters. As part of that mission FEMA has developed flood maps for the entire country. The FEMA website presents free on-line Flood Insurance. The hard copy maps are distributed nationwide to emergency managers, local governments and insurance companies. FEMA also offers FIRMettes which are common paper size maps specific to precise localities also available to print or view on line in a searchable database. Digital FIRMs (DFIRMs) are electronic versions of the larger FIRM maps. FIRMs are used for planning as well as determining properties within flood zones that would require flood insurance. (APPENDIX E)
FIRM utilizes the National Geodetic Vertical datum of 1929 (NGVD1929) as the base reference point for mapping. NGVD1929 elevation points are noted as well as a description of the location of the point using copper plugs, fire hydrants and boulders. Flood elevations are for landward of 0.0 of NGVD1929, the determinate of Mean Sea Level (MSL).

FIRM maps delineate several different flood and non-flood zones. The primary zones of concern are darkly shaded to outline 100 year flood zones and are noted as “A” and numbered “A1-A30” and lettered “AO” or “AH” depending on elevation and flood rating factors. The dark shaded areas are also letter as “V” for velocity zones. Velocity zones are “A” zones that are particularly vulnerable to intense wave action. Lightly shaded portion of the maps determine 500 year flood zones or areas subject to 100 year flooding at less than one foot in depth. These areas are letter as “B” on maps. Non flood prone areas are non-shaded and lettered as “C” on maps.

The United States Army Corps of Engineers (USACE) has developed “worst case scenario” hurricane flood inundation maps for Falmouth based on the SLOSH models. The USACE map on the website depicts three inundation areas labeled “Inundation Area A-B” for different forward speeds, Saffir-Simpson Scale Hurricanes landfall point and astronomical high tide. (APPENDIX F)

Barnstable County Geographical Information Systems (BCGIS) developed a “Risk and Vulnerability Assessment Map Town of Falmouth” at the Cape Cod Commission Coastal Resources website outlining FEMA flood zones “A” and “V” in Falmouth from
SLOSH and FIRM maps. Critical Infrastructures such as hospitals, schools, electric transmission lines, railroads, ferry terminals, public water supplies and bridges are noted on the map. Critical infrastructures within SLOSH zones are highlighted for notice. This mapping project was completed in 2004. (APPENDIX G)

Town of Falmouth Geographical Information Systems has created a “Hurricane Surge Inundation Worst Case Scenario” map as well. This map is available digitally through the Falmouth GIS department on a “request only” basis. The map outlines topographic elevations, churches, public safety facilities, government facilities, hospitals and schools. Hurricane surge inundation is outlined in color for hurricane categories one through four. Mapping is based on SLOSH mapping and does not delineate velocity zones. (APPENDIX H)

The Commonwealth of Massachusetts Office of Coastal Zone Management Coastal Hazards Commission May 8, 2006 meeting summary addressed the issue of Sea Level Rise (SLR) due to global warming as an impact on coastal zones as well as hurricane flood inundation. A presentation by Jeff Williams, of United States Geological Survey (USGS), on the “Potential Impacts of Sea Level Rise on the Coast” was summarized. Mr. Williams states that “according to tide gauges, sea level has risen 26 cm (10.23 inches) in the last 100 years.” (Commonwealth of Massachusetts, 2006 p.1)

Robert J. Nicholls and Anny Cazenave in Science (June 2010) researched SLR from 1850 to 2009 and calculated projections for future SLR in the 21st century. The trend for SLR of MSL from 1993-2009 was 3.26 millimeters per year. This equates to a two inch SLR over a 16 year period. Nicholls and Cazenave predict a potential 10 millimeter (.40 inch) rise in SLR by 2050 and 20 millimeters (.787 inch) by 2100.
Storm surge mapping and computer modeling in multiple forms is important to comprehend the areas of greatest impact and danger zones. Scientific computer modeling for predicted storms allows residents to acquire knowledge in order to make evacuation and property protection decisions. Rescue personnel also need to be keenly aware of maps and models to assist in pre-planning rescue missions and adequate safety procedures.

The Town of Falmouth Census reports a population of 31,531. Housing units total 20,055. Slightly more than 30% of the housing is listed as ‘vacant’ due to the stock of seasonal housing units. Historical populations at historical hurricanes strikes to the community were 27,960 in 1990, 8662 in 1950 and 6,878 in 1940.

Town of Falmouth GIS maps are available on line at the Town of Falmouth public website. These maps highlight dwelling units and topographic mapping. Locations and total housing within surge zones can be researched accurately from this site.

