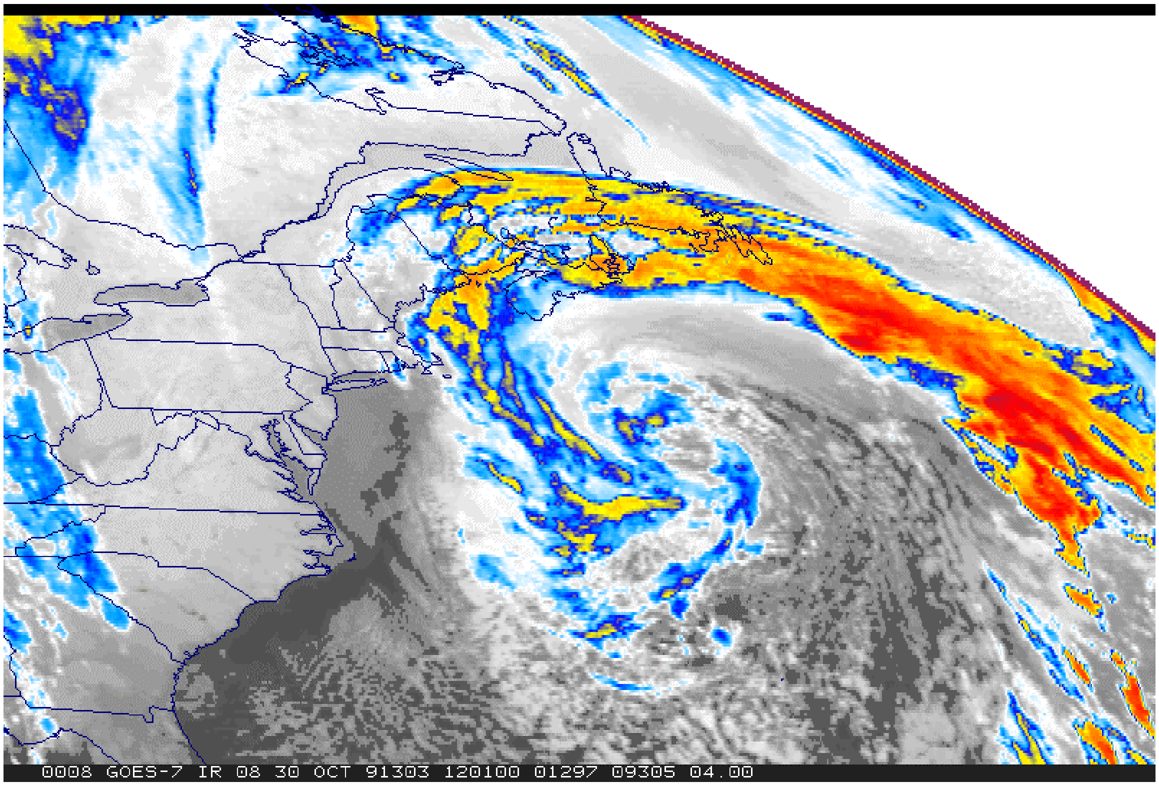
New Jersey Sea Grant College Program

Manual for Coastal Hazard Mitigation

Compiled by
Thomas O. Herrington



PREFACE

New Jersey is often used as an example of a natural system gone awry. The unflattering term "New Jerseyization" was coined by a prominent scientist to describe a developed, eroding coast, where natural beaches have been replaced by engineering structures. This view may have been correct in the past, when seawalls and bulkheads replaced many of our beaches, but our beaches are being brought back by artificial nourishment projects. Hard protection structures are only one phase in the cycle of changes on a developed coast. Human efforts can help regenerate landforms and biota, providing we take a pro-active approach to shore protection that accommodates a wide range of resource values.

The preferred method of shore protection in New Jersey has changed from groins, to bulkheads and seawalls, to beach nourishment. Hard protection structures are less likely to be built in the future, but many structures still exist, and some new structures may have local usefulness. Accordingly, it is important to know how these structures function. It is also important to know that all protection strategies have usefulness, but they are not readily interchangeable at a given location.

Beach nourishment can help restore lost natural values, but many municipalities have elected to grade and rake their nourished beaches, preventing them from evolving into topographically and biologically diverse natural environments. The large amount of sand scheduled to be pumped onto New Jersey beaches in the future represents an invaluable resource, but the full potential of nourishment will not be realized without addressing habitat improvement and nature-based tourism in addition to the goals of protection from erosion and flooding and provision of recreation space. A dune is another valuable natural resource that is often overlooked. Dunes provide protection from flooding and valuable habitat, but they are often eliminated or prevented from growing because they restrict views or access to the beach. It is within our capability to recapture many of the natural values of beaches and dunes that have been lost by building too close to the water, but we must know the tradeoffs involved in selecting the best management option.

Successful mitigation of coastal hazards requires preparedness by municipalities and individual residents. This preparedness, in turn, requires knowledge of the processes causing these hazards and the alternatives available to reduce vulnerability and maintain our future options. This manual will help in that decision-making process by providing information stakeholders can use in managing properties and becoming more involved in decisions made by municipal, state and federal managers. Management of beaches and dunes is not simply a government responsibility. Property owners and visitors can help determine the kind of coast we will have in the future and help maintain that coast as stewards of the resources we own and use. Millions of dollars are spent to keep our beaches viable and protect valuable shorefront property. It is up to all of us to make sure that the money is well spent.

Karl F. Nordstrom
Rutgers University

FOREWORD

Beginning on March 6, 1962, the most devastating coastal storm in modern history assailed the New Jersey coast for three days. At its peak on March 6th and 7th, the storm generated a 3.5 ft storm surge over three successive high tides, each tide peaking at 8.8 ft above mean lower low water (MLLW). Massive waves of up to 40 ft high generated by sustained winds of 45 knots blowing over a 1000 miles of open ocean came crashing toward the New Jersey coast. By the end of the storm, 9 people lost their lives, 16,407 structures suffered damage and 21,533 structures experienced significant flooding. A total of $120 million (1962 dollars) in damages resulted from this event. On December 11, 1992, the New Jersey coast was once again battered by a major coastal storm. A peak storm surge of 4.3 ft was measured on the 11th as the water reached an elevation of 9.14 ft MLLW. The water never receded until December 14th, three days later. Waves of up to 44 ft were measured 25 miles offshore of Long Branch during the storm. By storm's end, 2 deaths were recorded, 3,200 homes were damaged and $750 million (1992 dollars) in damages were assessed.

Why were the damages so different between the two storms? The answer lies in the proactive measures – *hazard mitigation-* taken to prevent further damage after the March 1962 storm. The engineering of shore protection structures, beach replenishment projects, dune construction, improved siting and building codes, and the establishment of sound floodplain management through the National Flood Insurance Program all contributed to reducing the vulnerability of New Jersey's coastal communities. Thirty years of ongoing mitigation efforts were tested on December 11, 1992, and they proved successful. Hazard mitigation, however, is a continuous endeavor and although our coastal communities weathered the 1992 storm, we must be prepared for the next major and possible more severe storm.

This Manual for Coastal Hazard Mitigation (MCHM) introduces the concept of coastal hazard mitigation through community and individual preparedness, identifies the unique hazards associated with living in the coastal zone and provides information for implementing effective hazard reduction efforts. Broad in scope, and presenting a wide range of mitigation techniques from grassroots initiatives to regional efforts promoted by the federal government, the MCHM is a comprehensive document that references the underlying coastal processes that form the basis of each coastal hazard mitigation technique.

The MCHM first provides an overview of the concept of natural hazard mitigation and risk assessment, followed by detailed descriptions of hazards present in the coastal zone. The mitigation tools and techniques section of the manual presents nine broad categories of mitigation practices; beach nourishment, coastal regulation, building elevation, siting, shore protection structures, coastal resource management, natural resource restoration, building techniques and community maintenance and preparedness. Each mitigation technique presented begins with a synopsis of the mitigated hazard, level of effort required and the agencies that typically implement the technique, followed by a detailed description of the technique and its application. Each section ends with a listing of local, state and national agencies that can be contacted to obtain more information. A complete listing of references and additional information resources is included at the end of the manual.

Throughout the MCHM an effort has been made to reference each hazard and mitigation technique to specific examples in New Jersey. However, the hazards and mitigation techniques presented are not just specific to this region but can be applied to almost any sandy coastline. The manual includes many figures, diagrams and photograph to illustrate the concepts and techniques presented, most of which depict the New Jersey coast. We hope it will be useful for individuals, communities and municipalities wishing to explore techniques to reduce their exposure to natural hazards in the coastal environment.

Thomas O. Herrington
NJ Sea Grant Coastal Processes Specialist

ACKNOWLEDGEMENTS

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FEMA granted permission to reprint many of the illustrations appearing in the text from the Coastal Construction Manual (FEMA, 2000). Other photographs were provided courtesy of S.D. Halsey and M.S. Bruno. N. Amey, M. Bruno, P. Griber, and K. Smith provided extensive review comments on the text. Finally, I would like to thank K. Kosko, and M. Samuel, for their expert guidance and abilities in converting this manual from a technical document to a readable Sea Grant outreach publication.

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COASTAL HAZARD MITIGATION

To many, a day at the shore conjures up images of wide sandy beaches, gentle sea breezes and rhythmically rolling surf. The beach, however, is a landscape of constant change; sometimes evolving gradually on a scale of days, weeks, months or seasons, and sometimes occurring nearly instantaneously in response to violent winds, tides or waves generated by coastal storms. These changes occur with every rise and fall of the tide. For those living along the coast, the dynamic nature of the coastline exposes communities, properties and people to a unique set of hazards. To reduce the risks presented by coastal hazards, it is important to understand that we can make informed decisions on how best to build our coastal communities. By understanding the environment we live in and taking the proper steps to mitigate the potential dangers in our environment, we can create sustainable coastal communities that reduce our impact on the very natural resources that make the coast a desirable place to live.

Over 50% of the U.S. population resides within 50 miles of the coast and that population is currently growing at 4-5% per year. The coast attracts another 180 million visitors annually. In order to sustain the Nation's coast as a desirable place to live, work and play, it is in the national interest to mitigate damage that occurs during severe coastal storms. Over the next decade, these issues will have a substantial impact on building codes, construction technology, storm hazard preparedness and emergency response, all aimed at saving lives and minimizing property damage.

This Manual for Coastal Hazard Mitigation (MCHM) provides interested parties with information for implementing effective hazard reduction efforts. Broad in scope, and presenting a wide range of mitigation techniques from grassroots initiatives to regional efforts promoted by the federal government, the MCHM is a comprehensive document that references and integrates underlying coastal processes. The MCHM is intended to serve as a resource for individuals, and federal, state, and local officials with which to form the basis of informed coastal hazard mitigation decisions.

All mitigation techniques are not interchangeable. Most are site specific and many may be constrained by local, state or federal regulations. The probability of any given technique being successful is dependent on a number of independent factors including the type of hazard, resources available, legal requirements and amount of public support. To facilitate the usefulness of the manual, each mitigation technique presented starts with a synopsis of the mitigated hazard, level of effort required and which agencies typically implement each technique.

HAZARD MITIGATION

Natural hazards expose people, property and communities to the risk of injury, damage and economic hardship. By recognizing the danger posed by natural hazards, individuals and communities can take proactive steps to minimize potential impacts. Best Management Practices (BMP) are available that can reduce or eliminate the long-term impacts of natural hazards. When applied prior to an impending natural disaster, these techniques are collectively known as Hazard Mitigation. The Federal Emergency Management Agency defines Hazard Mitigation as "sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects.[1]" It describes ongoing efforts at the Federal, State, local, and individual levels to lessen the impact of disasters upon our families, homes, communities and economy.

Reducing a community's potential loss due to natural hazards requires a balanced approach that applies mitigation measures to both new construction and the existing built and natural environment. Improved decision-making in coastal planning and development will decrease the vulnerability of the built and natural environment to damage and reduce the financial cost of disaster relief. Retrofitting existing structures and infrastructure will likewise reduce the risk of future damage.

Hazard Mitigation can be implemented through education, planning and practice. Through the application of sound mitigation practices, managers can ensure that fewer communities will become victims of natural disasters. Mitigation measures can be applied to strengthen homes and public buildings, so that people and property are better protected against natural hazards. Businesses can implement mitigation strategies to avoid damages to facilities and remain operational in the face of catastrophe. Mitigation technologies can be used to strengthen critical facilities such as hospitals, fire and police stations, and other public service facilities so that they can remain operational or reopen more quickly after a natural disaster.

Hazard Mitigation can be achieved in many different ways and at many different scales. Agencies responsible for coastal hazard mitigation planning at various levels include the:

Federal Government
Regional Shore Protection
Inlet Stabilization
Flood Hazard Mapping
National Flood Insurance Program

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[1] Information pertaining to Hazard Mitigation has been provided by the National Mitigation Strategy: Partnerships for Building Safer Communities, published by the Federal Emergency Management Agency. For more information see: http://www.fema.gov/mit/ntmstrat.htm

State Government
Coastal Land Use Regulation
Construction and Maintenance of Shore Protection Structures
Coastal Zone Management
Land Preservation and Restoration

Local Government/Community
Local Zoning Ordinances
Emergency Services
Maintenance of Public Works and Infrastructure
Building Codes, Permittin,g and Enforcement

Citizens and Property Owners
Knowledge of the Coastal Environment and Natural Hazards
Satisfying Minimum Building Standards
Acceptance and Enhancement of Natural Buffers including Dunes
Maintenance of Property and Structures

When individuals, local governments and independent organizations accept responsibility for mitigating natural hazards in their communities, cost-effective actions can be taken to reduce the loss of lives and property, damage to the environment, and economic and social disruption caused by natural disasters. When implemented, Coastal Hazard Mitigation will *lessen the likelihood that natural hazards will become natural disasters.*

RISK ASSESSMENT

Risk is broadly characterized as the measure of the potential *losses* associated with adverse events (e.g., a severe coastal storm), whereas, risk *assessment* is the means used to evaluate risks associated with a *specific hazard* in terms of the probability and frequency of occurrence, severity, exposure, and consequences. The MCHM is designed to help reduce risks by presenting ways to limit the exposure of coastal structures and residents. Hazards can include discrete events that recur over time, as well as continuous events the result in cumulative impacts. An accurate characterization of the risk of individual coastal hazards is necessary for the implementation of the most cost-effective mitigation technique for a given situation.

In a general sense the assessment *and* management of risk can be addressed by the answers to six questions:

Risk Assessment

1. What can go wrong?
2. What is the likelihood that it will go wrong?
3. What are the consequences?

Risk Management

1. What can be done?
2. What options are available and what are the associated tradeoffs in terms of costs, risks, and benefits?
3. What are the impacts of current decisions on future options?

Risk Assessment

Coastal Hazards *(or What can go wrong?)*

Hazards in the coastal zone encompass numerous unavoidable risks to life and property caused by natural forces in the environment. *Natural* hazards in this region include coastal flooding, waves, high winds, short-term and long-term shoreline erosion, storm surges and sea level rise. Each hazard creates associated risks to the built and natural environment as well as local communities.

Probability and Recurrence *(or What is the likelihood it will go wrong?)*

Natural hazards in the built environment can be characterized by the time between occurrences (recurrence interval) of a design event. Often, minimum building codes and regulations require that a building be designed to withstand the occurrence of a hazard with a magnitude and probability of the design event. As an example, in the coastal zones of the United States buildings must be constructed to withstand the 100-year flood, which occurs with a 1-percent probability of being exceeded in any given year. The 100-year storm event is chosen as the standard of protection or target state since such events generally are capable of permanently altering coastal landforms.

Once the recurrence interval and magnitude of the hazard is known, an architect and/or engineer can plan a structure to withstand the design event. Note however, that lifespan of the structure needs also to be considered in determining the actual probability that a design event will occur over the intended period of use. Using the 100-year flood event, as the period without the occurrence of a 100-year flood increases, so does the probability that a flood of this magnitude or greater will occur. For example, over a 30-year period (the length of a typical mortgage) the probability of a flood with a 1-percent probability of occurrence in a given year increases to 26 percent[2]. Over a 100-year period, there is a 63 % probability that a 100-year flood event or greater will occur. Clearly, in order to effectively mitigate the 100-year flood hazard one must determine how long the structure would likely remain in the hazard area.

What are the Consequences?

The nature and severity of a natural hazard's consequences is dependent on a number of factors, including: the magnitude of the event, how close you are to the hazard, the strength and integrity of the structure or system, and how well the structure or system is maintained. In many cases, an event will expose a structure or system to *multiple* hazards (e.g., flooding and erosion). Properly conducted, a risk assessment must account for *all* of potential hazards for a given event in order to accurately determine vulnerability. Additionally, many of these natural hazards have both short- and long-term consequences that complicate the risk assessment process. Overlooking one of the hazards or misrepresenting its associated risk can lead to disastrous consequences, including increased vulnerability, loss of property, damage to the natural ecosystem and even loss of life.

Risk Management

The management of natural hazard risk can be broadly categorized by:

- Hazard Mitigation
- Insurance
- Residual Risk

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[2] The formula for calculating the cumulative probability is $P_n = 1-(1-P_a)^n$, where P_a is the annual probability of occurrence and n is the length of the period.

Hazard Mitigation

Hazard mitigation is any sustained action taken to reduce or eliminate the long-term risk generated by hazards to people and the built and natural environment. Mitigation can take several forms, including: siting, construction techniques, protective works (erosion control structures, beach fills, dune construction), maintenance, land use regulation, coastal zone management planning, and enhancement of natural buffers. Hazard mitigation seeks to *permanently* reduce risk or over long durations, rather than preparing for, or responding to, an impending event.

Insurance

Insurance provides property owners with a financial resource to mitigate the consequences of natural hazards. There are a variety of financial tools available, including homeowners insurance, flood insurance (through the National Flood Insurance Program, NFIP), insurance pools and self-insurance plans. Homeowners insurance will generally cover wind and earthquake damage but not flood damage. If a community is part of the NFIP, a homeowner is eligible for federally underwritten flood insurance with rates that vary with risk level. If standard insurance is not available due to unacceptable risk levels or the assessed value of the property, insurance pools and self-insurance are methods used to provide financial security against hazard damage.

Residual Risk

Eliminating all risk is impossible. All structures, systems and protective works have costs associated with their design, construction and maintenance. Property also has an assessed value based on location, improvements and market worth ("willingness to pay"). In the course of risk assessment and hazard mitigation, the cost associated with these protective actions must be weighed against the value of the property or system over the duration of its useful life. If the BMP exceeds the value of the structure being protected, then the solution is not cost-effective and a lesser mitigation technique may be warranted. If a natural disaster exceeding the design event were to occur, a lower protection level may not completely cover the potential loss in value of the property or system. Such losses are a trade-off to the cost of complete protection. These trade-offs are collectively viewed as residual risk that must be accepted by the property or system owner. The principle of an acceptable level of residual risk underlies all protective works and mitigation techniques.

COASTAL HAZARDS

What are Coastal Hazards?

Hazards in the New Jersey coastal zone include unavoidable risks to life and property generated by: coastal flooding, waves, high winds and waves, short-term and long-term shoreline erosion, storm surges, and sea level rise. Each of these natural hazards creates a series of associated risks to coastal communities from hydrostatic and hydrodynamic forces on structures generated by coastal floodwaters and breaking waves, debris impacts, undermining of structures by scour and erosion and damage from high winds. A single severe coastal storm is capable of generating multiple short-term and long-term hazards. For instance, hurricanes will generate short duration hazards during landfall associated with high winds, storm surge, severe coastal flooding, large wave attack, and debris impact, as well as a long-term increased susceptibility to significant shoreline erosion. The effects of hazards associated with a specific event are often immediate, severe, and readily apparent, while those associated with longer term accumulative processes, such as shoreline recession and sea-level rise, become apparent only after extended periods.

Coastal Flood Hazards

Coastal flooding originates from tropical storms, hurricanes and mid-latitude low-pressure systems often referred to as extratropical storms or northeasters. Flooding often results from storm surge~~s~~ generated by high winds and low air pressure, heavy rainfall, or both. Coastal floodwaters expose coastal residents, structures, and public infrastructure to significant risks from standing water, high-velocity flows, and waterborne debris.

