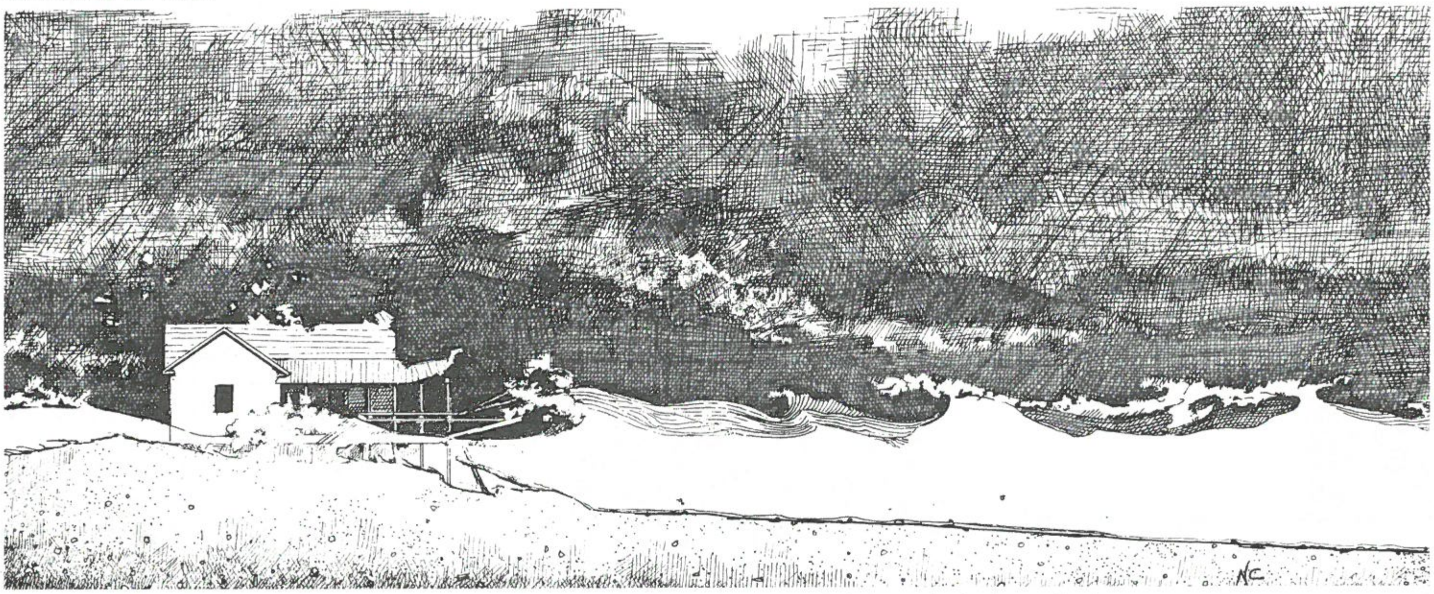
UNC Sea Grant
February, 1980

COASTWATCH

Illustration by Neil Caudle



As a hurricane moves ashore, crashing waves wrench buildings from their foundations

Hurricanes: when the roofs fly and the floors float

If you are at the coast and a hurricane warning is issued, leave. Get far away to high ground. Sure, you'll wonder what it would be like to stick around, watch the fireworks. Don't do it. Read this instead.

As the windspeed accelerates beyond 74 mph, you know you're in a hurricane (not like David, last summer. He was pooped before he got here). That's also about the time things start learning to fly. The clay flower pot just left a dent grinning in the hood of your car. The garbage can looks like Mercury I lifting off and is just about to dive through the $200 plate glass window and splash down on the coffee table. . .

Okay, maybe you had the good sense to board up those windows. The house shudders from the impact of the missile, but nothing cracks. The wind reaches about 80 mph, too much for the average roof. You can't hear them for the din of the storm, but the shingles are peeling off and sailing like frisbees. The wind shoves and lifts your roof, trying to make it into an airplane, a function for which it is fairly well designed. About now, were you in the attic, you might see the rafters rip loose from the wall, their little nails clutching air, so that the wind can really get a grip . . .

Or maybe your house was built in the last couple of years. The revised building code declares that new houses on the coast must have enough metal straps and connectors to hold everything together, so long as the blow doesn't get stronger than about 110 mph. Assume the contractor didn't fudge. Assume this is an average hurricane, not a Camille, for example, which struck Mississippi in 1969 at about 172 mph. The roof won't take wings. You shake your fist at the Big Bad Wolf, who just failed to blow your house down. Save it. He's just getting started.