SurgingSeas.org provides and interactive “Sea Level Rise and Coastal Flood Risk” maps for coastal areas of the United States. These maps are based on the National Elevation Dataset from the USGS merged with 2010 U.S. Census data. The data provided is calculated from Mean High Tide (MHT) from North American Vertical Datum of 1988 (NAVD1988). Coastal areas can be searched via “zip code” entry to accurate geographic zones. Maps are fully “pan-able” and allow “zoom” and satellite imagery. The website will also provide a spreadsheet for each zip code delineating “Elevation above local mean high tide” with values from 1 foot to 10 feet. Population below elevations, percentage of population below elevation, housing units below elevation and percentage of housing units below elevation at separately calculated.
The Fire Protection Handbook Vol. II by the National Fire Protection Association delves into critical infrastructure as it pertains to disaster management in “Disaster Planning and Response Services”. “The purpose of identifying critical facilities and infrastructure is to prioritize and identify those critical facilities, lifelines, or resources within a community that are essential to protect and ensure limited interruption in services.” (NFPA, 2008 p.12-205) Facilities that are specifically noted to be categorized include fire-rescue, police, communications, transportation, utilities, government, hospitals, shelters, nursing homes, pump stations and evacuation routes.

The National Incident Management System text from the U.S. Department of Homeland Security features Homeland Security Presidential Directive 7 (HSPD7). This directive authorized the Department of Homeland Security to work with federal, state, tribal and local entities to identify and prioritize critical infrastructure and key resources throughout the nation. The National Infrastructure Protection Plan (NIPP) is developed from this effort.

This author’s attendance at the “Executive Analysis of Fire Service Operations in Emergency Management” in December of 2011 provided further information on the importance of critical infrastructure identification prior to a natural or man-made disaster. The facilities are those that are necessary for day to day basic services for the community to function. Sites are categorized by content, occupancy and purpose. Content sites would be those that involve hazardous materials, large consumer occupancies, warehouses. Occupancy sites would involve those that contain a high resident volume, public assembly and those sites with special needs or injured civilians. Purpose sites involve locations that provide the basic utilities, vital transportation and government sites.
Research by others calculating populations affected, dwelling and critical infrastructure is highly important in pre-identifying risk. Local knowledge is important however scientific research and computer mapping can reveal locations not within a knowledge base and support local knowledge. Evacuation of population pre-storm is vital to saving lives. Locating and identifying structures prior to any level storm will enhance damage assessments and disaster aid. Critical infrastructure, within surge zones, need to be located and identified in order to mitigate hazards and restore the community back to normal.

In 2010 the Massachusetts Coastal Zone Management Agency (CZM, 2010) conducted a survey of Falmouth residents from August 30, 2010 to November 3, 2010 via the town website and paper surveys located in public occupancies. The purpose of this survey was to obtain the public’s input to “identify vulnerabilities and prioritize actions to minimize damages from flooding and other natural hazards.” The survey asked 12 questions about the respondents village of residence, natural disaster experience, personal concerns about local impacts, highest threat perceived to their neighborhood, second highest threat, highest threat to the town as a whole, personal acquisition of flood insurance, personal actions to harden home against threats, actions the community can do to reduce risk, level of importance of potential community actions, best way to receive information and other thoughts and ideas.

The works of others in obtaining the public perception and knowledge in regards to natural disasters is important as a ‘barometer’ to view where they are at and where the disaster managers need to go in order to gain a greater degree of safety for the community.
PROCEDURES

The process for this research actually began the day after Hurricane Bob in 1991. This category two hurricane had been the first significant storm since 1954 to provoke substantial damage to the community of Falmouth. The day after the event, firefighters of the FFRD were sharing tales of peril during the storm. Many harrowing tales of dangerous close encounters with death or injury were told. One firefighter sustained a serious head injury while clearing a storm damaged tree. Six firefighters had a close encounter with a storm surge. This author began to wonder if there was any method to properly prepare personnel for the next hurricane.

This author attended the National Fire Academy Executive Analysis of Fire Service Operation in Emergency Management during December 12-23, 2011. This course of study exposed students to an intense course of study addressing natural and man-made disasters. Several scenarios involved hurricane preparation, response and mitigation. Federal and private resources for hurricane forecasting and modeling were discussed. A plan was developed to move forward with researching hurricane storm surge and its effects on the community of Falmouth, MA.