Standing Water

Standing or slowly moving water can produce increased pressure against structures exposed to floodwaters. Such pressures are referred to as *hydrostatic forces* by engineers and builders. If the water level on different sides of a structure is unequal, significant hydrostatic forces can build in one direction leading to the displacement of the structure in the direction of least resistance (Figure 1). In cases where floodwaters rise equally along the exterior walls of a structure but the interior space remains dry, catastrophic collapse of the building can occur as the structure crumples inward under the exterior water pressure (Figure 2). Flooding can also cause significant vertical hydrostatic forces, or *flotation,* as floodwaters exert an upward pressure on floors and decking (Figure 3). Prolonged periods of flooding poses a health risk to coastal residents from waterborne pollutants, diseases, and pests such as mosquitoes.

Figure 1. Damage to breakaway walls under an oceanfront house in Brant Beach, Long Beach Island, as a result of a storm in December 1992. Note hole in wall facing the viewer and buckle in wall out to the ocean side due to hydrostatic load (Photo courtesy of Dr. Susan D. Halsey).

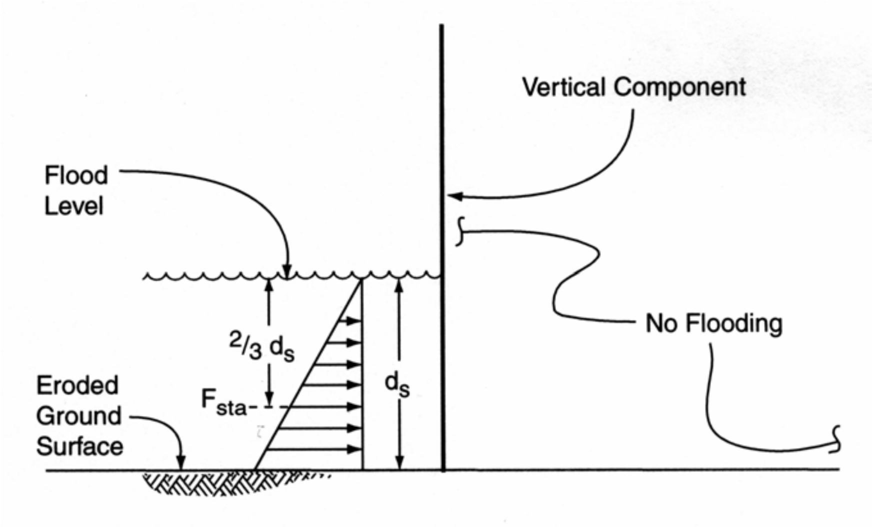

Figure 2. Pressure distribution due to standing water on the outside of a vertical wall. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

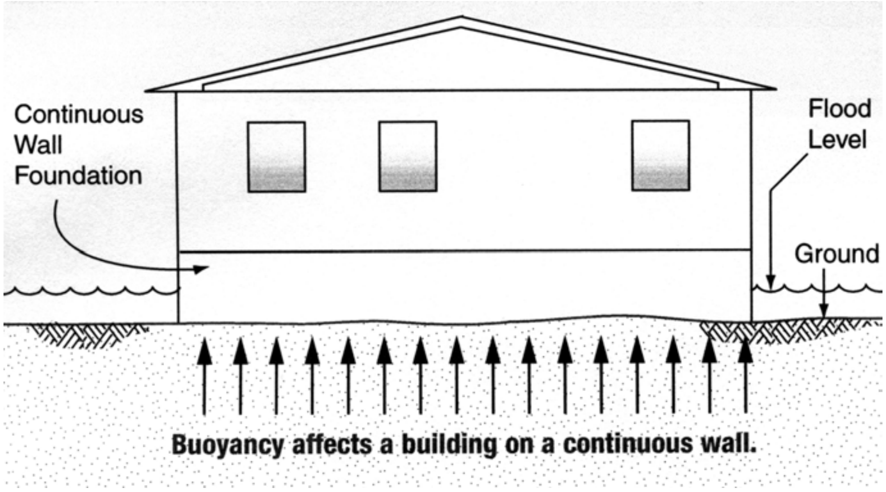

Figure 3. Vertical (buoyant) force generated by saturated soil. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

High-velocity floodwaters

When floodwaters exceed a velocity of 10 ft/sec tremendous force is applied to structures in its path. This added *hydrodynamic force* is related to the flood flow velocity and the shape of the structure. Fluid flowing around an object creates lift and drag similar to airflow around an airplane. If the resisting foundation forces are less than the net force against the structure, it will move in the direction of the flow (Figure 4). High-velocity flows can be created by storm surge and wave run-up flowing landward through breaks in dunes and/or across low-lying areas, by outflow of floodwaters as a storm surge relaxes and by wave generated currents flowing parallel to the shoreline.

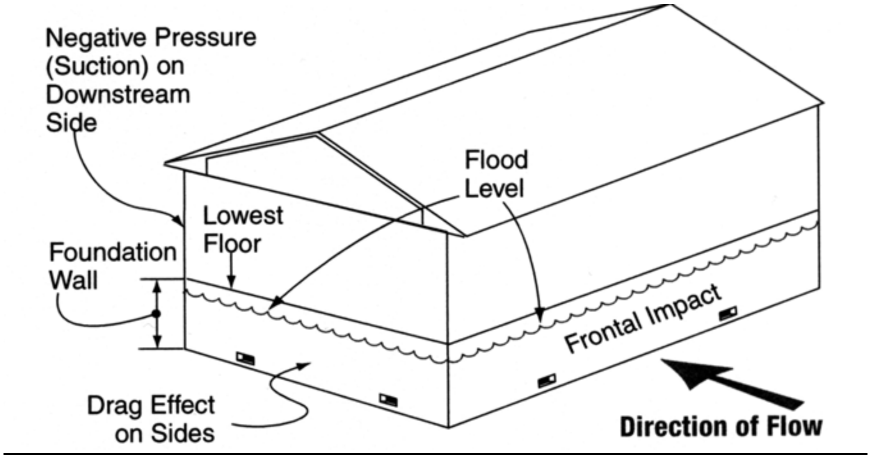

Figure 4. Hydrodynamic load applied to a foundation wall due to the flow of water around the structure. High pressure on the upstream side and a low pressure on the downstream (lee) side, combine to produce a net force in the direction of flow. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Waterborne Debris

Debris carried by floodwater generates short duration impacts when they strike stationary or slower moving objects. Waterborne debris typically include any floating object that that is not secure: decking, stairs, breakaway wall panels, pilings, fences, propane and oil tanks, boats, portions of buildings, and entire houses (Figure 5). Such objects are capable of destroying wood frame structures, masonry walls, and pile supported structures on impact. Debris trapped by cross bracing, closely spaced pilings, grade beams or other low elevation building components are capable of increasing the flood load on a structure. Storm generated debris is also one of the leading causes of fatalities during a coastal storm event.

Figure 5. Raft of debris left on Beach Ave. (Ocean Blvd.) just landward of the seawall in Cape May as a result of the March 1962 “Great Atlantic Storm.” Note segments of destroyed boardwalk with attached benches still bolted on in center (Photo courtesy of Dr. Susan D. Halsey).

Wave Hazards

The size and intensity of storm-generated waves depend on the magnitude of the storm, its sustained wind speeds and the duration of the storm. In general, the maximum breaking wave height at any point along the coast is a function of the water depth at that particular location. When a wave reaches a height equal to three-quarters of the water depth, the wave will break (Figure 6). During calm weather, large waves typically reach breaking depths a few thousand feet from the shoreline. During storm conditions, however, the elevated water levels generated by storm surge allow waves to penetrate much closer to the shoreline, exposing coastal structures to direct wave attack, wave run-up and wave-induced scour and erosion (Figure 7).

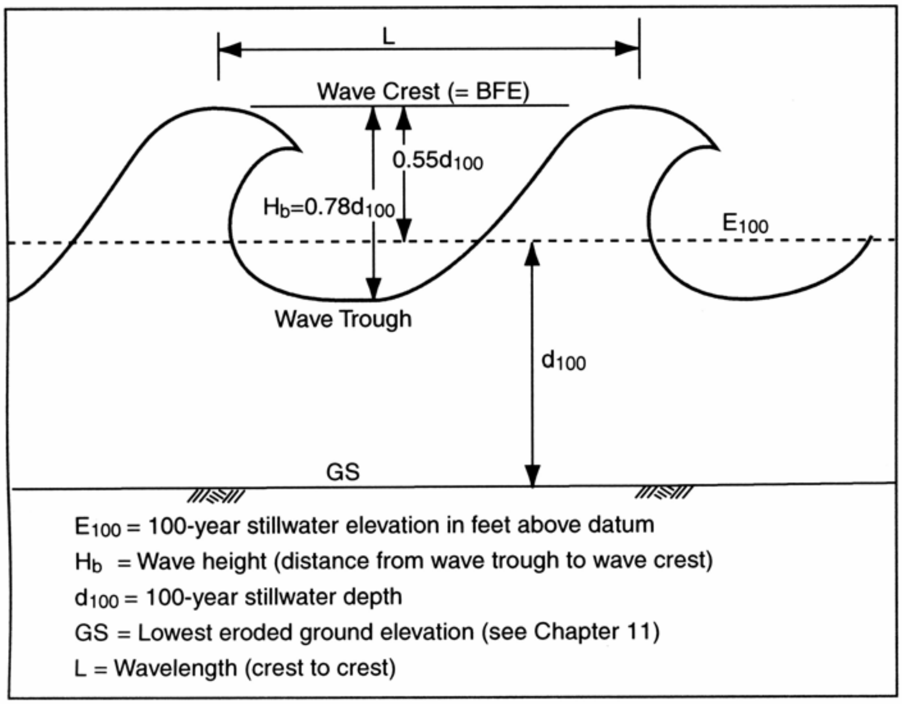

Figure 6. Determination of the Base Flood Elevation (BFE) for regions exposed to wave attack. A wave breaks when it reaches a height equal to 78% of the water depth. At breaking 75% of the wave height is above the still water level and must be added to the flood level. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Figure 7. Extensively damaged home south of Litchfield Camp, South Carolina as a result of Hurricane Hugo. In addition to the heavy damage to the structure of the building itself from wind and wave damage, note evidence of wave-induced erosion and scour under the house and around pilings and creation of channels toward the viewer (Photo courtesy of Dr. MaryJo Hall).

Non-breaking Waves

A wave can impact a structure prior to breaking, during breaking, and after breaking. If a wave strikes a solid structure prior to breaking, the wave energy is reflected back toward the ocean. If the incoming wave approaches the structure at an angle, the reflected wave will travel away from the wall at the same angle. Reflected waves apply two times the amount of wave-induced stress on the seabed as a single shoreward propagating wave. The increased bottom stress generates increased erosion and scour at the base of the structure, potentially leading to undermining and collapse (Figure 8).

Figure 8. Brant Beach section of Long Beach Island, New Jersey after the March, 1962 storm. Houses with regular foundations undermined by wave scour on the oceanfront, cinder blocks failed and houses tipped down the scarp (cliff) toward the ocean. The number of damaged homes from this storm led to FEMA subsequently requiring houses in specific zones to be built on pilings (Photo by Al Chance, courtesy of Dr. Susan D. Halsey).

Breaking Waves

The most extreme wave hazard to the built environment occurs when a wave breaks on a structure. As the crest of a breaking wave strikes a solid structure, wave forces 4 to 5 times greater than that from a non-breaking wave are measured. An air pocket formed between the wave crest and trough at impact, compresses during breaking (Figure 9). As the air pocket collapses, the structure is exposed to an exceedingly high-pressure burst of energy. Peak pressures from a 5-foot high breaking wave can exceed 2,000 pounds per square foot (FEMA, 1999). Post storm damage inspections have shown that breaking waves are capable of destroying all wood-frame or unreinforced masonry walls (FEMA, 2000).

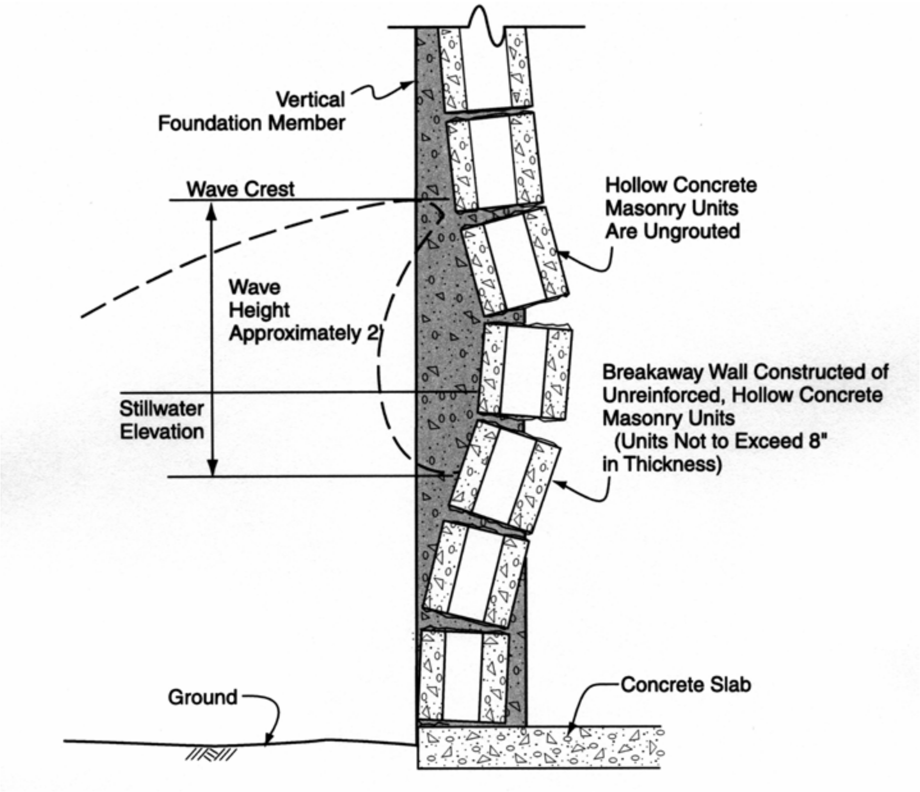

Figure 9. Compressed air trapped between a breaking wave and a vertical wall generates extreme horizontal pressure, often leading to structural failure. Reprinted with permission from the FEMA Technical Bulletin 9-99 (FEMA, 1999).

As a breaking or non-breaking wave passes under an open foundation, such as the pilings below a fishing pier, the structure experiences an oscillating, high-velocity horizontal flow that peaks under the crest and trough of the wave. Because there is ample open space below pile supported structures the wave energy is allowed to pass through the structure, eliminating any severe loading on the foundation (Figure 10). Maximum vertical velocities occur at the still water level, midway between the wave crest and trough. If the distance between the water level and the bottom of the structure is about ½ the wave height, the horizontal members of the structure, floor or decking, can experience significant uplift forces. Uplift damage frequently occurs to piers (Figure 11) and boardwalks (Figure 12) as waves lift the decking from the pilings and beams.

Figure 10. Large waves passing under a piling supported pier in Ocean Grove, New Jersey (Photograph by Dr. Thomas O. Herrington).

Figure 11. Damage to Atlantic City's Steel Pier from the March, 1962 storm. Note missing center portion removed by wave uplift during the height of the storm (Photo courtesy of Dr. Susan D. Halsey).

Figure 12. Damage to the Ocean City, NJ boardwalk from Hurricane Gloria, September 1985. This damage was caused by waves reflecting off the adjacent bulkhead, lifting up sections of the boardwalk and moving the loosened section landward (Photo courtesy of Dr. Susan D. Halsey).

Wave Runup

Wave run-up refers to the distance a non-breaking or broken wave will travel up a sloped surface or vertical wall. Wave run-up can drive large volumes of water and debris against coastal structures. Strong currents associated with run-up can cause localized erosion and scour (Figure 13). Wave run-up can extend up to the top of bulkheads, seawalls and revetments, allowing a significant volume of water to overtop the structure, causing localized flooding even in protected areas. Uplift forces generated by wave run-up are capable of destroying overhanging decks and porches, as well as flooring under pile-supported buildings (Figure 14).

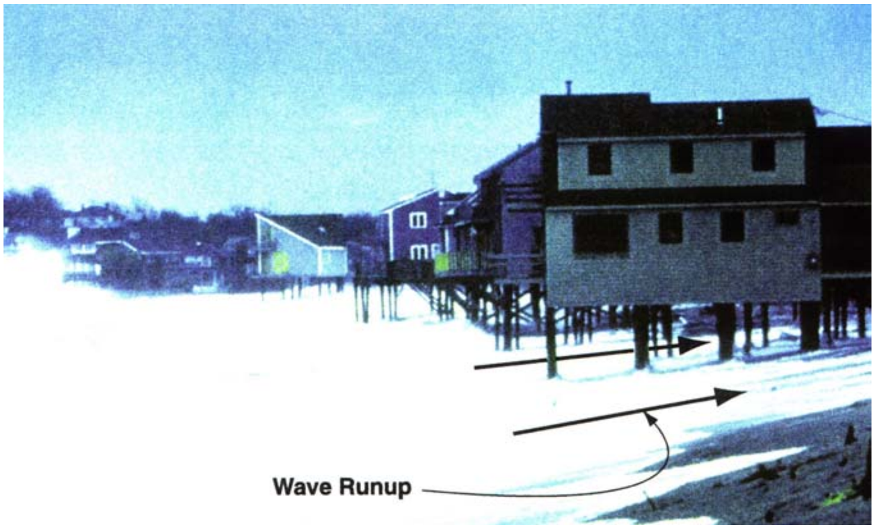

Figure 13. Erosion due to wave runup under elevated buildings in Scituate, Massachusetts (Photograph by Jim O'Connell).

Figure 14a. Brighton Beach Condominiums with decks overhanging primary bulkhead, 5th Street, Ocean City, New Jersey prior to March 28-29, 1984 northeaster. Storm waves lifted up the decks that had been tied into the interior of the house damaging the entire living rooms. The City condemned the buildings until the structure of the units were repaired, and passed an ordinance that prohibited decks to be tied into the main part of the house. Decks now have to be freestanding (Photo courtesy of Dr. Susan D. Halsey).

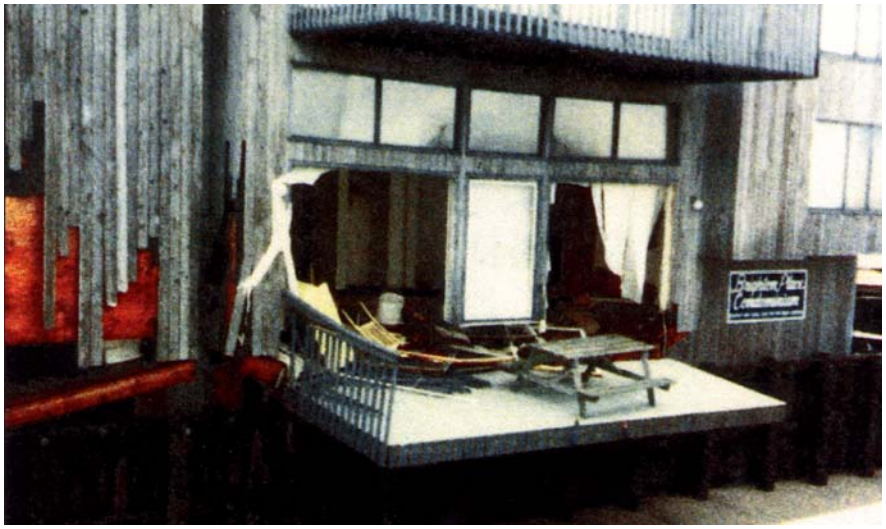

Figure 14b. Damage to an oceanfront residence in Ocean City, New Jersey due to wave run-up on a timber bulkhead (Photograph by Mark Mauriello).

