

Model Bylaw

For

Effectively Managing Coastal Floodplain Development

Woods Hole Sea Grant **Cape Cod Commission** **University of Hawaii Sea Grant**

Preface

The creation of this bylaw has been a cooperative effort of the Woods Hole Sea Grant Program at the Woods Hole Oceanographic Institute, Woods Hole Massachusetts; the Cape Cod Commission, Barnstable Massachusetts; the University of Hawaii Sea Grant College Program, Oahu, HI; and the Cape Cod Cooperative Extension, Barnstable Massachusetts.

The project authors, James F. O'Connell, Coastal Processes Specialist with the University of Hawaii Sea Grant College Program on Kauai, HI (began the project while with the Woods Hole Sea Grant Program and the Cape Cod Cooperative Extension, Massachusetts), and Stacey Justus, formerly the Coastal Resources Specialist with the Cape Cod Commission, Barnstable, Massachusetts, set out to develop a scientifically sound coastal floodplain regulation in order to advance the protection of the natural and beneficial functions of the shoreline and coastal floodplain, while facilitating appropriate uses of public and private property located within the coastal floodplain. The Model Coastal Floodplain District Bylaw presented herein is grounded in sound floodplain management and coastal processes science, as well as land use and regulatory planning as it relates to floodplain management and regulation.

The initial roots of this model coastal floodplain bylaw began in 1998 when the Cape Cod Commission (a department of Barnstable County and a state regional planning agency governing regional development practices in the 15 coastal communities of Cape Cod, Massachusetts) developed a model floodplain district bylaw. Many of the standards promoted in that early model bylaw were generated by the Massachusetts Coastal Floodplain Task Force, a group of public and private coastal resource managers, private consultants and coastal scientists, which was initiated and chaired by James F. O'Connell, co-author of this project. The Task Force released *Scientific Recommendations for Performance Standards for Land Subject to Coastal Storm Flowage*, 1995. However, since the development of the Commission's 1998 model bylaw many precedent-setting floodplain cases have been decided by the courts, as well as additional research conducted relating to the importance of the physical function of the coastal floodplain, including predicted impacts as a result of relative sea-level rise. New legal and technical understanding of floodplain management necessitated the need to fully revisit that model. Additionally, there is a need to construct a model that could be consulted nationally.

This report provides scientific and technical information, incorporated into specific bylaw language, to consider implementing many progressive coastal floodplain management practices.

The value of this report will ultimately lie in the adoption of local floodplain bylaws and the hope that this product will assist communities in the development of a regional or local bylaw that fits their particular geographic area. "It is the local implementation of risk reduction programs that make the difference" (Maurstad, 2007). "Through the implementation of local floodplain ordinances alone, it is estimated that $1.1 billion in flood damages are prevented annually" (Maurstad, 2005).

Acknowledgments

Sincere thanks are extended to those people and organizations who were instrumental in the successful completion of this report. Judy McDowell, Director of the Woods Hole Sea Grant Program, housed at the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, for support of the authors initial undertaking of this project. Jon D. Witten, Esq., Daley and Witten, LLC, for his thoughtful and thorough peer review of the Model Bylaw. His planning and legal expertise was invaluable and enabled this bylaw to be legally grounded and planning appropriate. Spencer Rogers, Coastal Engineering Specialist with the University of North Carolina's Sea Grant College Program, and Christopher P. Jones, P.E., Durham, NC, for their comprehensive review of the technical report and model bylaw. Their coastal processes, floodplain and coastal construction technical expertise provided a check and balance to that of the authors, and their comprehensive peer review enabled this product to be well grounded in applied coastal construction science. The National Sea Grant Law Center is also thanked for providing the initial impetus for beginning this project.

The views expressed in this document represent those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies.

Table of Contents

Section 1. Technical Report Supporting the Model Coastal Floodplain Bylaw/Ordinance

Section 2. Model Coastal Floodplain Regulation

Section 1. Technical Report Supporting Standards in the Model Coastal Floodplain Bylaw/Ordinance

Introduction

By the year 2000, flood damages in the U.S. approached $6 billion annually and the trend of increased disaster costs was continuing into the first decade of the 21st Century. In 2005, Hurricane Katrina alone caused 1,300 deaths and more than $120 billion in flood damage (Association of State Floodplain Managers (ASFPM), 2007; Kusler and Thomas, 2007). The National Flood Insurance Program (and state building codes) minimum requirements alone will not reverse this trend because they do not take into account future conditions, do not address all coastal hazards, and do not protect against large flood or storm surge events (ASFPM, 2007). The National Flood Insurance Program (NFIP) has paid nearly $36 billion in claims since 1978 and today has 6 million policies in force in more than 20,600 participating communities (FEMA, 2008). The history of U.S. Treasury Borrowing under the NFIP (Suburban Emergency Management Project (SEMP), 2009) reveals that approximately $21.7 billion has been borrowed; $4.36 billion has been re-paid; leaving $17.36 billion in cumulative debt. The only way out of this financial conundrum is a span of disaster-free years that would allow the Treasury debt to be paid off with in-coming NFIP premiums (SEMP, 2009).

However, even with wide-spread public dissemination of predictions of a more-than-likely significant rise in the rate of relative sea level, and potentially more intense and perhaps increased frequency of major coastal storms, coastal floodplains continue to attract extensive development. By 2015, the population of coastal counties is predicted to increase by an additional 12 million people (NOAA, 2005). FEMA's Assistant Administrator for Mitigation and Insurance stated, in part, 'communities must proactively take steps to reduce risks based on their own knowledge of local risks. It is the local implementation of risk reduction programs that make the difference' (Maurstad, 2007). 'Through the implementation of local floodplain ordinances alone, it is estimated that $1.1 billion in flood damages are prevented annually' (Maurstad, 2005).

Potential damage from storms currently about $10 billion yearly, is growing at a rate that may pose severe burdens on exposed communities, and avoiding huge losses will require a change in the rate of population growth in coastal areas, major improvement in construction standards, or other mitigation actions. Economic damage in the U.S. has been doubling every 10 to 15 years. If more people continue to move to the hurricane-prone coastline, future economic losses may be far greater than previously thought (Pielke, et al, 2008).

The U.S. coastal population is predicted to expand from approximately 100 million people to 177 million by 2010 (Sea Grant, 2006). Furthermore, over the past few decades, property losses from coastal disasters have skyrocketed, reaching more than $150 billion in the 1990s (Sea Grant, 2006). This upward trend is likely to continue as investments in vulnerable coastal property rapidly increase, the rate of relative sea level rise accelerates, and a likely cycle of increased hazardous weather activity.

The emphasis in coastal floodplain management has historically relied on structural measures, such as dikes, levees, and seawalls, and post-disaster recovery. In more recent times, however, focus has shifted towards developing disaster-resistant building alternatives and pre-disaster mitigation planning. In testimony to the House of Representatives' Committee on Transportation and Infrastructure, Subcommittee on Water Resources and the Environment in 2005, Dr. Gerald E. Galloway stated, in part, that 'new development in the floodplain – without a specific need to be located in the floodplain – must be discouraged'. However, with the massive migration of the nation's population towards coastal counties continuing and anticipated to accelerate, the Association of State Floodplain Managers is championing 'no adverse impact' floodplain management as a major national initiative (see ASFPM, 2006).

However, the only way to achieve a true meaning of 'no adverse impact' is to prohibit all development in the floodplain. Humans cause adverse impacts for themselves and coastal ecosystems just by being there (ASFPM, 2007). Flooding is a natural event whose adverse impacts are exacerbated by human development. Any construction in the floodplain will alter the land surface and interfere to varying degrees with floodwater flow, oftentimes causing unanticipated adverse impacts to the developed and natural environment. The ASFPM (2008) is now calling for a 'renewed direction' and approach to floodplain management proposing a five-pronged strategy that, in part, calls for 'preventing new development from encroaching on flood-prone and environmentally sensitive areas' and 'removing existing development from flood-prone and environmentally sensitive areas wherever possible'. However, the right to appropriately and safely develop property in the floodplain and along our coasts is also clearly recognized.

Thus, prohibiting development in specific, limited areas, and permitting appropriately sited and constructed development, while preserving the natural and beneficial functions of coastal floodplains is a balance to achieve. The ASFPM (2008) recently stated, 'to begin, we need to modify the widespread view of floods as destructive forces of nature. Floods do not cause damage or suffering. Our decisions about where we live, work and play are the cause. Instead of controlling the water, we should control how and where we allow human activities to adversely affect it. Future development should avoid high-hazard and ecologically sensitive areas. State and local governments should guide development away from these areas by applying land-use planning and management techniques. This is the most effective way to minimize cumulative losses and degradation of our water resources'. In this statement, however, they neglected to mention federal government agencies. Effective floodplain management must be a consolidated effort of all levels of government. The National Flood Insurance Program (NFIP) is probably the most widespread floodplain management program in the Country.

The NFIP recognizes that while it helps reduce the risks to development from flood-related hazards, it does not make the development "safe" from flooding. Development practices that go beyond the minimum requirements of the NFIP are encouraged in FEMA's Coastal Construction Manual. In fact, 'every Federal Emergency Management Agency (FEMA) coastal construction publication since the 2000 update of 'FEMA 55 Coastal Construction Manual' has recommended the use of VE zone construction practices in coastal A-zones: however, only since 2005 the landward limit of the Coastal A-zone has been taken as the landward limit of the 1.5 foot wave height occurring during the base flood (Chris Jones, 2009, personal communication). Thus, based on actual on-the-ground post-storm experiences, FEMA has recommended more stringent coastal construction practices in coastal high hazard areas, including the Coastal A-zone, than their minimal construction practices presently required for participation in the National Flood Insurance Program (Buckley, 2008). More strict state and local floodplain regulations with the purpose of protecting public health, safety and welfare, and the protection of natural resources take precedence over the minimum NFIP requirements.

Beyond FEMA encouraging stricter floodplain development standards in their advisory Coastal Construction Manual, as well as every other FEMA coastal construction publication since 2000, FEMA also states in their regulations, "community officials may have access to information or knowledge of conditions that require, particularly for human safety, higher standards than the minimum criteria set forth in…this part. Therefore, any floodplain management regulations adopted by a state or community, which are more restrictive than the criteria set forth in this part are encouraged and shall take precedence" ((44 CFR 60.1(d)), in Coastal No Adverse Impact Handbook, ASFPM, May 2007).

Thus, 'avoiding' flooding impacts to the built environment, particularly in known coastal high hazard areas, by prohibiting or severely limiting building in the coastal floodplain is the only true and ultimately effective floodplain management approach. The authors have attempted to meet this approach by the standards outlined in the model bylaw presented in the next section of this report.

Floodplain case law and legal references that support many of the standards in this model bylaw are available, most notably, on the Association of State Floodplain Managers and The National Sea Grant Law Center's web sites. Additionally, the legal framework of support for coastal floodplain management is presented clearly by the Massachusetts Coastal Zone Management Agency's (2008) StormSmart Coasts program Fact Sheet 2, *No Adverse Impact and the Legal Framework of Coastal Management*. Readers seeking legal basis and analysis are directed to these sources for information.

Making Development more Sustainable: Siting and Construction based on the Life Expectancy of the Dwelling

Although a building's foundation has been reported as critical to building performance (Chris Jones, 2009, personal communication), from a coastal floodplain management perspective there are 2 primary issues that will be considered in this report for making coastal or waterfront buildings and occupants hazard resilient: 1) *siting* location of a building on a waterfront or coastal lot; and, 2) building *elevation*. Development siting and elevations are addressed considering both present and future floodplain and storm-related conditions.

Siting buildings to minimize their vulnerability to coastal hazards, such as flooding and coastal erosion, is one of the most important aspects of the development process. Properly siting a building on a waterfront lot or within the coastal floodplain requires knowing the coastal hazards present at that particular location. Present and future storm surge and wave heights relative to the *100-year base flood elevation* and *coastal erosion* are the primary coastal hazards factored into the Model Coastal Floodplain Bylaw in this report.

Flooding elevations, inundation limits and coastal erosion, along with the level of risk, will more than likely increase in the future due to predicted increases in the rate of relative sea level rise and possibly more intense storms and increased rainfall. Fletcher and Merrifield (2009) reviewed recent studies of global warming, sea-level observations, global ice volume, ocean heating, and estimates of sea level rise by the end of the 21st century and state, 'based on current scientific understanding, a global mean sea level rise of approximately 1 meter around the turn of the century is indicated by present research and constitutes an appropriate planning target at this time'. Pielke (2008) points out that observed sea level rise has exceeded the best case projections thus far. Importantly, sea level rise is highly variable in different locations, and in addition eustatic or worldwide sea level rise predictions do not consider land mass movement, e.g. subsidence. Thus, planners need to mindful of local relative sea level rise rates in implementing progressive floodplain practices (see Sea Level Variations of the United States 1854-1999, NOAA, NOS, 2001).