This author conducted an interview with Firefighter Russell Ferreira specific to the rescue of a civilian at New Silver Beach. The interview was conducted at the North Falmouth Fire Station on March 13, 2012. F/F Ferreira was a member of the responding crew. The questions asked were simple open ended questions. “Could you tell me about your experience in Hurricane Bob at New Silver Beach?”
Many hours at the Falmouth Public Library were spent gleaning information from multiple books, microfilm, and science publications. Initially an understanding of the development and characteristics of weather and hurricanes had to me researched to gain a base understanding of the natural force. Characteristics that directly make Falmouth, MA vulnerable to particular hurricanes had to be researched from multiple weather related resources.

Local annual town reports of the Town of Falmouth from years that featured a hurricane landfall were read. Reports from highway, civil defense, fire department, police department and beach departments were mined for information on response, injuries, deaths, damage and other local effects. Microfilm of the local ‘Falmouth Enterprise” pertaining to significant hurricane strikes were researched extensively.

Extensive on-line research was accomplished. This avenue of research provided a treasure trove of current information and scientific resources. Current scientific research is being developed at a fantastic rate due to the ever increasing sophistication of computerized data collection. Information sharing and the accuracy of that information are greatly enhanced with on-line resources. Instant access to historical storm surges utilizing graphical displays were compared and contrasted with contemporary displays from the National Weather Service.

Multiple Geographical Information Systems (GIS) maps from various sources were compared and contrasted for storm surge values. Town of Falmouth GIS, Barnstable County’s Cape Cod Commission, Massachusetts Coastal Zone Management, US Army Corps of Engineers, FEMA and SurgingSeas.org all provided digitized mapping of Falmouth, MA hurricane storm and flood zones utilized in this research.
GIS mapping also was research intensively to provide the ability to hand count dwellings, located population centers and assess locations of critical infrastructure. Limitations were encountered with the Falmouth and Cape Cod Commission GIS department. Initially this researcher understood that computer analysis of GIS storm surge zones could calculate and list population, dwelling and critical infrastructure. Personnel in these departments were initially cooperative however upon a secondary contact each was non cooperative in following through. No particular reason was given. The author had to resort to hand counting of houses and infrastructure utilizing GIS as well as windshield surveys. Surge Zones for a worst case scenario category 3 hurricane were the parameters for this count using Town of Falmouth GIS surge zone maps.

Populations were estimated from dwelling unit counts using Town of Falmouth Census population per dwelling average of 2.2 persons per unit. Since the Falmouth Census counts only year round residents, seasonal population estimates from various sources including Falmouth Chamber of Commerce were used. Seasonal homes during the summer season in Falmouth may be vacant or may house upwards of 10 or more persons on vacation making a definitive count impossible.

The author conducted a verbal survey of a representative sampling of businesses located in flood zones. This section was made easier by the fact that there are not many businesses on Falmouth in surge zones. The business survey was accomplished verbally by the author with management from the Seacrest Resort in North Falmouth, Inn Season Resorts for their location in Falmouth Harbor and East Falmouth, The Woods Hole Market, Woods Hole Oceanographic Institution and Marine Biological Laboratory and National Oceanic and Atmospheric Administration field office all in Woods Hole Ma.,
and Green Harbor Boatyard’s two locations in East Falmouth, MA. The survey was precise to pinpoint knowledge of their location in a storm surge zone and knowledge of the effects of storm surge.

These surveys were at-site visits with management staff during the week of March 6-10, 2012. The Closed End questions of “Are you aware of your businesses location in a hurricane storm surge zone?” and “Has your business been impacted by storm surge?” The businesses were chosen due to their location within designated flood zones. The purpose of the survey was to gain a representative sample of awareness and experience with hurricane storm surge.

Similar questions were asked of a sampling of 25 residents in various flood prone areas of Falmouth during the same week. The purpose was the same as well.

The author also conducted an on-line survey utilizing “Survey Monkey” computer program to address firefighter knowledge and experience with hurricane storm surge. The survey link was emailed to all members of the Falmouth, MA Fire Rescue Department. These participants would be the prime emergency responders to emergencies during hurricanes. Thirty two of eighty possible participants responded from May 9, 2012 to May 20, 2012. All thirty two completed one hundred percent of the survey. FFRD are the lead agency in the community tasked and trained for rescue operations therefore their input would be important. The survey gauged firefighter awareness of surge zones, effects on emergency operations, experience in hurricane emergency operations and life risk during hurricane surge rescue operations.
Four Closed-Ended questions were asked to force a direct answer either yes or no or very aware/somewhat aware/not aware at all.

Question 1: Are you aware of Hurricane Storm surge zones in Falmouth?

Question 2: Are you aware of the effects of hurricane storm surge on fire rescue emergency operations?

Question 3: Have you operated as a member of the FFRD during an actual hurricane?