If you could see through the hurtling clouds of water that have replaced the air outside, you might notice the swollen belly of the storm surge crawling landward, sucked up into a mound about ten feet higher than the mean water level, with waves breaking on top like frosting on the cake. This is when you start thinking about what's under you. It's plain that little sand dune in front of your house has about as much chance of stopping that wall of water as the Havelock High cheerleading squad has of stopping the

Continued on next page

front four of the Pittsburgh Steelers.

But as the waves chew it away, that dune is buying you time. Time to recall certain scriptures, not the least of which speaks to the practice of building one's house on sand.

What if your house is built low to the ground, on a solid masonry slab or foundation? You're sitting pretty, right? That's what the people at Holden's Beach thought in 1954, until Hurricane Hazel taught them differently. Down there, you're in the combat zone. And because buildings are bouyant, your house is about to become a boat. Floating houses come to rest in interesting, asymmetrical configurations, but on someone else's property. Even if the house has been bolted to the foundation and holds on, the surge will probably dismember it, beginning with the weakest section. Or, the water will scour soil from under the foundation, and whole sections will collapse. Or, floating battering rams—campers, picnic tables and trailers—will ram great holes in the walls. That's all the foothold the winds need to finish the job.

But let's assume, since you've been ahead of the game so far, that your house is built up on pilings, AS EVERY BEACH HOUSE SHOULD BE, and is above the storm surge. The surge passes on under the house, with nothing much down there to shove around. Don't relax yet. If the floor frame of the house is just nailed to the pilings, those waves cresting against the floor may just lift the whole house free. If the floor frame is well made, and anchored to the piles with ¾" carriage bolts for each supporting pile, and the piles are notched only an inch or so, you may be safe.

By now, the last of that little sand dune is washing across the street. If your pilings were sunk only about as deep as the dune, so that what used to be under ground isn't, your house is about to become a ship. Those piles will behave something like bowling pins when the next wave rolls through.

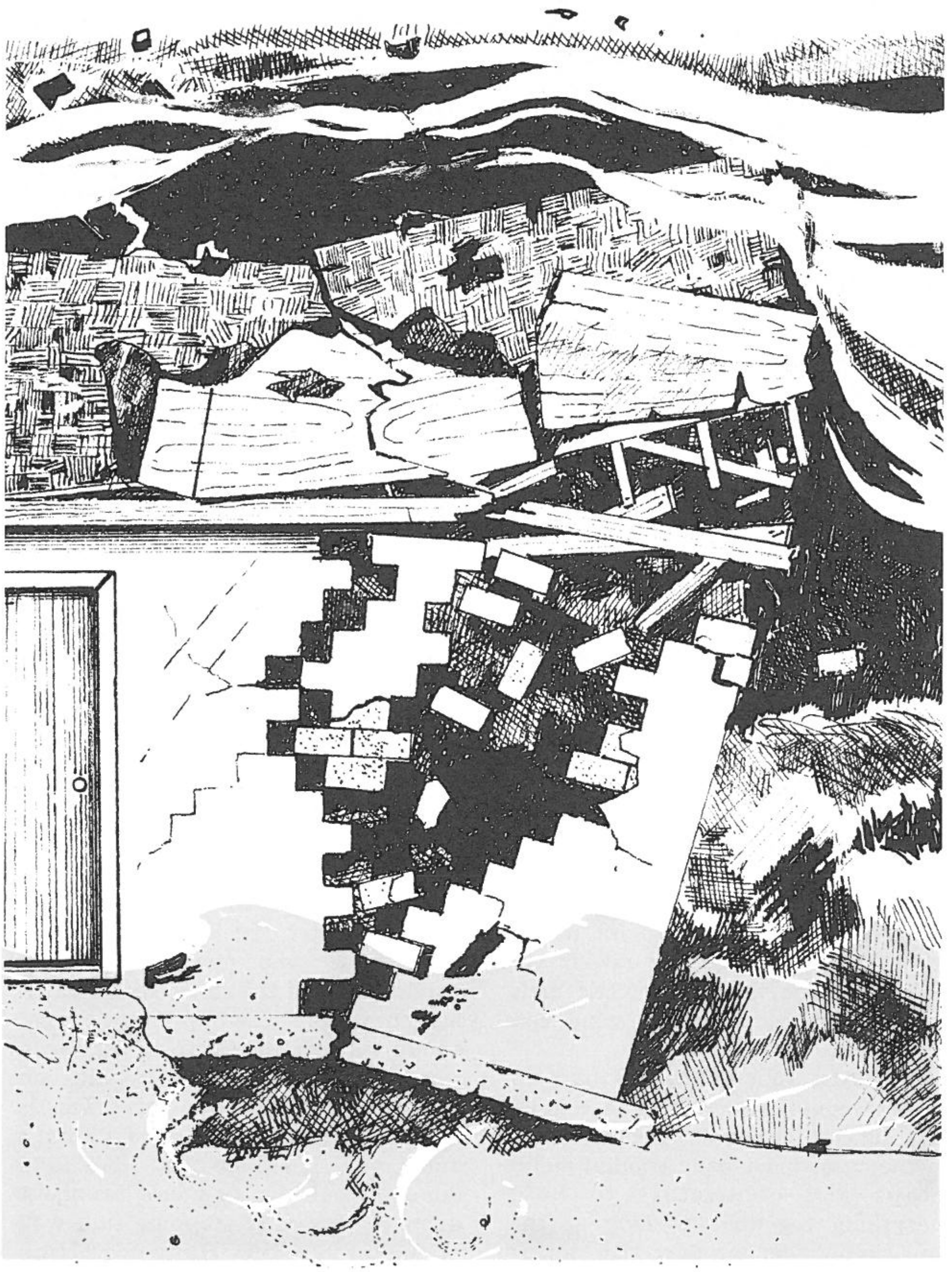
Okay, let's assume you're blessed with the perfect beach house: pilings sunk at least eight feet into the profile of the shoreline; metal bolts and fasteners holding everything together; well-fastened roofing and well-shuttered windows. Odds are you'll make it. That is, unless this baby turns into one of those "200-year storms," so called because they're expected to hit a shoreline only about every couple of centuries.