Development on coastal lots should not ignore the effects of these coastal hazards on future property owners. Therefore, the *probability* of a coastal hazard affecting a building in the future should be factored into the location and elevation of any structure built in the coastal floodplain. This requires knowing the erosion rate and relative sea level rise rate at the site and factoring the 'probability' of erosion and/or elevated flood and surge waters affecting the building for the *life expectancy of the structure*.

Coastal Building Life Expectancy

Most building codes and other design standards have only one opportunity to minimize risk of future hazard damage: at the time of initial permitting and initial construction. The level of safety after initial construction generally determines the risk to the building for its entire lifetime (Rogers and Jones, 2002).

The FEMA Coastal Construction Manual recommends that for the lifetime of a coastal structure/building, a *minimum* of 50 years be used. However, it is recommended that a minimum 70 year coastal building lifetime be used for residential buildings (Hwang, 2005). The 70 year timeframe is based on a study for the Federal Insurance Administration to establish reliable estimates for the life of residential coastal structures. In that study, the National Association of Home Builders (Anderson, 1978) evaluated the average useful lifetime of various building types, materials and locations.

In the Anderson (1978) study, ten regions in the U.S. were studied for life estimates of coastal buildings based on the time in years from the initial construction to the termination of use as a habitable structure. The estimate was based on maintenance, economic use of the appreciating land, structural failure, water damage, habitability, and outmoded style or utility, among other factors. For a single family wood residence without block or bricks walls, the base life in years ranged from 50 to 100 years, with the average for the 10 regions in the U.S. at 70 years.

If a new house is properly maintained every 10 years, and re-roofed every 30 years, it could last indefinitely (Hwang, 2005). Building materials also affect building life expectancy. For example, use of brick in a single-family home raises the life expectancy to an average of 104 years (Anderson, 1978).

These building life times have direct implications for both elevating the house and lot placement location in relation to relative sea level rise-related increases in storm surge elevation and inland inundation limits, increased erosion and the future security of the buildings, occupants, and rescue personnel. Thus, at present, seventy years appears to be the best average estimate for the life expectancy of a small wood frame residential building. Structures made of brick, stone, concrete or steel may have a longer average life. However, importantly, the 70-year lifetime for structures should not be viewed as conservative, since it is based on the "average" of structures nationwide (Rogers and Jones, 2002).

Thus, factoring in a 70-year life term of a typical, small, wood residential building to accommodate storm surge and waves, erosion and sea level rise is prudent and safe coastal floodplain management. For larger buildings or buildings made of materials more resistant than wood (brick, stone, or block), a longer life term could be factored into a coastal floodplain regulation and setback provisions.

The Case for Promulgating Higher Standards than Presently Required

Probability of Flooding and Storm Damage to a Properly Built Structure

The 100-year flood elevation – or the 1% chance flood elevation in any given year - is calculated for communities that participate in the National Flood Insurance Program (NFIP) so that buildings can be constructed to prevent flood and storm damage to the building if properly elevated and flood-proofed. In a FEMA-mapped coastal floodplain, there is a 1% chance in any given year that a 100-year storm elevation will inundate a mapped area and storm waves and flood waters will equal or exceed the predicted elevation.

With no safety factor, the chance of a 100-year flood damaging a building over the 70-year average useful life of a house is about 50%: the chance of a flood exceeding the 100-year flood elevation over the 70-year period is 51%. That is not particularly good odds on avoiding flood damage when something as important as a home is at stake (Rogers and Jones, 2002). Furthermore, those probabilities and the calculated flood elevation are valid *when the flood studies were conducted* (emphasis added).

As a result of coastal erosion and relative sea level rise, through time buildings constructed to the suggested 100-year flood elevation will not be safe from flooding and storm damage after only a short time - the time depending on the rates of erosion and relative sea level rise in the area of the construction. A conservative estimate of a worldwide rise in sea level is approximately 2 to 3 vertical feet over the next 100 years (see Fletcher and Merrifield, 2009).

Probability of Coastal Erosion Damaging a Building

The risk of most natural hazards can be described as a ‘constant’ risk in any given year (annual return frequency). For example, there is a 1% chance in any given year that the specified flood or wave elevations associated with a 100-year storm will be reached in a FEMA-mapped 100-year floodplain. Thus, the probability of this storm is the same in year one as in year 70 (absent consideration of sea level rise). However, the risk of loss or damage due to coastal erosion varies from year to year, accompanied by concomitant annual elevated flood waters and storm surge as the shoreline moves toward or away from the building.

Theoretically for example, if a building is constructed 51 feet landward of the shoreline on a lot that has a uniform 1-foot per year erosion rate (and no variability in the data), there is a 0% chance of loss due to erosion within the first 50 years from the date of construction. However, after only one year there is an increase in the probability of loss, and a substantial increase in the probability of damage every following year as the high water line migrates closer to the building and as a result flood elevations concomitantly increasing. Note that it is important to be mindful that shorelines do not erode (or accrete) at a constant rate per year. Accelerations and decelerations in the rate of shoreline change, as well as trend reversals, routinely occur. Thus, if there is high variability in an average annual rate of shoreline change, a building could be in jeopardy long before the predicted time if the prediction is based simply on the average annual rate. Thus, a safety factor should be considered.

Furthermore, flood and wave loads on buildings, including flood and wave elevations, increase the closer an eroding shoreline gets to a structure, thus, the potential for damage increases. Without taking erosion into consideration in sitting a structure along an eroding shore, the building may be susceptible to damage shortly after it is built.

(For a more detailed explanation, with examples, on increasing probabilities of wind, snow, flood and erosion through time, see Rogers and Jones, 2002.)

Coastal Erosion Setbacks

Approximately two-thirds of coastal and Great Lakes states have some type of construction set-back or construction control line requiring that development be a certain distance from the shoreline or other coastal feature (OCRM, 2008). Twenty-two of the 29 coastal states have some form of set-back line (Bernd-Cohen, 1999). Seven states have setback distances based on expected years from the shoreline, the remainder specify a fixed distance from the shoreline or other feature (Heinz Center, 2000).

A wide variety of erosion rate multipliers are in use for setbacks, ranging from 10 to100 years. A typical mortgage lifetime, 30 years, has been commonly used but based on weak reasoning. Most buildings are sold long before the mortgage is paid. In many cases the selection of low multipliers appears to have been politically expedient at the time of adoption and recognized as better than no setback (Rogers and Jones, 2002).

Some states have fixed set-back lines, while others have developed scientifically-based erosion rate based set-backs. For example, several communities on Cape Cod, Massachusetts have established fixed 30 to 50 foot development setbacks from the top of coastal banks or bluffs. The State of Hawaii has a 40 foot setback from the 'upper reach of the wash of the waves', but several Counties in Hawaii have established more stringent setbacks (see below). North Carolina has established 30 or 60-year setbacks from specified shoreline features based on the size of buildings. (See the Heinz Center 2000 report, Table 4.4, for examples of setbacks in various states.)

These fixed setbacks were established in the absence of calculated erosion rates in an attempt to protect the beneficial functions of the coastal banks, such as storm damage and flood protection and wildlife habitat, as well as protecting buildings, occupants and financial investments. A fixed set back distance, while the simplest to establish, does not reflect the true erosion threat to shorefront structures.

Consider, for example, a fixed 40-foot set-back from a shoreline. A building constructed 40 feet from the shore with an erosion rate of 2 feet per year will be in jeopardy of loss within 20 years. Based on recent analysis, the fixed 40-foot Hawaii statewide shoreline setback simply did not work everywhere and has in many eroding regions allowed past development to occur in inappropriate locations. One common response to potential loss of a building due to coastal erosion is coastal shoreline armoring which if constructed along an eroding shore will result in the loss of dry sandy beaches. This has serious ramifications due to the loss of storm wave energy reduction provided by beaches, loss of habitat, loss of public access and enjoyment, as well as impacts to local and state economies (e.g. tourism) in many coastal areas. Inappropriate citing of buildings without considering coastal erosion rates has resulted in a proliferation of shoreline armoring that has led to the loss or narrowing of beaches in Hawaii (Eversole and Norcross-Nu'u, 2008). Studies indicate that 10.7 miles of sandy beach has been narrowed and 6.4 miles has been lost by shoreline hardening on Oahu, HI, alone (Fletcher, et al, 1997).

Rationally, shoreline setbacks should be based – at a minimum - on the expected lifetime of the structure. Given that that it has been documented that an average useful life of a small, wooden building is 70 years, it seems reasonable and legally justifiable to use 70 times the average annual erosion rate for a shoreline setback (plus a factor for shoreline variability and uncertainty in the data used to calculate erosion rates). However, the 70-year life of small, wooden buildings is actually an *average*. Thus, erosion may threaten half the buildings located at the 70 year erosion setback line. Thus, given that the 70-year life expectancy of a wood building is an *average*, and that larger building are generally constructed of more durable materials, a 100-year erosion rate multiplier for a shoreline setback could ensure more buildings will be safe for the building lifetime.

The erosion risk is approximately equal to the flood risk 70 years after building at the 70-year erosion setback line, regardless of variability. Thus, shoreline setbacks based on a 70-year rate multiplier is recommended as the best goal to balance erosion risk with flood, wind and snow hazards to a building (Rogers & Jones, 2002; Hwang, 2005). Due to generally smaller lots along the shore, setbacks greater than 70 years may render many lots unbuildable, and/or result in numerous variance proceedings. To gain support for a coastal construction setback Ordinance, the County of Kauai, Hawaii, combined an ‘erosion rate setback’ and a ‘fixed setback’ that is based on an average lot.

With University of Hawaii Sea Grant Program assistance, the County of Kauai, HI, has adopted erosion rate-based shoreline set-backs that require using a 70-year multiplier for small buildings, and a 100 year multiplier larger buildings that are proposed on lots that have an average lot depth of >160 feet.

On Kauai, setbacks for oceanfront lots that have an average lot depth <160 feet are predetermined, e.g. if the average lot depth is <100 feet the predetermined setback from a certified shoreline is 40 feet; if the average lot depth is between 141 and 160 feet the setback is 70 feet. However, for lot depths that are >160 feet, the ‘minimum’ setback is 80 feet, with the actual setback for buildings <5000 square feet calculated by multiplying the erosion rate by 70, plus an additional 40 feet as a safety factor and to compensate for potential data calculation uncertainty.

If the lot depth is >160 feet and the proposed building is >5000 square feet, the minimum setback is farther from the shoreline, with the erosion rate multiplier being 100, plus a 40-foot safety factor. The reason narrower setbacks for smaller lots (<160 feet) were considered was to minimize potential negative feedback and potential public opposition to the proposed setback rules if they were to negatively impact a large portion of the community (Eversole and Norcross-Nu’u, 2008). There is an alternative setback methodology option available, but the setback distance can not be less than that prescribed for the average lot depth, and never <40 feet without a variance (Kauai County, HI, ‘Shoreline Setback and Coastal Protection Ordinance).

In North Carolina, setbacks are based on building size, using a minimum of 2′ per year erosion rate. A 30-year setback is required for single-family and commercial buildings less than 5,000 square feet. For multi-family and commercial buildings >5,000 square feet the setback is 60 years (Rogers and Jones, 2002), even though this distance is less than the expected life of the building. A previous study found that most buildings in North Carolina are constructed as close to the ocean as allowed by the setback regulations (Stutts, et al, 1985).

Setbacks will reduce the likelihood of erosion-related damage over a buildings lifetime, and reduce storm wave and surge impacts to buildings. In addition, setbacks: avoid or forestall shoreline armoring that will eventually eliminate the dry coastal beach; protect marine (beach and near-shore) habitat; and, protect public lateral beach access.

Sea Level Rise and Increased Coastal Flood and Surge Elevations

Eustatic or worldwide sea level is rising. More importantly, it has been documented that the rate of sea level rise has accelerated in recent decades. Responding to sea level rise requires careful consideration regarding whether and how particular areas will be protected with structures, elevated above the tides, relocated landward, or left alone and potentially given up to the rising sea (EPA, et al, 2009).

This rise in ocean levels will affect the natural environment, as well as the built environment. Sea level rise is expected to increase flood water inundation, storm surge, coastal erosion, and other coastal hazards thus threatening vital infrastructure, settlements and facilities. Sea level rise will also cause salt water intrusion into wells, septic systems, and ground water close to the shore. Thus, an important consideration for coastal floodplain management is factoring sea level rise into the design of development projects.