Question 4: Would you risk your life in an attempt to save another person in grave danger during a hurricane? (APPENDIX I)

RESULTS

Hurricanes have impacted Falmouth for thousands of years. Documentation of “Great Storms” and Native American Lore has been part of the history of the region. The major emphasis of this portion of the research is to determine the documented impacts of storm surge of the 20th century in order to better understand the impacts that may occur in the 21st century.

RESEARCH QUESTION #1 What are the historical impacts of hurricane storm surge on life and property in Falmouth?

Falmouth’s greatest hurricane impact is storm surge due to the community’s south facing coastal location. Hurricanes produce greater storm surge, elevations in ocean water level greater than normal tidal levels due to internal hurricane pressures, on the upper right quadrant of the system. Three storms that reached historic levels were researched
they are by no means the only hurricanes to impact the area however they are the storms with the greatest historical impacts.

Falmouth is historically impacted by hurricanes that track to the west of the community in the area of Rhode Island and Long Island, New York. The Hurricane of 1938, Hurricane Carol in 1954 and Hurricane Bob in 1991 all tracked to the west of Falmouth. All three occurred from mid-August to mid-September, historically a period where Falmouth waters are warmest. It is also a period of greatest population density due to the community’s designation as a tourist destination.

Two other major factors in historical impacts are timing and condition of tidal flow and natural land formations. The greatest impacts have occurred when the storm made landfall at or near high tide and or astronomical high tides. Impacts are far less when a hurricane arrives at low tide. Tracking is important but so is the tide condition upon landfall.

Natural land formations of Falmouth contribute to increased storm surge effects. The area has a shallow sloping ocean bottom which increases the buildup of storm tides. Beachfront areas along the southern shore of Falmouth are particularly vulnerable to this effect. Falmouth also has multiple natural bays where water is ‘funneled’ or compressed resulting in an increased height of water at the apex of the bays. This effect is known as a ‘velocity zone’. Buzzards Bay on the western shore of Falmouth is a prime example. Damage in locations facing this bay has been greater than elsewhere.

The 1938 hurricane arrived with no pre-warning systems. The storm has been rated as a category three according to Saffir-Simpson Hurricane rating scale capable of a 12 foot
surge on top of high tide. Residents of Falmouth were aware of rough weather but were completely unaware of the intensity of the system. Eight deaths were the result. Three were United States Coast Guardsmen attempting to rescue two civilians in an exposed section of Woods Hole. Three lives were lost in the New Silver Beach section of North Falmouth. Both areas are velocity zones. Damage was extensive to roadways, bridges, shorefront structures and government infrastructure. Documented high water levels were 14 feet in Buzzards Bay.

The 1954 hurricane did arrive with some pre-warning due to advancements in weather forecasting the result of World War II. This storm was a category three as well, capable of a 12 foot surge on top of high tide. The residents were aware an intense hurricane was arriving however landfall prediction was four hours to late. Residents were making evacuation movements when the surge arrived. Five lives were lost in the south facing, low lying area of Falmouth known as Menahaunt. Damage was extensive throughout the community. High water levels were documented at 14 feet causing damage to roadways, water distribution systems, bridges, waterfront structures and government facilities. (APPENDIX J)

The 1991 hurricane of August rated as a marginal Category two storm that also coincided with high tide and landfall to the west of Falmouth. This storm resulted in zero fatalities. A fire rescue crew in the process of rescuing a civilian was caught in a storm surge however they were able to escape danger. The storm tide ranged from 6-12 feet causing damage to a few ocean front homes, minor roadway damage and little infrastructure damage.
The interview with F/F Russell Ferreira delved into his experiences with rescue operations during Hurricane Bob. He related that the crew responded to a reported building collapse at the “Tea Room”. This structure is 30 feet from the ocean at an elevation of approximately two feet above MSL. The crew drove a 40,000 pound, six wheel drive brush breaker to the scene due to downed trees. Upon arrival they saw a two story building with some collapse damage and one victim on the second level who was unharmed. No standing water was in the roadway. They were unsure what caused the collapse focusing instead on the victim and the wind.

Within five minutes on scene the crew noticed water rising steadily at their location near the structure. All were unsure what was occurring except that they needed to rescue the person and head to higher ground. The victim was removed, the crew headed to higher ground as the water rose within five minutes to a level of approximately five feet reaching upper chest level as they were retreating. The fire apparatus was seen floating in the water with water up to the tall vehicle’s cab doors.