Or, unless your neighbor's house is less perfect than yours. That is when you honestly, truly, get that sinking feeling. When you see that three-bedroom house next door rock, slowly, to one side, snap its piles like pencils, belly-flop into the water, and glide straight for you. . .

Not a direct hit. Just a chunk is missing from one corner of your house, but suddenly, your house starts trembling, the water-fattened winds come blitzing through the hole. The rugs go squishy with water. The wallboard resembles something like painted oatmeal, and the siding is springing off one side of the house.

Let's say you're extremely lucky. Your well-constructed beach house is not a total loss. That is, if you can get it back together in time for the next storm. These big, bad wolves like to run in packs.

Remember? On August 30 and September 10, 1954, Carol and Edna came chasing through like pranksters. Then, on October 15, just when everybody was getting good and sick of cleaning up after hurricanes, Hazel came howling. She licked up miles of dunes, leveled hundreds of houses and killed 19 people.



Wave action scours soil from under shallow, masonry foundations, so that walls collapse and the wind gains leverage against the roof

How to arm buildings for life in nature's combat zone

Jerry Machemehl doesn't conduct a research project; he submerges himself in it. Paper is perched over every square inch of his office—coastal maps, erosion studies, aerial photographs, engineering calculations, hurricane records. This is one giant jigsaw puzzle, and Machemehl wants all the pieces out where he can see them.

"In the past, we've treated a hurricane as if it were a very idealized, organized storm," Machemehl says, "and that's just not the case. Few people who haven't experienced a hurricane understand what it's all about."

Machemehl is an engineer, and an associate professor of marine science and engineering at North Carolina State University. He is knee-deep in hurricane studies because, sooner or later, almost every coastal building expected to outlast its mortgage is likely to get a visit from a Hazel or a Connie or a Belle.

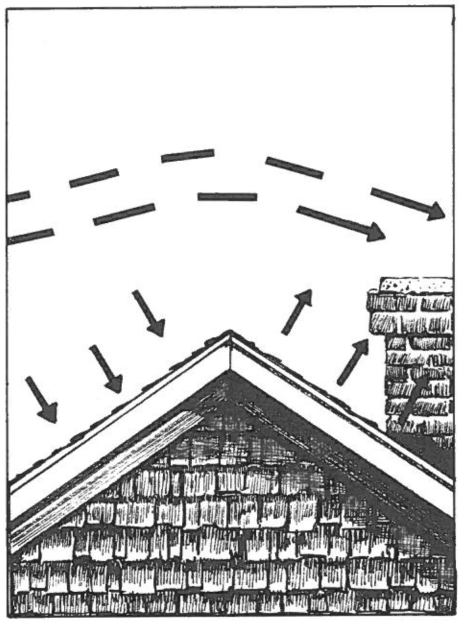
This winter, Machemehl is winding up a Sea Grant study designed to answer two key questions: What parts of the shoreline are most vulnerable to storm damage, and how can property owners armor buildings to survive the sometimes brutal environment of coastal North Carolina?

Yes, brutal. Sure, the beaches are mild and heavenly most of the year. But come winter, heavy waves and currents rake real estate out to sea. And then there are the hurricanes . . .

"Many people have not been here and were not on the coast during our major hurricane period in the nineteen-fifties," Machemehl says. "They don't understand the forces that we're dealing with."

