Considerations for Control of House Construction in Coastal Dunes

Karl F. Nordstrom
James M. McCluskey

Center for Coastal and Environmental Studies
Rutgers University
New Brunswick, New Jersey

Abstract This study was conducted to determine if maintenance of the integrity of coastal dunes as a form of storm protection should require restrictions on the types of buildings located within the dune zone. A properly built house does not appear to endanger the integrity of the dune to a point where the hazard potential is increased. Active human uses of the dune and programs of dune stabilization can play a more important role in changing the configuration of coastal dunes than elevated structures. Buildings constructed landward of the dune should be built in a manner which is compatible with an eventual location within the dune. Construction standards should be specified in land-use controls along with regulations to control the active human uses such as sand stabilization programs.

Purpose

Coastal dunes are an important component of the shoreline for their ecological values and for the protection they provide to buildings (Clark, 1977; CERC, 1977). Dunes are fragile landforms, however, and they can be easily destroyed by human

Coastal Zone Management Journal, Volume 12, Number 4
0090-8339/84/040385-00$02.00/0

activities or displaced by natural processes. Because of this, scientists and planners have called for more stringent controls over the use of the dune zone (Nordstrom and Psuty, 1980; Gares, 1983), and some states and local jurisdictions have implemented restrictions to prohibit the construction of buildings in the dunes (Hildreth, 1980). The most frequently cited goal of these restrictions is to minimize hazards to public health and safety by locating buildings landward of the zone of greatest damage potential. The dune is thus viewed as an indicator of safe development. Some regulations which restrict construction in the dunes have as a goal the need to prohibit uses that endanger the physical integrity of the dune because destruction of the dune would increase the potential for damage from flooding and overwash during severe storms (Commonwealth of Massachusetts, 1978; Town of Islip, 1978; Town of Brookhaven, 1981). This kind of restriction stresses the specific protective qualities of the dune.

The exclusion of new buildings from the dune will not necessarily achieve these two goals. Attention should also be focused on houses and support infrastructure constructed landward of the dune and on active uses of the dune. In most locations where shoreline erosion occurs, the response of the natural system is onshore displacement of the beach and dune through a combination of erosion and subsequent construction of these features landward of their original location (Godfrey, 1977). At some future time, buildings which were at one time located landward of the dune will be within the dune. The buildings will then be subject to increased damage resulting from their proximity to the water. The land-use controls which have been implemented by many jurisdictions allow buildings and support facilities behind the dune to be constructed in a manner that is incompatible with an eventual location in the dune. The presence of these buildings in the dune may disrupt natural processes to the point where alterations to the dune will diminish its value as a barrier against storm waves.

We suggest that attention should be devoted to the design of structures in addition to the specific location of their placement. This study was intended to identify how buildings should be

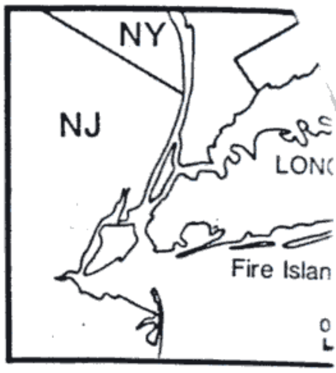

FIGURE 1. Long Island, New
Island to Westhampton Beach

designed to minimize in
create a protective dun
morphic basis for legal r
coastal dunes on eroding
comparison of the form o
developed communities
land, New York.

Characteristics of the St

Fire Island (Figure 1) is
because the communitie
velopment (Figure 2) with
are natural areas near the
dimensions in the commu
frontage occupied by the
of the length of develope
elevated on pilings, and
buildings by elevated wal
houses (Figure 3). These
with breakaway walls, an
house type interacts diffe
across the dune. Commun
development were select

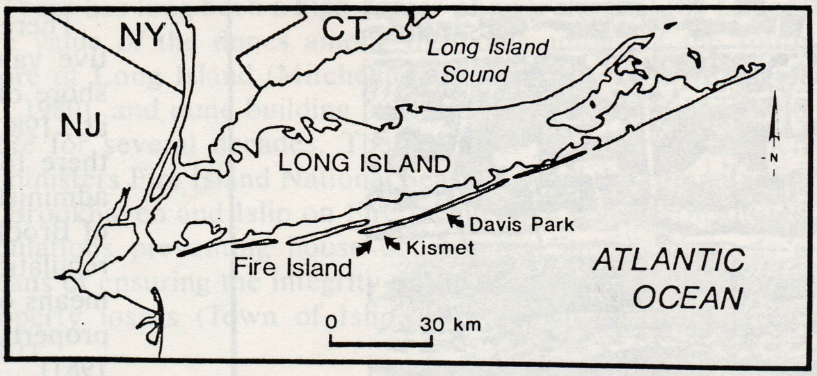

FIGURE 1. Long Island, New York, showing location of study area from Fire Island to Westhampton Beach and field site at Watch Hill.

designed to minimize interference with the processes which create a protective dune. The assessment provides the geomorphic basis for legal restrictions on buildings in and behind coastal dunes on eroding shorelines. The analysis is based on comparison of the form of the dune in undeveloped areas and in developed communities on an eroding barrier island at Fire Island, New York.