Nationally, most current coastal regulations and building codes do not accommodate sea-level rise. Floodplain maps, which are used to guide development and building practices in hazardous areas, are generally based upon recent observations of topographic elevation and local mean sea level. However, often these maps do not take into account sea-level rise or possible increases in storm intensity. As a result, most shore protection structures are designed for current sea level, and development policies that rely on setting development back from the coast are designed for current rates of coastal erosion and flood heights, not taking into account sea level rise. The prospect of accelerated sea-level rise underscores the need to rigorously assess vulnerability and examine the costs and benefits of taking adaptive actions (EPA, et al, 2009).

'Relative sea level rise' is an important consideration in coastal floodplain management in both *vertical* and *horizontal* dimensions. Flood and wave crest elevations along a particular coast will rise commensurate with the rate of relative sea level rise. Flood water inundation will also reach farther inland as sea level rises. Buildings constructed to be safe from flood levels today will not be safe in the future as sea levels continue to rise. Thus, it is important to factor sea level rise into building elevation and site locations for the anticipated life of the building into a local coastal floodplain bylaw.

The IPCC (2007A) reported that global average sea level rose at an average rate of 1.8 (1.3 to 2.3) mm per year over the 1961 to 2003 period. However, importantly the rate was faster over 1993 to 2003 period: about 3.1 (2.4 to 3.8) mm per year. Whether the faster rate for 1993-2003 reflects decadal variability or an increase in the longer term trend is unclear. There is high confidence that the rate of observed sea level increased from the 19^{th} to the 20^{th} century. The total 20^{th} century rise is estimated to be 0.17 (0.12 to 0.22) meters. Contributions to this rise are from thermal expansion of the ocean, melting glaciers and ice caps, and melting polar ice sheets (IPCC, 2007B, Summary for Policy Makers, Working Group I (p.5) & Synthesis Report p.1).

While the IPCC (2007) projected sea level would reach 0.18 to 0.59 meters above present by the end of the 21^{st} century, they lacked an estimate of ice flow dynamics. Considering more recent studies of global warming, sea-level observations, global ice volume, ocean heating, and estimates of sea level rise by the end of the 21^{st} century, Fletcher and Merrifield (2009) and as reported by the University of Copenhagen (in Science Daily, 2009), there is a building consensus among scientists that sea level rise will approach and perhaps pass 1 meter by the end of the century. For a comprehensive synthesis and review of recent studies of global warming and sea level rise see Fletcher and Merrifield, 2009.

The reported rates of sea level rise are generally eustatic or world-wide *averages*. However, sea level is highly variable from area to area. In addition, eustatic rates consider solely the rise in sea level. Land masses are also oftentimes rising or subsiding. Together, worldwide sea level rise coupled with the landmass movement constitute 'relative sea level rise'. It is this 'relative sea level rise rate' for any particular state or community that is the figure to be considered for use in any coastal floodplain management initiative. For example, 'relative' sea level is falling at a rate of 12.69mm/year in Juneau, Alaska, while sea level is rising at 1.53mm/year in Nawiliwili Harbor, Kauai, HI (NOAA, 2001). The rate of relative sea level rise measured at specific locations along the Atlantic coast of the U.S. varies from 1.75mm to as much as 4.42mm per year (EPA, et al, 2009). The global rate is 1.7 +/-0.5mm per year (EPA, et al, 2009; Bindoff, et al, 2007).

For a list of rates of relative sea level rise for selected long-term tide gauges on the Atlantic coast of the U.S. see Table 1 in Zervas, 2001. This table, along with an explanation of relative sea level rise, its impacts and possible consequences along the mid-Atlantic region, can also be viewed in Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region (EPA, et al, 2009). For sea level variations of the United States 1854-1999, see NOAA, 2001.

Sea Level Rise Considerations in the Elevation of Buildings

In areas subject to coastal storm surge but not coastal waves, the increase in flood elevations can be approximated by the rise in relative sea level. However, in areas where coastal waves accompany storm surge, the increase in flood elevations will exceed the increase in relative sea level (IEP, Inc, 1990).

Using the standard equation Hw/D = 0.78, with 70% of the wave height assumed to lie above the stillwater storm surge level, where Hw is the wave height and D is the stillwater depth, the flood elevation is derived by adding 0.70 times Hw to the surge elevation. Therefore, a 1- foot rise in sea level will result in the following (modified from IEP, Inc, 1990 by C. Jones, 2009):

	Existing Condition	Future Condition
Given:	Surge elevation = 11.0′ Depth = 4.0′	Surge elevation = 12.0′ Depth = 5.0′
Then:	Hw/4.0 = 0.78 Hw = 4.0 x 0.78 = 3.1′	Hw/5.0 = 0.78 Hw = 5.0 x 0.78 = 3.9′
So:	11.0 + 0.70 x 3.1 = 13.2′	12.0 + 0.70 x 3.9’ = 14.7′

As a result, there can be up to a 1.5′ increase in total wave and surge elevation that will result from a 1-foot increase in sea level in coastal areas subject to wave effects during a 1% annual chance flood (modified from IEP, Inc, 1990, by C. Jones, 2009, personal communication).

Vertical Considerations for Building to Accommodate Relative Sea Level Rise

Freeboard

Considering relative sea level rise in the *vertical dimension*, as relative sea level continues to rise over time, the lowest horizontal structural member or the lowest floor of buildings elevated to a specified flood or storm surge elevation today, e.g. the 100-year base flood elevation, will no longer be protected from storm waves, surge and flooding as sea level rises. So, it is prudent coastal floodplain management to elevate buildings to accommodate the relative sea level rise rate for the expected life of the building in the area in which building is taking place.

Freeboard is an additional amount of height added to the elevation determined to make a building hazard resilient from flooding, e.g. base flood elevation. Freeboard equates to the height added to the Base Flood Elevation (BFE) to account for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as relative sea level rise, wave action, blockage of bridge openings, and the hydrological effect of urbanization of the watershed. The BFE *plus freeboard* is commonly taken to yield a more flood resilient Design Flood Elevation to be used for construction design.

Freeboard is the practice of raising a building's lowest floor or lowest horizontal structural member an additional height above predicted flood elevations. Raising a buildings floor or structural members higher than predicted flood elevations is a cost-effective approach that can lead to substantial reductions in flood insurance premiums, significantly decrease the chances a structure will be damaged by storms and flooding, and help protect against relative sea level rise. Additionally, increasing elevation by providing freeboard provides an added margin of safety to address the flood modeling and mapping uncertainties associated with FEMA's National Flood Insurance Rate Maps (FIRMs). FEMA's Community Rating System also gives credit and thus reduces flood insurance premiums for communities that incorporate freeboard into floodplain building standards.

Incorporating 'Freeboard' into Construction Design

Some amount of *uncertainty* regarding predicted flood elevations, flood frequencies and inundation studies should be accounted for in new and retrofitting buildings in the coastal floodplain. A minimum of 1-foot of 'freeboard' is suggested by FEMA to include in elevating a house (FEMA, 1998). However, this FEMA-recommended 1-foot freeboard is based solely on uncertainties in flood elevation and inundations calculations.

Given that new model predictions indicate that the ocean will rise between 0.9 and 1.3 meters (Science Daily, January 17, 2009), with a mean of 0.95 meters (Fletcher & Merrifield, 2009), coupled with the anticipated 70-year life expectancy of a typical small, wood building and longer (e.g. 100 years) for buildings constructed of more durable material or well maintained in the coastal zone, it may be prudent to factor a 1 meter (approximate 3-foot) rise in sea level over the next 100 years in building standards. Keep in mind that this prediction is world-wide sea level rise (eustatic): subsidence of the land, if appropriate, should also be considered, i.e. 'relative' sea level rise.

Freeboard can also reduce flood insurance rates. The Massachusetts Coastal Zone Management's StormSmart web site (www.mass.gov/czm/stormsmart/) includes information based on previous studies of saving on flood insurance as a result of incorporating 'freeboard' into building design.

Horizontal Considerations for Building to Accommodate Relative Sea Level Rise
Since the IPCC Third Assessment, confidence has increased that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century (IPCC, 2007 – Summary for Policy Makers, p.17). Considering relative sea level rise in the *horizontal dimension,* coastal resources, such as salt marshes, barrier beaches, coastal beaches, and coastal dunes have often been documented to migrate landward in response to rising sea levels. Obstructions, such as coastal engineering structures (revetments, bulkheads, and seawalls), can inhibit landward migration of coastal resources and result in the diminishment/narrowing or complete loss of these important coastal resources and their beneficial functions as the high water line continues to migrate landward and is finally stopped and forced against these static structures. Titus, et al (2009) estimated that on the basis of 131 state and local land use plans, that almost 60% of the land below 1 meter along the U.S. Atlantic Coast is expected to be developed and thus unavailable for the inland migration of wetlands.

Those portions of the coastal floodplain which are immediately landward of salt marshes, coastal beaches, barrier beaches, coastal dunes or coastal banks require special protection. These areas are likely to be in a state of transition as the entire complex of coastal wetland resources gradually moves landward in response to relative sea level rise and storms. As sea level rises and coastal storms continue these areas will become more frequently inundated. Activities occurring in these 'special transitional areas' of coastal floodplains may interfere with the natural landward migration of these coastal resources. If landward migration of these resources, including the coastal floodplain, is affected they may be narrowed or lost, along with their beneficial functions. Therefore, maintaining these special transitional areas is their natural state is necessary to protect the interests of all other coastal wetland resources and their beneficial functions (O'Connell, et al, 1995).

Therefore, a portion of the coastal floodplain should be protected from development and alteration in order to allow the landward migration of the most frequently flooded floodplain area and to preserve the beneficial functions of storm wave energy reduction and flood control, as well as habitat and pollution prevention, provided by other coastal wetland resources, such as salt marshes, beaches, dunes and barrier beaches.

The Massachusetts Coastal Floodplain Task Force (O'Connell, et al, 1995) recommended prohibiting development and alteration of the 10-year floodplain due to its frequency of flooding and potential for coastal resource migration into this area. Furthermore, for ease of application and development of coastal floodplain standards to preserve this area, the 10-year still-water elevation contour is readily available in a community's FEMA Flood Insurance Study. Several states have instituted development 'buffer areas' surrounding wetland resource areas and water bodies to help protect wetlands and water quality.

Coastal A-zones
'Present NFIP regulations make no distinction between the design and construction requirements for *coastal* AE Zones and *riverine* AE Zones' (Buckley, 2008). Coastal A-Zones delineate the 'limit of moderate wave action', whereas riverine AE zones do not exhibit similar oceanic wave characteristics. It has been determined that within a FEMA-mapped A-Zone, a breaking wave of 1.5′ or greater can cause structural damage.

Coastal AE-Zones are areas of the coastal floodplain that are subject to wave action sufficient to potentially cause damage and/or failure to typical AE Zone construction techniques. For example, wood-frame, light gauge steel, or masonry walls on shallow footings or slabs, etc, are subject to damage when exposed to waves less than 3 feet in height. FEMA Memo #50 (Buckley, 2008) states that wave heights as small as 1.5 feet can cause failure of the above listed wall types. Because Coastal A-Zones may be subject to the types of hazards present in Velocity Zones, such as wave effects, velocity flows, erosion, scour, and high winds, FEMA recommends that buildings in Coastal A-Zones meet the NFIP requirements for V-zone building, i.e. the performance requirements concerning resistance to floatation, collapse, and lateral movement, and the prescriptive requirements concerning elevation, foundation type, engineering certification of design and construction, enclosures below the BFE, and use of structural fill (FEMA, Coastal Construction Manual, 2000: Sec 6.4.3.3 & 6.5, p.6-15).

Procedure Memorandum #50 – Policies and Procedures for Identifying and Mapping Areas Subject to Wave Heights greater than 1.5 feet as an Informational Layer on Flood Insurance Rate Maps was recently issued by FEMA (Buckley, 2008). Importantly, this memorandum states that, 'The 2006 International Building Code references the American Society of Civil Engineers (ASCE) 24-05 Flood Resistant Design and Construction Standard, which has specific design requirements that apply to areas that may be affected by waves greater than 1.5 feet' (which ASCE refers to as Coastal A-Zones). In addition, the Memo states that every FEMA coastal construction publication since the issuance of 'FEMA 55 Coastal Construction Manual', dated June 2000, has recommended the use of VE Zone construction in Coastal A-zones. However, only since 2005 has the Coastal A-zone been determined to be areas subject to wave heights between 1.5 and 3 feet.