In 1954, Hazel, the worst of a series of hurricanes in the state, killed 19 people and caused an estimated $125 million in damage. Of the 357 buildings on Long Beach before the storm, five were left intact afterward.

Largely because of Hazel, building codes and construction standards have been improved. Practically all beachfront buildings erected since the storm have been elevated to clear most storm tides. But despite these improvements, Machemehl says many new buildings going up on the coast will not stand up to a major hurricane. Part of the problem is a lack of information.



Winds lift and press roofs

Machemehl says that homeowners are not the only ones who don't know the meaning of "hurricane."

"I recently found a developer building condominiums on the coast who was not aware that there was such a thing as a hurricane in North Carolina," he says.

In fact, so little information has been available on the forces of hurricanes that architects and designers working on coastal structures have relied on formulas derived for building inland, where the only major force to contend with is gravity.

"These consulting firms are using manuals written in the nineteen-forties," Machemehl says. "The design engineer does not have an adequate manual for building in the coastal environment."

Machemehl believes the results of his study, when they are published, will change all that. His first task was to pull together data and technology already available and to initiate new research for some uncharted problems.

The most familiar culprit is the wind. A hurricane, by definition, has windspeeds of 74 mph or faster. Hurricane Camille, which hit the Mississippi coast in 1969, had gusts recorded at 220 mph—twice what North Carolina's coastal building code sets as the "design windspeed" (the force buildings must be able to withstand) for structures on the Outer Banks. And, as windspeeds increase, the forces they exert on a building increase manyfold, so that the 125 mph wind of a severe hurricane would exert about five times the force of a 60 mph wind.

Hurricane winds over 100 mph are infrequent in North Carolina. Meteorologists estimate that such storms occur on the coast about once every 100 years; hence the term "100-year storms." But there are no guarantees that two such monsters won't come in the same week.

"Hurricane-force winds can occur anywhere on the North Carolina coast," Machemehl says. "A rule of thumb would be that any structure built in an area where there are high winds and wave and surge forces should be tied together from the tip of the roof to the bottom of the foundation, so that there is an integrity among all the parts, and the structure acts as a unit."

To "tie" a building together, contractors use corrosion-resistant metal straps and anchors, rather than nails alone, to attach roof parts to walls, and wall frames to foundations.

But designing for high winds, Machemehl says, is far easier than designing a building to withstand the other big bandits in a hurricane: the storm surge and waves.

The storm surge is a dome of water pushed up by the combination of rotating storm winds and atmospheric low pressure during a hurricane. It is not a wave. It is a gross distortion in the water level that can stretch as much as 100 miles along the coastline. During Hazel, the surge rose 11 feet above mean sea level, topping dunes and submerging whole islands. During Camille, the storm surge rose to 23 feet.

Breaking waves and swells ride the top of this surge inland. In many cases, erosion during the hours preceeding a storm carves away great quantities of sand from the dunes. The weakened dunes can do little to protect the structures behind them.

"The dunes are only a reservoir of sand," Machemehl says. "They are not really adequate hurricane protection."

As the water surges inland, more

Continued on next page

forces assault the buildings there. The surge itself lifts many structures, which are bouyant, right off their foundations. The water, as it passes, also creates a "form drag," a force that tries to tug the building along with the flow. Once the building is freed from its underpinnings, it too becomes a destructive force.

Machemehl describes the scene as a large storm surge moves ashore:

"Those structures on slabs would tend to be picked up and floated away, and they would become battering rams against the other structures. The beach profile would recede, and some of the structures on piles would overturn because their pile foundations were not deep enough. As the surge came in, the exterior walls of many buildings would be destroyed."

How will the state's coastal buildings fare during all this lifting, dragging, smashing and blowing, the next time a hurricane comes? Not well, Machemehl says.

"Some of our structures, maybe fifty to sixty percent, would be destroyed in a one-hundred-year-frequency storm," he says, "and possibly all of them with a two-hundred-year-frequency storm."

The "two-hundred-year storms," the extreme hurricanes like Camille, show up every couple of centuries. They leave very little trace of civilization in their wakes. Engineers don't even bother designing structures to resist them.

"It would be impossible to design and build a structure that would survive all events," Machemehl says.

The building most likely to survive an extreme hurricane would be one of cast concrete (not concrete blocks), reinforced with steel. Something like a bunker or a pillbox. But not many people want to spend their vacations in pillboxes, and concrete and steel, while practical for large motels and hospitals, are far too expensive to be used extensively in houses.

Building almost anything within reach of the sea is a risk many have found worth taking partly because of federal flood insurance.