Wind Hazards

The most significant coastal wind hazards originate from tropical storms, hurricanes, northeasters, and storm spawned tornadoes. Hurricanes can generate sustained winds ranging from 74 mph (Category 1) to greater than 155 mph (Category 5) over durations of 12 to 24 hours (Table 1).

SAFFIR-SIMPSON HURRICANE SCALE

Class	Pressure (millibars)	Velocity (mph)	Storm Surge (feet)	Classification
1	980	74-95	4-5	Minimal
2	965-979	96-110	6-8	Moderate
3	945-964	111-130	9-12	Extensive
4	920-944	131-155	13-18	Extreme
5	< 920	>155	>18	Catastrophic

Table 1. The Saffir-Simpson Hurricane Scale was developed by employees of the NOAA's National Weather Service to rank different hurricane magnitudes and their potential extent of damage. The storm's barometric pressure and wind speed will determine its storm surge, and all these factors will determine the storm's capacity for damage (NOAA-NWS Technical Report 2).

Mid-latitude northeasters typically generate much lower sustained winds of between 35 and 45 mph but can last for 2 to 3 days. Tropical storms and hurricanes are characterized by strong onshore winds as the cyclone approaches the coast, followed by strong offshore winds after the center passes or makes landfall. Northeasters are large (synoptic-scale) coastal low-pressure systems that intensify offshore of the coast. As the extratropical storm develops, the winds gradually build out of the northeast, peaking as the storm reaches maximum intensity, and then gradually decrease as the storm moves northeast, out to sea.

Because there is no topographical relief over the ocean, high winds are unimpeded by friction and can impose large lateral (horizontal) and uplift (vertical) forces on coastal structures. Coastal buildings can suffer extensive structural damage when they are improperly designed and constructed, or when wind speeds exceed design levels (FEMA, 2000). Buildings elevated well above sea level, containing large areas of window space, or with low-pitched gabled roofs and overhangs are particularly susceptible to wind damage. Any structural failure that compromises the building envelope (outer walls and roof of the structure) will result in severe structural damage (Figure 15).

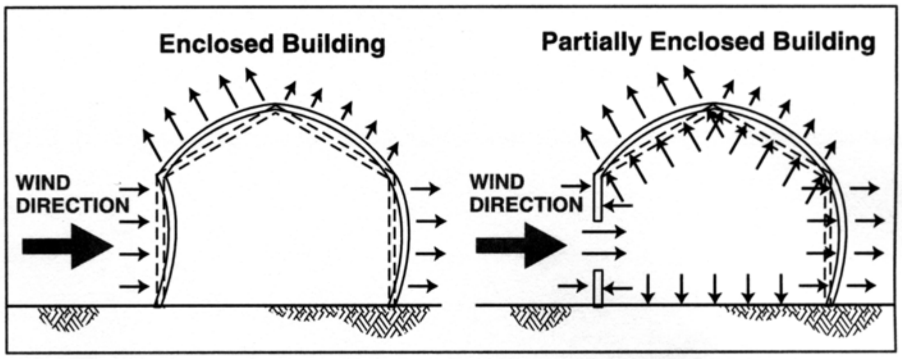

Figure 15. Enclosed buildings experience wind-induced pressure on the upwind walls and suction forces on the roof and lee walls. A partially enclosed building experiences increased loads due to the pressurization of the interior of the building. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Wind loads and windborne debris are both capable of damaging the building envelope (Figure 16). When a building envelope is breached, interior damage by rainfall and wind is certain, and interior pressurization, roof loss and structural failure a possibility (FEMA, 2000). In forested areas, high-winds can topple trees and break large branches creating the risk of injury and property damage from falling debris. In many communities, storm related power outages are caused by trees falling on elevated power lines.

Figure 16. Extensive wind damage to house near Myrtle Beach, South Carolina as a result of Hurricane Hugo. Note loss of not only front plate glass windows, but also loss of side windows (Photo courtesy of Dr. MaryJo Hall).

Erosion Hazard

Erosion hazards to buildings, infrastructure and personal property due to coastal erosion are often the most difficult to recognize. Coastal sediments are constantly in motion, moving along the shore, offshore and onshore at numerous time scales. The long-term evolution of the shoreline, in response to decades and centuries of storm events, changes in sediment supply, fluctuations in sea level, land subsidence or rise, and the migration, formation, and closing of tidal inlets may not be evident on a day-to-day or even year-to-year basis. The cumulative changes imposed on the beach by these forces, however, can have a dramatic effect on the coast over the 50 to 100 year lifetime of most coastal structures. In contrast, the changes to the coast generated by short-term storm events are immediately recognizable. Storm surge and waves can rapidly transform the coast by moving a large volume of sand over a relatively short duration.

Because of these different periodicities, long-term and short-term erosion hazards are usually evaluated independently. *Long-term erosion* is defined as the gradual recession of the coast over a period of decades. *Short-term erosion* is defined as a rapid recession of the shoreline in response to coastal storms and flood events. It should be noted that along some coasts the trend is for long-term accretion – an expansion of the coast seaward and sometimes vertically, so it is more accurate to speak of long-term and short-term shoreline change rather than erosion. Since hazards associated with accretion are relatively minor compared to those of erosion, we will use the term erosion as defined above.

Short-term Erosion

Storm generated erosion ranges over periods of hours (tropical cyclones) to several days (northeasters). Although the storm events are short-lived, the resulting erosion can be equivalent to *decades* of long-term erosion. The actual quantity of sediment eroded from the coast is a function of storm tide elevation relative to land elevation, the duration of the storm and the characteristics of the storm waves. During severe coastal storms, it is not uncommon for the entire *berm* (dry beach above the normal high water line) and part of the dune to be removed from the beach (Figures 17a & 17b). The amount of erosion is also dependent on the pre-storm width and elevation of the beach. If the beach has been left vulnerable to erosion due to the effects of recent storms, increased erosion is likely (Figure 18). In fact, the cumulative effects of two closely spaced minor storms can often exceed the impact of one severe storm (Halsey, 1986).

Figure 17a. Extensive dunes at Mantoloking, New Jersey shown prior to a northeaster in March 1984. This oceanfront municipality has one of the most comprehensive dune ordinances in New Jersey requiring homeowner's to plant and apply other techniques for dune building (Photo courtesy of Dr. Susan D. Halsey).

Figure 17b. Similar view of the dune field in Mantoloking, New Jersey after the March 1984 northeaster. Despite horizontal erosion of up to forty feet (40 feet) back into the dune, as well as vertical beach erosion, there were few breaches in this dune field throughout the municipality (Photo courtesy of Dr. Susan D. Halsey).

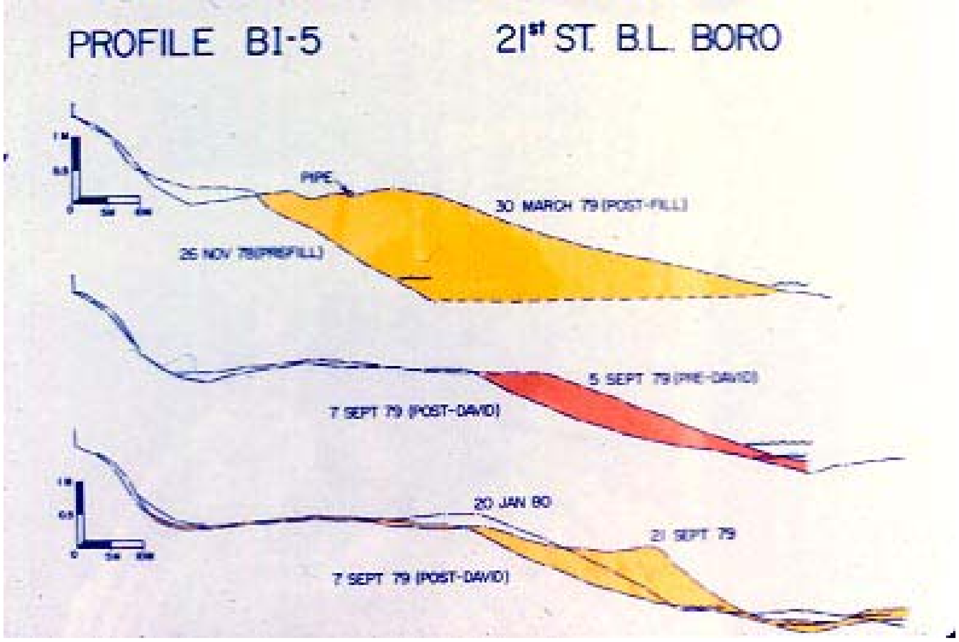

Figure 18. Beach profiles at 21st Street, Barnegat Light, New Jersey, plotted at a 5:1 vertical to improve visualization of sediment dynamics. The top profile depicts the volume of fill placed at the site by the 1979 Army Corps of Engineers beach nourishment project. The middle profile contrasts the post-fill profile on 5 September 1979 with the loss of berm from the offshore passage of Hurricane David. Note also small loss of both back beach and dune. The lower profile contrasts the post-David profile with a post-

storm berm recovery profile of 21 September 1979 after a period of only 14 days. The 20 January 1980 profile shows the loss of about half of this volume as well as a change of shape as a result of a small northeaster in late December 1979, and subsequent recovery (Figure courtesy of Dr. Susan D. Halsey).

The impact of short-term erosion to private and public property can be severe. Dunes and other natural protective features of the coast can be breached and destroyed. The erosion and/or destruction of dunes expose the structures behind them to further damage from subsequent storms. The removal of sand from the beach will lower ground elevations, possibly leading to the undermining of shallow foundations, exposure of underground utilities and infrastructure, and reducing the penetration depth (or carrying capacity) of piles. Low-lying inland structures, such as roads, driveways and storm drains, can be buried by *washover fans* - sand pushed landward by waves and surge (Figures 19 and 20). The base of coastal bluffs can be undermined by erosion leading to bluff failure and the potential loss of structures at the top of the bluff. Storms that generate significant surge can generate breaches in barrier islands as the build up of water behind the island seeks the path of least resistance to return to the sea. Breaches are one of the most destructive short-term erosion hazards as swift currents create deep channels across the island, undermining everything in its way (Figure 21).

Figure 19. Newly created washover fans along Island Beach State Park, New Jersey, as a result of a severe northeaster. The white fingers of sand with bulbous ends reach westward into the vegetated back dune are washover fans resulting from storm surge (Photography courtesy of Dr. Susan D. Halsey).

Figure 20. Front end loaders removing extensive storm washover from Long Beach Boulevard, New Jersey, in the Loveladies section of Long Beach Island. At some locations, washover was over four feet deep (Photo courtesy of Lawrence Wagner).

Figure 21. Aerial photograph of a former barrier island breach on the south shore of Long Island, NY (Photograph by Dr. Michael S. Bruno).

Erosion hazards during storms can occur despite the presence of shore protection structures. Significant storms can overtop or damage poorly sited, designed, constructed or maintained erosion control devices such as revetments, seawalls and bulkheads (Figure

22). When a coastal protection structure fails, the buildings and infrastructure behind them are very vulnerable to damage (Figure 23). Protective dunes, if not correctly maintained with vegetation and proper pedestrian walkovers, can be breached, exposing landward structures to increased wave attack and flood loading.

Figure 22. Hurricane Hugo induced failure of an ocean front bulkhead in Myrtle Beach, South Carolina that resulted in substantial damage to a condominium building (Photo courtesy of Dr. MaryJo Hall).

Figure 23. Catastrophic building damage caused by the failure of a protective timber bulkhead in Westhampton, NY (Photograph by Dr. Michael S. Bruno).

Short-term erosion unrelated to coast storms can also occur along coastlines stabilized by shore protection structures. Groins, breakwaters and jetties are designed to slow the movement of sand along the beach, but when a reversal in the usual direction of sand transport occurs (due to hydrodynamic events), it can lead to short duration erosion adjacent to the protective structure. Such effects are usually short-lived, however, prolonged reversals on eroded shorelines can generate a significant erosion hazard (Figure 24).

Figure 24. Localized erosion on the downdrift side of a timber groin in Manasquan, NJ, caused by prolonged unidirectional sediment transport (Photograph by Dr. Michael S. Bruno).

Scour

Scour refers to localized erosion in addition to that caused by flooding or wave action. This effect is generated by the acceleration of water flow around an object. As water moves past a fixed structure such as a pile, it accelerates, creating turbulence above the bottom. Erodible materials will be re-suspended by turbulence and transported away from the pile, resulting in localized erosion (Figure 25).

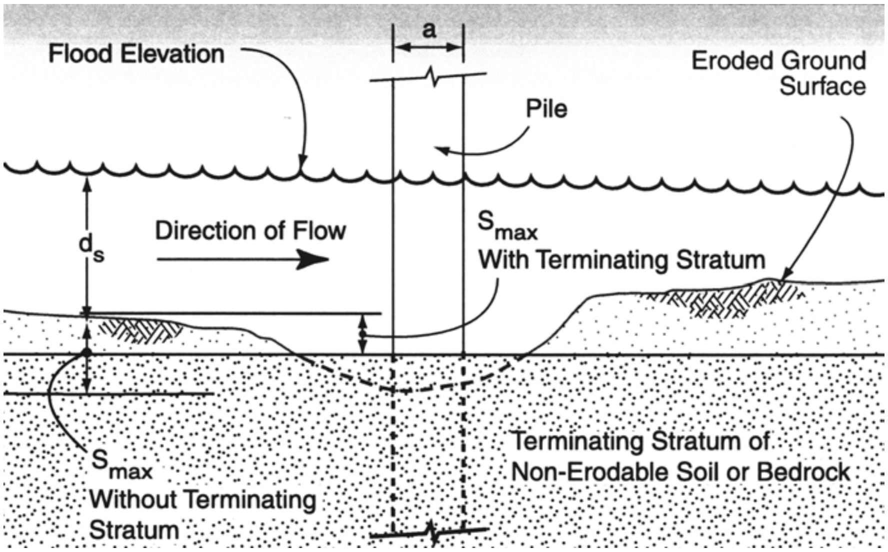

Figure 25. Scour generated by accelerated water flows around a piling. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Post-storm surveys have indicated that scour around piles and similar objects is generally limited to cone-shaped depressions less than 2 feet deep (FEMA, 2000). However, the maximum depth of scour that can occur during the storm events is unknown. Horizontal beams and on-grade slabs can be undermined by scour, leading to structural failure (Figure 26).

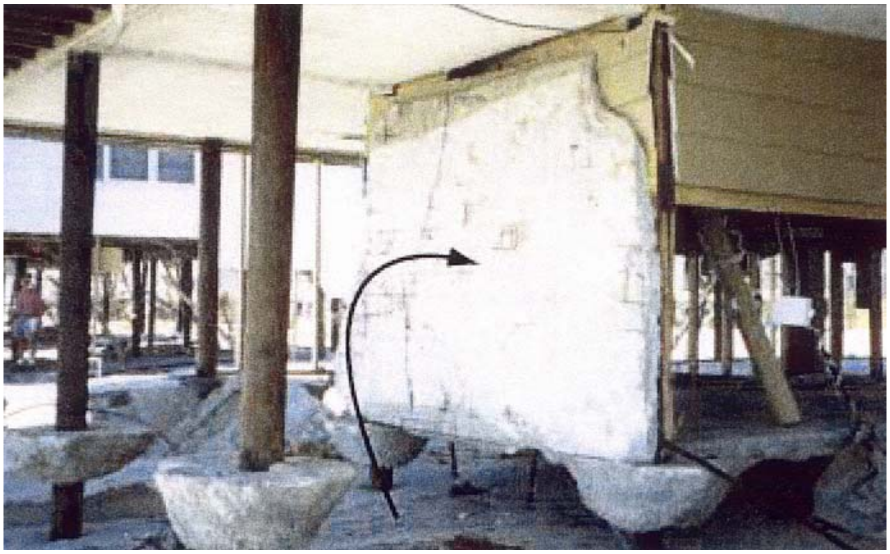

Figure 26. Scour around pilings and under on-grade slab. Notice that the slab broke free of the pilings and flipped up vertically. Poured concrete under a pile supported structure can generate unexpected loads on the structure, if undermined like above. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Long-term Erosion

Long-term shoreline recession along a coastal reach is a manifestation of the cumulative impacts of storms, sea level rise, land subsidence, manmade impacts, and sediment supply, among other factors. As storms rework the coastal landscape, a portion of the beach is deposited offshore in water depths deep enough that sand is permanently lost from the system. Over decades, the net loss of sand due to storms results in a recession of the shoreline. Sea level rise and land subsidence combine to produce a more gradual shoreline recession (National Research Council, 1987). Due to global climate change, the average level of the oceans has been rising by approximately 2 mm/yr (0.078 in/yr). Although variable, the general subsidence of land along the East and Gulf coasts of the United States has lead to localized increases in the rate of sea level rise along the coast (Figures 27 and 28).

New Jersey has the highest measured relative sea level rise on the Atlantic coast of the U.S, about 4 mm/yr (0.16 in/yr), while Boston has the lowest, 0.9 mm/yr (0.035 in/yr). For an average beach slope of 1 foot vertical rise for every 30 horizontal feet of beach, a 4 mm/yr (0.013 ft/yr) rise in sea level translates into a horizontal beach recession of 0.39 ft/yr, or 1 ft every 2.5 years. One may wonder why there is any beach left at all given the rapid rate of horizontal beach recession. The reason the coast of New Jersey has not retreated 250 ft over the last 100 years is because a much larger volume of sand is redistributed along the coast due to the day-to-day wave and current action than due to the rate of sea level rise. The coast evolves by redistributing large volumes of sand from regions of high wave and current energy to areas of low energy, masking the long-term recession due to sea level rise.

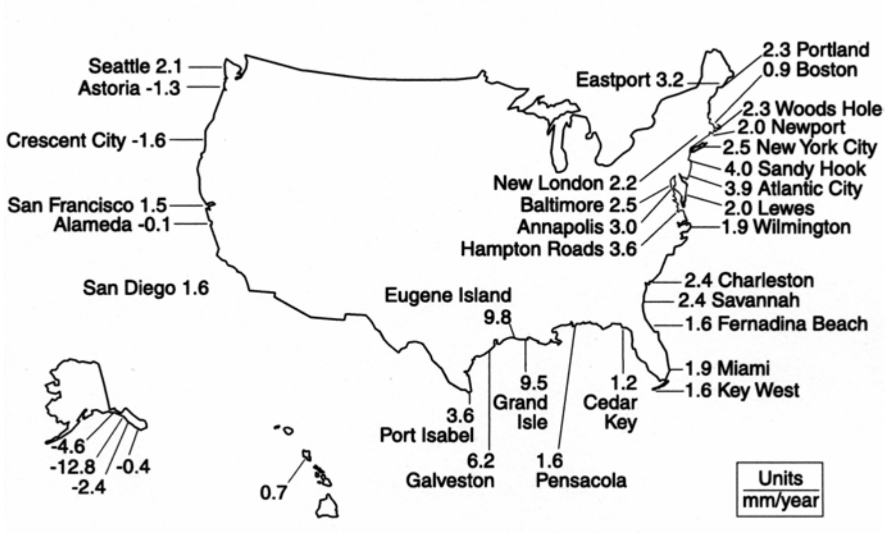

Figure 27. Estimates of relative sea level rise along the continental United States in millimeters per year. Negative values indicate falling sea levels (from National Research Council, 1987). Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

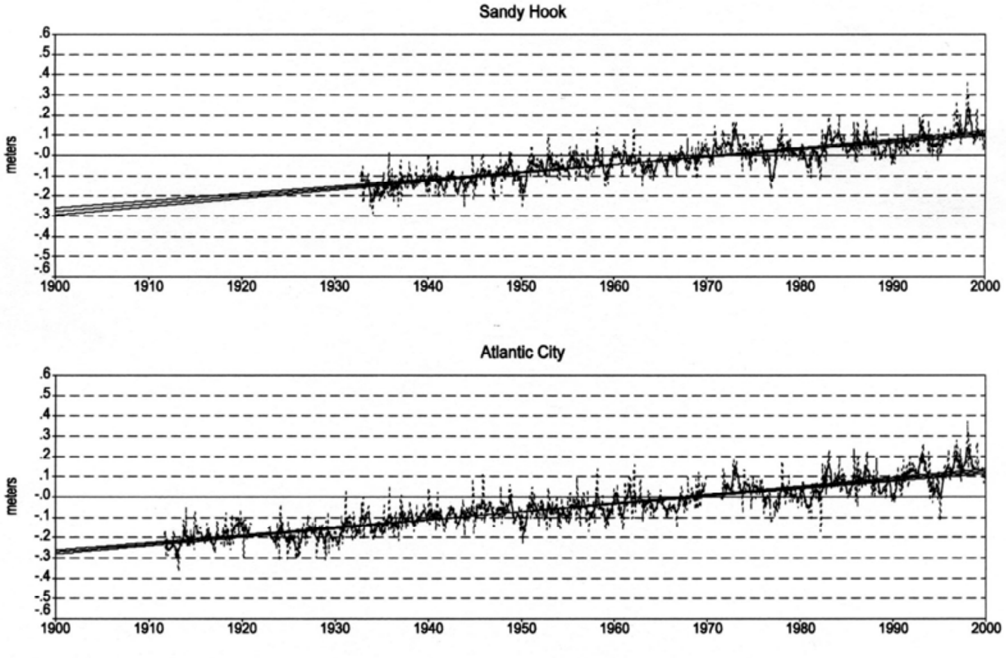

Figure 28. Sea level rise graphs for the last 100 years from tide gauges in New Jersey. Although the rates vary, all show an upward trend (Reprinted from NOAA, 2001).