Characteristics of the Study Area

Fire Island (Figure 1) is considered a good prototype location because the communities there have a moderate level of development (Figure 2) with a good mix of house types, and there are natural areas near the communities for comparison. Building dimensions in the communities are 105 m² on the average. The frontage occupied by the first row of houses averages 43 percent of the length of developed shoreline. Many of the buildings are elevated on pilings, and access is frequently provided to the buildings by elevated walkways. There are three general types of houses (Figure 3). These are houses on pilings, houses on pilings with breakaway walls, and houses with solid foundations. Each house type interacts differently with the flow of wind and sand across the dune. Communities which have a moderate amount of development were selected because the intent of the study is to

FIGURE 2. Davis Park, New York. (1976 National Park Service photo no. 3216–4–143).

provide suggestions for management of communities which can be designed to be compatible with a dynamic, migrating barrier island. The suggestions are not directly applicable to the management of highly developed shorelines which emphasize a static shoreline position and engineering solutions to shoreline erosion.

The south shore of Long Island has been the focus of many geomorphic investigations (reviewed in Taney, 1961; Leatherman and Joneja, 1980). The shoreline is very mobile, with a rate of erosion as high as 2–3 m per year in places (Panuzio, 1968). In the last five years, the dune crest at Fire Island has migrated as much as 27 m landward and 28 m seaward in places. During that period approximately 9 km of the length of Fire Island were stable, 6 km were erosional, and 5 km were accretional (Psuty, 1982). The communities on Fire Island are subject to damage by hurricanes and northeasters. The last major storm to strike the area occurred in February 1978, when much of the foredune along Fire Island was eroded back to the location of the first row of houses, and 8 houses were destroyed.

There has long been a hi
tive value of the dunes an
shore of Long Island (Mitc
al., 1980), and dune building
there for several decades.
administers Fire Island Nati
of Brookhaven and Islip on
regulations preventing hous
means of ensuring the integr
property losses (Town of I
1981).

Beach and Dune Processes

The beach and dunes underg
from the interaction of wind
of storms. The winds on the
with the highest frequency a
northwest. These winds mo
Sediment removed from the
ited on the seaward side in th
or is moved onto the beach w
Vegetation landward (upwin
velocity on the surface of
through it, which limits the a
transport occur over bare gr
dune (blowouts) and at gaps
channelized. Isolated lobes o
ward of these areas.

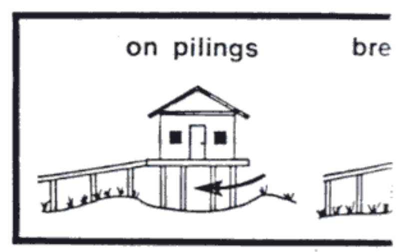

FIGURE 3. House foundation type

There has long been a high degree of awareness of the protective value of the dunes among the communities of the south shore of Long Island (Mitchell, 1974; Heikoff, 1976; Butler et al., 1980), and dune building programs have been implemented there for several decades. The National Park Service, which administers Fire Island National Seashore, and the communities of Brookhaven and Islip on Fire Island have recently instituted regulations preventing house construction in the dunes as a means of ensuring the integrity of the dune and reducing future property losses (Town of Islip, 1978; Town of Brookhaven, 1981).

Beach and Dune Processes

The beach and dunes undergo cyclic changes (Figure 4) resulting from the interaction of wind and waves associated with passage of storms. The winds on the northeast coast of the United States with the highest frequency and velocity blow from the west and northwest. These winds move sediment offshore (Figure 4a). Sediment removed from the landward side of the dune is deposited on the seaward side in the wind shadow formed by the dune or is moved onto the beach where it is transported into the water. Vegetation landward (upwind) of the dune crest lowers the wind velocity on the surface of the dune, and traps sand moving through it, which limits the amount of sand moved. High rates of transport occur over bare ground in unvegetated portions of the dune (blowouts) and at gaps in the dune crest where winds are channelized. Isolated lobes of accretion form on the beach landward of these areas.

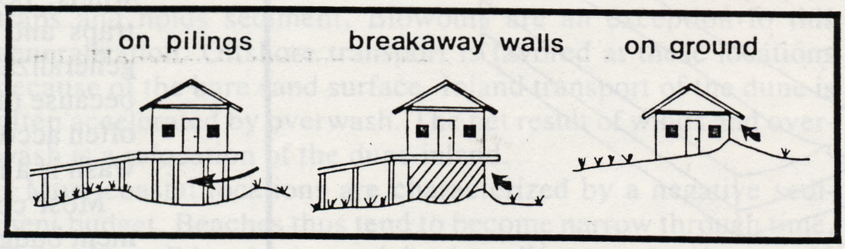

FIGURE 3. House foundation types found in the shorefront communities.