To provide a greater level of protection against hazards in Coastal A-zones (& V-zones), FEMA (2000) recommends:

- The building be located landward of both the long-term erosion set-back AND the limit of 100-year storm erosion (rather than simply the reach of mean high water);
- An open foundation, as opposed to a solid foundation;
- The bottom of the lowest horizontal structural member should be elevated *above*, rather than to, the BFE (and provide freeboard – see Fig, 6.4);
- Use of space below the BFE be used only for parking, storage, and access;
- Open lattice or screening used in lieu of breakaway walls in the space below the elevated building (minimizing the use of solid break away walls).

In addition:

- the lowest horizontal structural member should be oriented perpendicular to the expected wave crest;
- The placement of fill for structural support in Coastal A-zones should be prohibited;
- Placement of non-structural fill in Coastal A-zones is not recommended.

The issue was that 'the AE Zone areas subject to wave heights between 1.5 and 3 feet were not differentiated from other AE Zone areas on FIRMs'.

Recognizing this need, FEMA took action in Memorandum #50 (Buckley, 2008) requiring that, 'for all new detailed coastal study starts in Fiscal Year 2009, the landward limit of waves 1.5 feet in height will be delineated on the FIRMs and included in the DFIRM data base as an informational layer with no NFIP floodplain management requirements or special insurance ratings.' With the Limit of Moderate Wave Action (LiMWA), i.e. landward limit of the 1.5 foot wave, now delineated on all preliminary FIRMs, the Memo encourages but does not require communities to adopt higher standards than the minimum NFIP requirements in these Coastal A-Zone areas that lie between the 1.5 and 3 foot wave. The Memo reminds us that the NFIP Community Rating System provides credits for communities that adopt and enforce more stringent floodplain management requirements in these areas.

FEMA Memo #50 (Buckley, 2008) states that for areas where VE designations are related to wave run-up or primary frontal dunes, the Limit of Moderate Wave Action (i.e. area of the coastal floodplain supporting waves between 1.5 & 3 feet) be delineated 'immediately landward of the mapped VE/AE Zone boundary'. This, however, does not specify a specific landward distance to require appropriate construction based on the risk.

Because the mapped Coastal A-zone area, i.e. landward limit of 1.5 foot waves, will be only provided 'for all new detailed coastal study starts in Fiscal Year 2009', and it may be years before a community's flood insurance rate maps are updated to include the LiMWA, and it is clearly demonstrated that structural damage is highly likely in the area immediately landward of a Velocity Zone, the model bylaw in this report (below) has included an area 200 feet landward of all Velocity Zones to ensure the intent and purpose of this model coastal floodplain bylaw are met. This zone is suggested to be incorporated into a community bylaw until official FIRMs delineating this additional high hazard area are accepted by the community. This 200-foot Coastal A-Zone area could be conservative in many areas where a gentle, gradual slope exists landward where waves could propagate a considerable distance landward, i.e. beyond 200 feet. Conversely, in very steep areas waves will dissipate rapidly. Within the model bylaw there is an opportunity to incorporate a provision to allow the applicant the alternative to calculate where the landward limit of the 1.5′ breaking waves ends on their property. (See a further discussion of the Coastal A-Zone within the commentary of the model bylaw below, Article 4(1)).

Lessons Learned

The conclusions of post disaster event assessments can be classified according to those factors that contribute to both building damage and successful building performance: hazard identification, siting, design, construction, and maintenance (FEMA Coastal Construction Manual, 2000, p. 2-37).

The authors have attempted to address all of these technical issues raised above in this Section 1 with associated coastal floodplain regulatory standards. In effect, the regulation presented below is the culmination of the lessons learned that are presented in this technical report. By including comprehensive floodplain management techniques, the model aims to present a local regulation that exceeds the minimum NFIP requirements and will therefore provide increased flood protection and may result in lower flood insurance premiums. (For a summary of National Flood Insurance Program regulatory requirements and their 'recommendations' for exceeding these requirements see Table 6.1 in FEMA's Coastal Construction Manual, 2000; also see FEMA-499 (2005) Home Builders Guide to Coastal Construction, Fact Sheet 2.)

II. Model Coastal Floodplain Bylaw

Instructions for Use of the Model Bylaw

In conjunction with undertaking the technical report above, an extensive review of existing coastal floodplain bylaws was conducted. A variety of regulations were reviewed, including several from Cape Cod and other Massachusetts south shore communities, as well as other model floodplain bylaws from coastal states such as Maine and North Carolina. (See Appendix A for a list of bylaws reviewed by the project authors).

The model presented below fairly applies hazard based regulations to promote the property rights of all in the community by preventing development that will cause harm to future occupants of that development, emergency workers who perform evacuations when disaster strikes, and the economic basis of a coastal community. Primary in the development of this bylaw, and one main purpose of the regulation itself, is the need to preserve and protect the natural beneficial functions of the coastal floodplain.

Section I above details the scientific basis for this proposed regulation. That basis is presented throughout this model bylaw in italicized, explanatory text and justifies a specific section of the bylaw. It is important to consult and understand this internal *commentary*, but that text should not be part of or referenced in a community bylaw.

In several places the model language is presented as a "menu of choices," where the authors present a choice of regulatory language in italicized text. Additionally, there are blanks to be completed with terms appropriate to the adopting municipality. Such places are formatted within brackets, using italicized and underlined text. As an example, [*permit issuing authority*] appears within the bylaw. Below it the following commentary appears explaining how that blank should be completed:

> *Cities and towns should determine which board/body has the authority to be a special permit issuing authority and of those, which is most appropriate to deliberate on proposed coastal development. For example, in Massachusetts the local Zoning Boards of Appeal typically serve as the Special Permit granting authorities, however, there is much local debate as to whether the local Planning Board would be better suited to review the impacts of development in the floodplain.*

This format is used throughout the document to alert the user of a choice to be made, or language that needs to be tailored to the adopting community. Not every blank will have associated commentary, as some will be self-explanatory.

For clarity, the word "bylaw" is used to denote bylaw, regulation or ordinance.

ARTICLE 1. Findings of Fact

Overall, coastal floodplain regulation carries out the duty of government to protect public health, safety, and welfare by recognizing the inherent dangers of coastal flooding to residents, rescue personnel, environmental resources, and economic resources. Coastal floodplain regulation establishes appropriate development and use standards for land subject to coastal flooding and erosion. It is recommended that this reasoning be stated as a finding of fact:

(1) The flood prone areas within the jurisdiction of *[community]* are subject to periodic inundation which results in loss of life, property, health and safety hazards, disruption of commerce and governmental services, extraordinary public expenditures for flood protection and relief, and impairment of the tax base, all of which adversely affect the public health, safety, and general welfare.

(2) Flood losses are caused in part by the cumulative effect of obstructions in floodplains causing increases in flood heights and velocities and by development and occupancy in flood prone areas of uses and structures vulnerable to floods or other hazards.

(3) The topography, soil characteristics (e.g. composition, size, density, and shape of soil material), vegetation, erodibility and permeability of the land surface within the coastal floodplain are critical characteristics which determine how effective an area is in dissipating wave energy and floodwater flow and in protecting areas within and landward of flood zones from storm and flood damage. The more gentle and permeable a seaward-sloping land surface is, the more effective that land surface is at reducing the height and velocity of incoming storm waves and flood waters. Wave energy and flood water flow may be expended in eroding and transporting materials comprising the land surface of the coastal floodplain, as well as percolation or the downward movement of storm water through more permeable land surfaces, thereby lessening the effects of backwash, scour and erosion.

(4) Fill or the placement of structures within Coastal High Hazard Zones may cause the refraction, diffraction and/or reflection, of waves and moving flood water, thereby forcing floodwater onto adjacent property, natural resources and public or private ways potentially resulting in otherwise avoidable storm damage. When struck with storm wave, solid structures within Coastal High Hazard Zones may also increase localized rates of erosion and scour. An engineered beach nourishment project or dune enhancement may be exceptions to this rule, and if properly designed may reduce wave energy.

(5) In some cases, the placement of fill in hydraulically constricted portions of the coastal floodplain may increase flood levels in conjunction with heavy rain fall events.

(6) Velocity zones, AO-zones, and Coastal A-zones of Land Subject to Coastal Storm Flowage (a term of art denoting the 100-year coastal floodplain) are areas that are subject to hazardous flooding, wave impact, velocity flows, erosion, scour, and high winds, which can result in loss of life and property, increasing public expenditures for

storm recovery activities, taxpayer subsidies for flood insurance and disaster relief, and increased risks for personnel involved in emergency relief programs. Alteration of land surfaces in A-zones could change drainage characteristics that could cause increased flood damage on adjacent properties. The FEMA Coastal Construction Manual recommends that construction in Coastal A-zones be subject to the same NFIP regulatory requirements as for V-zone construction.

(7) Those portions of coastal floodplains which are immediately landward of salt marshes, coastal beaches, coastal dunes, barrier beaches and coastal banks require special protection. These areas are likely to be in a state of transition as the entire complex of coastal wetland resource areas gradually migrates landward in response to relative sea level rise, resulting in inundation of more landward area. As sea level rises, the shoreline may retreat and areas are successively inundated more frequently by storm and tidal activity. Activities carried out in these 'special transitional areas' of coastal floodplains may interfere with or prohibit the natural landward migration of the adjacent coastal resource areas. Therefore, maintaining these special transitional areas in their natural state is necessary to allow these coastal resources to migrate and, thus, continue to exist and continue to provide the storm damage prevention and flood control beneficial functions of these coastal resources. The International Panel on Climate Change, among others, has predicted that the worldwide sea level rise rate will more than likely accelerate in the near future, making protection of these transition areas even more critical in order to prevent concomitant future flood damage acceleration.

ARTICLE 2. Purpose and Intent:

The following is a list of purposes and intentions that serve as the needed basis for coastal floodplain management. There is clearly a link between the number of structures located in a known hazard area and the ability of a community to provide public safety and to protect its public safety personnel. A greater number of structures in a flood hazard area equates to more collateral damage, more lives to protect, and a greater threat to public safety personnel. Therefore, decreasing the number of structures allowed in hazard areas equates to a legitimate state interest. Similarly, doing everything possible to protect the natural beneficial functions of coastal resources serves a legitimate interest by enabling the environment to perform its flood and damage control functions.

The **primary purposes and intentions** of these *Coastal Floodplain District* regulations are:

(1) To protect public health, safety and welfare;

(2) To restrict or prohibit development and uses on Land Subject to Coastal Storm Flowage (i.e. 100-year coastal floodplain) and its buffer zones in order to minimize potential loss of life, destruction of property, and environmental damage inevitably resulting from inappropriate development on land known to be subject to storms, flooding, erosion, relative sea level rise and other coastal zone hazards;

(3) To prevent loss or diminution of coastal resources and their natural beneficial functions that contribute to storm and flood damage prevention or pollution prevention, including by allowing them to migrate landward in response to relative sea level rise;

(4) To restrict or prohibit development in known hazard areas where the provision of public safety may be jeopardized or where public safety personnel may be endangered, thereby minimizing the need for rescue and relief efforts associated with flooding and generally undertaken at the expense of the general public and to enable safe access to and from coastal homes and buildings for homeowners and emergency response personnel in order to effectively provide public safety services;

(5) To be fiscally responsible by minimizing expenditures of public funds for costly flood control and damage recovery projects;

(6) To help maintain a stable tax base by providing for the sound use and development of flood prone areas, which could minimize prolonged business or economic losses and interruptions caused by structural damage and/or flooding;

(7) To reduce or prevent public health emergencies resulting from surface and ground water contamination from inundation of or damage to sewage disposal systems and storage areas for typical household hazardous substances;

(8) To minimize monetary loss and public health threats resulting from storm damage to public facilities and infrastructure (i.e. water and gas mains, electric, telephone and cable lines, sewer infrastructure, streets, bridges, etc.);

(9) To maintain vegetative buffers to coastal wetlands and water bodies so as to reduce and/or eliminate runoff, and other non-point discharges of pollutants in order to protect coastal water quality and public health for reasons including the propagation of fish and shellfish, and for recreational purposes;

(10) To preserve and enhance the community character and amenities of [*community*] and to conserve natural conditions, wildlife and open space for the general welfare of the public and the natural environment; and

(11) To ensure that potential buyers are aware that property is located in a Special Flood Hazard Zone.

If (11) is selected as an objective, the bylaw should later include a filing requirement for hazards disclosure prior to a transfer of any title.

ARTICLE 3. District Location or Delineation

The Coastal Floodplain District is intended to be an overlay district, serving as an expansion of the regulatory scope of the underlying district. Where the overlaying district's regulations conflict with the underlying district's regulations the more restrictive regulation(s) applies.