Tidal inlet migration can also significantly impact long-term shoreline erosion rates. Many natural tidal inlets slowly migrate in response to the prevailing wave climate. If waves primarily transport sediment in one direction along the coast, the updrift side of the inlet channel will fill in, shifting the inlet toward the downdrift beach. Inlet migration rates as great as 300 ft/yr have been measured in North Carolina, prompting the state to map Inlet High Hazard Zones along the coast (Cleary and Marden, 1999). In New Jersey, significant inlet migrations have been observed at all inlets unconstrained by jetties; Hereford, Corsons, Townsends, Great Egg, Little Egg, and Beach Haven Inlets.

Shorelines adjacent to inlets also undergo much more rapid and variable erosion and accretion cycles as the evolution and migration of inlet shoals alter the local wave and current climate (Figure 29). Inlet impacts can be experienced as far away as a few miles updrift and downdrift from the actual inlet channel. In many cases, the stabilization of an inlet by *jetties* – impermeable shore perpendicular structures designed to keep the inlet from shoaling - will stop the inlet from migrating. The impact of the inlet on the adjacent shoreline, however, will still be present and may be exacerbated by a reduction in the amount of sediment reaching the downdrift shoreline (Figure 30).

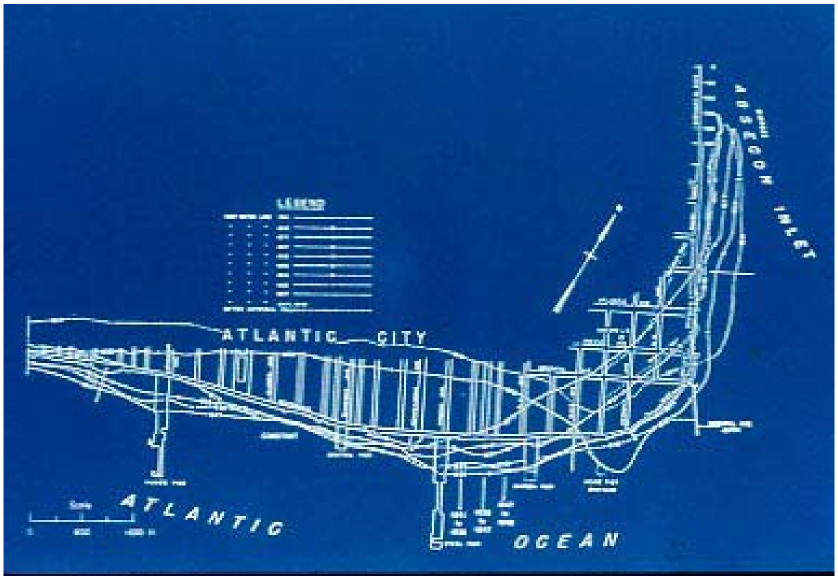

Figure 29. Blueprint showing the variation in the position of the Atlantic City Inlet shoreline.

Figure 30. Sediment offset at Manasquan Inlet, New Jersey. Note sediment build-up on south (updrift) side of the inlet along Point Pleasant Beach, and sediment deficit on the north (downdrift) side of the inlet at Manasquan. Average alongshore current direction in this area is to the north (Photo by Dr. Susan D. Halsey).

Sea level rise and human activities within coastal watersheds can lead to long-term reductions in sediment supply to the coast. The damming of rivers and the bulk-heading of highlands has reduced the amount of erosion and consequently the sediment loads reaching coastal areas. Although it is difficult to quantify, the cumulative reduction in sediment supply from human activities may contribute substantively to the long-term shoreline erosion rate. Along coastlines subject to sediment deficits, the amount of sediment supplied to the coast is less than that lost to storms and coastal sinks (inlet channels, bays, and upland deposits), leading to long-term shoreline recession. Shore protection measures, stabilized inlets and coastal development can also exacerbate long-term erosion. Many shore protection structures slow the movement of sand along the coast. Bulkheads, revetments and seawalls actually remove sediment from the system by encapsulating sand behind the structure (Figure 31). By slowing the transport of sand or removing it from the area, long-term erosion rates increase as one moves farther downstream (downdrift) from the sediment source.

Figure 31. Stone and concrete revetment placed along an eroding bluff in Long Branch, NJ. Although the structure stops erosion, it also reduces the natural sediment supply to the beach (Photograph by Dr. Michael S. Bruno).

Regardless of the cause~~s~~, long-term shoreline erosion increases the vulnerability of coastal structures to damage by exposing them to increased risk over the usable lifespan of the structure. In essence, long-term erosion acts to shift the flood and wave hazard zone landward so that a building once protected from direct wave attack by a wide beach is increasingly susceptible to wave damage (Figure 32). In most instances, the Federal Emergency Management Agency (FEMA) assumes that the usable life span of a private structure is 30 years, the length of most homeowner mortgages. Any coastal structure should therefore be built to withstand the maximum coastal hazard expected over the 30-year life of the structure. Of course, this cannot be applied universally as many New Jersey communities contain structures more than a hundred years old. In many cases, alternative mitigation strategies such as extensive beach fill must be implemented to insure that the maximum coastal hazard level experienced by a structure does not change (Figure 33).

Figure 32. Concrete retaining wall, originally constructed to prevent wind blown sand from depositing on Ocean Avenue, in Belmar, New Jersey, under direct wave attack during the October 31, 1999 northeaster (Photograph by Dr. Michael S. Bruno).

Figure 33. Belmar, NJ retaining wall shown in 1999 after the completion of a beach fill project designed to protect the coast from a 1 in 100 year storm event (Photograph by Dr. Thomas O. Herrington).

Additional Hazards

Coastal communities are exposed to a number of minor hazards that may occur less frequently than flooding or wave attack but that can still cause localized property damage and personal injury.

Burial

Sediment eroded from the beach during a storm or blown inland by onshore winds can be deposited around structures and in roadways. Washover fans are generated by large volumes of sand transported landward through breaches in the dunes. Depths as great as 4-5 feet have been measured on coastal roadways following hurricanes (FEMA, 2000). High onshore winds can create large sand drifts similar in character to drifting snow. This is especially problematic in areas that have unvegetated sand dunes, as there is little or no resistance to the movement of sand. In such cases, migrating sand can potentially bury shorefront structures (Figures 34 and 35).

Figure 34. Ortley Beach, New Jersey after a severe storm. Significant erosion of sand from the beach overwashed the boardwalk and was deposited onto local streets. The piles of sand just landward of the boardwalk resulted from post-storm bulldozing of the streets (Photograph by Dr. Susan D. Halsey).

Figure 35. Underground parking garage with partially buried vehicle in Point Pleasant Beach, New Jersey in the aftermath of the December1992 northeaster. The ripple marks on the top of the sand indicate active water flow (Photograph by Dr. Susan D. Halsey).

Rain and Snow

Coastal storms often produce large amounts of precipitation. Rainfall from tropical storms and hurricanes can exceed an inch or more per hour as the system moves inland or along the coast. Extratropical storms can spread heavy precipitation over regions as large as the entire east coast. Snow and ice from winter storms can paralyze large areas under blizzard conditions. Power outages, river and stream flooding, and the interruption of public services are all hazards associated with heavy snow and icefall. Wind driven rain and snow can also penetrate into buildings through damaged siding, windows and roofing posing additional hazards to private property. Heavy rain, prior to the onset of high winds will soften the ground and make large trees more susceptible to toppling.

Ice

As the surface of bays and coastal waterways freeze, ice formed on the surface will rise and fall with the tide. Significant forces can be generated as the ice pushes up along pilings and under buildings and other structures suspended over the water. During flood events, ice flows can also pose a debris and impact hazard to coastal structures. Ice damning can lead to localized elevated flood water levels. Ice storms can produce heavy damage to trees, power lines and other infrastructure sometimes paralyzing communities for days.

Salt Spray

During a storm, high winds will transport a significant amount of saltwater spray inland. Salt residue accumulates on building surfaces, utilities, roadways, trees and landscaping, or on just about everything else that is exposed to the elements. The accumulation of salt spray on metal surfaces leads to accelerated corrosion, shortening the useful life of metal connectors, wiring and utilities. Salt spray can also be damaging to non-native ornamental plants.

COASTAL HAZARD MITIGATION TOOLS AND TECHNIQUES

Beach Nourishment

Responsible Agency/Party:	Federal and/or State sponsored projects
Mitigation for:	Long- and short-term erosion Flood hazards Wave hazards
Management Effort:	High

Although the management an funding levels of a beach nourishment projects are extremely high, on chronically eroding coastlines like in New Jersey, it is the only alternative that directly mitigates the lack of sand along the coast. In New Jersey, beach nourishment is the fundamental component of the state's shore protection plan. Since 1962, almost every segment of the New Jersey coast has been maintained or protected by a local or state funded beach nourishment project. As of 2002, over half of the 127 miles of Atlantic Ocean coastline in New Jersey was, or about to be, protected by a federal shore protection project designed to create and maintain a 100+ foot wide beach within the limits of each project. Beach nourishment is extremely important to all aspects of coastal maintenance and will become the fundamental component of future coastal management and habitat restoration efforts.

Beach nourishment is the process of extending a beach seaward along designed contours both above and below the tideline. Newly placed sand protects property and infrastructure from wave attack, inundation, undermining, and increased vulnerability due to long-term shoreline erosion/recession (Figure 36). Beach nourishment is often referred to as beach fill as these projects are designed to mitigate long-term shoreline erosion through "filling" large quantities of sand into the coastal zone. However, beach nourishment does not directly address the underlying *causes* of erosion, rather it simply reduces the *sand deficit* by adding sand to the coast from sources outside of the eroding system. Beach nourishment, therefore, serves as a "sacrificial" protection measure rather than a fixed barrier solution to the problem (National Research Council, 1995).

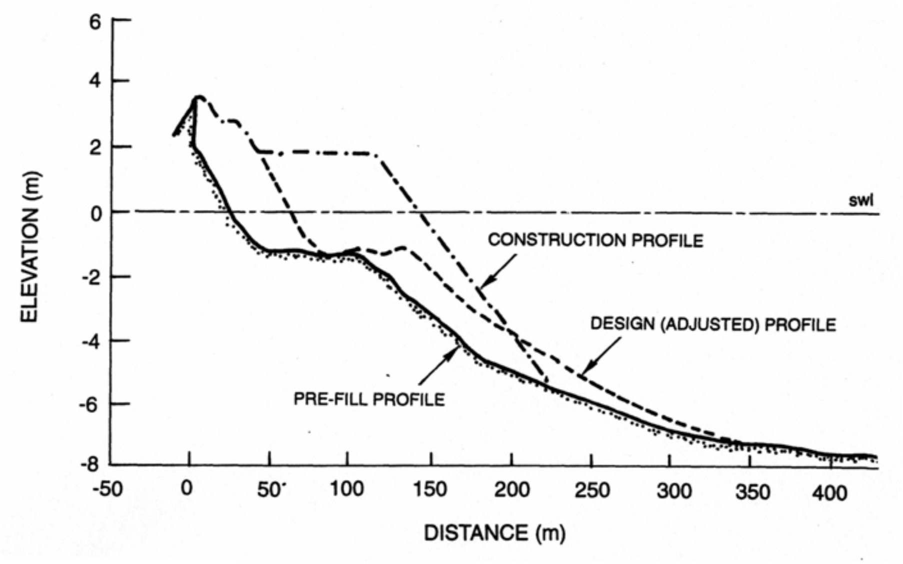

Figure 36. Beach fills are designed to shift the entire beach profile seaward by a sufficient horizontal and vertical distance to account for both long-term and short-term erosion during the project's anticipated lifetime. Due to construction limitations, the constructed beach profile is often much wider and steeper than the final projected form design. Wave action will naturally redistribute the sand into the preferred design template (Reprinted from National Research Council, 1995).

Beach nourishment is an accepted hazard mitigation technique but its application is not suitable for all locations. Prior to undertaking a project, detailed cost-benefit analysis is usually performed to determine if the benefits of incremental protection outweigh the cost of constructing and maintaining the new beach (Figure 37). Moreover, the protection provided by a newly constructed project will vary significantly over the anticipated lifetime of the project; i.e., the longevity of the protection provided will be dependent on volume of sand added, characteristics of the fill used, background erosion rates, and the frequency, duration and severity of coastal storms after the completion of the project.

Figure 37. Emergency beach nourishment project underway on Long Beach Island, NJ, March 1979. Sand from Barnegat Inlet was pumped through pipes at two locations; one further up the beach profile and one near the proposed low tide line. Note pipes on upper beach waiting for placement near the dune scarp created by a trio of northeasters in the winter of 1978-1979. After the nourishment project, groins seen in this photograph were not visible. (Photograph by Dr. Susan D. Halsey)

Most beach nourishment projects are designed to include periodic re-nourishment to assure that an appropriate level of protection is maintained. The process of designing and constructing an effective beach nourishment project is complex and costly, to the degree that effective mitigation is often cost prohibitive for property owners and communities. Consequently, the federal government in cooperation with state and local governments (as in New Jersey) usually undertakes most large-scale shore protection projects including beach nourishment.

In general, beach nourishment projects are designed to provide protection against the occurrence of a storm that has a 1-percent probability of being exceeded in any given year for a period of 50 years. Consideration is usually given to constructing a beach that will protect coastal structures over their useful lifespan, including a buffer to build protective dunes. Ultimately, protection is also a function of the sponsors' (federal, state and local) willingness to maintain (renourish the beach) over the lifespan of the project (FEMA, 2000). The cost of *maintaining* adequate protection over say 50 years added to the *initial* cost of the fill can be on the order of millions to billions of dollars depending upon the length of the project and volume of sand required. Given the cost of nourishment projects, their use is generally restricted to densely populated coastal regions, where significant secondary benefits can be achieved including, maintenance of federal navigation channels and the restoration of recreation beaches that are significant contributors to the local and regional economy.

For more information regarding beach nourishment projects in New Jersey contact:

New Jersey Department of Environmental Protection
Natural and Historic Resources
Division of Engineering and Construction
1510 Hooper Avenue
Toms River, New Jersey 08753
Phone: (732) 255-0770
Fax: (732) 255-0774

New Jersey Department of Environmental Protection
Office of Coastal Planning
P.O. Box 418
401 East State Street
Trenton, New Jersey 08625
Phone: (609) 292-2662
Fax: (609) 292-4608
Web: http://www.state.nj.us/dep/cmp/

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

U.S. Army Corps of Engineers
Philadelphia District Office
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390
Phone: (215) 656-6516
Fax: (215) 656-6820
Web: http://www.nap.usace.army.mil/

U.S. Army Corps of Engineers
New York District Office
26 Federal Plaza
New York, NY 10278
Phone: (212) 264-0100
Web: http://www.nan.usace.army.mil/

Regulation

Responsible Agency/Party:	Federal and State Regulations Local Ordinances
Mitigation for:	Long- and short-term erosion Flood hazards Wave hazards Wind hazards
Management Effort:	Moderate to High

An effective means of achieving hazard mitigation goals is through regulatory oversight of land use practices, and the siting, design and construction of structures in hazardous areas. These requirements including building codes and standards, and locally adopted floodplain management and land use ordinances and laws. Regulatory requirements are established with the intent of reducing the loss of life and damage caused by natural disasters as well as protecting the natural environment. Requirements vary from state to state and among individual localities and can have a substantial impact on the allowable location and design of structures in specific areas. Designers, property owners and builders should be cognizant of these regulations and fully investigate the restrictions that may apply to individual properties.

Land Use Regulations

State and local governments establish regulations for governing the development and use of land within their jurisdictions to promote sound physical, social and economic development. New Jersey statutes that govern land use[3] include the Freshwater Wetlands Protection Act, Flood Hazard Area Control Act, Coastal Area Facility Review Act (CAFRA) (Figure 38), Waterfront Development Act, Wetlands Act of 1970 and the Tidelands Act. In addition, New Jersey has adopted Coastal Zone Management (CZM) regulations in partnership with the Federal Government to protect coastal resources, manage development in high hazard areas, provide public access to the coast and coordinated state and Federal actions, among other initiatives. Coastal states adopt their own CZM plans and review the plan every three years for consistency with State and Federal goals and regulations. Taken together, the land use regulations oversee all aspects

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[3] For more information about New Jersey Land Use Regulations see http://www.state.nj.us/dep/landuse/about/about.html

of land development and building in the coastal zone including prohibiting or restricting development in specified areas, establishing minimum site requirements, floodplain management, natural resource management, utility easements and planting requirements.

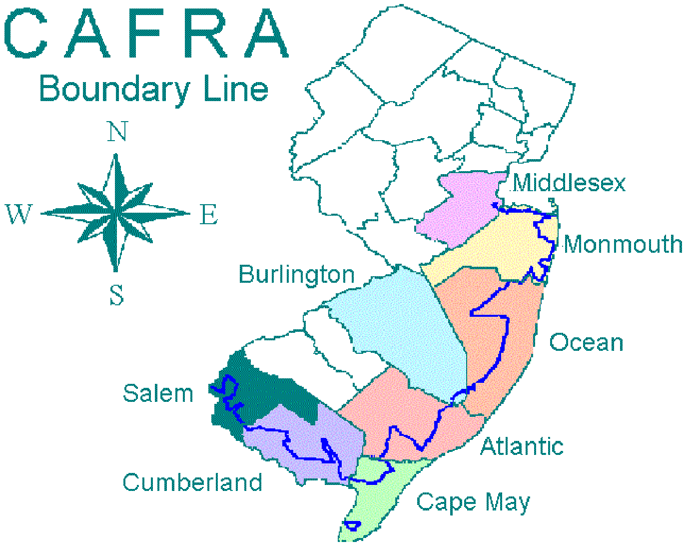

Figure 38. The New Jersey Coastal Area Facilities Review Act boundary indicated in blue. Structures built seaward of the boundary must meet CAFRA standards. Reprinted from the New Jersey Department of Environmental Protection, Land Use Regulations web page.

Building Codes and Standards

Building codes set forth the requirements for protecting public health, safety and the welfare of the built environment. There are literally hundreds of standards related to design and construction practices and even more standards related to construction materials. Although too numerous to cite most state and local building codes are based on model building codes established in the early 20th century. Some states simply adopt one of the model codes, while others add local amendments or adopt their own codes to address specific hazards and needs in their communities. In 2000, The International Code Council (ICC) unified 3 model-building codes together under the International Building Code 2000 (International Code Council, 2000a) and the International Residential Code for One- and Two- Family Dwellings 2000 (International Code Council, 2000b) in order to simplify minimum building standards[4]. It must be stressed that these codes provide minimum standards that *may or may not* provide for safe construction in all hazard areas, especially if a state or local jurisdictions have only adopted one of the minimum codes verbatim.