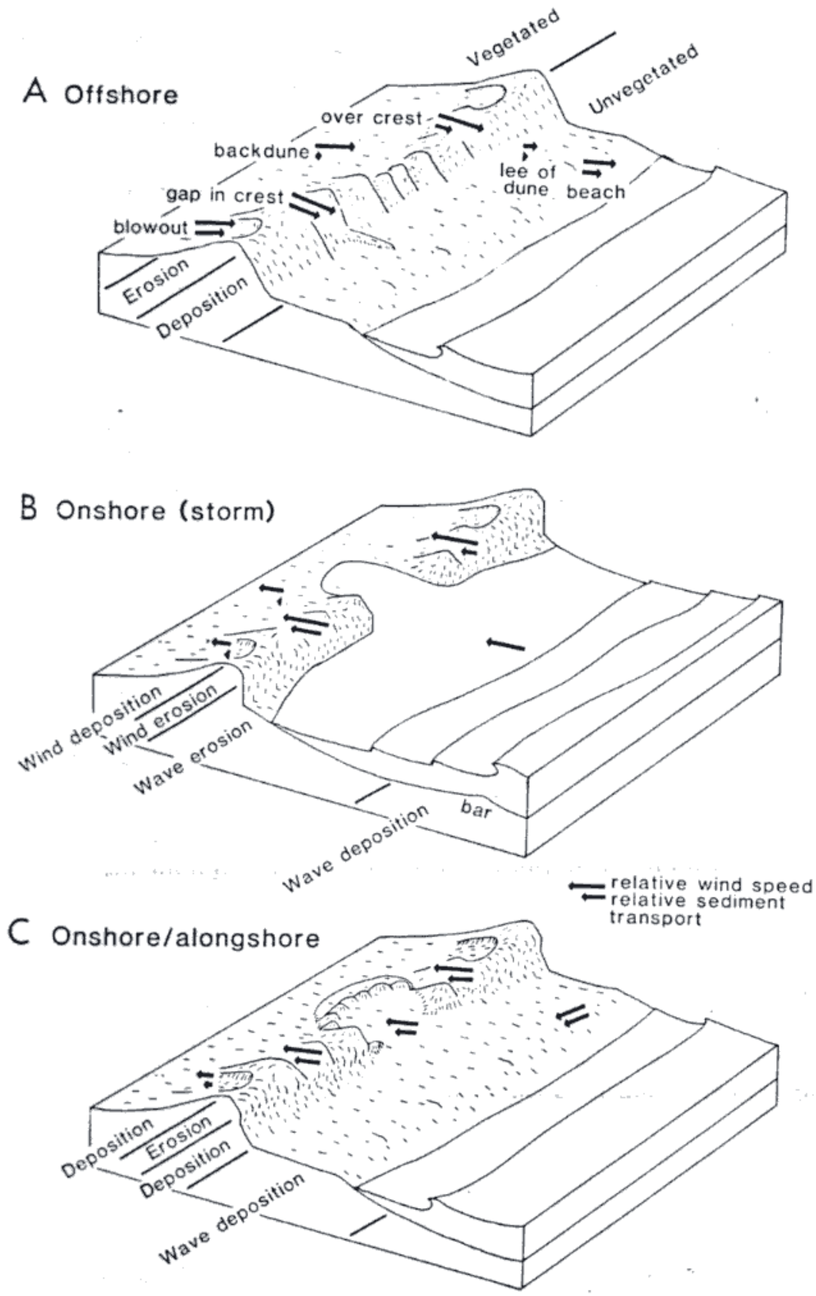

FIGURE 4. Processes causing change on coastal dunes on undeveloped north-east coast barrier islands.

Storms bring strong o
the height and frequency
These waves and winds ca
in direct attack on the dune
forming a scarp on the sea
literated. Overwash occurs
the dune, transporting sand
then deposited. Much of t
and upper beach is moved o
Wetting of the beach surfa
during storms reduces the
but some sediment will be
seaward side of the dune
where there is little veget
creased. The sediment pas
vegetation on the landward

Post-storm waves reple
deposited on the overwash
dunes begin to form. Seeds
the debris result in growth
sand and increases the si
1979). A considerable amo
because the dune scarp act
through low gaps in the du
ally created seaward of th
location or due to the colla
ment of sediment from the

Net movement of sand b
tion, despite the greater f
winds, because vegetation
traps and holds sediment.
generalization. Offshore tr
because of the bare sand s
often accelerated by overw
wash is a relocation of the