F/F Ferreira stated that neither he nor any member of his crew were prepared in any way for the rising water. There was no information concerning hurricane storm surge effects. The crew did not know the building collapse was actually due to a previous surge. The also did not know that they were in an area that might be vulnerable to storm surge although the location was very near the ocean. They were not provided with floatation gear nor did they have a safety plan. (R. Ferreira, Personal Communications March 13, 2012)
RESEARCH QUESTION #2 What are the predicted impacts of hurricane storm surge on Falmouth?

Predicted storm surge impacts are heavily researched and reported due to enhanced computer technology. The National Hurricane Center, Army Corps of Engineers, Federal Emergency Management Agency and private science entities have each contributed to surge and flood mapping. Graphic computer models have been developed for multiple scenarios particular to Falmouth’s geography.

The greatest predicted storm surge for Falmouth is modeled to occur in the western shores particular in the more northern reaches of Buzzards Bay. This is directly due to the reverse “V” shape of the bay. These areas can see a 14 foot rise in sea level. This would equate to a 100 year flood zone. The southern shore of Falmouth is protected by the Martha’s Vineyard land mass to the south which lessens wave action from the storm. Storm surge is a threat due to the area’s low elevation however the waters are not funneled or compressed.

Sea level rise due to global warming is a concern for the future of storm surge. Research has confirmed a ten inch rise in the waters around Falmouth over the previous 100 years. Future projections from various scientific organizations predict that rate will double over the next 100 years. This will require extensive remapping due to varying mean sea level delineations.

RESEARCH QUESTION #3 What is the population census within the hurricane storm surge zone in Falmouth?

Population census and tracking within hurricane storm surge zones provides a basis for evacuation and response planning. The largest population center at risk for a
category three surge is the upper western shore of Falmouth in the areas of North Falmouth called New Silver Beach, Bay Shores and Megansett. The citizens are in a low lying area within a velocity zone of Buzzards Bay. An estimated 996 citizens reside in 453 dwellings. 300 of these dwellings are within the New Silver Beach velocity zone. (APPENDIX K)

SurgingSeas.org data was compared and contrasted to test the hand count. This data set was far less than the hand count. Upon further examination of the SurgingSeas.org mapping this author found large areas not signified as flood zones in this dataset. SurgingSea.org disclaimers state that perhaps the cause of this discrepancy is the elevation of this area is at or near high tide level and would not be mapped. All other GIS maps utilized MSL to determine surge zones.

The southern shore of Falmouth Center facing Martha’s Vineyard was the second highest at risk area. This area contains approximately 318 dwellings and 699 inhabitants. The majority concentrated along the Surf Drive area. The third center is located in the East Falmouth villages of Maravista, Acapesket and Menahaunt. These villages are all south facing shorefront locations. Approximately 525 citizens dwell in 240 homes. The highest concentrations of homes are in the areas abutting Great Pond being Maravista and Acapesket with 131 dwellings. (APPENDIX L)

SurgingSeas.org data was off significantly for the Falmouth Center surge area due to the same disclaimer of measurement from high tide. The mapping and data for the east Falmouth areas was more accurate.

All three of these areas have been historic “death zones” in the 38 and 54 storms.
West Falmouth, along the western shore was the fourth largest surge zone census with 98 dwellings housing an estimated 215 residents. The fifth largest residential location in the surge zone is the Woods Hole section of Falmouth. This area comprises 46 dwellings in the surge zone with an estimated 101 residents. This area saw five people, including three Coast Guardsmen, perish in the 1938 Hurricane. Lastly the East Falmouth area of Seacoast Shores comprises 30 dwellings in the surge zone in that area housing approximately 66 residents.

RESEARCH QUESTION #5 What Critical Infrastructures are located in the hurricane storm surge zone?

Critical Infrastructure analysis of the Town of Falmouth “Worst Case Scenario Surge” compared with on-line Town of Falmouth GIS and windshield surveys yielded important data. The New Silver Beach area recently converted to municipal sewerage. Frequent flooding at astronomical high tides had resulted in a health hazard. The systems pump house is elevated above surge height and the treatment center is outside the zone. However the individual home systems and pipes in the ground would be impacted.

Municipal Sewer infrastructure exists in the Woods Hole and Falmouth Center areas within the surge zones. Pump structures are located below ground in both locations and would be inundated with storm water. Significant miles of sewer pipes are buried in sand beds along the shorefront and are vulnerable to washout.

There are six bridges within Falmouth storm surge zones. None are vital to transportation for the community. There are alternative road networks to the areas served by the bridges. The same situation exists for the roadways within the storm surge zones.
The Steamship Authority, a vital Massachusetts ferry transportation system to Martha’s Vineyard, is within the storm surge zone of Woods Hole. Destruction and damage to this facility would impact a transportation lifeline to the island.