Federal flood insurance was begun in 1968 and is available for buildings in all the nation's flood-prone areas. Since the program offers, through private companies, low-cost insurance in high-risk areas, it has helped encourage development at the coast. To qualify for coverage, new buildings have to meet only one requirement: floor elevations must be above the expected surge during a "100-year storm." Buildings constructed before 1968 qualify automatically, with no elevation requirements.

But Machemehl believes that just because a building qualifies for insurance doesn't mean it's a reasonable risk.

"I think the contractors, the engineers and architects must accept their responsibility to refuse to design and build inadequate structures on the coastline," he says. "That insurance program is a program underwritten by the government. So that if there's great destruction in an area because of the quality of construction, then, in general, everybody pays for it."

Machemehl says builders weaken structures by using too few metal anchors, by using paper or "fiberboard" rather than wood or plywood for sheathing, by using piles that are too shallow, by skimping on roofing materials and by failing to adequately secure porches, overhangs, awning and corners.

> "The exterior walls of many buildings would be destroyed"—Jerry Machemehl

Since it became necessary to elevate new beach residences in order to meet insurance requirements, wood pilings have sprouted like forests under new houses at the beach.

"The reason to put a house on piles is to get up above the storm surge," Machemehl says.

Most of the state's new beach houses have an elevation of sea level plus 12 feet—just enough to clear another 100-year storm like Hazel, whose surge reached 11 feet. Piles also have the advantage of allowing water to pass under the building, and so don't absorb much of the force. Wall foundations, especially those of concrete block, perform very poorly during hurricanes.

Almost as soon as he began putting together his picture of buildings in coastal hazard zones, Machemehl found several pieces missing.

There were, for one thing, no reliable data on the pressure exerted by waves cresting against the floor of a building. So an NCSU graduate student, under Machemehl's direction, began using scale models, a mechanical wave tank and electronic pressure transducers to determine wave uplift under buildings. Machemehl believes that when the study is finished, sometime this year, information will help designers determine how strong floor structures and their connections to piles must be to resist waves.

Missing, too, was information on the speed and extent of erosion likely during storms on the coastline—information vital to engineers trying to calculate how deep piling foundations should be.

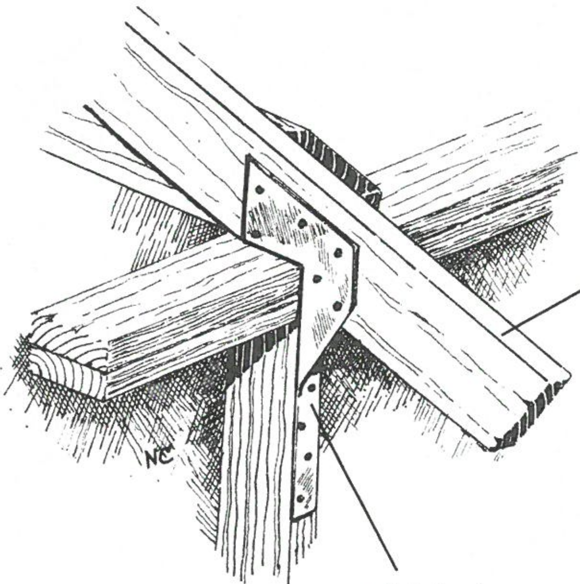
"Right now, nobody can say how deep piles should be," Machemehl says. "Some say eight feet below the profile, but that may not be deep enough."

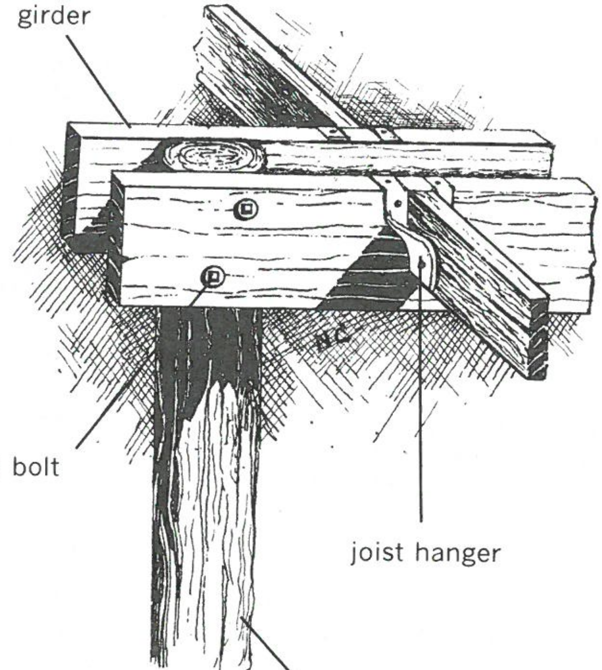
Machemehl has been devising a numerical model that could project the rate of erosion for building sites along the coast.