Most coastal locations a
ment budget. Beaches thus
If the dune did not migrat

Storms bring strong onshore (easterly) winds which increase the height and frequency of occurrence of waves (Figure 4b). These waves and winds cause a rise in water level which results in direct attack on the dune by waves. Large dunes are cut back forming a scarp on the seaward side, while small dunes are obliterated. Overwash occurs as waves pass through these gaps in the dune, transporting sand landward of the crestline where it is then deposited. Much of the sediment removed from the dune and upper beach is moved offshore to form a bar in deeper water. Wetting of the beach surface by wave uprush and precipitation during storms reduces the ability of the wind to transport sand, but some sediment will be moved inland, particularly from the seaward side of the dune crest and through gaps in the dune where there is little vegetation and where wind velocity is increased. The sediment passing the dune crest line is trapped by vegetation on the landward side.

Post-storm waves replenish the beach (Figure 4c). Flotsam deposited on the overwash surface traps wind-blown sand and dunes begin to form. Seeds and bits of beach grass deposited in the debris result in growth of new vegetation which traps more sand and increases the size of the new dune (Godfrey et al., 1979). A considerable amount of sand will be moved alongshore because the dune scarp acts as a barrier, but sand can pass freely through low gaps in the dune (Rosen, 1979). A ramp is eventually created seaward of the dune scarp by sand blown to that location or due to the collapse of the scarp when it dries. Movement of sediment from the beach to the dune is then facilitated.

Net movement of sand by wind is generally in the inland direction, despite the greater frequency and magnitude of offshore winds, because vegetation on the landward side of the crest traps and holds sediment. Blowouts are an exception to this generalization. Offshore transport is favored at these locations because of the bare sand surface. Inland transport of the dune is often accelerated by overwash. The net result of winds and overwash is a relocation of the dune inland.

Most coastal locations are characterized by a negative sediment budget. Beaches thus tend to become narrow through time. If the dune did not migrate inland, sediment starvation would

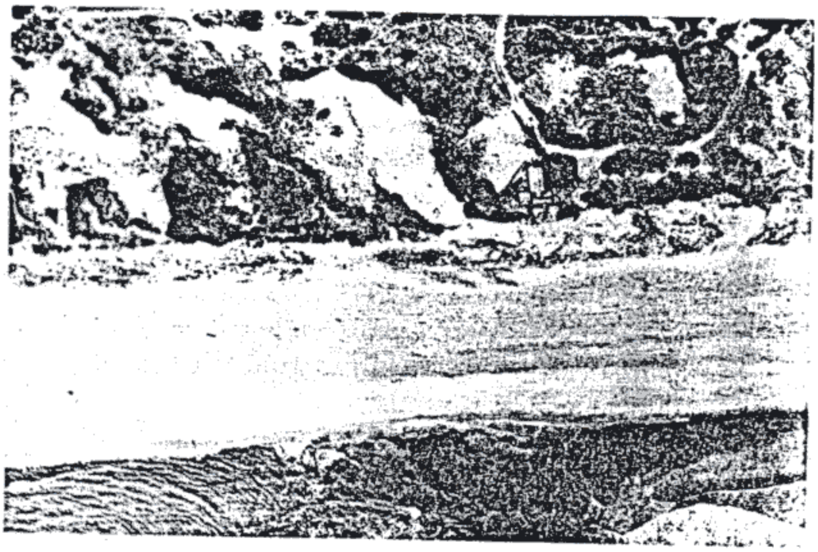

FIGURE 5. Dunes in the undeveloped portion of Fire Island east of Davis Park. (1976 National Park Service photo no. 3216–4–163).

result in more frequent attack on the dune and increase the likelihood of overwash.

Contrasts in Dune Conditions on Developed and Undeveloped Shorelines

The characteristics of the dunes in the developed communities on Fire Island contrast markedly with the dune forms in the undeveloped areas adjacent to them. There is generally more bare ground in the undeveloped areas (Figures 2 and 5). Bare areas can occur under natural conditions and are common in undeveloped dune locations (Gares, 1983). Many of the large expanses of bare ground in the undeveloped areas on Fire Island, however, appear to have been initially created as a result of former human activity, through removal of houses by the National Park Service. These bare areas do not recover rapidly, and they frequently become blowouts, increasing in size and migrating seaward as a result of net southeastward movement of sediment by the dominant northwesterly winds. When these active

bare areas (blowouts)
resulting low elevation
ment-laden storm waves
celerated sediment exc
areas of bare ground and
crest using sand fences
vice does not revegetat
volved and the lack of
human investment.

There is less bare gr
munities (Figure 2) beca
activity is prevented by p
people off the dunes, or
vegetation. These huma
tion of the dune and cre
form is the result of the
dents to maintain a con
Dunes in developed area
undergo the rapid chang
undeveloped dunes.