The United States Coast Guard operates a base command in Woods Hole. This facility is within the surge zone of Woods Hole. Damage and destruction would impact vital ocean rescue and homeland security missions.

Several research structures are located in Woods Hole, MA within the storm surge zone. Although these building are multi story their fuel and power supplies as well as lower levels would be inundated.

No critical municipal water system piping is within the surge zone. Some pipes may be exposed or fractured by erosion they would only compromise small areas. Other critical infrastructures such as police, fire, hospital, town government, electrical transmission lines and hurricane evacuation routes are outside the storm surge zones.

RESEARCH QUESTION #6 Are the effected population and businesses within the storm surge zone aware of their location?

The sampling survey of nine businesses within the storm surge zone produced similar responses. All of the respondents were aware of their locations as being vulnerable to severe storms. All had been impacted by Hurricane Bob in 1991. Prior storms were beyond the experience of the respondents.

The sampling survey of 25 residents at various locations throughout storm surge areas of Falmouth produced similar results as well. All were aware that their dwelling
was located in a vulnerable location. All had to have flood insurance which enhances their awareness. All had been impacted by some flooding from Hurricane Bob in 1991. The general experience was “some water” but none had to evacuate. Again, prior hurricanes were beyond the experience of the respondents. This survey mirrored the results of the Massachusetts CZM survey.

RESEARCH QUESTION #7 and #8 Are Falmouth Fire Rescue Department personnel aware of Falmouth’s storm surge zone? Are Falmouth Fire Rescue Department personnel aware of the effects of storm surge on emergency operations during a hurricane?

The survey of FFRD personnel produced useful results. Most of the personnel were “somewhat aware” of storm surge zones in Falmouth. An even distribution of personnel were “very aware” of the effects of surge on emergency operations as were either “somewhat aware” or “not aware at all”. A large percentage of personnel expressed that they had operated as a responder during a hurricane. A large percentage also expressed that they would risk their lives to save another person in danger during a hurricane. (APPENDIX I)

DISCUSSION

The impacts of hurricane storm surge are a fact of life for coastal communities up and down the east coast and Gulf of Mexico regions of the United States. These storms have been forming for millennia and will continue. Falmouth is no stranger to hurricane strikes and near misses. The community is particularly vulnerable due to its location jutting out into the Atlantic ocean, facing south-southwest and being close to the Gulf Stream. The unique geographic particulars of Falmouth also enhance the storm surge.
Forecasting and preparation are keys to limiting loss of life and damage to structures and critical infrastructure. Falmouth residents have to be wary during August and September for the potential of hurricanes. Particular caution is for those storms that track to the west along Rhode Island and Long Island, NY. coinciding with high or astronomical high tides. Historical impacts are direct indicators of future impacts. The Category three and two storms studied here directly correlate to predicted storm surge models. The mapping exists, the flood maps exist and the precise computer modeling technology exist to predict where, when and how the storm surge will hit.

One factor that will affect future storm surges is Sea Level Rise due to global warming. Historical scientific measurements have gauged SLR at ten inches over the last 100 years. That equates to approximately seven inches since 1938 and approximately five inches since 1954. In fact many mean sea level measurement have been calculated from NGVD1929 reference points. Even the NGVD1988 measurements are inaccurate if the current science of SLR is correct. The current science calculates a doubling of the previous rate for the next 100 years due to the increased melting rate of glaciers.

Falmouth is highly vulnerable in the New Silver Beach area. This area is densely populated during the hurricane season with summer residents. Many of these homes are not built to modern construction standards. Nearly 1000 residents live in the velocity surge zone during the summer. This area has seen the worst of the category two and three storm surges. Each significant storm has produced damage and taken lives. Many more homes exist today than existed in 1938 and 1954 in this area. The newer homes may be built to better standards however there have not been any category three hurricanes since 1954 to test the construction.
The other highly vulnerable area is along the entire south facing coast of Falmouth from Nobska Point to Waquoit Bay. The villages of Falmouth Center and Menahuant are within this zone. This area is very low in elevation with extensive barrier beach areas. Approximately 1228 people reside along this stretch of land. Several lives were lost along this area during the 1938 and 1954 storms. This is not a velocity zone and is somewhat protected by Martha’s Vineyard.

Highly critical infrastructure does not exist within the predicted hurricane surge zones. Neighborhood sewer pump stations and distribution lines are in these areas however the treatment and transport infrastructure is located elsewhere. Bridges do span rivers prone to storm surge and have been impacted by historical storm surges. These structures are not vital to the community and there are alternate means of access to most of the areas. Roadways would be impacted however no vital roads exist in Falmouth’s storm surge zones. These roadways have been highly damaged in the past and repaired in time.