The following areas are included and defined as within the boundary of the Coastal Floodplain District (the District) and are subject to the provisions of this bylaw:

All lands within the 100-year floodplain as mapped and designated on the *[community's]* most recent Flood Insurance Rate Maps (FIRMs) that lie seaward of the State Coastal Zone Management program's regulatory boundary or if available, the documented landward inundation caused by the coastal storm of record (also termed land subject to coastal storm flowage or LSCSF). Therefore, where LSCSF has been documented and mapped the more inclusive boundary shall apply. This bylaw establishes two regulatory zones within the Coastal Floodplain District as follows:

(1) **Coastal High Hazard Zone**: For the purposes of this bylaw and its regulation the Coastal A-Zone, AO-Zone, and all V-zones will together constitute the Coastal High Hazard Zone and shall be treated concurrently. Additionally, due to wave action and storm surge, coastal erosion, increasing flood elevations due to relative sea level rise, and flood elevation and inundation modeling uncertainty, the Coastal High Hazard Zone shall, absent a site specific analysis, also include a buffer landward of the V-zone delineated as:

i) All land *200 feet landward* from the landward boundary of FEMA designated V-zone, which is intended to capture the Coastal A-zone; unless,

ii) An area landward of 200 feet landward of the V-zone can be delineated where buildings have been documented to have been structurally damaged by prior storm waves; unless,

iii) FEMA has included the Limit of Moderate Wave Action (LiMWA) on the community FIRM.

If FEMA has not already provided FIRMs depicting the 1.5-foot wave landward limit (LiMWA), as an alternative to the 200-foot landward V-zone buffer an applicant can conduct a site-specific analysis to determine the actual landward limit of the 1.5-foot breaking wave. If such analysis is conducted, that calculated landward limit of the 1.5-foot wave shall be the landward limit of the Coastal High Hazard Zone, as defined in this bylaw.

(2) **Tidal A-Zone**: For purposes of this bylaw and its regulation, Tidal A-Zone shall include all areas subject to inundation by the 100-year flood as designated on a community

FIRM as A, AE, A1-30, AH, or AR, and is subject to some degree of tidal influence but is not within the Coastal High Hazard Zone as delineated above in (1). Additionally, the Tidal A-Zone shall also include a 100-foot landward buffer delineated from the landward boundary of FEMA designated A-zone.

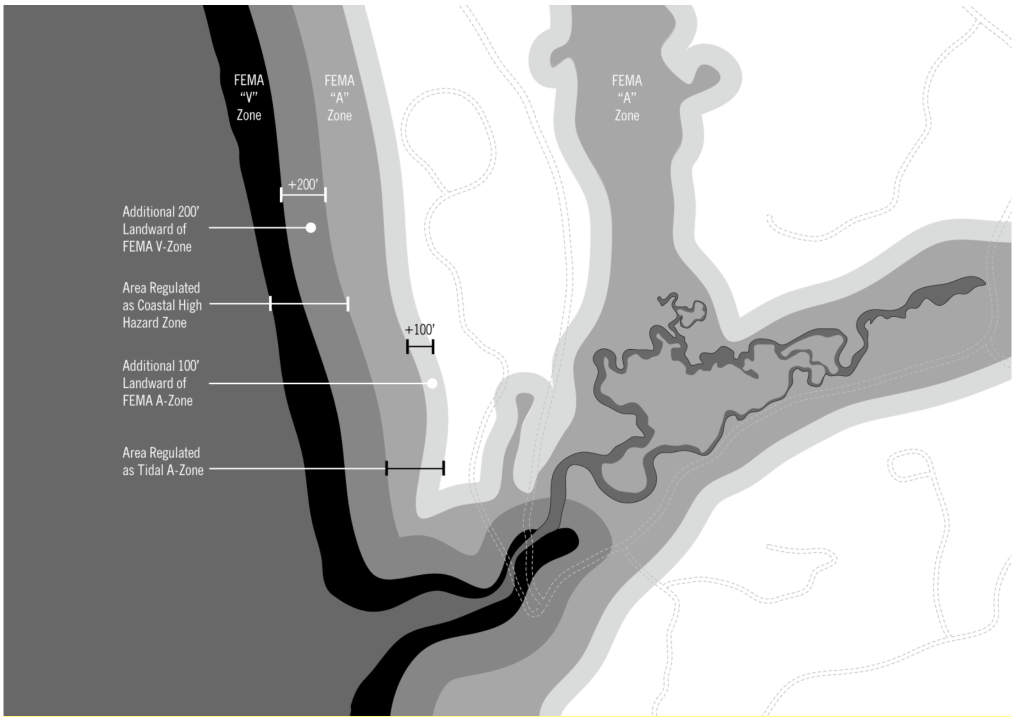

Diagram: The above diagram illustrates the delineation of the Coastal High Hazard Zone and the Tidal A-Zone as defined above in Article 3 (1) and (2). These zones together comprise the Coastal Floodplain District regulated by this bylaw.

Many reports, including FEMA's Coastal Construction Manual (2000), have determined that Coastal A-zones may be subject to the types of hazards present in V-zones, such as wave effects, velocity flows, erosion, scour and high winds, thus structural damage can occur to buildings similar to those located in V-zones. The Coastal Construction Manual recommends that buildings in Coastal A-zones meet the NFIP regulatory requirements for V-zone buildings.

Within the Coastal A-zone, it has been documented that a breaking wave height of 1.5 feet or greater can cause structural damage. This evidence is now supported by FEMA Memorandum #50 (Buckley, 2008). Thus, the Coastal A-zone landward boundary is determined to be the limit of the 1.5-foot wave, which occurs where the wave crest is one foot above the mean water elevation. FEMA Memo #50 states that the Limit of Moderate Wave Action (i.e. Coastal A-zone) shall be placed immediately landward of the VE/AE Zone boundary

If this zone is not delineated on your community's FIRMs, it is impossible to precisely determine the landward extent of this 1.5-foot breaking wave zone without a site-specific analysis. Thus, absent a site-specific analysis, the recommended 200-foot landward buffer to all V-zones, as recommended here in Article 3(1)(i), is considered to include part or all of the Coastal A-zone, *and shall be treated concurrently as part of the Coastal High Hazard Zone. ASFPM (2007) recommends that when a community's Flood Insurance Rate Map is being updated, they should request that Coastal A-zones be included.*

The NFIP regulations do not differentiate and thus the FIRMs do not distinguish between coastal or tidal/storm surge influenced A-zones and non-coastal A-zones. Therefore, it is recommended that A-zones delineated on a community FIRM that are located within a state's coastal zone as delineated by the state Coastal Zone Management program's regulatory boundary <u>and</u> exhibiting tidal fluctuations due to being hydraulically connected to the ocean should be considered as tidal/storm surge influenced A-zone and regulated by this bylaw.

Managing development and activities in a buffer area landward of the present-day 100-year coastal floodplain is important in order to protect what is likely to be flood-prone area in the future as relative sea level rise increases the lateral floodplain area, and as coastal resources (e.g. salt marsh, dunes, beaches) migrate landward over time in response to relative sea level rise. Furthermore, the FIRMs that most communities and FEMA rely on for flood insurance and flood zone delineation purposes are often outdated or contain mapping uncertainties. Therefore, in the interest of "plan for the worst, hope for the best" communities should consider managing development in a buffer area to the existing coastal floodplain, and an area landward of migrating coastal resources. It is recommended that a 200-foot buffer zone landward of V-, Coastal A-, and/or AO-Zones that lie within the 100-year coastal floodplain be established and managed/regulated as part of a Coastal High Hazard Zone, and that a 100-foot buffer zone landward of migrating coastal resources (salt marshes, dunes, beaches) be considered and regulated to preserve these areas and resources to provide their beneficial functions of storm damage prevention and flood control, and provide for the safety of the public and rescue personnel.

ARTICLE 4. Scope of Authority

The Coastal Floodplain District is an overlay district and shall be superimposed on the other districts established by the town of ___________. All regulations in the _____ Zoning Bylaw applicable to such underlying districts shall remain in effect. The Coastal Floodplain District is intended to be an overlay district, serving as an expansion of the regulatory scope of the underlying district. Where the overlaying district's regulations conflict with the underlying district's regulations, the more restrictive regulation(s) applies.

If a building or structure is being proposed that crosses more than one designated flood zone the more restrictive standards shall apply to the entire building or structure.

Lots with portion(s) of the lot in different flood zones should be regulated to the more restrictive zones' standards, therefore building in a margin of error in mapping or on-the-ground changes (<u>i.e</u>. due to erosion, relative sea-level rise, etc.).

<u>ARTICLE 5. Use and Activity Regulations for the Coastal Floodplain District</u>

Communities need to decide what types of development, if any, they will allow in the Coastal Floodplain District. Authors suggest there be different allowances depending on whether land is within the Coastal High Hazard Zone or the Tidal A-Zone portion of the District. There are multiple scenarios that coastal communities need to debate in order to regulate development to the extent desired and practical. Decisions need to be made and regulations set forth as to whether to allow new construction, residential development, redevelopment, water dependent development, and, if allowed, what types of restrictions (e.g. no increase in the footprint or intensity of a use) and rebuilding allowances will be required.

As an excellent example, the town of Chatham, Massachusetts, made the choice to prohibit all new ***residential*** *development in FEMA A-Zone, and to prohibit* ***all*** *development in the V-Zone. This A-zone prohibition on residential development has been upheld by the state's highest court, when in 2005 they affirmed the lower courts decision, which states that "restricting residential development within the path of floodwater, the floodplain, is a direct, logical, and reasonable means of safeguarding persons and property from those hazards occasioned by a flood and advances a substantial State interest, that is, the health, safety, and welfare of the general public…" (*Gove vs. Zoning Board of Appeals of Chatham*, 831 N.E.2d 865 (Mass. 2005)).*

Coastal High Hazard Zone versus Tidal A-Zone structure allowances
Within the Coastal High Hazard Zone the following development scenario is recommended:

- *Prohibit all new structures , except*
- *Allow water dependent structures*
- *Allow reconstruction of substantially flood-damaged structures (without expansion)*

Within the Tidal A-Zone, there are certainly several development scenarios to be considered. Some are:

<u>Option 1</u> (same as Coastal High Hazard Zone allowances)

- *Prohibit all new development*
- *Allow only water dependent structures*
- *Allow reconstruction of substantially flood-damaged structures (without expansion)*

<u>Option 2</u>

- *No new building for residential purposes (those that provide for human occupancy such as private residences, nursing homes, hotels, and motels)*
- *Allow water dependent structures*
- *Allow reconstruction of substantially flood-damaged structures (without expansion)*

<u>Option 3</u>

- *Allow any development*

The following model language for this Article 5 implements the authors' recommended development scenario for the Coastal High Hazard Zone and Option 2 for Tidal A-Zone. Similar *to the Town of Chatham, Massachusetts, this Article 5 prohibits structures in the V-zone, however, because of the district's delineation (per Article 3), extends prohibitions into the Coastal A-zone by including a buffer to FEMA V-Zone. Option 2 prohibiting residential development in the Tidal A-Zone was selected in order to remain consistent with the purpose and intent of this bylaw, which, in part, is to prohibit development in areas vulnerable to flooding to ensure public safety and to protect public safety personnel.*

SECTION A. Uses and Activities Prohibited in the District

Notwithstanding any other provision of this bylaw and unless allowed under this Article 5, Sections B and C below, the following uses, structures, and activities are **prohibited** in the Coastal Floodplain District:

(1) Residential dwelling unit(s), *[or the foundation for]*;

(2) If within the Coastal High Hazard Zone of the District no new building/structure shall be constructed, [*nor any new foundation for a building/structure placed*], and no existing structure shall be enlarged, moved to a more vulnerable location, or altered except to upgrade for compliance with documented existing health and safety codes;

The clauses "or the foundation for" and "nor any new foundation for a building/structure placed" are recommended in order to stop an argument being made that once the lowest structural member of the lowest floor is elevated above the BFE, that structure is then "out" of the flood zone. This position does not serve all purposes of the bylaw—particularly, to protect and provide public safety. Such elevation may, in fact, place the structure itself above the floodwater and keep it from becoming damaged or waterborne debris, but it will not remove the hazard to public health, safety and welfare, or serve to protect public safety personnel. Only a prohibition on development in known hazard areas can achieve this.