In another Sea Grant study, Stan Riggs, Mike O'Connor and Vince Bellis of East Carolina University found ways to predict how susceptible estuarine shorelines are to erosion. Their methods for predicting erosion are described in a flyer, "Relative Estuarine Shoreline Erosion Potential in North Carolina," which is available from the Sea Grant office in Raleigh.

But even though there are still questions to be answered, the profile of a durable beach structure is already clearer: The building site should be well behind the primary dunes. The pile foundation should reach at least 8 feet into the profile of the shoreline, not including the depth of the dunes. Piles should be bolted to the floor structure. Walls should be braced with rigid wood or plywood sheathing. All corners, overhangs and other windcatchers should be well-anchored. And the whole building should be tied together with metal connectors.

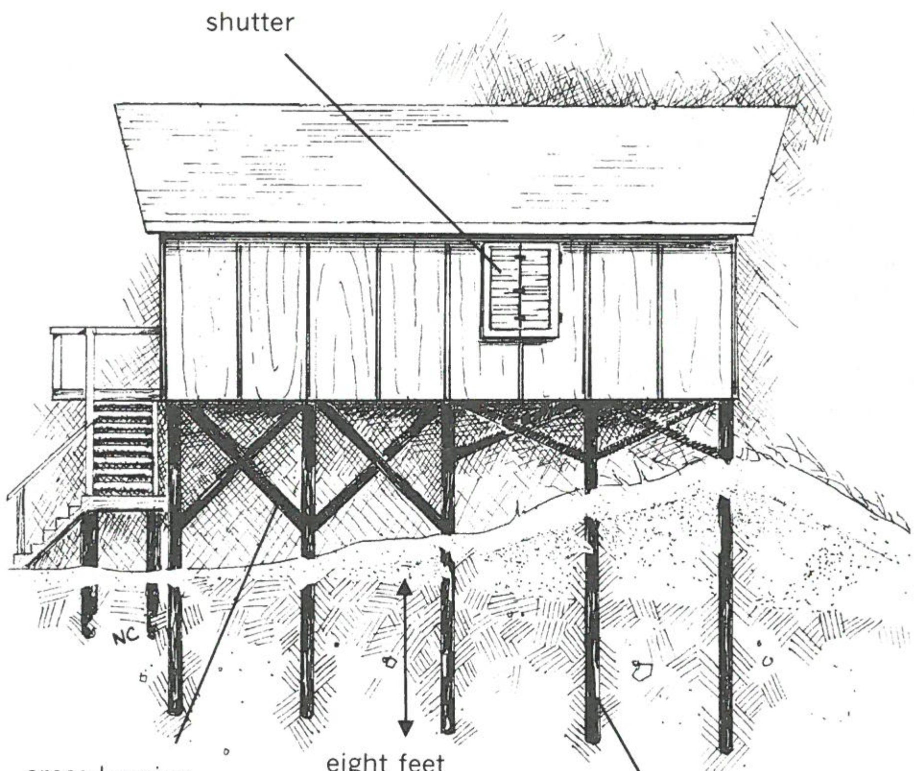
Of course, the most hazardous building sites are generally those on the beachfront, where erosion and wave action are most intense. But even sites several blocks from the shoreline are vulnerable to flooding, winds and floating or blowing debris.





Storm-proofing

Houses in hurricane-prone areas need to be constructed to resist the action of wind and water. Metal tie-downs (above left), used with each rafter, secure the roof frame to the walls. Steel bolts installed in girders and pilings (above right) anchor the floor structure to the foundation. Pilings under beach houses (right) should be cross-braced and should penetrate well below the beach profile. Windows should have sturdy storm shutters.



'Frederic' erased miles of houses

Photo by Jerry Machemehl

Frederic left open wounds in many Gulf Shores buildings

On September 23, Spencer Rogers picked his way through the odd, broken stumps in the beach of Gulf Shores, on the eastern side of Mobile Bay, Alabama.

The beach was deserted, almost barren, as if it had been shaved, leaving just the stumps, like razor stubble, poking through the sand. Eleven days before, those stumps were the wooden pilings under houses, dozens of them. Now most of those houses, or what pieces remained of them, were strewn through the woods far inland.

Rogers, Sea Grant's coastal engineering specialist, had come with Jerry Machemehl to see first-hand what happens to buildings during a hurricane. Rogers and Machemehl were on the beach, taking photographs and searching the ruins for clues, long before the major cleanup was underway.

"That stretch of beach had been almost completely developed," Rogers recalls. "When we saw it, most of the houses were gone."