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[4] Detailed information about ICC codes can be found at http://www.intlcode.org/

Due to the variation in building codes, property owners should investigate the minimum requirements for their location[5]. New Jersey, for instance, does not implement a national code but instead uses a State Uniform Construction Code based on the 1995 One and Two Family Dwelling Code (1995 CABO). This code is applied to all 1 and 2 family dwellings in the state and local jurisdictions cannot amend the code. The construction of commercial structures in New Jersey is regulated under the 1996 National Building Code (1996 NBC) with some state modifications. The code applied to all commercial structures and cannot be amended by local jurisdictions.

National Flood Insurance Program (NFIP)

Perhaps the single most important regulatory statue governing the construction of buildings in New Jersey flood prone areas was set forth by the Federal Government through the National Flood Insurance Program (NFIP). Established by Congress in 1968, the NFIP is a voluntary program designed to reduce the loss of life and damage caused by flooding, to help victims recover from floods and to promote an equitable distribution of costs among those who are protected by flood insurance and the general public (FEMA, 2000). The NFIP operates through a voluntary partnership between the Federal Government, the states, and local communities.

The New Jersey Department of Environmental Protection (NJDEP) is authorized under N.J.S.A. 58:16A-50, the Flood Hazard Area Control Act, to delineate and mark flood hazard areas, adopt land use regulations for flood hazard areas, authorize the delegation of certain administrative and enforcement functions to county governing bodies and integrate the flood control activities of the municipal, county, State and Federal Governments. Based on flood hazard studies, the state adopts rules and regulations that delineate flood hazard areas that, in the judgment of the NJDEP, the improper development and use of which would constitute a threat to the safety, health, and general welfare of the public. Such delineations identify the various subportions of the flood hazard area for reasonable and proper use according to relative risk levels. Wherever practicable, floodway delineations identical to the delineations approved by the NFIP are made by the NJDEP.

The Federal Emergency Management Agency (FEMA) administers the NFIP conducting flood hazard studies, Flood Insurance Studies (FIS) and by developing Flood Insurance Rate Maps (FIRMs) for individual communities. A FIRM consists of one or more maps delineating the flood hazard by ground elevation as shown in Figure 39 (FEMA, 1995). Each FIRM outlines the areas of a community that will be impacted by a 100- and 500-year flood event. FEMA also provides funding to New Jersey communities for flood hazard mitigation and affordable, federally backed flood insurance to property owners and residents living in flood hazard areas. In return, participating communities adopt and enforce floodplain management ordinances that control development and the construction

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[5] Additional information pertaining to regional building codes can be found on the Institute for Building and Home Safety web page at http://www.ibhs.org/building_codes/

of new buildings, substantial improvements to existing buildings and the reconstruction of substantially damaged buildings.

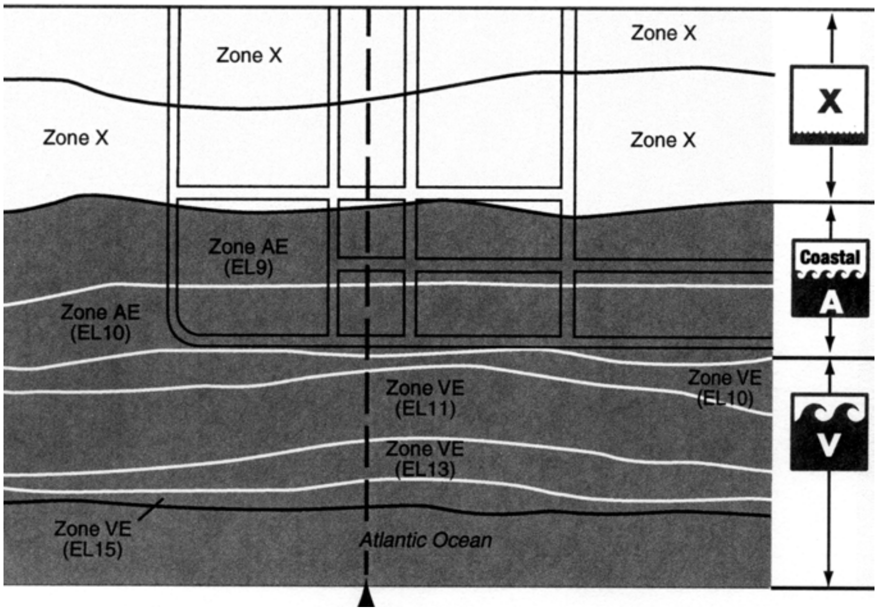

Figure 39. Idealized Flood Insurance Rate Map showing the delineation of flood hazard zones. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

A participating community's floodplain management ordinance must, at a minimum, meet the requirements of the NFIP regulations, but FEMA encourages communities to establish additional or more stringent requirements (FEMA, 2000). To provide incentives for communities to adopt more stringent regulations, FEMA established the NFIP Community Rating System (CRS) in 1990. The CRS awards points to communities for activities that will reduce flood losses, facilitate accurate insurance ratings and promote the awareness of flood insurance. Through the CRS, FEMA recognizes a community's floodplain activities in excess of the minimum standards by reducing flood insurance premium rates.

For more information regarding coastal regulations in New Jersey contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

New Jersey Department of Community Affairs
Division of Codes and Standards
Bureau of Code Services
P.O. Box 816
Trenton, New Jersey 08625-0816
Phone: (609) 984-7609
Web: http://www.state.nj.us/dca/programsbook/dcs.htm

Federal Emergency Management Agency
Region II
26 Federal Plaza, Room 1337
New York, NY 10278
Phone: (212) 225-7200
Web: http://www.fema.gov/regions/ii/

Federal Emergency Management Agency
Federal Insurance Administration
500 C Street, S.W.
Washington, D.C. 20472
Phone: (202) 566-1600
Web: http://fema.gov/

Elevation

Responsible Agency/Party: Homeowner or builder initiated to new or established structures

Mitigation for: Flood hazards
Wave hazards

Management Effort: Low

In coastal flood zones, elevating structures is an effective way to mitigate potential damage from flooding, wave action and debris. In New Jersey communities participating in the National Flood Insurance Program (NFIP), ordinances and laws require buildings to be sited at an elevation above the Base Flood Elevation (BFE); i.e., the flood elevation that has a 1-percent probability of being equaled or exceeded in any given year (determined on an individual community basis). The 100-year storm event is chosen as the standard of protection or target state since such events generally are capable of permanently altering coastal landforms. The type of structural elevation required, open or closed foundation, is determined by the flood hazard potential at the location of the structure (Figure 40). The NFIP designates flood hazards into three broad categories:

V-Zone: Coastal High Hazard Area extending from the ocean to the inland limit of the primary dune and/or any area subject to high-velocity wave heights (3 feet or greater), and wave runup depths greater than 3 feet.

A-Zone: Areas outside of the Coastal High Hazard Area but still exposed to high velocity flood flows (greater than 10 ft/s) and breaking waves heights less than 3 feet in height.

Coastal A-Zone: Presently, the NFIP makes no distinction between the A-zones of inland and coastal areas. Because structures in an A-zone along the *coast* are still subject to wave action (less than 3 ft in height), FEMA is recommending that structures in the Coastal A-zone be built to meet V-zone requirements (FEMA, 2000).

X-Zones: Areas of moderate flood hazard outside of the 100-year base flood elevation but inside the 500-year flood limit~~s~~

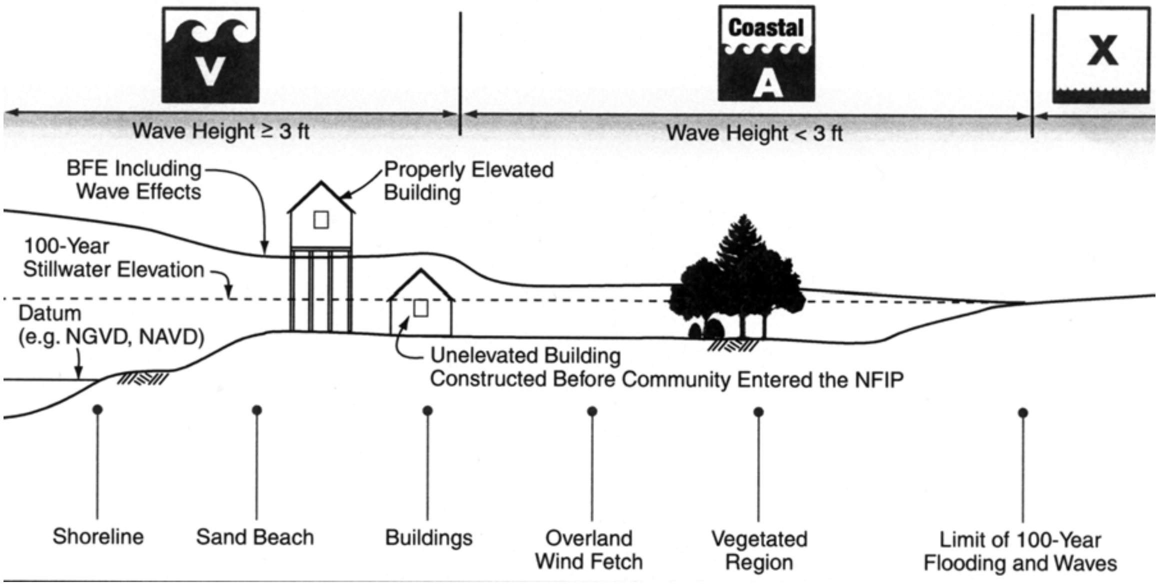

Figure 40. Cross-section of a typical shoreline showing the variation in flood hazard from the shore to the upland limit of flooding. Note the proposed delineation of a Coastal A-zone as an indicator of the higher flood velocities associated with waves less than 3 ft in height and storm surge flooding. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Structures built in V- or Coastal A-Zones in New Jersey should be elevated on pilings to a height where the lowest horizontal member of the structure is at or above the BFE (Figure 41). In addition, any enclosures, - carports, storage areas, showers, etc - built below the BFE must include structural elements that will “breakaway” when impacted by waves. The latter is extremely important because wave loads can exceed typical wind pressures that are generated by hurricanes and typhoons (FEMA, 2000). FEMA NFIP Technical Bulletin 9-99 discusses the design of breakaway walls in detail (FEMA, 1999). In addition to the use of breakaway elements, all concrete slabs and grade beams should be poured so that the concrete is not attached to the supporting piles. Many elevated structures that would have otherwise survived direct wave attack, have failed due to concrete slabs damaging the support piles (see Figure 26).

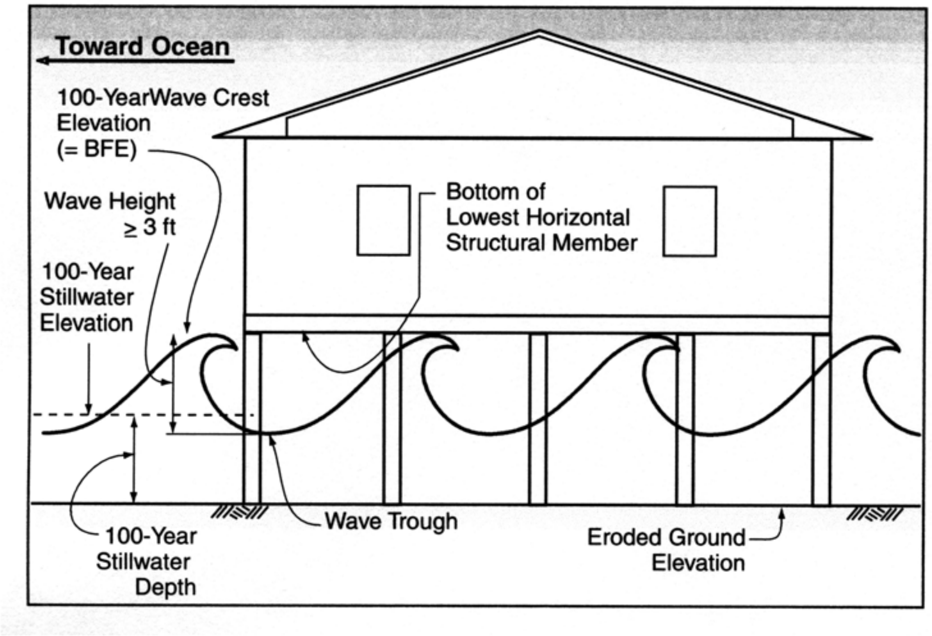

Figure 41. Minimum NFIP standards applied to New Jersey coastal dwellings in the V-zone require that buildings be elevated on an open foundation so that the lowest horizontal structural member is above the Base Flood Elevation. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Structures built in A-zones should be elevated to a level where the lowest floor of the structure is at or above the BFE (Figure 42). They can be built on pilings or on solid foundation walls as long as openings are included in the wall to allow floodwaters to enter Proper openings in a solid foundation are critical to insure that internal and external hydrostatic pressures are equalized, otherwise the foundation has the potential to collapse inward.

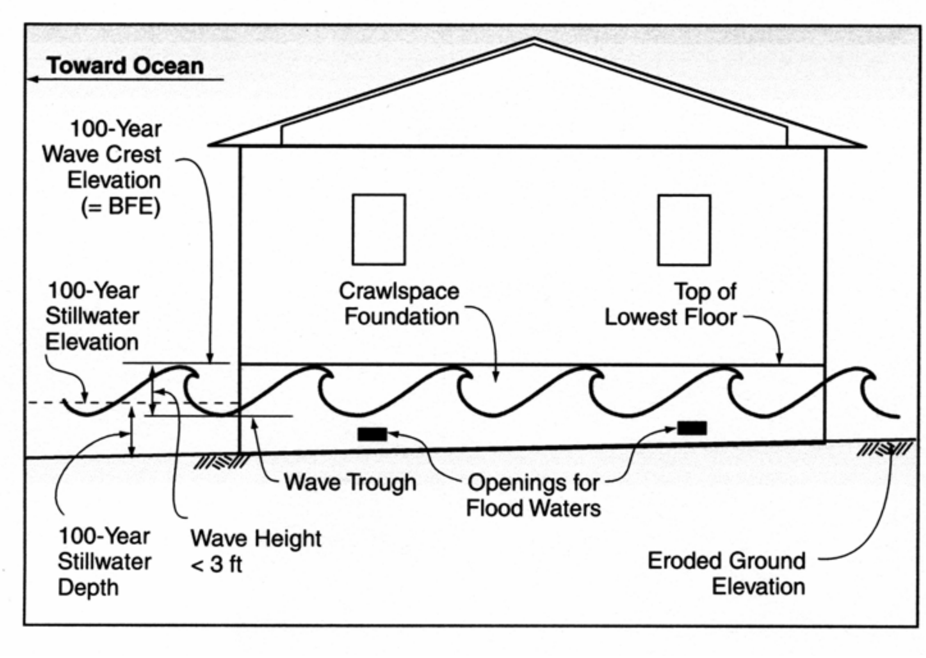

Figure 42. Minimum NFIP A-zone standards require that the lowest floor be at or above the Base Flood Elevation (BFE). Foundation walls below the BFE must be equipped with openings to allow equal interior and exterior hydrostatic pressures. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Structures built in either flood zone should also be designed to resist impacts from waterborne debris. Consideration should be given to elevating the structure an *additional* increment above the BFE to provide added protection against floods (Figure 43). This is especially prudent in regions where sea-level rise and shoreline recession and deflation may act to lower the ground elevation relative to mean sea level over the lifespan of the structure (Figure 44).

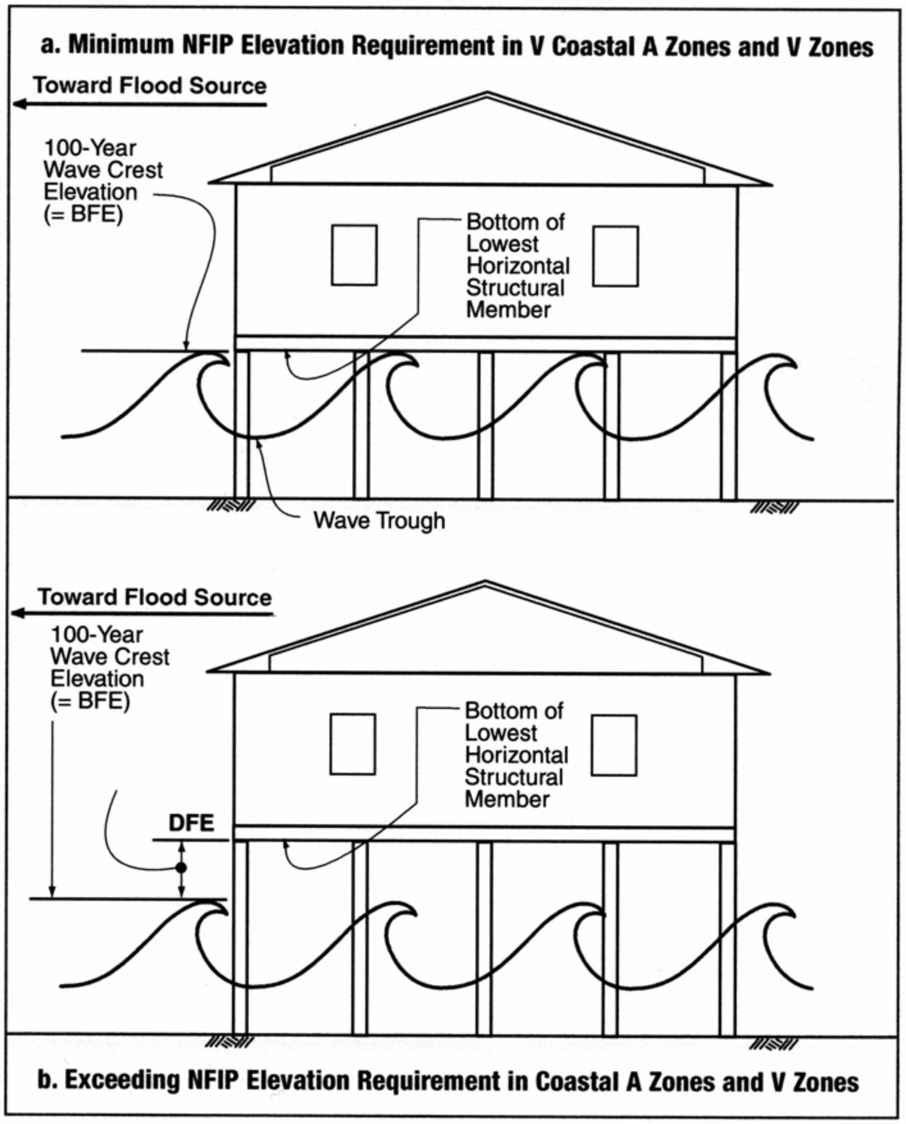

Figure 43. Since the NFIP provides *minimum* standards, consideration should be given to elevating structures above the Base Flood Elevation to provide an added level of protection. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

Figure 44. House on pilings left standing after March 1962 northeaster in Holgate, New Jersey. Almost all oceanfront houses not on pilings were either destroyed or heavily damaged as a result of this storm. The pilings to the right of the houses had just been driven in anticipation of building. The comparison between those houses left standing and those destroyed led to changes in FEMA's construction code (Photograph by Lawrence Wagner; courtesy of Dr. Susan D. Halsey)

In all instances, outside utilities (including air conditioning units) should be elevated along with the structure to or above the BFE. Designers and builders should be careful not to elevate the structure too high in regions exposed to exceptionally high winds as the benefit of reducing the flood hazard may increase the risk associated with the other hazards. Structures or infrastructure build below the BFE may encounter significant uplift forces due to buoyancy. Such structures should be sufficiently heavy or be anchored to withstand the uplift force.