(3) New non-water dependent infrastructure or expansion of existing non-water dependent infrastructure, unless there is a documented and accepted overriding public benefit, and unless it is shown there is no feasible alternative location, and provided that the infrastructure will not promote new growth or development in the District;

(4) Draining, excavating, dredging, dumping, filling, removing or transferring loam, peat, sand, soil or other material substance, which will reduce the natural storage capacity of the land, interfere with the landward migration of coastal resources (such as salt marshes) in response to relative sea level rise, interfere with the natural drainage or flow patterns of any watercourse, or degrade the water quality of surface or ground water within the district, except activities that are incidental to aquaculture, established agricultural uses, otherwise approved beach nourishment projects, or flood or mosquito control work;

(5) Alteration of a sand dune, unless demonstrated that its beneficial functions of storm damage and flood reduction characteristics are enhanced;

(6) New development on a coastal bank or coastal bluff;

(7) New discharge of hazardous substances;

(8) Construction of any pipeline designed to carry crude oil or unprocessed natural gas; and

This prohibition may be untenable in communities that serve oil and gas industry distribution systems. Instead of a prohibition, municipalities should consider moving (8) to Section B below so that through the adjudicative permit process such construction is at least subject to heightened scrutiny and mitigation can be required.

(9) Use of land in any manner that will irreversibly or permanently destroy the natural vegetation, substantially alter the existing patterns of tidal flow, or otherwise alter or permit the alteration of the natural beneficial functions of land and resources within the district.

SECTION B. <u>Uses and Activities Permitted by Adjudicative Permit in the District</u>

Uses and activities in Section B are considered potentially harmful to the beneficial functions of the coastal floodplain and could be counter the purpose and intent of this bylaw. Therefore, heightened scrutiny should be applied. If a municipality has the ability to require an adjudicative permit (often referred to as a special permit or conditional use permit) for certain uses, the following section should be included. If no adjudicative permit granting authority exists, these uses should be discussed and either prohibited or subject to other available heightened permitting scrutiny.

(1) Notwithstanding any other provision of this bylaw, and upon issuance of a special permit by the [<u>*permit issuing authority*</u>] and subject to such special conditions and safeguards as are deemed necessary to fulfill the purposes of this bylaw, the following

uses and structures can be permitted in the Coastal Floodplain District by [adjudicative permit]:

Cities and towns should determine which board/body in their town has the authority to be an adjudicative permit granting authority and of those, which is most appropriate to deliberate on proposed coastal development. For example, in Massachusetts the Zoning Boards of Appeal typically serve as the special permit granting authorities, however, there is much local debate as to whether the Planning Board would be better suited to review impacts of development in the floodplain.

(a) Municipal parks and municipal water supply facilities including reservoirs, wells and pumping stations;

(b) Temporary storage of materials or equipment, provided such storage does not affect the water quality or the natural drainage patterns in the area;

(c) Nonresidential structures used only in conjunction with fishing, shell fishing, or the growing, harvesting or storage of crops raised on the premises, that do not affect the water quality or natural drainage patterns in the area;

(d) The construction of catwalks, piers, ramps, stairs, unpaved trails, boathouses, boat shelters, roadside stands, fences, wildlife management shelters, foot bridges, observation decks, and similar. Elevated structures, where appropriate, are preferred.

Burden of Proof. The applicant for an [*adjudicative permit*] shall have the burden of proving by a preponderance of credible evidence that the work proposed in the permit application will not have significant negative or cumulative effects upon the beneficial functions of storm damage prevention and flood control provided by coastal landforms, particularly the coastal floodplain, which serves the intent and purposes of this bylaw. Failure to provide adequate evidence to the *[permit issuing authority]* supporting this burden shall be sufficient cause for the *[authority]* to deny an adjudicative permit application.

(2) Uses and Activities Permitted in the District

Structures and other development in the coastal floodplain cause adverse impacts to the beneficial functions of the land surface and other coastal resources. Thus, very few uses should be allowed by right within the District. Typically the very nature of development within a floodplain requires conformance and compliance with additional state and local regulations.

The following uses allowed without need for an adjudicative permit generally do not involve structures or require alteration of any land in the district, thus the coastal floodplain is able to perform its natural function of absorbing storm surge, wave impacts, and coastal flooding. It is assumed that these permitted uses would not cause or contribute, directly or indirectly, to any harm should the land, on which they occur, flood.

Notwithstanding any other provisions of this bylaw, the following uses and activities are **permitted** as follows in the Coastal Floodplain District:

(3) Reconstruction shall be permitted where fire, storm, or similar disaster caused substantial damage of buildings. Reconstruction after substantial damage shall include all local, state and/or federal applicable code and regulatory requirements for the building, however, shall not increase floor area or the intensity of the use, and if located in the Coastal High Hazard Zone shall not convert a seasonal to a year-round use.

(4) For a water dependent use with no other alternative, development or redevelopment shall be permitted provided that the structure will not compromise the beneficial functions of coastal resources and that the applicant obtains permits from the appropriate authorities. If the development or redevelopment is >50% of the assessed value prior to work, the structure shall meet all existing requirements of this bylaw, including for example elevation including freeboard.

(5) Existing structures in Coastal High Hazard Zone and Tidal A-Zone of barrier beaches or coastal dunes may be reconstructed or renovated, provided there is no increase in floor area or intensity of use, or conversion from seasonal to year-round use. If the reconstruction or renovation is greater than 50% of the assessed value prior to work, the structure shall meet all existing requirements of Article 6 of this bylaw, for example elevating on open piles including freeboard.

(6) Outdoor recreation, including but not limited to play areas, nature study, boating, fishing and hunting where otherwise legally permitted, but excluding buildings and structures, unless allowed by other provisions of these regulations;

(7) Wildlife management or conservation areas, foot, bicycle, and/or horse paths and bridges, provided such uses do not affect the natural flow pattern of floodwaters or any water course;

(8) Agriculture or forestry uses;

(9) Accessory uses such as flower or vegetable gardens;

(10) Maintenance dredging of existing public and private channels and marine facilities;

(11) Repair or replacement of existing water and/or sewer systems in order to avoid impairment of or contamination from them during flooding.

ARTICLE 6. Development Standards for Use and Activity in the District

This Article presents performance or development standards for any development that may be allowed to proceed within the Coastal Floodplain District. This Article suggests standards in three sections. Some apply to the entire District (Section A), and others only apply to either the underlying Coastal High Hazard Zone (Section B) or Tidal A-Zone (Section C).

SECTION A. Development Standards for Use and Activity in the District

Any allowed use or activity within the boundaries of the Coastal Floodplain District shall meet the following standards in addition to all other applicable provisions of this bylaw:

(1) **Setback from Coastal Beach, Coastal Dune, and Coastal Bank Resources**

All new buildings and structures shall be setback from the landward edge of the landward-most coastal resource (excluding Land Subject to Coastal Storm Flowage, aka 100-year floodplain) [*70 times*] the average annual erosion rate for buildings <5,000 square feet, and [*100 times*] the average annual erosion rate for buildings >5,000 square feet. The erosion rate shall be calculated over the longest time frame available, but not less than 50 years, unless it is demonstrated that a different time frame is more appropriate in reflecting current and future shoreline conditions. If other standards apply, the stricter of the standards shall be adhered to.

The requirement for a 70 or 100-year erosion rate multiplier is based on a study of the average life expectancy of buildings in coastal areas around the U.S. conducted for the Federal Insurance Administration (see accompanying Technical Report, 'Coastal Building Life Expectancy' section). If a community is concerned that too many lots would be rendered unbuildable due to the 70 and 100-year safety setback requirements and anticipates untenable legal challenges or opposition in implementing safety setbacks, an alternative approach is to set an increasing minimum setback distance based on increasing lot depth (see Kauai County (HI) Ordinance #863). All buildings should be located landward of the long-term erosion setback for the life expectancy of the structure (e.g. 70 years X erosion rate for a small building (<5,000sf) and 100 years x erosion rate for larger buildings (>5,000sf), rather than simply landward of the reach of mean high tide (See FEMA Coastal Construction Manual, p.6-16).

(2) **Setback to Coastal Bank.**

(a) New Development: The setback from the top of the coastal bank for all new non-water dependent development shall be at least 70 times the average annual erosion rate of the bank or 100 feet, whichever is greater. The average annual rate of erosion shall be determined by averaging the erosion over the previous 70-year period at a minimum or other time frame determined by the permit issuing authority to appropriately reflect current and future shoreline conditions.

(b) Reconstruction/Renovation: Redevelopment shall be designed to have no adverse effect on the height, stability, or the use of the coastal bank as a natural sediment source to beaches, dune, barrier beaches and sub-tidal areas. All coastal banks are sediment sources to one degree or another for beaches, dunes, barrier beaches, salt marshes and/or near- or off-shore areas. Every feasible effort shall be made to reduce impacts to the resource, such as to maintain the same footprint or relocate structures landward.

(c) Water-dependent marine infrastructure or public recreation facilities exception: The setback from the top of the coastal bank for all new water-dependent marine infrastructure [*or public recreation facilities*] shall be as far landward as feasible and shall be designed to minimize impacts to the greatest extent feasible.

(3) **Setback to stable natural vegetation**. All new construction and substantial improvements shall be located a minimum of 40 feet landward of the first line of stable natural vegetation.

Often, bylaws require that construction be located landward of the reach of mean high tide, however mean high tide does not indicate stability. Dry sandy beaches landward of mean high tide are highly dynamic, normally eroding or narrowing in winter and becoming wider in summer. Short-term storm fluctuation in dry beach width is more critical, allowing storm waves and flood waters to inundate farther landward. The 40-foot additional buffer is necessary to accommodate a safety/design buffer for a storm erosion event and a margin to allow a homeowner sufficient time to consider alternatives to coastal armoring (see Hwang, 2005).

(4) **Accommodating relative sea level rise.** Relative sea level rise and the landward migration of coastal resources in response to relative sea level rise shall be incorporated into the design and construction of structures and other activities allowed within the District. Based on coupling the average life of a residential building (70 years) and current conservative predictions of eustatic sea level rise over the life-expectancy of the building, freeboard shall be provided according to this Article 6, Sections B(1) and C(1) below.

The practice of designing with freeboard is an important requirement within the District. Freeboard is the practice of raising a building's lowest floor in an A-zone or lowest horizontal structural member in coastal high hazard zones (V-, Coastal A-, and AO-Zones) above predicted flood elevations—a cost-effective approach that can lead to substantial reductions in flood insurance premiums, significantly decrease the chances a structure will be damaged by storms and flooding, and help protect against relative sea level rise. Additionally, providing freeboard provides an added margin of safety to address the flood modeling and mapping errors and uncertainties associated with generating FIRMs.

(5) **Accommodating the migration of coastal resources in response to relative sea level rise**. Any activity within the 10-year coastal floodplain shall not have an adverse effect by impeding the landward migration of coastal resources in response to relative sea level rise, therefore**:**

(a) No new construction shall be allowed;

(b) No fill shall be placed; and,

(c) New development, redevelopment, and other activities shall be located and designed so as not to impede the landward migration of coastal resources.

The 10-year 'still-water' flood elevation as shown on a community's FEMA Flood Insurance Study can be used as a topographic contour to delineate this area.

(6) **Flood water flow characteristics**. Any activity shall not have an adverse effect by increasing the elevation or velocity of flood waters or by increasing flows due to a change in drainage or flow characteristics (e.g. change in direction) on the subject site, adjacent properties, or any public or private way.

(7) **Inter-tidal aquatic vegetation.** No destruction or impairment of inter-tidal aquatic vegetation is permitted.

Aquatic vegetation creates a baffling effect that reduces wave energy.

(8) **Fill.** No fill is allowed in tidally restricted areas.

A tidally restricted area can be identified by a lag in the timing and phase of high tide between two adjacent water bodies.

(9) **Repair or Replacement of Existing Foundations**. Existing foundations may be repaired, unless the work replaces the foundation in total, replaces the foundation so as to constitute new construction, or constitutes a substantial repair of a foundation, which is defined as a repair to greater than 50% of its total linear distance as measured around the foundation perimeter. In such events, the foundation shall be brought into compliance with the applicable provisions of the development standards for the flood zone within which the activity takes place.

(10) **Datum.** The most recent applicable datum available for the site shall be used to determine the base flood elevation, and all other construction required elevations.

Use of the most recent Mean Sea Level datum available for a site should be required to determine base flood elevation and inform all coastal construction activities. When possible use of the 1988 datum of NAVD88, rather then the more commonly used 1929 datum of NGVD29 should be required. The difference can be as large as between 0.8 feet and 1.2 feet (e.g. Massachusetts) and accounts for relative rise in sea level, as well as the increased accuracy of newer measuring devices.