Frederic was not an "extreme" hurricane, or even an unusually severe one. It was about average. But its 90 mph winds and 12-foot storm surge had reshaped the coast, eroding as much as 100 feet of shoreline, topping dunes, submerging miles of land and wrecking houses, condominiums and motels.

"The problem was not so much the wind," Rogers says. "Most of those houses could have taken the winds. The problem was that the pilings, in most cases, were either too short or inadequately attached to the floor structure."

Rogers says that he found most of the wrecked houses were toppled when erosion removed sand from around the pilings. When key pilings were exposed, with no sand to support them, they collapsed. Unbalanced on their foundations, the houses then snapped the remaining pilings and floated away.

"Most of the destruction could have been prevented if they had just had those pilings eight or ten feet deep, instead of four or six," Rogers says.

There were clues other than the stumps. There were empty nail holes in the tops of pilings that used to support houses. A few little spikes, Rogers says, will not hold a building in place during a hurricane. There were mounds of concrete block, the remains of foundation walls. Some of the larger commercial buildings collapsed when the storm surge rammed their load-bearing walls broadside.

In the mobile home parks, the story was even grimmer. In one park, not a single trailer remained on its foundations. Even those that had been tied down were kicked around like cans.

What can North Carolina learn from the tragedy at Mobile Bay? Rogers and Machemehl say that even though many of our newer buildings are better than those lost at Mobile Bay, much of the destruction would be repeated on the North Carolina coast during a similar storm.

"The hardest thing was to get all those houses up on pilings," Rogers says. "Now that they're up there, that's going to cut off most of the problems. But we need to work with the building inspectors and contractors to see that the pilings are deep enough and the fastening techniques are strong enough."

Toward that end, Rogers has put together a slide show that he is presenting to groups of contractors, building inspectors, civic leaders and property owners. The slides include many of the shots he took at Mobile Bay, plus some examples of vulnerable buildings on the North Carolina beaches. (People interested in having Rogers speak to their groups can contact him at the Marine Advisory Service office in the N. C. Marine Resources Center/Ft. Fisher, 458-5780).

With other experts, Rogers also has been working out ways to define an "ocean erodible area" for the Coastal Resources Commission, which issues permits for beach development. The ocean erodible area is the part of the shoreline, nearest the beach, that is likely to be eroded over 30 years (including the erosion expected during one 100-year storm).

Rogers is also helping the state to estimate the amount of destruction that might result if a severe hurricane were to hit a segment of the state's coastline. The investigators have chosen Surf City as their model, and will consider possible waves, tides and winds to predict which buildings would be lost, which would survive, and what the damage would add up to in dollars and cents.

THE BACK PAGE

"The Back Page" is an update on Sea Grant activities—on research, marine education and advisory services. It's also a good place to find out about meetings, workshops and new publications. For more information on any of the projects described, contact the Sea Grant office in Raleigh (919/737-2454).

The TV cameras have been moving in on Tyre Lanier's lab at North Carolina State University (NCSU). In mid-January, a Durham station filmed Lanier at work on his current Sea Grant project. The spot was subsequently picked up by CBS affiliates all over the country.

What's causing all the stir is a product Lanier has cooked up, with the help of NCSU scientists Frank Thomas and Don Hamann. Lanier starts with minced fish and shrimp, which he grinds into a paste, squirts into a metal mold and heats briefly. Presto: whole shrimp. According to Lanier and others who have sampled the product, it's as good as most frozen whole shrimp. And, if it makes the commercial market, as Lanier predicts it will, the product will probably sell for about half the price of whole breaded shrimp now available in grocery stores.

The new product is similar to "refabricated shrimp" (minced shrimp pressed into a shrimp shape) now on the market. But it actually contains between 50 and 75 percent fish. It's all part of Lanier's scheme to develop ways to make better use of some unpopular fish, including the abundant croaker. Lanier is particularly interested in using surimi, or washed, minced fish, which is used as a base for many products in Japan. He contends that the excellent texture of surimi is what makes his new product so good.

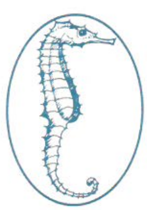
The traditional seafood platter costs a bundle these days, but there are still bargains in the seafood market.

To help keep consumers informed about seafood's role in good nutrition, Sea Grant, in cooperation with the N.C. Agricultural Extension Service, will sponsor a three-day training session for county home economics and extension agents.

The aim of the session is to bring North Carolina agents up-to-date on developments in the seafood industry. The agents will use the training to keep their communities abreast of changes in the industry, and to show families how to prepare nutritious, economical seafood dishes.

In the workshop, agents will visit marine laboratories and seafood processing companies, and will learn about the latest techniques for handling and preparing seafoods. Sea Grant's advisory staff will introduce the agents to several "under-utilized" species—unfamiliar seafoods that offer plenty of flavor and food value.