The ferry service to Martha’s Vineyard from Woods Hole is in the surge zone. This facility could be damaged in a category three storm. As a regular course of action the ships are relocated to a protected shipyard in the event of a storm. This would directly impact Martha’s Vineyard however not Falmouth directly.

The homeowners and businesses seem to be highly aware of their location within the storm surge zones. This is an encouraging sign considering that the last large storm was 55 years ago. This author believes that FEMA flood insurance mandates and private insurance companies are mostly to applaud for this positive sign. The prime issue of
concern is that the current owners have no experience with a large storm. Yes they know that are close to the water and know about hurricane however their experience base is with smaller tropical storms and category one hurricanes. This experience may foster a false sense of security as to the impacts of significant surge and hinder a decision to evacuate.

Falmouth has grown immensely since 1938 and 1954 and even 1991. Houses once dotted the shoreline now they are packed one on top of another. Older native residents that had experienced hurricanes had passed on or moved away. Newcomers have set up homes in nearly every corner of the community. Waterfront and water view properties line the coast. Each resident and each structure untested by a severe hurricane.

Falmouth Fire Rescue Personnel have always been at the forefront of rescue and evacuation operations during hurricanes. Hundreds of successful rescues were made in the 1938 and 1954 hurricanes. Numerous references in town reports are made of fire vehicles stuck in high water and sand during storms, human chains being formed to rescue civilians and post hurricane victim searches of waterways. Three Coast Guardsmen drowned in 1939 attempting to rescue civilians. One would think that these men would be experienced and skilled in water rescue however the opposite was true. These men had no protective gear and had no experience with tidal surge; none of them were from coastal areas. Bravery came at a high cost.

Fifty three years later history nearly repeated itself. A crew of six firefighters was caught in a storm surge attempting to rescue a civilian in 1991. The interview with Firefighter Russell Ferreira details a harrowing tale. The crew had no knowledge of storm surge, did not know they were in a vulnerable area and certainly did not have personal
floatation devices (PFD) or even ropes. None of them had experience with intense storms. None had been on the force in 1954 or 1938. Bravery once again could have come at a high cost.

It is clear that the last major category three hurricane to effect Falmouth with a westerly track and high tide landfall was 1954. Fifty eight years have passed with no major impacts. Hurricane Bob in 1991 was a low category two, even perhaps a low category one storm. It did arrive on a high tide and did take a westerly track. A storm surge of approximately six feet did impact the community. Twenty one years have passed since this storm. In late August 2011, Hurricane Irene threatened to be the “big one” arriving on an astronomical high tide. The storm veered too far westward and too early to impact Falmouth to a great degree. The storm arrived in Falmouth with only tropical storm force winds and very little storm surge. This was the latest “experience” for the resident of Falmouth and the members of the Falmouth Fire Rescue Department.

The survey of department members revealed some interesting insight into the knowledge and experience base of the rescuers. 56% stated that they feel they are “somewhat aware” of storm surge zones on Falmouth. 28.1% feel they are “very aware” and 15.6% of the respondents to the survey felt they were “not aware”. Nearly 72% are somewhat or not aware at all of what areas of Falmouth are prone to hurricane storm surge.

Regarding awareness of the effects of hurricane storm surge on fire/rescue emergency operations only 50% felt they were very aware. These two questions show that the rescue personnel not only do not know where they can be caught in a hurricane surge but they are not fully aware of the effects of storm surge on their rescue operations.
As to the question gauging the experience level of personnel in operating during a hurricane fully 75% felt they had fire/rescue experience in a hurricane. This number is only 32 respondents out of 80 personnel. This survey did not separate out years of experience with this answer so it is impossible to correlate years of service with this question. It is however interesting to note that the last hurricane of significance was in 1991. The storm was a minimal hurricane. There are currently only 24 department personnel out of 80 that were employed in the FFRD in 1991. That is only 30% of the current personnel with potential experience during a minimal hurricane. This author speculates that the recent experience of Tropical Storm Irene has been a decision factor for those personnel selecting ‘yes’ in this response.

Finally and perhaps most importantly is survey question number four “Would you risk your life in an attempt to save another person in grave danger during a hurricane?” 90.6% of the respondents stated “yes” they would risk there life to save another in a storm surge. This is just a bare question without asking if you were properly trained, properly equipped and so on. (FFRD Survey, APPENDIX I)

Clearly, the majority of the respondents feel they have enough fire/rescue experience during a hurricane to risk their lives saving others although they feel they do not know where the storm surge zones are or how it will impact how they do their job. They feel they have experience and they will jump into rushing water to save someone although they have never seen a storm surge or major hurricane.