For more information pertaining to construction in New Jersey flood hazard areas contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

New Jersey Department of Community Affairs
Division of Codes and Standards
Bureau of Code Services
P.O. Box 816
Trenton, New Jersey 08625-0816
Phone: (609) 984-7609
Web: http://www.state.nj.us/dca/programsbook/dcs.htm

Federal Emergency Management Agency
Preparedness and Prevention Library
500 C Street, S.W.
Washington, D.C. 20472
Phone: (202) 566-1600
Web: http://fema.org/library/prepandprev.shtm

Institute for Business & Home Safety
4557 E. Fowler Avenue
Tampa, FL 33617
Phone: (813) 286-3400
Fax: (813) 286-9960
Web: http://www.ibhs.org

Siting

Responsible Agency/Party:	State regulations, local ordinances and homeowner/builders
Mitigation for:	Long- and short-term erosion Flood hazards Wave hazards
Management Effort:	Low to Moderate

The proper siting of buildings and infrastructure is one of the most effective methods of coastal hazard mitigation (Figure 45). Unfortunately, prudent siting has often been overlooked or ignored by property owners, builders and local building and zoning codes. Poorly sited construction exposes coastal structures to increased vulnerability to erosion hazards, flooding, wave attack and wind loads.

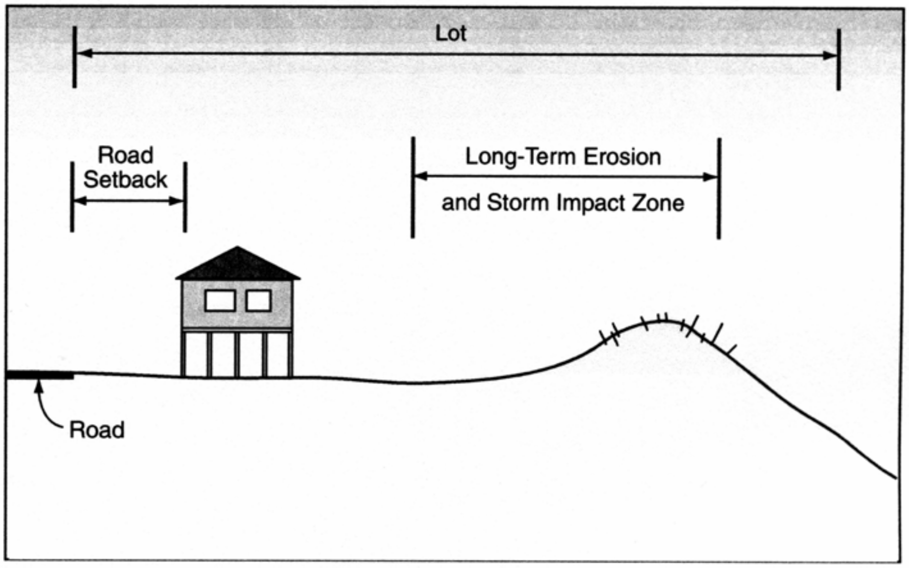

Figure 45. Oceanfront lots should be sufficiently wide to allow for ample space between the present shoreline and the anticipated location of the shoreline due to long-term erosion trends. Reprinted from the FEMA Coastal Construction Manual (FEMA, 2000).

The suitability of a coastal development site should be carefully investigated prior to its purchase, otherwise the new owner may be subjected to unwanted constraints in location, design, and construction techniques, all of which determine the sites long-term vulnerability to hazards. In addition to conducting an in-depth hazard analysis, the prospective buyer should also investigate the regulatory requirements for the location, including land use regulations, zoning ordinances, setback requirements, floodplain management requirements, building codes, coastal zone management regulations and allowable responses to erosion and flood hazards. It must be emphasized, however, that compliance with all of the regulatory requirements does not *ensure* the future safety of a building or development (FEMA, 2000).

Even with proper siting, the vulnerability of a coastal structure may increase over time. The presence of existing erosion control structures or constrained navigation inlets is an indication of prior (and most likely future) changes in the location of the shoreline (Figure 46).

Figure 46. Long Branch, New Jersey in May 1983 showing the location of old shore protection structures exhumed by storm action. (Photograph by Ed Schwartz, Toms River, New Jersey)

In addition, future coastal development and shore protection projects may have impacts on the vulnerability of the existing built environment. For example, the California Coastal Commission (1994) developed a set of comprehensive guidelines for coastal site planning, development and redevelopment that are relevant for all coastal residents:

- Ensure that the proposed land use is consistent with local, regional, and state planning and zoning requirements;
- Account for all types of erosion and governing erosion control policies;
- Avoid areas that require extensive drainage;
- Identify all potential hazards, including multi-hazard impacts;
- Consider existing public access and resource areas;
- Incorporate setbacks from identified high-hazard areas;
- Do not rely on engineering solutions to correct poor planning decisions;
- Do not rely on relocation or restoration efforts to replace resources impacted by poor planning;
- Do not overlook the effects of infrastructure location on the hazard vulnerability of building sites;
- Do not plan development on beaches or dunes;
- Do not forget to consider future site and hazard conditions; and
- Do not assume that engineering and architectural practices can mitigate all hazards.

The 3rd edition of FEMA's Coastal Construction Manual (FEMA, 2000) recommends additional siting practices based on prior experience with coastal development patterns and ensuing damages from poor planning:

1. Establish sufficient setbacks and building relocation plans for oceanfront lots (Figure 47). At a minimum, the structure should be landward, or capable of being moved landward, of the projected shoreline location at the end of the useful life of the structure. In some instances, the commitment to a long-term beach nourishment project can provide the appropriate setback over the useful life of the structure.

2. The placement of utilities near and parallel to the shoreline should be avoided. Potential damage to infrastructure can be reduced by configuring the oceanfront lots so they have access and utility feeds from shore perpendicular roads.

3. The creation of building lots or the redevelopment of existing lots on low-lying, narrow landforms should be avoided.

4. Development that places structures in line with environmental features that can concentrate floodwaters should be avoided (Figure 48). Such features may include areas of historic breaching, roads or paths across dunes, drainage features or canals. Lots should not be developed in such a way that floodwater and waves are potentially channeled through gaps.

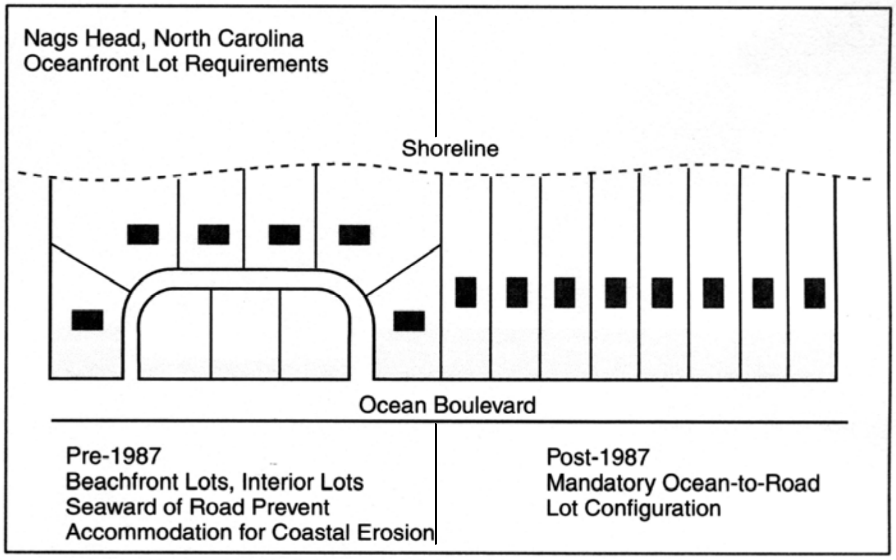

Figure 47. Example of improved lot requirements allowing for sufficient oceanfront setbacks. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

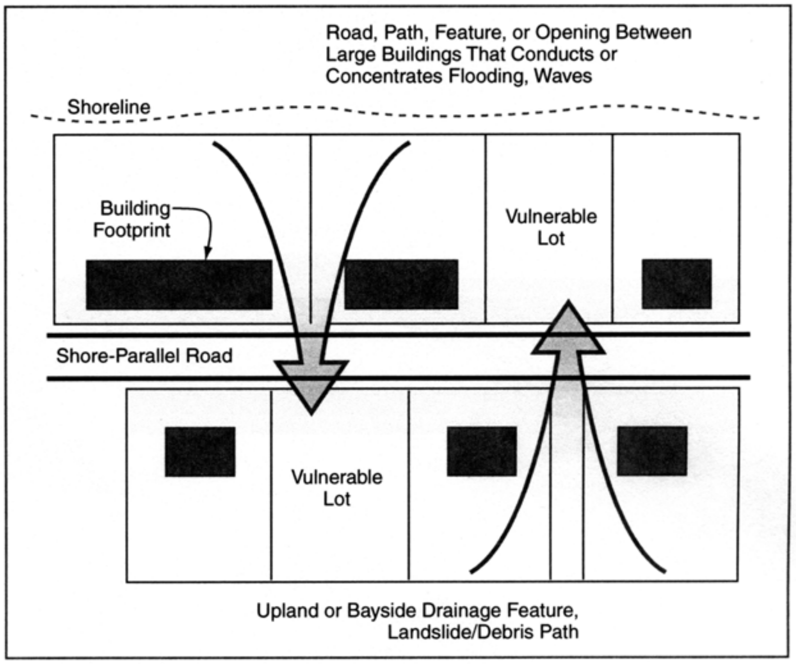

Figure 48. Lots sited landward of breaks in the dune line or openings between structures are vulnerable to channalized flow. Lots should not be developed in a way that places landward lots in gaps between seaward lots. Reprinted with permission from the FEMA Coastal Construction Manual (FEMA, 2000).

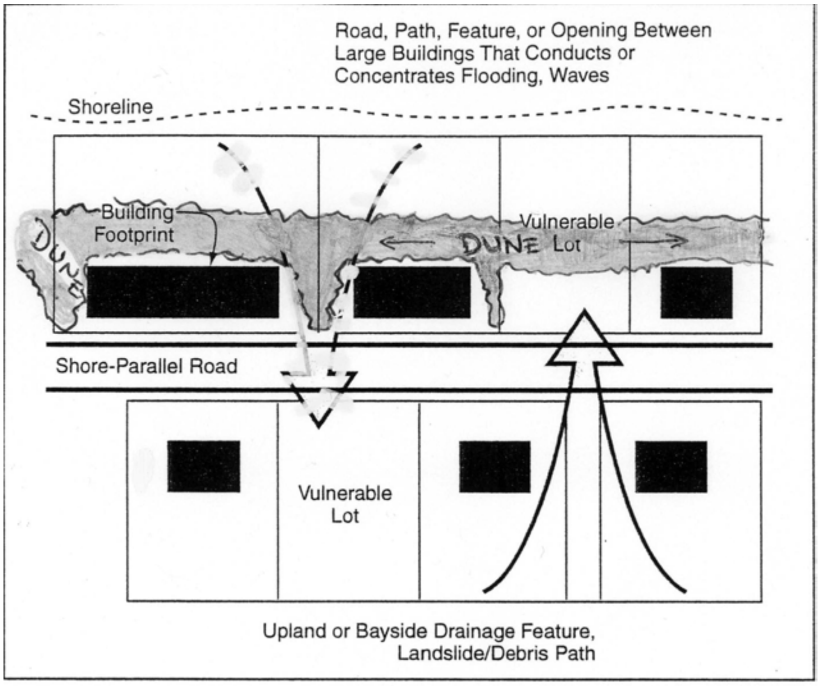

Figure 48b. Careful construction of dunes seaward and/or between structures can create a natural barrier around coastal structures that can mitigate channelized flow. Municipalities that construct dunes along their oceanfront (regardless of whether or not there are structures present) will decrease the opportunity for overwash. Vulnerable lots without existing structures may be designated as "sacrificial areas" for bayside drainage to return to the ocean. (Diagram modified by Dr. Susan D. Halsey)

5. Development or redevelopment along reaches of coastline that have historically undergone large variations in erosion and accretion should be avoided. Such areas can include locations close to tidal inlets and on barrier spit formations.

6. The siting of a building as far seaward as allowed under the existing regulations should be avoided as well as siting buildings too close to erosion control structures, dunes, or inlets. Avoid extending the oceanfront side of any building seaward of the existing building line.

A properly sited and designed building will minimize its vulnerability to damage from coastal hazards. Although a structure may be designed to withstand conditions exceeding the design flood, wind, and wave loads, if improperly sited, it may still be rendered a loss, if a storm makes the building inaccessible. The success of a coastal building starts with proper siting.

For more information pertaining to land use planning in New Jersey contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

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Davidson Laboratory
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Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
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4557 E. Fowler Avenue
Tampa, FL 33617
Phone: (813) 286-3400
Fax: (813) 286-9960
Web: http://www.ibhs.org

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Preparedness and Prevention Library
500 C Street, S.W.
Washington, D.C. 20472
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Web: http://fema.org/library/prepandprev.shtm

Shore Protection Structures

Shore protection structures, also referred to as fixed or hard structures are designed to mitigate the effects of shoreline erosion. When appropriately sited, constructed and maintained, fixed structures are capable of providing effective protection for upland property and infrastructure. It should be noted, however, that no structure or device can *create* sand, thus any accumulation of sand in the vicinity of the structure is at the direct expense of an adjacent section of the shore (National Research Council, 1995).

Although shore protection structures have a proven track record (National Research Council, 1995) their deployment without adequate attention given to natural coastal processes will almost always lead to adverse impacts in the vicinity of the structure. It is for this reason that all coastal protection structures should be designed or certified by a professional coastal engineer. In addition, individual shore protection structures should always be constructed as part of a larger shore protection scheme to protect an entire reach or region of the coast. In most instances, shore protection structures are not an option for the individual property owner but rather a coastal management tool for local, state or regional authorities.

Sometimes the use of a fixed structure along the coast is a necessity; e.g., when siting jetties along navigational inlets or when using terminal groins in beach nourishment projects to retain sand. In other instances, shore protection structures can be used to increase the longevity of beach nourishment projects by reducing alongshore sand transport. Shore protection structures can also be used where severe flooding is a distinct possibly and no other options are available (e.g., sand dunes) to protect the backshore. In all cases, the potential for adverse effects of proposed shore protection structures should be analyzed very carefully prior to their construction (National Research Council, 1995). Once a structure is constructed, it should be monitored to determine its performance and impact on adjacent shorelines. Adaptive management plans with thresholds should be developed at the onset of a coastal protection project to mitigate any unanticipated adverse effects, if and when they occur.

Clearly, there is a great deal of responsibility associated with the decision to construct shore protection structures. Because the coast is constantly evolving, a state, municipality or community that decides to use hard structures as part of a shore protection plan must be committed to long-term monitoring, maintenance, and possibly altering or removing the structures. This commitment requires diligence and a stable financial base.

There are generally three broad categories of shore protection structures; shore perpendicular, shore parallel and non-traditional that are summarized below:

Shore Perpendicular Structures

Responsible Agency/Party:	Federal and/or State sponsored projects
Mitigation for:	Long -term erosion Flood hazards Wave hazards
Management Effort:	High

Shore perpendicular protection structures are designed to either reduce the rate of transport of sand along a specific reach of shoreline or to completely block the alongshore movement of sand beyond a certain point. Groins are often constructed in series (called a groin field) forcing the sand to fill in to a specified level on one beach before allowing sand to be transported to the next beach in the field. Down. A groin field is analogous to a series of weirs that will not allow water to flow over a point until a certain level has been reached. Terminal groins and jetties are impervious shore perpendicular structures constructed to keep sand from moving into an undesirable areas including navigational inlets, harbors and submarine canyons.

Groins

Used singularly or in groups, groins are constructed perpendicular to the shore to trap and reduce the alongshore transport of sand (Figure 49). Groins typically extend from the toe of the primary dune, offshore to the seaward limit of the surf zone (Figure 50). Extending the structures beyond the surf zone will usually force sand too far offshore to return to the downdrift beach.

Figure 49. Extensive groin field along the Monmouth County, New Jersey coast. Note the recession of the shoreline from south (bottom of photo) to north as less and less sand is transported around each successive groin (Photograph by Ken Cadmus).

Figure 50. Overhead view of a rock groin showing the underwater extent of the structure (Photograph by Ken Cadmus).

The height of a groin varies depending on the desired amount of sand bypassing. High profile groins will effectively block the transport of sand (Figure 51) while low profile groins will allow the tide and waves to transport sand over the structure. In addition to their length and height, the distance between groins is important to the stability of the shoreline. Groins spaced too far apart lead to excessive erosion between structures and groins spaced to close together generate strong currents that limit the amount of sand deposited in their lee.

Figure 51. Aerial photograph of high profile rock groins along Ocean City, New Jersey after a severe March 1984 storm. Note the little sand left on beaches (shown by the whiter shade of dry sand). (Photography by Dr. Susan D. Halsey)

Groins do not create sand; they only influence its deposition. Groins are only effective when there is a *net* alongshore transport of sand in one direction. The evolution of the shoreline in response to the construction of a groin is dependent on the predominant wave direction. Once constructed, the predominant waves begin to deposit sand along the updrift side of the groin. As the shoreline continues to evolve, the fillet reaches its capacity and sand begins to pass around and over the groin to the downdrift beach. In regions where there is very little net alongshore transport of sand, it takes a very long time to create a sand "surplus" available for migration over and around the seaward extent of the groin. It should be recognized that a groin will negatively impact the downdrift beach by reducing the amount of sand available to it until the fillet has reached capacity.

Groins are constructed with a number of different materials depending on availability, cost, and longevity. In high-energy environments, groins are typically constructed of granite, basalt or pre-cast concrete interlocking units (e.g., dolos) that resist movement. In lower energy environments, groins can be constructed of timber sheeting, poured or pre-cast concrete, metal sheeting, plastic sheeting, pilings, rock filled wire baskets (gabions), and sand filled geotextile tubes. Groins are often constructed of two or more materials to improve performance and cost-effectiveness.

Groins also vary in the shape of the cross-shore profile, depending on the intended function of the structure. Groins can be constructed with low profile sections along the beach berm to allow the wind and storm tides to transport sand across the structure. Groins can be "notched" – lowered down to the mean water level in sections – along the beach foreshore and surf zone to allow breaking waves and wave runup to transport sand across the structure (Figure 52). Groins can also be tapered at the offshore end to allow for unimpeaded sand transport offshore of the structure. The porosity – size of the voids in the structure – can also be altered to allow a certain percentage of sand to move through the structure.

Figure 52. Notched groin – groin with a section removed within the surf zone, in Spring Lake, NJ. Photograph by Thomas O. Herrington.

Jetties

Jetties are shore perpendicular structures constructed to eliminate the alongshore transport of sand around, across, or through the structure, in order to maintain and stabilize the location of an inlet of coastal navigation channel. As such, jetties are high profile, impervious structures stretching between the upland limits of wind-borne sediment transport, offshore into water depths deep enough that no significant wave- or current-induced sediment transport occurs. Because jetties extend through the surf zone and absorb direct wave attack, they are typically constructed of very heavy quarrystone or concrete armor units placed in a trapezoidal cross-section. The individually armor units are placed to limit the size and number of interior voids that will allow sediment to flow through the structure. To limit the amount of wave overtopping, the top elevation of a jetty is commonly above the maximum wave height expected in conjunction with the design storm event (Figure 53).

Figure 53. Jetties constructed to stabilize Barnegat Inlet, NJ interrupt the along shore transport of sand in order to control the location of the inlet channel (Photograph courtesy of the Jersey Shore Partnership).

Jetties, by definition, are designed to interrupt the alongshore transport of sand and stabilize the random transgressions of a coastal inlet. This interruption in sediment transport generates a sand deficit along the shoreline downdrift of the inlet. In order to mitigate the negative impacts of a stabilized inlet, variations in the design or operation of inlet stabilization structures have been implemented, including the use of weir sections – lowered portions of the structure that allow sand to cross the jetty and deposit in a deposition area – and bypassing of sand across the inlet by pumping, trucking or dredging.