Some Fire Island comm
houses and a more variab
generally occurs where i
destroys vegetation. Ba
houses block the sedime
are necessary for growth
of buildings can channeli
reducing the likelihood o
then become subject to
which buildings are con
managed are thus import

Most of the houses bu
have a scour pit of ba
vegetated lip of sand aro
The scour is due to high
coupled with the absence
of sand around the house
due to reduced wind vel

bare areas (blowouts) migrate through the dune crest line, the resulting low elevations become subject to overwash by sediment-laden storm waves (Leatherman, 1979). This cycle of accelerated sediment exchange can be altered by revegetating areas of bare ground and by repairing any breaches in the dune crest using sand fences or fill, although the National Park Service does not revegetate these areas because of the costs involved and the lack of a need for a dune as a protection for human investment.

There is less bare ground in many of the developed communities (Figure 2) because destruction of vegetation by human activity is prevented by proper house construction or by keeping people off the dunes, or it is mitigated by using sand fences and vegetation. These human modifications help stabilize the position of the dune and create a high, linear crest line. The dune form is the result of the conscious attempts of shorefront residents to maintain a continuous foredune for shore protection. Dunes in developed areas like these are mobile, but they do not undergo the rapid changes in position which occur in regard to undeveloped dunes.

Some Fire Island communities have more bare ground around houses and a more variable dune crest elevation (Figure 6). This generally occurs where increased pedestrian and vehicle traffic destroys vegetation. Bare areas are also created where large houses block the sediment exchanges and the sunlight, which are necessary for growth of stabilizing vegetation. Close spacing of buildings can channelize winds, increasing their velocity and reducing the likelihood of survival of vegetation. The bare areas then become subject to increased deflation. The manner in which buildings are constructed and the way the property is managed are thus important in causing changes to the dune.

Most of the houses built on pilings without breakaway walls have a scour pit of bare ground beneath them and a well-vegetated lip of sand around the building on all sides (Figure 3). The scour is due to high wind velocities beneath the structure coupled with the absence of stabilizing vegetation there. The lip of sand around the houses appears to be the result of deposition due to reduced wind velocity in the lee of the structure. The

FIGURE 6. Kismet, New York. (1976 National Park Service photo no. 3216–3–053).

bottoms of scour pits under houses that are on the dune crest are commonly about 0.5 m below the line of the undisturbed ground surface next to the house; the lip may be about 0.5 m above the surface. Observations by the authors and long-term shorefront residents indicate that the pits do not show much evidence of growth, either downward or outward, once the typical configuration has been reached, and wind and sediments can pass under the house.

Houses on pilings landward of the dune crest and at a lower elevation cause greater modification of the dune form than similar houses located on top of the dune. Landward migration of the dune crest does not always bury these buildings because channelization of wind under the structures maintains relatively high wind velocities which prevent deposition. The dimensions of the depression created by this process are a function of the elevation of the bottom floor of the structure and the height of the dune crest. The gap which is created in the dune at houses built at low elevations may be quite large.

Some of the elevated houses in the study area have breakaway walls composed of wooden slats. The breakaway walls are bar-

riers which cause son
house. The deposition
elevation at which time t
the ground on a solid foun
as a barrier to the wind a
all directions, and they a
elevated houses. If these
crest at lower elevations.
become weak points in th
House sites are not nec
shoreline along Fire Islan
the damaging storm of Fe
tion of the dune crest afte
location of the houses. In
crest line resulted from
houses which had low fir
cases, however, there wa
the dune line beneath ho
within the communities
tions were elevated a suf

Implications for Manag

The developed scenario
breaching by waves und
the undeveloped scenari
and dune profile. The pr
appear to endanger the i
storm wave overwash
jeopardize the lives and
dune during severe sto
based on the need for th
exclude buildings but sh
standards for their const

Building Site Characterist

It is likely that most fu
structed on pilings as aw

riers which cause some deposition of sand at the sides of the house. The deposition can be sufficient to reach the first floor elevation at which time the structure functions like one built on the ground on a solid foundation. Houses built on the ground act as a barrier to the wind and to the movement of sediment from all directions, and they are more complete sediment traps than elevated houses. If these structures are located behind the dune crest at lower elevations, they would eventually be buried and become weak points in the dune.

House sites are not necessarily weak points in the dune. The shoreline along Fire Island was examined following passage of the damaging storm of February 7, 1978 to determine the condition of the dune crest after the dune had been eroded back to the location of the houses. In a few locations, low points in the dune crest line resulted from erosion of the dune where it fronted houses which had low first floor elevations (Figure 7a). In most cases, however, there was no major difference in the integrity of the dune line beneath houses and at adjacent areas of the dune within the communities (Figure 7b). The houses at these locations were elevated a sufficient distance above the crest.