SECTION B. <u>Development Standards for Use and Activity in the Coastal High Hazard Zone</u>

Coastal High Hazard Zones have special flood hazards associated with high velocity waves from storm surges and, therefore, any allowed use or activity shall meet the following provisions in addition to all other applicable provisions of this bylaw:

(1) **Freeboard provision.** Any structures and other activities proposed in the Coastal High Hazard Zone shall be designed to have their lowest horizontal structural member three feet above Base Flood Elevation (BFE) in order to accommodate relative sea level rise and the landward migration of coastal resources in response to relative sea level rise, and to allow a margin for potential FEMA mapping uncertainties.

(2) **Damage prevention and flood minimization.** To maintain the storm damage prevention and flood control functions of land subject to coastal storm flowage:

(a) No activity shall increase the existing site elevations, except beach nourishment and/or dune enhancement; and

(b) No activity shall increase the velocity of flood waters or increase flows due to a change in drainage or flowage characteristics on the subject site, adjacent properties, or any public or private way; and

(c) Placement of fill in tidally restricted areas shall not be permitted.

(3) **Use of open foundation or piles.** For any new construction, substantial improvement, or lateral addition in a Coastal High Hazard Zone, or on a barrier beach or coastal dune located in any zone, the structure must be built on open pilings without breakaway walls and shall be adequately anchored to such pilings. Columns are allowed only when pilings cannot be driven. Pilings shall have adequate soil penetrations to resist the combined wave and wind loads (lateral and uplift) to which such piles are likely to be subjected during a flood to the base flood elevation. Pile embedment shall include consideration of decreased resistance capacity caused by scour of soil strata surrounding the piling.

(4) **Enclosures below the BFE**. All new construction and substantial improvements shall have the space below the lowest horizontal structural member free of obstruction so as not to impede the flow of flood waters, and to help reduce the potential accumulation of debris below the building. Open wood latticework or insect screening may be permitted [*<u>however, breakaway walls are prohibited</u>*.]

<u>Option</u>: Any material, including breakaway walls, located below the lowest floor will ultimately become wind or water debris during a storm. It is recommended in the FEMA Coastal Construction Manual that open lattice or screening be used for enclosures below the BFE instead of breakaway walls.

(5) Existing structures that can be reconstructed or renovated, including water-dependent structures and uses and maintenance of marine infrastructure, shall minimize impacts to coastal resources and not compromise the beneficial functions of storm damage prevention and flood control provided by coastal resources.

SECTION C. Development Standards for Use and Activity in the Tidal A-Zone

(1) **Freeboard provision**. All new buildings, including substantial improvements to existing structures, shall be designed to have their lowest horizontal structural member a minimum of three feet above Base Flood Elevation (BFE) in order to accommodate relative sea-level rise and the landward migration of coastal resources in response to relative sea level rise, and to allow a margin for potential FEMA mapping uncertainties.

(2) **Damage prevention and flood minimization.** To maintain the storm damage prevention and flood control functions of land subject to coastal storm flowage no activity shall increase the velocity of flood waters or increase flows due to a change in drainage or flowage characteristics on the subject site, adjacent properties, or any public or private way; and the placement of fill in hydraulically constricted areas shall not be permitted.

(3) **Enclosures below base flood elevation in a flood-hazard zone**. Enclosed spaces below the base flood elevation shall not be used for human occupancy with the exception of structural means of egress, entrance foyers, stairways and incidental storage. Fully enclosed spaces shall be designed to equalize automatically hydrostatic forces on exterior walls by allowing for the entry and exit of floodwaters. Designs for meeting this requirement shall either be certified by a registered design professional or conform to the *[State Building Code]* or NFIP standards.

Option: The following language is taken from the Massachusetts State Building Code, and serves as an example: [or conform to the following minimum criterion: a minimum of two openings having a total net area of not less than one square inch (645 mm2) for every one square foot (0.1 m2) of enclosed area subject to flooding shall be provided. The bottom of all openings shall not be higher than 12 inches (305 mm) above grade immediately adjacent to the location of the opening. Openings shall not be equipped with screens, louvers, valves or other coverings or devices unless such devices permit the automatic entry and discharge of floodwaters.]

ARTICLE 7. Reconstruction, Expansion, or Alteration of Pre-existing, Nonconforming Uses and Structure

Seek legal advice as to the laws applicable to pre-existing, non-conforming uses in your state/municipality and the statutes governing vested rights. The goal of any provision in this section would be to remove inventory from the coastal floodplain by not allowing for the reconstruction, expansion, or alteration of preexisting, nonconforming uses and structures, or by setting a time limit on rebuilding (often referred to as a sunset clause) after damage from a disaster. Typically, there are few opportunities to do this, short of purchasing property and/or development rights. It is suggested that communities take this opportunity if possible.

ARTICLE 8. Effect on Outstanding Floodplain Development Permits

Nothing herein contained shall require any change in the plans, construction, size, or designated use of any development or any part thereof for which a floodplain development permit has been granted by _____________ before the time of passage of this ordinance; provided, however, that when construction is not begun under such outstanding permit within a period of six (6) months subsequent to the date of issuance of the outstanding permit, construction or use shall be in conformity with the provisions of the ordinance.

ARTICLE 9. Definitions

The following words and terms shall, for the purposes of this bylaw have the meanings shown herein:

A-Zone: A-, AE-, A1-30 and A-99 zones are those portions of Land Subject to Coastal Storm Flowage (LSCSF) which are subject to inundation by types of 100-year flooding where waves <3 feet can occur but stillwater flooding predominates; AO-Zone is the area subject to inundation by moving water (usually sheet flow on sloping terrain) where average depths are between one and three feet.

Barrier Beach: A narrow low-lying strip of land generally consisting of coastal beaches and coastal dunes extending roughly parallel to the trend of the coast. It is separated from the mainland by a narrow body of fresh, brackish or saline water or a marsh system. A barrier beach may be joined to the mainland at one or both ends.

Base Flood Elevation (BFE): The flood having a 1% chance of being equaled or exceeded in any given year and shall be used to define areas prone to flooding, and describe at a minimum, the depth or peak elevation of flooding.

Breakaway Wall: A wall that is not part of the structural support of the building and intended, through its design and construction, to collapse under specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system.

Coastal A-Zone: Flood hazard areas inland of and contiguous to flood hazard areas subject to high velocity wave action. Areas subject to this classification are those where the still water depth is greater than or equal to 2 feet, and the breaking wave heights are greater than or equal to 1.5 feet. ASFPM (2007): areas where the resulting wave run-up elevations above storm surge are between 1.5 and 3 feet.

Coastal Bank: The seaward face or side of any elevated landform, other than a coastal dune, which lies at the landward edge of a coastal beach, land subject to tidal action, or other wetland.

Coastal Beach: Unconsolidated sediment subject to wave, tidal and coastal storm action which forms the gently sloping shore of a body of salt water and includes tidal flats. Coastal beaches extend from the mean low water line landward to the dune line, coastal bank line or the seaward edge of existing man-made structures, when these structures replace one of the above lines, whichever is closest to the ocean.

Coastal Dune: Any natural hill, mound or ridge of sediment landward of a coastal beach deposited by wind action or storm overwash. Coastal Dune also means sediment deposited by artificial means and serving the purpose of storm damage prevention or flood control.

Coastal Floodplain: Coastal resource managers use certain terms interchangeably to reference the area considered to be the coastal floodplain. The following terms and resource areas are synonymous and equal the coastal floodplain:

- Land Subject to Coastal Storm Flowage
- The sum of V-Zone, Coastal A-zones, AO-Zones, and tidally influenced A-Zones

Coastal High Hazard Zone: For the purposes of this bylaw and its regulation the *Coastal A-zone*, *AO Zone, and all V-zones* will together constitute the Coastal High Hazard Zone. Additionally, due to wave action and storm surge, coastal erosion, increasing flood elevations due to relative sea level rise, and potential map errors the Coastal High Hazard Zone shall include all land *200 feet landward* from the landward boundary of all FEMA V-zones, unless the LiMWA has been delineated on the community FIRM.

As an alternative to the 200-foot landward buffer from the landward edge of all V-zones (considered Coastal A-Zone), if FEMA has not mapped the Coastal A-zone on recent community FIRMs, an applicant can conduct an analysis to determine the actual landward limit of the 1.5-foot breaking wave (see definition of Coastal A-Zone). If such analysis is conducted, that landward limit of the 1.5-foot wave shall be the landward limit of the Coastal High Hazard Zone for regulatory purposes.

Coastal Wetland Resource Area/Coastal Resource: Coastal Wetland Resource Areas (also referred to as Coastal Resources within this bylaw) include barrier beaches, coastal beaches, coastal dunes, rocky intertidal shores, tidal flats, land subject to 100 year coastal storm flowage, coastal banks, land containing shellfish, lands subject to tidal action, and lands under an estuary, salt pond or certain streams, ponds, rivers, lakes or creeks within the coastal zone that are anadromous/catadromous fish runs.

Elevation: The placement of a structure above flood level to minimize or prevent flood damages or to preserve the flood control and storm damage prevention functions of a coastal resource.

Flood Zones: Areas of flood hazard designated by FEMA to represent the potential extent of flooding based on 100-year storms. Various zones are determined by topographical analysis done under a Flood Insurance Study. Areas of minimal flood hazard are outside of the Special Flood Hazard Area (A- and V-zones).

Floodproofing: Any combination of structural and non-structural additions, changes or adjustments to structures which reduce or eliminate flood damage to new or substantially improved structures.

FEMA: Federal Emergency Management Agency

Flood Insurance Rate Map/FIRM: Flood insurance rate map (FIRM) means an official map of a community, which delineates both the special hazard zones and the risk premium zones applicable to the community published by the Federal Emergency Management Agency.

Freeboard: The height added to the Base Flood Elevation (BFE) to account for the many unknown factors that could contribute to flood heights greater than the height calculated for a selected size flood and floodway conditions, such as relative sea level rise, wave action, blockage of bridge openings, and the hydrological effect of urbanization of the watershed. The BFE plus the freeboard establishes the Design Flood Elevation.

High-hazard zones: See definition of Coastal High Hazard Area/Zone.

Land Subject to Coastal Storm Flowage (LSCSF): Land subject to inundation caused by coastal storms from the seaward limit at mean low water up to and including that resulting in a 100-year flood, surge of record, or flood of record, whichever is greater. The 100-year flood (or the base flood as it is also referred to) means the flood having a one-percent chance of being equaled or exceeded in any given year. LSCSF is considered significant to storm damage prevention, flood control, the protection of wildlife habitat and the prevention of pollution.

Lateral Addition: an addition that expands the footprint of a building or structure including a manufactured home.

Lowest Floor: The lowest floor of the lowest enclosed area (including basement/cellar). An unfinished or flood resistant enclosure, usable solely for parking of vehicles, building access, or incidental storage in an area other than a basement/cellar with appropriate hydrostatic openings as required in 780 CMR 120.G.501.4 is not considered a building's lowest floor.

Scouring: The erosion or washing away of soil and/or the reduction of slope angles by velocity waters.

Special Flood Hazard Areas (SFHA): This is the term given to the Land Subject to Coastal Storm Flowage (LSCSF) and is comprised of the V-zones plus A-zones. SFHA is an area having special flood, and/or flood-related erosion hazards and shown on a Flood Hazard Boundary Map or FIRM as Zone A, AO, A1-30, AE, A99, AH, VO, V1-30, VE, V.

SLOSH Zone: The SLOSH, or Sea, Lake and Overland Surges by Hurricanes, is a computer model developed by the National Weather Service designed to forecast surges that could occur from wind and pressure forces of hurricanes. The SLOSH maps show surge limits that represent potential flooding that may occur from critical combinations of hurricane track direction, forward speed, landfall location, and high astronomical tide, which are tailored to likely Hurricane scenarios in a particular geographic region.

Structure: A walled and roofed building, including a gas or liquid storage tank, that is principally above ground and affixed to a permanent site, as well as a manufactured home.

Substantial Damage: Damage of any origin sustained by a building or structure including a manufactured home whereby the cost of restoring the building or structure to its before damaged condition would equal or exceed 50 percent of the *assessed* value of the building or structure before the damage occurred.

Option: Use assessed value instead of the more commonly used market value. Market value is highly variable and subject to interpretation. Also, when a structure is damaged it may be difficult or impossible to determine what the prior present market value was. The assessed value will be on record for tax purposes.

Substantial Improvement: Any combination of repairs, reconstruction, rehabilitation, addition, or other improvement of a structure, taking place during any one-year period for which the cost[1] equals or exceeds 50 percent of the *[assessed]* value of the structure before the "start of construction" of the improvement.