Terminal Groins

Terminal groins are impermeable groins designed to stop the transport of sand around, through or over the structure. Terminal groins are very similar to jetties in that they are impervious structures placed in the cross-shore to eliminate the movement of sand beyond a certain point along the coast (Figure 54).

Figure 54. Aerial photograph showing advanced terminal groin effects, Stone Harbor Point, NJ in early March 1984 (before the late March storm). Erosion caused by terminal rock groin in foreground has caused erosion in an arcing pattern behind the structure actually flanking it. Subsequently, the entire Point eroded away (dune field and spit visible in background. (Photograph by Dr. Susan D. Halsey)

Generally not as long or high as jetties, terminal groins are constructed to guard against the permanent loss of sediment from the coastal system. The most common use of a terminal groin is at the downdrift end of a sediment transport system. Some examples include immediately updrift of a submerged canyon, at the edge of an inlet to prevent the movement of sand landward into a bay or estuary and at the limit of a sand spit. Terminal groins can be constructed of many different materials as long as the structure is relatively impervious to sand. The benefits of a terminal groin should be weighed against the potential negative impacts since the structure will permanently interrupt the alongshore transport of sand (Figure 55).

Figure 55. Aerial photograph of the “Cape May Meadows” area, Cape May Point, NJ after the March 1984 storm. Terminal groin effect from Cape May City (in top distance) has eroded the meadows area in the classical arced pattern. Note extensive washover fans with sand reaching into the ponds and salt marsh, and old World War II bunker in surf zone. Originally the bunker was approximately 1000 feet behind the dune line when built. (Photograph by Dr. Susan D. Halsey)

Shore Parallel Structures

Responsible Agency/Party:	Federal and/or state sponsored projects; bulkheads and revetments for private property protection
Mitigation for:	Long -term erosion Flood hazards Wave hazards
Management Effort:	Moderate to High

Shore parallel protection structures are built both onshore and offshore of the coast. Viewed as the last line of defense against coastal storms, onshore structures, (e.g., bulkheads, revetments and seawalls) limit the landward extent of erosion or retain land behind the structure. Offshore structures, or breakwaters, are designed to limit the magnitude of wave energy in their lee. Breakwaters can be built either above or below the water's surface depending on the desired level of wave protection.

Bulkheads

Bulkheads are designed to prevent the loss of sediment landward of the structure (Figure 56).

Figure 56. A sheet metal bulkhead installed to prevent the undermining of a dune and adjacent home. Bulkheads exposed to direct wave attack can result in the loss of sediments fronting the structure (Photograph by Dr. Michael S. Bruno).

Because bulkheads function to retain sediments, they are not necessarily designed to withstand direct wave attack. For this reason, bulkheads are not usually found fronting the ocean, but rather are constructed along bay and harbor shorelines to reduce erosion, and to provide direct access to deeper water. Bulkheads are generally thin structures built of wood, metal or plastic sheeting that are driven deep into the ground to resist deflection of the above ground portion of the structure. In areas where there is poor soil or where high structures are required, a tieback anchoring system may be required. However, where the subsurface soil can support the weight of heavier structures, bulkheads may be constructed of poured or pre-cast concrete, rock, gabions or sand- and cement-filled bags. Care must be taken to insure adequate penetration of the substrate as reflected wave energy can accelerate erosion at the base of the bulkhead (Figure 57). In cases where a bulkhead is needed to withstand moderate wave attack, rock facing is often placed along the seaward side of the structure to dissipate wave energy and provide scour protection (Figure 58).

Figure 57. Timber bulkhead at Bradley Beach, New Jersey under direct wave attack. Note rock placed at the base of the structure to prevent scour (Photograph by Dr. Thomas O. Herrington).

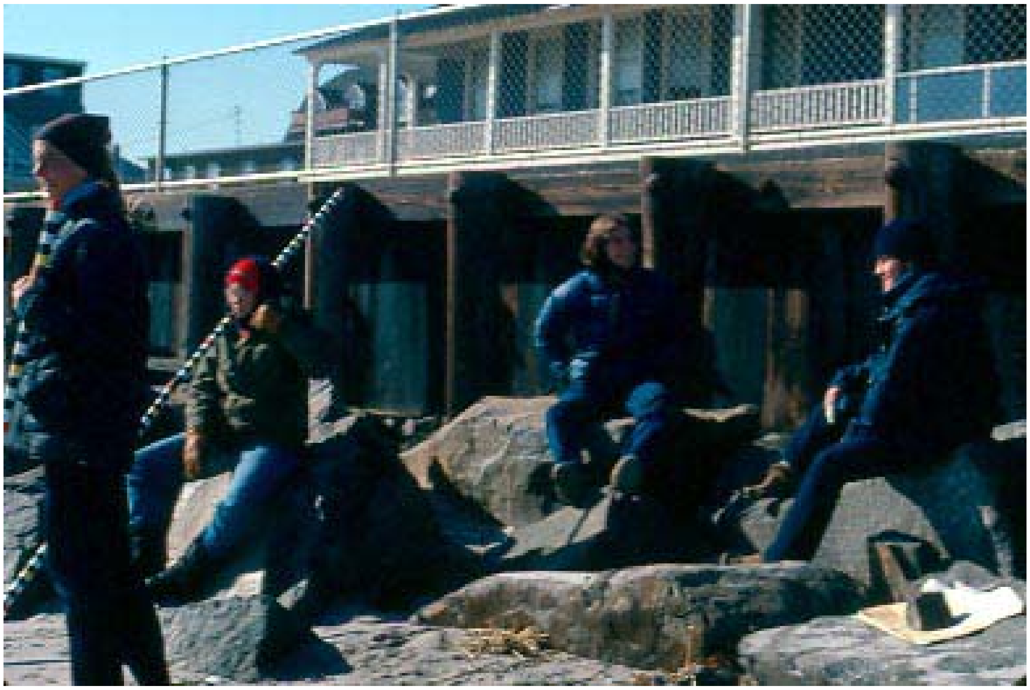

Figure 58. Students on Revetment boulders placed in front of new timber bulkhead, Sea Isle City, New Jersey in January 1979. Subsequent beach nourishment has completely covered these structures up to the level of the promenade above. (Photograph by Dr. Susan D. Halsey)

Revetments

Revetments are sloped structures built of heavy material (armor) to protect the upland from wave- and scour- induced erosion. The structure is designed to absorb direct wave attack and dissipate wave and current energy by inducing wave breaking, reducing wave runup, and by dissipating the water's energy along their slope (Figure 59). Because a revetment is sloped, the structure depends on the subsurface soil for support and should be built on a very stable shore or bank slope. In many instances, the original soil must be removed and replaced with high-quality fill material contoured to an approximately 1:1.5 (1 foot vertical for every 1.5 feet of horizontal distance) slope. Usually, an impervious filter fabric is placed on top of the soil and the structure is built in layers of increasing grain size (sand, pebbles, small rock, and large quarry stone). Any revetment designed to absorb direct wave attack should have a top layer constructed of heavy interlocking quarrystone or pre-cast concrete armor units. These rubble mound structures are flexible in the sense that individual armor units can settle or move without compromising the overall strength of the structure.

Figure 59. Rock revetment fronting a timber bulkhead along the Avalon, New Jersey coastline (Photograph by Dr. Thomas O. Herrington).

Where direct wave attack is of lesser concern, revetments can be constructed of a wide variety of materials. Along riverbanks and embayments, revetments have been constructed of poured concrete, tong-and-groove concrete blocks and slabs, gabions and plastic. Revetments are frequently constructed with smooth slopes for aesthetic reasons. Because revetments dissipate energy along the slope of the structure, smooth structures increase the risk of overtopping and can fail catastrophically, if one of the interlocked units is displaced.

In all cases, revetments should be constructed with adequate toe protection to prevent the undermining and collapse due to wave and current scour. Although wave reflection is of ~~a~~ lesser concern than in the case of bulkheads or seawalls, the action of waves should still be considered in the design of the structure. Because revetments only protect the area immediately behind them, wave overtopping and erosion at the ends of the structure (flanking) can be a problem (Figure 60).

Figure 60. “Flanking” around the end of a gabion revetment in Cape May Point, New Jersey (Photograph by Dr. Thomas O. Herrington).

Seawalls

Seawalls are massive structures designed to protect the land behind them from direct wave attack. They are generally built along reaches of coast that contain some type of critical infrastructure such as an evacuation route, water or sewer main, utility easement or rail line (Figure 61). Because seawalls are designed to withstand direct attack by very large waves (Figure 62), they are usually trapezoidal in cross-section, and constructed of very heavy outer armor units placed on top of smaller rock or a solid core (soil berm or concrete). The top of the structure is typically set at an elevation that will prevent wave overtopping and minimizes the amount of saltwater spray crossing the structure. In some instances, a walkway or emergency access road will be constructed along the crest of the structure.

Figure 61. Sea Bright – Monmouth Beach Seawall in Monmouth County, New Jersey. Originally constructed to protect a rail line, the seawall now protects a main evacuation route and local community (Photograph courtesy of the Jersey Shore Partnership).

Figure 62. Waves breaking over seawall at Sea Bright, New Jersey (Photograph by Dr. Susan D. Halsey).

To minimize the planform (“footprint”) required for a seawall, the structure is usually built with steep side slopes (1:1.5). A negative consequence of this design is the generation of reflected waves during storm events that accelerate erosion at the toe of the structure and can lead to instability, undermining and eventual collapse. Research has indicated the seawalls built landward of shorelines with a stable sediment supply are exposed to wave action only during the most severe storm events and allow for the natural recovery of the beach afterwards (Griggs, et. al. 1994). Along eroding shorelines, it may be important to have a protective beach in front of the seawall to ensure its long-term stability, especially if it protects critical infrastructure.

Breakwaters

Breakwaters are shore parallel structures placed offshore to intercept the energy of the incoming waves. Breakwaters are constructed as either emerged (crest above the water level) or submerged structures, and in some instances are designed to float. The type of construction depends on the location and intended use of the structure.

Emerged Breakwaters are constructed to provide maximum shelter from approaching waves. Such devices reduce the incident wave energy through reflection or wave breaking along the seaward side of the structure, creating a low energy environment on the lee side. In bays and harbors, emerged breakwaters are often used to create sheltered areas for marinas and port facilities. Along open coasts, emerged breakwaters are used to stabilize eroding shores as the reduction in wave energy reduces the transport of sand in the lee of the structure, creating areas of localized deposition (Figure 63). The amount of sediment deposited is a function of the length and height of the breakwater. In many instances, a reach of shoreline is protected by a series of breakwaters separated by gaps (Figure 64). Because the structures are effectively trapping sand in their lee, coastal breakwater fields can act very much like a groin field by slowing the movement of sand along the coast and reducing the amount of material available to downdrift beaches.

Figure 63. Engineered beachfront in Malaga, Spain. The Spanish provincial government has created beach reentrants with large T-groins and smaller interior bulbous-ended groins tied together by a wide promenade (right) along extensive sections of the Spanish Mediterranean coast. These designs are created to provide protected beaches and bathing areas for recreation, and shops and restaurants for the burgeoning tourist industry (Photograph by Dr. Susan D. Halsey)

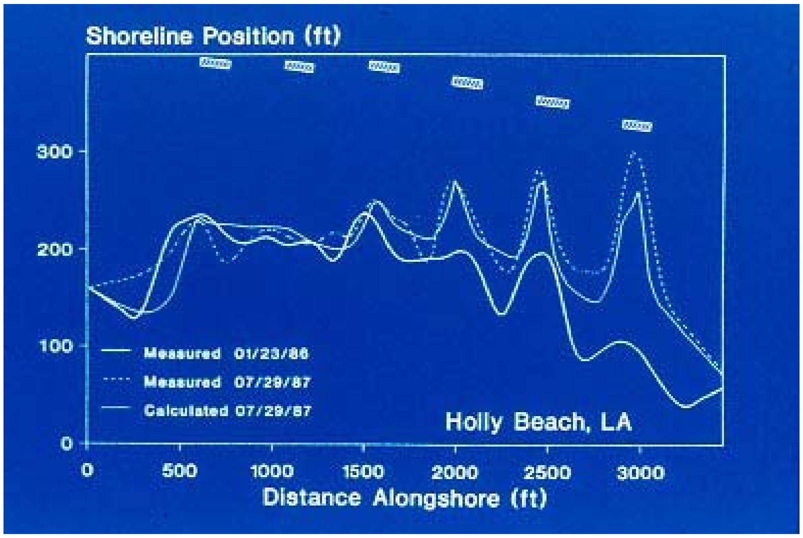

Figure 64. Shore evolution landward of an emerged breakwater field in Holly Beach, LA.

Like seawalls, emerged breakwaters require large “footprints”, are trapezoidal in cross-section, and are almost always constructed of large quarrystone or pre-cast concrete units. When placed in deep water, the structures are often constructed by dumping rock from a barge or ship until a stable slope is achieved. When space is a concern, emerged breakwaters can be constructed by driving sheet metal piling and filling the interior area with rock and rubble. Such “cofferdam” breakwaters are typically constructed in ports and harbors.

Submerged Breakwaters are often used for situations where reduction in wave heights combined with an allowance for sand movement along the beach is desired. The amount of wave energy transmitted across the breakwater is dependent upon the structures length, width, and depth underwater. The wider and higher the structure, the more effective the breakwater is in dissipating wave energy. In high-energy environments, submerged breakwaters must be hundreds of feet wide to effectively dissipate wave energy. Narrow-crested submerged breakwaters (crest width on the order of feet) have been constructed in regions of strong currents to act as barriers between the scouring effect of currents and the shoreline (Figure 65). In addition to sheltering the coast, the structures also act to trip larger storm waves and provide a barrier to offshore transport of sediment. Narrow-crested reefs or sills have been used to create “perched beaches”; i.e., beaches elevated above their normal level and held in place by an~~d~~ offshore sill.

Figure 65. Cross-section of a narrow-crested reef module being installed at Cape May Point, New Jersey (Photograph by Dr. Michael S. Bruno).

Submerged breakwaters may be constructed of rock, pre-cast concrete, or sand-filled geotextile bags and tubing. Wide-crested submerged breakwaters are becoming more prevalent along coast where both coastal protection and habitat and recreational resource creation are desired. In all applications, extreme care is necessary to insure that the components of a submerged breakwater are able to resist movement due to waves, currents and scour.

The term artificial reef is often erroneously used to describe a submerged coastal breakwater designed to reduce the amount of erosion along the coast. It should be noted that all structures built in coastal waters become habitat for marine organisms; however, this is a secondary benefit of the structure. Artificial reefs are structures built for the sole purpose of creating habitat for marine organisms and are often constructed in deeper offshore waters.

Floating Breakwaters are constructed of buoyant material, deployed in the upper portion of the water column. The effectiveness of a floating breakwater is dependent on the structure width, stiffness, porosity, and depth of penetration below the water surface. Floating breakwaters are most effective in reducing wave heights in the lee of the structure when its width is greater than the distance between successive wave crests (wavelength). When the wavelength exceeds the width of the structure, the structure begins to float up and down along the wave surface just like a boat, allowing all of the energy in the wave to propagate under the structure. Because open-ocean wavelengths generally exceed 200 feet, floating breakwaters are generally ineffective in providing cost-effective coastal protection. However, they can be cost effective in ports and harbors where existing water depths are too deep to make the construction of a fixed breakwater practical. Floating breakwaters are often used for marina protection where boat wakes and water quality are of concern.

Floating breakwaters are constructed of a number of materials~~,~~ including timber, plastic, epoxy coated foam, hollow metal cylinders, rubber, pre-cast concrete, among others (Figure 66). In addition to prefabricated materials, many floating breakwaters are constructed with materials of opportunity, such as old boats and floating barges.

Figure 66. Whisprwave$^{©}$ floating breakwater constructed of rotationally modeled high-strength plastic at the Themesport Marina, New London, CT (Photograph by Dr. Thomas O. Herrington).

Non-traditional Shore Protection Structures

Responsible
Agency/Party: Federal and/or state sponsored projects
Municipal or community initiated
Homeowner or industry initiated

Mitigation for: Long– and short-term erosion
Flood hazards
Wave hazards

Management
Effort: Low to High

As research and experimentation continue, new techniques for shoreline stabilization will be proposed and developed (Herrington et al., 1998). In many instances, these approaches "work with nature" rather than simply constructing a barrier as a solution to erosion or wave attack. Increasingly, a shoreline stabilization structure can be hidden in the natural environment and only exposed, if at all, during severe storm events.

Dewatering Systems

Dewatering refers to the drawdown of the water table under the beach foreshore by a system of perforated pipes and pumps. By lowering the natural water table, the porosity of the beach is increased allowing water that would normally run up and down the foreshore slope to percolate down through the sand. Any sediment being carried by the water is deposited on the beach creating a zone of sand deposition (Figure 67). The beach response to a dewatering unit is similar to that of an offshore breakwater system however, in the absence of wave energy reduction, sediment is more easily eroded during storm events. The effectiveness of the system is also dependent on the reliability of the pumps, the maintenance of the pipes and the availability of sand.

Figure 67. STABEACH$^{©}$ dewatering system in Cod Fish Park, Nantucket. Dashed line indicates the location of the buried dewatering pipe. Note the bulge in the shoreline generated by the deposition of sediment in the swash zone over the pipe (Photograph courtesy of Coastal Stabilization, Inc.).

Hardened Dunes

Dune hardening refers to the process of constructing a solid core in the center of a man-made dune system to act as a shore-parallel barrier to wave attack during severe storms. The dune core can be constructed of clay berms, rock revetments or seawalls, pre-cast concrete units or sand filled geotextile tubes. In all cases, the core is designed to promote the development of a natural dune on top of, and around the structure and can include appropriate drainage and soil conditions for the establishment of dune grasses and other plants. Some pre-cast concrete units include hollow interiors to promote sand deposition and plant establishment. Once exposed during a storm, the core of the dune acts as a traditional shore protection structure and must be re-covered with sand after the storm event.

Hardened dunes have been used extensively in New Jersey. Sand filled geotubes have been used in Whale Beach, Avalon, and Atlantic City. Clay berms have been used in Long Beach Township on Long Beach Island. Many relict rubble mound seawalls have also become the core of natural dune systems over time (Figure 68).

Figure 68. Exhumed portion of small rock seawall under dunes in northern section of Bay Head, New Jersey after a severe storm. Many residents were unaware that this seawall existed because it was completely covered by extensive dunes (Photograph by Dr. Susan D. Halsey).

Viscous Drag Mats

Sometimes refereed to as artificial seaweed, viscous drag mats are comprised of buoyant, high-strength plastic fronds woven into a weighted or anchored mat that is placed on the seabed. The fronds create a high-density, vertical lattice that interrupts fluid flow and decreases the velocity of near bottom currents. By interrupting currents, the mat promotes the deposition of sand thereby reducing erosion. Viscous drag mats have worked extremely well in deep water applications, by reducing scour around submerged pipelines and the bottom of drilling rigs. In coastal environments, the mats are only effective in low wave energy environments and are well suited to use in front of bulkheads and revetments where scour is a problem or the re-establishment of a more natural shoreline is desired.

Geotubes

Geotubes are porous textile tubes designed to hold sand but allow water to percolate through. Although geotubes are not in themselves a shore protection device, they are commonly used in shore protection structures. When filled, geotubes are as hard as traditional shore protection structures, but their use is considered by many as a “soft solution” to shore protection as the tubes can be easily removed by cutting the geotextile and pulling the bag out, leaving the sand fill on the beach. Geotubes have been used to create hardened dunes, revetments, groins and submerged sills (Figure 69). However, geotubes have a tendency to degrade over time and are prone to tearing, punctures and settlement. Proper maintenance and foundation preparation is required.

Figure 69. Sand filled geotube used to create the core of a protective dune line (Photograph by Dr. Michael S. Bruno).

Biodegradable structures

In a relatively new approach, biodegradable materials are being used to create biotextile tubes capable of being filled with sand or other soil materials for use in bank stabilization. Natural materials such as hemp and coconut strands are used to create woven tubes that are filled with soil and placed along marsh banks or estuarine riverbanks to reduce wave and current energy. The biotextiles promote the re-establishment of the natural vegetation by offering a protected base for root establishment. Over time the biotextile degrades leaving only the natural vegetation.