Implications for Management

The developed scenario can result in a lower likelihood of dune breaching by waves under present management conditions than the undeveloped scenario, given the same sediment in the beach and dune profile. The presence of buildings on pilings does not appear to endanger the integrity of the dune as a barrier against storm wave overwash and flooding and therefore does not jeopardize the lives and property of residents landward of the dune during severe storms. Restrictions on use of the dune based on the need for the dune to provide protection should not exclude buildings but should be designed around performance standards for their construction and use.

Building Site Characteristics

It is likely that most future shorefront buildings will be constructed on pilings as awareness of the safety values of this mode

A

B

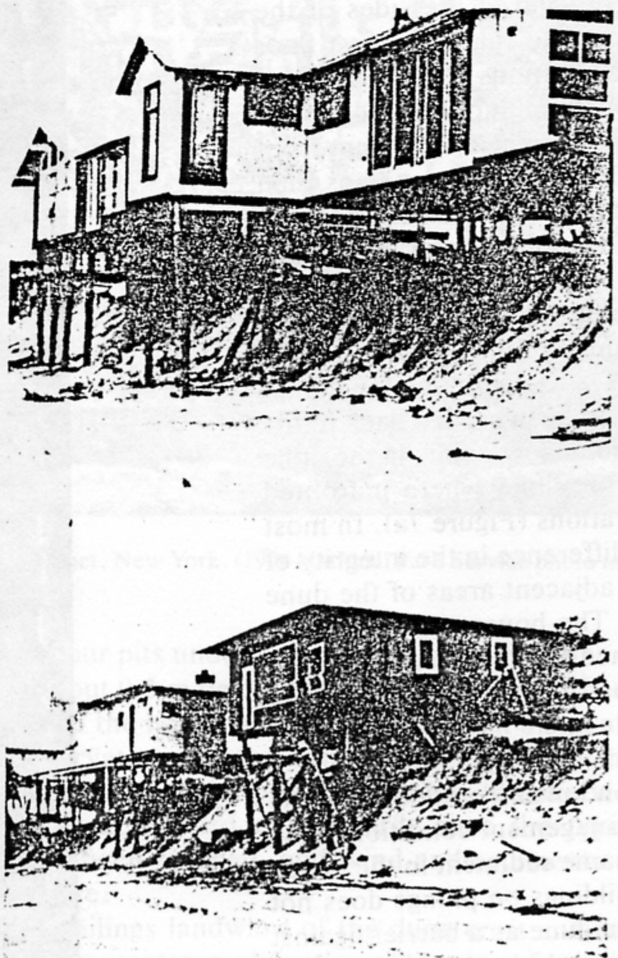

FIGURE 7. Condition of the dune beneath houses elevated on pilings after passage of the storm of February 7, 1978.

of construction increases. Many buildings have already been constructed on pilings because this method of construction was required in communities in the Federal Insurance Administration National Flood Insurance Program (FEMA, 1981). The emphasis of these old criteria has been on the effects of natural

hazards on the build
devised to minimize th
system (Clark, 1982).

Existing performance
structures generally spe
tion should be above t
breaking wave cresting
1977; Machemehl, 1978)
not result in a house tha
sufficient distance to al
Also, there is nothing i
standards which preven
the pilings. Buildings c
thus may result in a dun
ent rates along its length

The elevations of u
shoreline, and the eleva
ment may change throug
ditions will thus fluctua
may be interpreted as
should be built to be co
rather than with some a
will be closer to equilibr

A maximum plot occu
ensuring that there is su
structures for natural pro
tions could state that str
of the lot on which they
ence with eolian sedime
tive to the present housin
McCluskey, 1982).

Regulations should als
within each parcel of lan
neighbor, and the metho
and orientation). The le
vegetation growth, and
occur where structures a
buildings will not interf

hazards on the buildings. New performance criteria must be devised to minimize the effects of the buildings on the natural system (Clark, 1982).

Existing performance standards for protection of coastal structures generally specify that the minimum first floor elevation should be above the elevation of the highest calculated breaking wave cresting on a 100-year storm tide (Collier et al., 1977; Machemehl, 1978). The application of these standards may not result in a house that is elevated above the ground surface a sufficient distance to allow for natural exchange of sediment. Also, there is nothing in regulations designed to meet FEMA standards which prevents the use of breakaway walls between the pilings. Buildings constructed to meet existing standards thus may result in a dune crest which will be displaced at different rates along its length.

The elevations of unmodified dunes will vary along the shoreline, and the elevations within a particular shoreline segment may change through time. Dune height under natural conditions will thus fluctuate around some mean condition which may be interpreted as the equilibrium dune height. Houses should be built to be compatible with the mean crest elevation rather than with some arbitrary elevation. In this way the dune will be closer to equilibrium with the natural processes.

A maximum plot occupancy requirement would be a means of ensuring that there is sufficient open ground available between structures for natural processes to prevail. For example, regulations could state that structures occupy no more than 25 percent of the lot on which they are located. This will reduce interference with eolian sediment movement by about 13 percent relative to the present housing density of 43 percent (Nordstrom and McCluskey, 1982).