Option: Use assessed value instead of the more commonly used market value for the substantial improvement calculation. Market value is highly variable and subject to interpretation. Assessed value is generally lower than market value. Thus, upgrading to safer building codes will be achieved sooner using assessed value, and is therefore the recommended valuation for this type of bylaw.

When and if discrete building or structure improvements made over a consecutive five-year period cumulatively exceed 50% of the structure or buildings assessed value, the proposed improvement will be considered a substantial improvement, and the entire building or structure must meet all applicable performance standards for the flood zone within which the building or structure is located.

[1] The following items can be excluded from the cost of improvement or repair:
plans, specifications, survey, permits, and other items which are separate from or incidental to the repair of the damaged or improved building. i.e. debris removal/cartage.

This language makes the calculation of substantial improvement ***cumulative****. Often homeowners make incremental changes to avoid elevation and retrofitting requirements. While understandable, this however, is counter to intent and purposes of this bylaw--to protect the health, safety and welfare of the public.*

Substantial Improvement includes structures that have incurred "substantial damage", regardless of the actual repair work performed. The term does not, however, include either:

(a) any correction of existing violations of State or community health, sanitary, or safety code specifications which have been identified by the community code enforcement official and which are the minimum necessary to assure safe living conditions; or

(b) any alteration of a historic structure, provided that the alteration will not preclude the structure's continued designation as a historic structure.

Exception: If a substantial improvement consists exclusively of a lateral addition that does not rely on the support of the existing structure, only the lateral addition must be erected in accordance with the applicable provisions for the flood zone within which the building is taking place.

Substantial Repair of a Foundation: Work to repair and/or replace a foundation that results in the repair or replacement of the portion of the foundation walls with a perimeter along the base of the foundation that equals or exceeds 50% of the perimeter of the base of the entire foundation measured in linear feet. The term "substantial repair of a foundation" also includes a building or structure including a manufactured home that has incurred a failure of a foundation regardless of the actual work done to repair or replace the foundation.

Tidal A-Zone: Tidal A-Zones are the area of the 100-year coastal floodplain landward of the Coastal A-zone, where tidally-influenced stillwater flooding predominates.

Tidal Flat: Any nearly level part of a coastal beach that usually extends from the mean low water line landward to the more steeply sloping face of the coastal beach.

Velocity Zone/V-Zone: Area extending from the mean low water line to the inland limit within the 100-year floodplain supporting waves greater than three feet in height. V-Zones are mapped on a FEMA Flood Insurance Rate Map (FIRM), but also include all land area extending to the landward toe of the frontal dune (which area is often not depicted on the FIRM but defined as V-Zone by FEMA). V-zones are subject to hazardous flooding, wave impact, and in some cases significant rates of erosion as a result of storm wave impact and scour. V-Zone is synonymous with High-hazard Zone, and for purposes of this bylaw constitutes part of the Coastal High Hazard Area/Zone.

ARTICLE 10. Severability

If any provision of this bylaw is held invalid by a court of competent jurisdiction, the remainder of the bylaw shall not be affected thereby. The invalidity of any section or sections or parts of any section or sections of this bylaw shall not affect the validity of the remainder of this bylaw.

This section is a generic severability clause. Severability clauses are intended to allow a court to strike or delete portions of a regulation that it determines to violate state or federal law. In addition, the severability clause provides limited insurance that a court will not strike down the entire bylaw should it find an offending section(s).

REFERENCES

Anderson, C.M., 1978, Coastal Residential Structures Life Time Determination, prepared for the Federal Insurance Administration, Department of Housing and Urban Development.

Association of State Floodplain Managers, 2008, Natural and Beneficial Floodplain Functions: Floodplain Management – More Than Flood Reduction, Position Paper.

Association of State Floodplain Managers, 2007 (May), Coastal No Adverse Impact Handbook, Madison, WI (www.floods.org)

Association of State Floodplain Managers, 2006, No Adverse Impact in the Coastal Zone, http://www.floods.org

Bernd-Cohen, T. and Gordon, M, 1999, State Coastal Program Effectiveness in Protecting Natural Beaches, Dunes and Bluffs, and Rocky Shores, Coastal Management, 27:187-217.

Bindoff, N.L., J. Willebrand, V. Artale, A. Cazenave, J. Gregory, S. Gulev, K. Hanawa, Le Quere, S. Levitus, Y. Nojiri, C.K. Shum, L.D. Talley, and A. Unnikrishnan, 2007, Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, and H.L. Miller (eds), Cambridge University Press, Cambridge, UK and New York, pp. 385-432.

Buckley, M.K. 2008, Procedure Memorandum No. 50 – Policy and Procedures for Identifying and Mapping Areas Subject to Wave Heights Greater than 1.5 Feet as an Informational Layer on Flood Insurance Rate Maps, Memo for Regional Mitigation Division Directors, Regions I –X, December 3, 2008, Effective Immediately.

Environmental Protection Agency, U.S. Geological Survey, NOAA, Department of Transportation, 2009, Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region, U.S. Climate Change Science Program, Synthesis and Assessment Product 4.1.

Eversole, D.N. and Norcross-Nu'u, 2008, Hawaii Sea Grant College Program Extension and Outreach Efforts: Kauai Shoreline Setback Ordinance Amendments, Solutions to Coastal Disasters, ASCE, Oahu, HI.

FEMA, 2008, Disaster News, National Flood Insurance: 1989-2008, DR-1768-WI-NR-149, September 6, Joint Field Office, Madison, WI.

FEMA, 1998, Homeowners Guide to Retrofitting: Six Ways to Protect Your House from Flooding, Mitigation Directorate, Washington, DC.

FEMA, 2000, Coastal Construction Manual, FEMA 55.

Fletcher, C., 2009, The Blue Line, University of Hawaii, SOEST, at www.soest.hawaii.edu/coasta/sealevel/

Fletcher, C. H., and Merrifield, M.A., 2009, Sea Level by the End of the Century: A Review, University of Hawaii, Honolulu, HI, Position paper, May 29.

Fletcher, C.H., Mullane, R.A. and Richmond, B.M., 1997, Beach Loss Along Armored Shorelines of Oahu, Hawaiian Islands, *Journal of Coastal Research*, V.13, p.209-215.

Gutierrez, B.T., Williams, J.W. and Thieler, E.R., 2007, Potential for Shoreline Change Due to Sea Level Rise Along the Mid-Atlantic Region, U.S.G.S. Report Series 2007-1278.

H. John Heinz Center, (2000), Evaluation of Erosion Hazards, prepared for FEMA, Washington DC.

IEP, Inc, (1990), Sea Level Rise Implications: An Action Plan for Buzzards Bay, prepared for the New England Interstate Water Pollution Control Commission.

Intergovernmental Panel on Climate Change (IPCC), 2007(A), Climate Change 2007: The Physical Science Basis, Summary for Policy Makers, Contribution of Working Group 1 to the Fourth Assessment Report, Alley, R, et al.

Intergovernmental Panel on Climate Change (IPCC), 2007(B), Summary for Policy Makers. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

Jones, C., Coulbourne, W.L., Marshall, J., and Rogers, S.M., 2006, Evaluation of the National Flood Insurance Program's Building Standards, prepared under sub-contract to the American Institutes for Research as part of the 2001-2006 Evaluation of the National Flood Insurance Program.

Kauai County, 2008, Shoreline Setback and Coastal Protection Ordinance, Ordinance #863, Hawaii.

Kusler, J.A. and Thomas, E.A., November 2007, No Adverse Impact and The Courts: Protecting the Property Rights of All, prepared for the Association of State Floodplain Managers (www.floods.org)

Massachusetts Coastal Zone Management Agency, StormSmart Coasts program Fact Sheet 2, *No Adverse Impact and the Legal Framework of Coastal Management: How communities can protect people & property while minimizing lawsuits*, April 2008.

Maurstad, D, 2007, FEMA, Asst. Administrator, in Natural Hazards Observer, Vol. XXXI, No. 6, pp. 1-3.

Maurstad, D., 2005, FEMA, Acting Director, Mitigation Division, Memo to Division Directors.

NOAA, National Ocean Service, Sea Level Variations in the United States 1854-1999, NOAA Technical Report NOS CO-OPS 36, Silver Springs, Maryland, July 2001.

NOAA, 2005, Population and Trends along the Coastal U.S., 19802 – 2008.

Ocean and Coastal Resources Management, 2008, (web site – http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_setbacks.html)

O'Connell, James, F., 1995, Scientific Recommendations for Performance Standards for Land Subject to Coastal Storm Flowage, report presented to the Massachusetts Department of Environmental Protection by the Coastal Floodplain Task Force, unpublished.

Pielke, R.A., Gratz, J., Landsea, C., Collins, D., Saunders, M.A., and Musulin, R., 2008, Normalized Hurricane Damage in the United States: 19000-2005, Natural Hazards Review.

Pielke, R.A, 2008, Climate Predictions and Observations, Nature Geoscience, V.1, p. 206 (in Fletcher and Merrifield, 2009).

Rogers, S.M, and Jones, C.P., 2002, Selecting Erosion Setbacks for Balanced Multi-Hazard Risk, in Proceedings of Solutions to Coastal Disasters Conference, ASCE.

Sea Grant, NOAA, Coastal Natural Hazards Theme Team, 2006, Reducing the Nation's Vulnerability to Coastal Natural Hazards, http://www.haznet.org.

Suburban Emergency Management Project, 2009, Recent Treacherous US Treasury Borrowing by National Flood Insurance Program, Biot Report #538, September 17.

Stutts, A., Chrystos, S. and Rogers, S., 1985, Effect of Ocean setback Standards on the Location of Permanent Structures in Coastal North Carolina, Coastal Zone '85, ASCE.

Titus, J.G. Hudgens, D.E., Trescott, D.L., Craghan, m., Nuckols, W.H., Alexander, J.A., Clark, w., Hersner, C.H., Kassakian, J., Linn, C.J., Merritt, P.G., McCue, T.M., O'Connell, J.F., Tanski, J., Wang, J., 2009, State and Local Governments Plan for Development of Most Land Vulnerable to Rising Sea Level along the U.S. Atlantic Coast, Environmental Research Letters, V.4.

U.S. Army Corps of Engineers, 1988, Tidal Flood Profiles New England Coastline, Hydraulics and Water Quality Section, New England Division September.

University of Copenhagen, 2009, Sea Level Rise of One Meter within 100 Years, (in ScienceDaily, retrieved January 17, 2009).

Zervas, C., 2001, Sea Level Variations of the United States 1854-1999, NOAA Technical Report NOS Co-OPS 36, (in Gutierrez, B.T., Williams, J.W. and Thieler, E.R., 2007, Potential for

Shoreline Change Due to Sea Level Rise Along the Mid-Atlantic Region, U.S.G.S. Report Series 2007-1278).

APPENDIX A

Bylaws, Regulations and Model Bylaws Reviewed by Project Authors

Cape Cod Commission, Barnstable County, Massachusetts, Model Floodplain District Bylaw, November 1998.

Maine Floodplain Management Handbook, Executive Department, State Planning Office, Model Floodplain Management Ordinance, May 1998.

Massachusetts Association of Conservation Commissions, Non-Zoning Wetlands Protection Bylaw/Ordinance, 9th Edition of the MACC Environmental Handbook for Massachusetts Conservation Commissioners, 2006.

Middlesex County Department of Planning and Community Development, Middlesex County Virginia, Floodplain Ordinance, February 20, 2007, as adopted.

North Carolina Department of Crime Control and Public Safety, Division of Emergency Management, Floodplain Management Branch, North Carolina Model Flood Damage Prevention Ordinance (and instructions), July 3, 2007.

Town of Bourne, Massachusetts, Zoning Bylaws, Section 3110, Flood Area Provisions, Lowland Regulations.

Town of Chatham, Massachusetts, Zoning Bylaws, Section IV Conservancy District and Floodplain District.

Town of Falmouth, Massachusetts, Zoning Bylaw, Article XVIII, Chapter 240. Zoning, Floodplain Zone.

Town of Mashpee, Massachusetts, Zoning Bylaws, Article XI, Sections 174-58 to 174-68, Flood Zone Provisions.

Town of Orleans, Massachusetts, Zoning Bylaws, Section 164-15, Conservancy District.

Town of Scituate, Massachusetts, Zoning Bylaw, Section 470, Flood Plain and Watershed Protection District.

Photo Credits (Cover)

1. Winds Cottage, Southern Cottage House Plans, website (accessed November 9, 2009).
2. Coastal Home, O'Connell, 1991.
3. Salt marsh against bulkhead, Urbanization & Southeastern Estuarine Systems Project, website (accessed November 9, 2009).