The author asks himself, is this 1938, 1954, 1991 or 2012? Bravery once again could come with a high cost. It is important not to lose any lives in the coming hurricanes.
RECOMMENDATIONS

1. The Falmouth Fire Rescue Department should train all members in hurricane operations. The following topics should be covered as part of a comprehensive hurricane training program.

   a. Historical storms and areas of damage and loss of life

   b. Contemporary storm surge mapping resources and hurricane prediction resources.

   c. Locations in the community that are prone to storm surge

   d. Look outs, Communications, Escape, Safety Zone (LCES) type safety planning for these areas

   e. Swift water rescue

2. The Falmouth Fire Rescue Department should position itself to be the lead agency in hurricane preparedness for the community. The following topics should be covered as part of a comprehensive community program:

   a. Planning pre-hurricane evacuation systems

   b. Public information for residents, businesses and seasonal guests

   c. Structure and infrastructure protection planning
REFERENCES


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Hurricane Storm Surge Graph showing Mean Sea Level to Storm Tide
APPENDIX B

Hurricane Anatomy Showing Storm Surge Values

Wind and Pressure Components of Hurricane Storm Surge

- Storm motion
- Wind-driven Surge
- Pressure-driven Surge (5% of total)

Water on ocean-side flows away without raising sea level much
As water approaches land it “piles up” creating storm surge

©The COMET Program
NOAA Total Historical Hurricane Tracks 1910-2010 65 Nautical Miles from Rhode Island
Storms to the West of Circle Effect Falmouth with Storm Surge Dependent on Tide Height
Falmouth Highlighted in White Circle
NOAA Storm Surge Graphic Depicting Actual Storm Surge for Hurricane Bob 8/91

Top Graphic---Maximum Surge of 2.5 Meters in Upper Buzzards Bay
Bottom Graphic ---Maximum Wave Height 8 Meters along South Shore of Falmouth

Greater Surge in Buzzards Bay w/o High Wave Heights, South Shore had Higher Waves w/ Less Surge
APPENDIX E

FEMA Flood Insurance Rate Map (FIRM) for New Silver Beach Area

Dark Shade is 100 year Flood Zone, light Shade is 500 year flood --Note “V” zones
APPENDIX F

United States Army Corps of Engineers Hurricane Inundation Map: Falmouth, MA  12/94

Dark Shade = Cat 1 & 2 Hurricane Surge   Light Blue=3 & 4 Hurricane Surge
Cape Cod Commission Risk and Vulnerability Assessment Map Town of Falmouth, MA

Medium Blue Shade areas denote Storm Surge Velocity Zones

Upper Left of Map locates New Silver Beach   Bottom Locates South Facing Shore
APPENDIX H

Town of Falmouth GIS Storm Surge Map

Upper left is New Silver Beach Area        Bottom is South Facing Shoreline
FFRD STORM SURGE SURVEY

SurveyMonkey - Survey Results

Firefighter Safety during Hurricane Storm Surge

1. Are you aware of Hurricane Storm Surge zones in Falmouth?
   - Very Aware: 28.1% (9 responses)
   - Somewhat Aware: 54.3% (18 responses)
   - Not Aware: 15.6% (5 responses)

2. Are you aware of the effects of hurricane storm surge on fire/rescue emergency operations?
   - Very Aware: 50.0% (16 responses)
   - Somewhat aware: 43.8% (14 responses)
   - Not aware at all: 6.2% (2 responses)

3. Have you operated as a member of the FFRD during an actual Hurricane?
   - Yes: 75.0% (34 responses)
   - No: 25.0% (8 responses)

Total Started Survey: 32
Total Completed Survey: 32 (100%)

http://www.surveymonkey.com/MySurvey_Responses.aspx?sm=70LE8AbbxyhDY8hF1... 5/20/2012
SurveyMonkey - Survey Results

3. Have you operated as a member of the FFRD during an actual hurricane?

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4. Would you risk your life in an attempt to save another person in grave danger during a hurricane?

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</table>

| Answered question | 32 |
| Skipped question  | 0  |
APPENDIX J

Damage in New Silver Beach from Hurricane Carol 1954
New Silver Beach (Rock St.) Hurricane Storm Surge Map: Falmouth GIS

Light Green=Cat 1 Dark Green=Cat 2 Yellow=Cat 3 Red=Cat 4 Storm
APPENDIX L

Depiction of Surge Effect on Housing at Falmouth South Facing Shoreline area of Menahaunt

6 foot Surge was realized from Cat 1 Hurricane Bob in 1991