For more information about shore protection structures in New Jersey, contact:

New Jersey Department of Environmental Protection
Natural and Historic Resources
Division of Engineering and Construction
1510 Hooper Avenue
Toms River, New Jersey 08753
Phone: (732) 255-0770
Fax: (732) 255-0774

New Jersey Department of Environmental Protection
Office of Coastal Planning
P.O. Box 418
401 East State Street
Trenton, New Jersey 08625
Phone: (609) 292-2662
Fax: (609) 292-4608
Web: http://www.state.nj.us/dep/cmp/

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

U.S. Army Corps of Engineers
Philadelphia District Office
Wanamaker Building
100 Penn Square East
Philadelphia, PA 19107-3390
Phone: (215) 656-6516
Fax: (215) 656-6820
Web: http://www.nap.usace.army.mil/

U.S. Army Corps of Engineers
New York District Office
26 Federal Plaza
New York, NY 10278
Phone: (212) 264-0100
Web: http://www.nan.usace.army.mil/

Coastal Resource Management

Responsible Agency/Party: Municipal or community initiated

Mitigation for: Long– and short-term erosion
Flood hazards
Wave hazards

Management Effort: Moderate

Along most coasts, sand is a finite resource that is always in motion in response to waves, currents and wind climate. In regions where the net yearly transport of sand is in one direction along the coast, coastal managers can use techniques to re-circulate the sand in the system, bypass or back-pass obstructions to sediment transport and redistribute sand across the beach profile. In addition, coastal managers can take steps to insure that sediment sources remain unconstrained (not encased behind bulkheads or similar structures) and that sediment sinks, such as inlets and offshore canyons, are avoided. By carefully managing our sand resources, the existing long- and short-term erosion, flood and wave hazard levels can be maintained and perhaps slightly reduced over time.

Regional Sediment Management

Regional sediment management refers to the process of recirculating sediment along specific reaches of coast with similar sediment transport patterns. The process may include the impoundment and mining of sand at the updrift end of the coastal reach and the transport and redistribution of that sediment along the downdrift beaches. Mechanical scraping and movement of sand by pan scrapers or front-end loaders can achieve similar results on smaller scales. By returning the sand to the beginning of the coastal reach, sand is conserved and long-term erosion is reduced. However, the amount of material removed from the updrift limit of a coastal reach should not, of course, exceed the volume of material expected to replenish the area between mining operations.

Sand Bypassing

Where a natural coastal feature or structure completely blocks the transport of sand, several techniques can be used to transfer (bypass) the sediment around the obstruction. *Natural* sand bypassing can be used to divert sand from the updrift shoreline out onto a natural bar or ebb shoal feature that extends around coastal headlands or inlets. This allows natural transport mechanisms to continue the motion of the sand down the coast. *Forced* sand bypassing employs mechanical methods such as mining and hauling to move sand around a barrier or pump sand across it. The volume, rate and frequency of sand bypassing are determined by the natural net sediment transport rate along the coast. At stabilized inlets, it is common to delineate an impoundment area that is mined once a specific volume of sand is deposited within it. In some instances, updrift jetties have been constructed with weir sections that allow sand to cross into the inlet and settle into a deposition basin (Weggel, 1981). At specific intervals the basin is dredged and the sand placed on the downdrift side.

Beach Scraping

Beach scraping is a technique used to move small volumes of sand that have accumulated in the intertidal zone to a beach berm or dune area during accretionary periods (Herrington, 1994). Bulldozers, pan scrapers or front-end loaders remove a veneer (< 6 inches) of sand from the low water line at low tide. The goal is to remove only that quantity of sand that can be replenished during the following tidal cycle. If repeated over a prolonged period of accretionary conditions, the technique can increase the volume of the dry beach, providing some mitigation for short-term erosion.

Beach scraping in New Jersey has often been used to build a protective dune immediately prior to the arrival of a coastal storm. Large volumes of sand are moved from the beach foreshore into the dune. Scraping in this manner actually makes the beach more vulnerable to severe erosion by steepening the slope of the dry beach and allowing the larger storm waves to undermine the lower beach foreshore (Herrington, 1994). To be effective mitigation, beach scraping must be conducted over a prolonged period of calm weather conditions.

For more information pertaining to coastal resource management in New Jersey, contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

New Jersey Department of Environmental Protection
Office of Coastal Planning
P.O. Box 418
401 East State Street
Trenton, New Jersey 08625
Phone: (609) 292-2662
Fax: (609) 292-4608
Web: http://www.state.nj.us/dep/cmp/

New Jersey Sea Grant
New Jersey Marine Sciences Consortium
Building 22, Fort Hancock
Highlands, New Jersey 07732
Phone: (732) 872-1300
Fax: (732) 291-4483
Web: http://www.njmsc.org

Natural Resource Restoration

Responsible Agency/Party:	Municipal or community initiated Homeowner or industry initiated
Mitigation for:	Long– and short-term erosion Flood hazards Wave hazards Wind hazards
Management Effort:	Low to Moderate

Most coastal landscapes are composed of two types of geologic features; loose granular soils and eroding headlands. This composition allows the land to rapidly adjust to varying amounts of wave and wind energy and reach equilibrium between the amount of incident energy and the amount of energy dissipated along the coast. In addition to the physical forces in the environment, saltwater flooding and salt spray creates an extremely harsh environment for plants and animals. The rather unique diversity of plant and animal life along our coastal margins is the result of millions of years of adaptation to these harsh conditions. As communities work toward mitigating hazards along the coast, careful consideration should be given to restoring the natural features of the coastal environment. Features such as dunes and coastal marshes naturally mitigate coastal erosion and flood hazards.

Dunes provide a buffer between the ocean and the most seaward buildings and infrastructure along the coast. In addition, dunes store a significant volume of sand that can be released during extreme storm surges and wave events, providing the eroding beach with an additional layer of protection. They can be easily created by placing obstructions along the backshore to trap windborne sand and other particles. Wooden dune fencing or natural vegetation, such as American beach grass, will quickly begin to accrete sand. As the dune grows horizontally and vertically, additional layers of fencing or plantings can be used to incrementally increase the volume of the dune and the level of protection it provides. Although dunes grow and migrate in response to the wind, a properly vegetated dune provides a windbreak for down-wind structures and reduces the amount of sand blown landward of the beach.

Dunes are a unique and valuable coastal resource, providing habitat and protection for a number of endangered and threatened species including shore birds, small mammals (e.g., red fox) and crustaceans. As beach restoration projects continue to recreate lost shoreline many of these species are returning to the New Jersey coast and consideration should be given to enhancing their habitat. Dunes are also a component of the natural landscape adding to the aesthetic beauty and value of the coast. As coastal communities work to restore coastal resources lost to development and natural processes, private and municipal shorefront property owners should consider allowing the establishment or preservation of coastal dunes as a way to enhance the natural environment as well as mitigate the level of flood and wave hazards. If planned correctly, buffer areas can be left on oceanfront lots that will accommodate the growth and potential migration of the dune.

Coastal wetlands provide a buffer between bays or sounds and coastal uplands. Wetlands dissipate wave energy, trap sediments, and via their storage capacity, reduce the velocity of floodwaters during storm events. Coastal wetlands are also extremely productive coastal habitats, providing nutrients, shelter and nurseries to the young of a multitude of species. As the coastal zones were developed, many wetlands were dredged, filled or bordered by bulkheads. An unintended consequence of these construction practices was the erosion and degradation of the surrounding wetlands. Increased wave energy from pleasure boats, or reflected waves (e.g., from bulkheads) and the subsidence of marshlands due to reduced sediment supply has lead to a rapid loss of coastal wetlands and a higher susceptibility of the bay shore to flood and wave damage. As development and redevelopment occurs along the coast, mangers should consider construction techniques that will reduce the rate of surrounding wetland loss. Shore protection measures that dissipate instead of reflect wave energy should be encouraged. Similarly, strong consideration should be given to restoring and conserving wetlands along the coast. Best management practices include planting marsh vegetation, shoreline nourishment and planting, creation of perched sills seaward of wetlands, and the deployment of temporary wave attenuation barriers along eroding wetlands. Although too voluminous to list here, a tremendous amount of useful information for coastal marsh and bay shore restoration and protection practices can be found in the *Soundfront Series*, published by North Carolina (e.g., Rodgers and Skrabal, 2001; Clark, 2001).

Coastal property owners considering landscaping alternatives should give thought to planting native species. Not only are these forms uniquely adapted to the coastal environment, proper landscaping also acts to reduce flood hazards by decreasing runoff and high velocity flood waters. Given the unique environment of the coast, property owners should be encouraged to plant natural vegetation rather than recreate suburban landscapes.

As a community seeks to restore the natural resources of the coastal environment, the dynamic nature of the coastal environment must not be forgotten. Our coastal margins are uniquely adapted to rapid changes in landform and climatic conditions. One significant storm event can radically alter the geography and distribution of native species for years. Restoring, manicuring, and building beaches, dunes and marshes through filling, scraping, grading, staking, planting and fencing can camouflage the mobility of the natural environment and convey a false sense of stability and permanence. Stability is not a natural attribute of the coastal zone and should not be depended upon for long-term mitigation. A truly functional and natural coastal ecosystem is highly variable.

For more information pertaining to natural resource restoration in New Jersey, contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

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Stevens Institute of Technology
Castle Point on Hudson
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401 East State Street
Trenton, New Jersey 08625
Phone: (609) 292-2662
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Phone: (732) 872-1300
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Building Techniques

Responsible Agency/Party: *Homeowner or industry initiated*

Mitigation for: Flood hazards
Wave hazards
Wind hazards

Management Effort: Low

Over the latter half of the 20th century, great strides have been made in the design and construction of residential buildings to withstand the extreme forces that occasionally occur in the coastal zone. Many best management practices have been derived from the analysis of structural failures during coastal storms. As a result, homeowners and builders now have a variety of low-cost building materials, building techniques, and design options to mitigate potential storm damage. Architects and engineers should ensure that all loads (wind and water) have a direct path from each structural member to the foundation. In more contemporary structures with large open interiors, the inclusion of appropriate interior shear walls should not be overlooked. Large windows should be surrounded by appropriate framing to reduce side loads. Gable roofs and porch overhangs should be properly designed to resist uplift forces from strong winds. Proper nailing patterns should be applied to sheathing and framing to reduce the chance of uplift. Deck and porch overhangs exposed to wave force~~s~~ should be properly anchored to prevent uplift. FEMA's coastal construction manual provides design details for those wishing to minimize hazards to their dwellings and businesses (FEMA, 2000).

Inexpensive approaches to reducing hazards to existing buildings include window shutters, hurricane straps placed on roof framing, unbreakable shingles and proper door connections. For flood and wave protection, enclosed areas under the base flood elevation should be constructed with breakaway walls, proper connections between pilings and floor framing should be used and maintained, and proper cross-bracing (perpendicular to the water motion) should employed. All connectors, fixtures and coatings should be constructed of anticorrosive materials and the regularly inspected and maintained over the life of the structure.

Homeowners should be aware of external utilities, tanks and furniture that are not part of the existing structure, or affixed to it. Propane, oil, gas and water tanks that can be lifted by floodwaters should be anchored to concrete pads or held in place with anchoring straps and earth anchors. Outside utilities, including air-conditioning units and electrical boxes should be elevated above the base flood elevation. Carports or storage areas under buildings should not have poured concrete pads or grade beams attached to support pilings. Also, outdoor furniture, decoration or anything that can be lifted by wind or water should be properly stored prior to a storm to eliminate the potential of those items becoming wind or water borne debris.

For more information on building techniques, contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
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Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

New Jersey Department of Community Affairs
Division of Codes and Standards
Bureau of Code Services
P.O. Box 816
Trenton, New Jersey 08625-0816
Phone: (609) 984-7609
Web: http://www.state.nj.us/dca/programsbook/dcs.htm

Federal Emergency Management Agency
Preparedness and Prevention Library
500 C Street, S.W.
Washington, D.C. 20472
Phone: (202) 566-1600
Web: http://fema.org/library/prepandprev.shtm

Institute for Business & Home Safety
4557 E. Fowler Avenue
Tampa, FL 33617
Phone: (813) 286-3400
Fax: (813) 286-9960
Web: http://www.ibhs.org

Community Maintenance and Preparedness

Responsible Agency/Party:	Municipal, community or individual initiated
Mitigation for:	Flood hazards Wave hazards Wind hazards
Level of Effort:	Moderate

The proper construction and maintenance of community infrastructure and private property is important to mitigating potential storm damage. There are many ways community and individuals can plan and prepare against coastal hazards:

1. Coastal communities should be diligent in maintaining clear storm drains. In addition, to prevent minor flooding from entering the streets through the storm drain system, flap valves should be placed on the end of all outfall pipes.

2. Utility companies serving the community should take preventive measures to reduce the potential for power and service interruption by maintaining utility easements, removing tree limbs around power lines and properly elevating substations, transformers and pump houses in the coastal zone.

3. If possible, evacuation routes should be sited and maintained along roads above the base flood elevation or along the highest road in the community.

4. Plans should be prepared in advance to insure a quick and orderly evacuation of the coastal community.

5. Bulkheads should be constructed and maintained at an elevation above the base flood event.

6. Elevated walkovers should be constructed across dunes to prevent breaks in the dune line. If unavoidable, breaks in the dune line should be oriented perpendicular to the predominant storm winds.

7. Dunes should be properly vegetated and maintained to ensure a continuous unbroken line of protection. Fencing should be installed to discourage people from walking across dunes and enhance their growth.

8. Coastal protection structures should be inspected and maintained on a regular basis.

9. Prior to the construction of a coastal protection structure, the potential benefits and negative impacts should be analyzed and the function of the structure should be clearly understood and accepted (i.e., groins trap sediment but do not stop erosion).

10. An approved coastal management plan should be developed and followed to reduce the probability of long-term degradation of coastal protection levels. A beach monitoring program should be established in order to establish a database of coastal change information with which informed coastal protection decision can be made by a community.

11. All coastal management plans should include an understanding of the regional coastal processes and limit the impacts to the larger coastal system.

12. If a coastal structure(s) that interrupts the flow of sediment along the coast (i.e., jetties at an inlet) is needed, a mitigation plan should be developed to limit the impact of the structure of the local and regional coastal processes.

13. All coastal structures should be designed and constructed by qualified engineers and contractors with experience in wind, wave, and flood loading.

14. Large signs, old trees and any light structure upwind of critical infrastructure and buildings should be removed or strengthened to eliminate the potential for damage from wind borne debris.

15. All objects that can be moved by high winds and flood waters should be placed in storage or anchored to ensure they don't become moving debris.

16. Property owners should abide by all regulations and codes governing the siting and construction of structures in the coastal zone. Variances that increase the vulnerability of private property should not be sought.

17. Communities with property in the floodplain should participate in the National Flood Insurance Program.

18. Structures in the floodplain should, at a minimum, be elevated above the base flood elevation and consideration should be given to elevating the structure an additional amount to provide freeboard for less frequent floods.

19. If possible, structures should be sited to account for future variations in shoreline position and long-term erosion trends.

20. Window area should be limited to a practical amount in the coastal zone or shutters/hurricane blinds installed to protect against the possible breaching of the building envelope due to debris impact.

21. Proper connections should be maintained between the building foundation, sill plates, floor beams and roof to reduce the risk of wind damage. Proper corrosion protection and periodic inspection of connections should be performed.

22. In the design of beach nourishment projects consideration should be given to the restoration of the natural environment, including vegetation and geologic features.

23. Coastal residents, property owners and communities should strive to be knowledgeable and aware of the dynamic nature of their environment and the hazards present.

24. Communities should consider instituting grassroots coastal stewardship programs to highlight and build awareness of their coastal resources and the value of their preservation.

25. For more information on community preparedness in New Jersey, contact:

New Jersey Department of Environmental Protection
Land Use Regulation Program
P.O. Box 439
501 East State Street
Trenton, New Jersey 08625-0439
Phone: (609) 292-1235
Fax: (609) 777-3656
Web: http://www.state.nj.us/dep/landuse/

New Jersey State Police
Office of Emergency Management
Hazard Mitigation Officer
P.O. Box 7068 River Road
West Trenton, NJ 08628-0068

New Jersey Coastal Protection Technical Assistance Service
Davidson Laboratory
Stevens Institute of Technology
Castle Point on Hudson
Hoboken, NJ 07030
Phone: (201) 216-5290
Fax: (201) 216-8214
Web: http://www.dl.stevens-tech.edu

Federal Emergency Management Agency
Preparedness and Prevention Library
500 C Street, S.W.
Washington, D.C. 20472
Phone: (202) 566-1600
Web: http://fema.org/library/prepandprev.shtm

Institute for Business & Home Safety
4557 E. Fowler Avenue
Tampa, FL 33617
Phone: (813) 286-3400
Fax: (813) 286-9960
Web: http://www.ibhs.org

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ADDITIONAL INFORMATION RESOURCES

Federal Organizations

Federal Emergency Management Agency (FEMA). http://www.fema.gov

National Oceanic and Atmospheric Administration (NOAA). http://www.noaa.gov/

National Sea Grant College Program. http://www.nsgo.seagrant.org/

Natural Resource Conservation Service. http://www.nrcs.usda.gov/

NOAA Coastal Service Center. http://www.csc.noaa.gov/

US Army Corps of Engineers (ACOE). http://www.usace.army.mil/

US Fish & Wildlife Service. http://www.fws.gov/

US Geological Service. http://www.usgs.gov/

NJ State and Regional Organizations

FEMA Region II. http://www.fema.gov/regions/ii/index.shtm

New Jersey Sea Grant College Program.
http://www.njmsc.org/Sea_Grant/Main_Page.htm

New Jersey Marine Sciences Consortium. http://www.njmsc.org/

New Jersey Department of Environmental Protection (NJDEP).
http://www.state.nj.us/dep/

NJDEP Land Use Regulation Program. http://www.state.nj.us/dep/landuse/index.html

NJDEP Coastal Management Program. http://www.state.nj.us/dep/cmp/

New Jersey State Information. http://www.state.nj.us/

US Army Corps of Engineers, Philadelphia District Office.
http://www.nap.usace.army.mil/

US Army Corps of Engineers, New York District Office. http://www.nan.usace.army.mil/

New Jersey Home Builders Association. http://www.njba.org/index.html

New Jersey County and Municipal Web Sites. http://www.state.nj.us/localgov.htm

The Jersey Shore Partnership. http://www.thejerseyshorepartnership.com/

Professional Organizations

American Institute of Architects. http://www.e-architect.com/

American Shore & Beach Preservation Association. http://www.asbpa.org/

American Society of Civil Engineers (ASCE). http://www.asce.org/

Association of Coastal Engineers (ACE). http://www.coastalengineers.org/

Association of State Flood Plain Managers (ASFPM). http://www.floods.org/

The Geology Society of America. http://www.geosociety.org/

National Association of Home Builders (NAHB). http://www.nahb.com/

National Society of Professional Engineers. http://www.nspe.org/

Northeast Shore & Beach Preservation Association. http://attila.stevens-tech.edu/~therring/nsbpa.html

Trade Organizations

Institute for Business and Home Safety (IBHS). http://www.ibhs.org/

National Association of Home Builders Research Center. http://www.nahbrc.org/

National Pile Driving Contractors Association. http://www.piledrivers.org/pdca/index.cfm

Codes and Standards Organizations

American National Standards Institute (ANSI). http://web.ansi.org/

Building Officials Code Administrators (BOCA). http://www.bocai.org/

International Code Council (ICC). http://www.intlcode.org/

International Conference of Building Officials (ICBO). http://www.icbo.org/

Research and Guidance

Natural Hazards Center. http://www.colorado.edu/IBS/hazards/index.html

The H. John Heinz III Center for Science, Economics and the Environment.
http://www.heinzctr.org/

US Army Corps of Engineers Coastal and Hydraulics Laboratory (CHL).
http://hlnet.wes.army.mil/