The workshop will be held March 11, 12 and 13 at the NCSU Seafood Lab in Morehead City.



If you're considering graduate study in marine science, then Sea Grant may be able to offer you some needed financial aid. Every year Sea Grant awards graduate fellowships to students for marine research and study. This year two fellowships are available and applications are now being accepted.

Prospective graduate students from any recognized public or private institution are eligible. Recipients must be accepted by graduate programs at the University of North Carolina at Chapel Hill (UNC-CH), North Carolina State University in Raleigh, East Carolina University (ECU) in Greenville or the University of North Carolina at Wilmington (UNC-W).

For more information and applications, contact Jay Langfelder, Department of Marine Science and Engineering, NCSU; Dirk Frankenberg, Curriculum in Marine Science, UNC-CH; William Queen, Institute for Coastal and Marine Science, ECU; Gilbert Bane, Program for Marine Sciences, UNC-W; or UNC Sea Grant, P.O. Box 5001, Raleigh, N.C. 27650. Completed applications must be returned by April 1.

This summer, Sea Grant will again offer three workshops designed to help school teachers enrich their students' studies of coastal North Carolina.

Lundie Mauldin, Sea Grant's marine education specialist, is organizing the workshops, which will offer teachers course credits through the Continuing Education Department at NCSU.

The first workshop, to be held June 22-28 at the N.C. Marine Resources Center/Ft. Fisher, is planned for fourth-, fifth- and sixth-grade teachers. The teachers will study the ecology of marshes, beaches and islands, will make field trips to historic sites, and will try their hands at fishing, clamming and collecting samples of marine life. Tuition for the workshop is $50.

Another workshop, to be held June 22-28 near Gloucester, will be conducted by archaeologist David Phelps of ECU. Phelps will lead teachers on an archaeological dig where they will learn how to excavate, collect, catalog and interpret Indian artifacts. Tuition for this workshop is $50 and teachers from any grade level may apply.

The third workshop, for seventh-, eighth- and ninth-grade teachers, will be held July 13-26 at the N.C. Marine Resources Center/Bogue Banks. Teachers will study the specialized occupations that have developed because of resources present in the coastal environment. Field trips will include visits to boatbuilders, fishing

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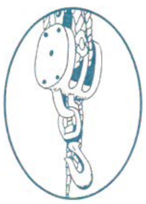
villages and research labs. Tuition for the workshop is $100.

For an application to enroll in any of the workshops, write: Lundie Mauldin, UNC Sea Grant, P.O. Box 5001, Raleigh, N.C. 27650. Applications must be returned by April 18.

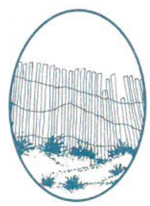


Sport fishermen once reeled in Spanish and king mackerel by the dozens off the North Carolina coast. But things have changed. Charterboat captains say fewer and fewer mackerel are being caught each season. Why? Many blame commercial fishermen in Florida, who are now catching large quantities of the mackerel with gill nets and seines. Because the mackerel migrate north and south each year, large catches in Florida may affect catches in North Carolina.

The Gulf of Mexico and South Atlantic Fishery Management Councils are concerned about the dwindling numbers of Spanish and king mackerel. Together, they have drafted a plan for the management of the fishery along the Gulf coast and the Atlantic coast from Florida to North Carolina. The plan also includes management plans for cobia.

The councils will present the proposed plan for public comment at three North Carolina locations—March 10, Hatteras Civic Center, Hatteras; March 11, Carteret Technical Institute auditorium, Morehead City; March 12, Hilton Inn, Wilmington. All three meetings will be held from 7 p.m. until 10 p.m. Anyone can attend. Comments by the public will be reviewed before the final management plan is adopted.

If you would like to know more about the South Atlantic Fishery Council, write for a free brochure—UNC Sea Grant, Box 5001, Raleigh, N.C. 27650.



Maybe you have been watching the shoreline in front of your beach house wash away and were wondering what you could do to slow the erosion. Then you might be interested in attending a workshop about planting dune and marsh grasses to stablize shorelines.

The workshop will be held at the Marine Resources Center at Bogue Banks on April 9 at 10 a.m. Sea Grant researcher Ernie Seneca of NCSU and Carteret County Agricultural Extension Agent Jim Bunce will conduct the workshop with the help of Bob Hines, Sea Grant marine advisory agent. Workshop participants will also get some practical experience planting grasses.

I want Coastwatch

Coastwatch is a free newsletter. If you'd like to be added to the mailing list, fill out this form and send it to Sea Grant. Box 5001, Raleigh, N.C. 27650.

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