Regulations should also consider where a structure is located within each parcel of land, the distance of the structure from its neighbor, and the method of construction (height, size, shape, and orientation). The least interference with eolian processes, vegetation growth, and dune formation and migration should occur where structures are small, isolated, and elevated. Round buildings will not interfere with the wind stream as much as rectangular structures (Pilkey et al., 1980). If the buildings are rectangular, they should have the long axis parallel to the dominant winds (northwest–southeast on Long Island).

An attempt to maintain the dune crest in a static position on an eroding shoreline will result in greater frequency of wave attack on the dune, which will result in a narrower dune fronting the buildings (Figure 6). The erosion will eventually extend landward of the crest of the dune and destroy its integrity as a barrier against overwash. The dune crest line must be allowed to be displaced inland by eolian processes at a rate which corresponds to the rate of beach retreat. This will allow for continued maintenance of the bulk and shape of the dune, thereby providing adequate protection for buildings which remain landward of it (Nordstrom and Psuty, 1980). This means that buildings constructed behind the dune should be built to be compatible with a location which, in the future, will be at the dune crest, and floors would have to be built at an elevation which would be high enough for the dune to form beneath them.

The use of a building does not affect its impact on geomorphic processes, as long as the requirements for such use do not result in a significant departure from the size, shape, and method of construction of the building. Public buildings and commercial structures may be treated conceptually in the same manner as single-family dwellings except that they may have a greater intensity of use. The effects of the more intense use can be mitigated by confining access to elevated walkways. The size of these structures should be kept as small as possible, consistent with their use. If they must be large, the adverse effects can be minimized by placing them on the landward side of the barrier island within the woody shrub vegetation zone where there is little eolian activity. The useful lives of such structures should reflect the rate of migration of the dune, and the buildings should be removed before they become obstructions to sand transfers by wind. Support infrastructure, such as roads, parking areas, and utility lines, should also be removed or simply abandoned if their continued use would begin to interfere with dune processes.

Mitigating Measures

The actual construction
buildings may endanger
tation and creating bare
such as walking, driving
rapid destruction of the
Vogt, 1979; Gares, 198
fences and vegetation pl
turbed areas, and the
should be controlled.

Dune building program
tivities, but control may
grams will accomplish
dune seaward through lo
create irregularities in th
the zone of development
ject to wave attack more
migrate inland to retain t
protection. Regulations
issue. The importance o
well as the ease with wh
indicates that sand fenci
nity-level adjustment, ra

Application to Policy

Buildings alter winds and
structed, they do not en
point where the hazard
excluded from the dune c
lations to control new c
the problem of shoreline
phasizing the control o
makers may lose sight of
buildings and support in
use of active means of m

Mitigating Measures

The actual construction of new buildings or removal of existing buildings may endanger the dune system by destroying the vegetation and creating bare ground. Active human uses of the dune, such as walking, driving, and bulldozing can also result in the rapid destruction of the form of the dune (Godfrey et al., 1978; Vogt, 1979; Gares, 1983). Mitigating measures such as sand fences and vegetation planting should be employed in these disturbed areas, and the activities of dune-dwellers and others should be controlled.

Dune building programs should be retained as permissible activities, but control may be required to ensure that these programs will accomplish the intended purposes. Extending the dune seaward through local implementation of sand fences can create irregularities in the crest line and advance the location of the zone of development seaward. The dune would then be subject to wave attack more frequently. Dunes must be allowed to migrate inland to retain their value as a resource and as a form of protection. Regulations on sand fences should address this issue. The importance of the dune to the entire community, as well as the ease with which the dune can be altered by fencing, indicates that sand fencing should be undertaken as a community-level adjustment, rather than as individual action.

Application to Policy

Buildings alter winds and cause local accretion. If properly constructed, they do not endanger the integrity of the dune to the point where the hazard is increased. Buildings should not be excluded from the dune on these grounds alone. Passage of regulations to control new construction in the dunes will not solve the problem of shoreline erosion and dune maintenance. By emphasizing the control of new buildings in the dunes, policymakers may lose sight of the need to control the construction of buildings and support infrastructure behind the dunes and the use of active means of modifying dunes.

It may be desirable to prevent the construction of buildings in the dunes in order to maintain the shoreline in an undeveloped state for habitat, for aesthetic values, for recreation, or to minimize expenditures for relief and protection. The achievement of these goals will require the application of different restrictions from those designed to maintain a protective dune.

The effects of shorefront development presented in this study were monitored in shorefront communities characterized by a moderate level of development and where the residents are aware of the value of the dunes as a form of shore protection. Alterations to coastal dunes have been more severe in many other coastal communities. The results of this study provide an estimate of effects of construction which are conservative in terms of adverse effects on the dune. The results suggest that people can occupy fixed buildings on migrating barrier islands, as long as the buildings are properly constructed and used. This conclusion should not be used to justify intensive development of shorefront land. Barrier islands are dynamic, environmentally sensitive, and hazardous landforms, and buildings should not exceed the minimum number required to accommodate essential uses.

Acknowledgments

This study was supported by the U.S. National Park Service North Atlantic Region, Boston, Massachusetts (Contract PX-1600-0-0363), P. A. Buckley, Chief Scientist. We are grateful to Peter S. Rosen for the insight he provided us in numerous conversations about eolian sediment transport.

References

Butler, K. S., K. N. Nichols, and R. Quay. 1980. "Managing barrier islands: the role of local government." *Coastal Zone '80* (New York: American Society of Civil Engineers), pp. 2036–2051.

Clark, J. R. 1977. *Coastal Ecosystem Management* (New York: John Wiley and Sons), 928 p.

Clark, R. R. 1982. "Structural design aspects of a coastal building code." *Proceedings*, 18th Coastal Engineering Conference. (New York: American Society of Civil Engineers), pp. 2285–2299.

Coastal Engineering
Army Corps of E
Collier, C. A., K. Esha
Beachfront Constr
tion Setback Line.
University of Flori
Commonwealth of Ma
agement Program.
Environmental Af
Federal Emergency M
manual for reside
ton, DC: US Dep
Emergency Manag
Gares, P. A. 1983. "B
Coastal Zone '83
pp. 1178–1191.
Godfrey, P. J. 1977. C
barrier beaches a
Biometeorology 21
Godfrey, P. J., S. P. Lea
Vehicles on Coasta
Society of Civil E
Godfrey, P. J., S. P. Le
proach to classific
(ed.). *Barrier Islan*
(New York: Acade
Heikoff, J. M. 1976.
Arbor, MI: Ann A
Hildreth, R. G. "Coast
Leatherman, S. P. 197
University of Mas
University of Mas
Leatherman, S. P., and
Barriers, Long Is
University of Mas
Machemehl, J. L. 197
Coastal Zone '78
pp. 1453–1468.
McCluskey, J. M., and
dune dynamics at
tional Park Servic
Mitchell, J. K. 1974. *C*
versity of Chicago
National Oceanic and

Coastal Engineering Research Center. 1977. *Shore Protection Manual.* U.S. Army Corps of Engineers, CERC. Fort Belvoir, VA. 3 vols.

Collier, C. A., K. Eshaghi, G. Cooper, and R. S. Wolfe. 1977. "Guidelines for Beachfront Construction with Special Reference to the Coastal Construction Setback Line." (Gainesville, Fla.: Department of Civil Engineering, University of Florida.)

Commonwealth of Massachusetts. 1978. "Massachusetts Coastal Zone Management Program." Commonwealth of Massachusetts. Executive Office of Environmental Affairs, Boston, MA. 439 p.

Federal Emergency Management Agency. 1981. "Design and construction manual for residential buildings in coastal high hazard areas." (Washington, DC: US Department of Housing and Urban Development, Federal Emergency Management Agency), 189 p.

Gares, P. A. 1983. "Beach/dune changes on natural and developed coasts." *Coastal Zone '83* (New York: American Society of Civil Engineers), pp. 1178–1191.

Godfrey, P. J. 1977. Climate, plant response, and development of dunes on barrier beaches along the U.S. East Coast. *International Journal of Biometeorology* 21: 203–215.

Godfrey, P. J., S. P. Leatherman, and P. A. Buckley. 1978. "Impact of Off-Road Vehicles on Coastal Ecosystems." *Coastal Zone '78* (New York: American Society of Civil Engineers), pp. 581–600.

Godfrey, P. J., S. P. Leatherman, and R. Zaremba. 1979. "A geobotanical approach to classification of barrier beach systems." In: S. P. Leatherman (ed.). *Barrier Islands: from the Gulf of St. Lawrence to the Gulf of Mexico* (New York: Academic Press), pp. 99–126.

Heikoff, J. M. 1976. *Politics of Shore Erosion: Westhampton Beach* (Ann Arbor, MI: Ann Arbor Science Publishers, Inc.), 173 p.

Hildreth, R. G. "Coastal natural hazards." *Oregon Law Review* 59: 201–242.

Leatherman, S. P. 1979. *Barrier Island Handbook.* National Park Service/University of Massachusetts Cooperative Research Unit (Amherst, MA: University of Massachusetts), 101 p.

Leatherman, S. P., and D. Joneja. 1980. "Geomorphic Analysis of South Shore Barriers, Long Island, New York: Phase I." National Park Service/University of Massachusetts Technical Report 47, 168 p. with appendices.

Machemehl, J. L. 1978. "Model Building Code for Coastal Hazard Areas." *Coastal Zone '78* (New York: American Society of Civil Engineers), pp. 1453–1468.

McCluskey, J. M., and K. F. Nordstrom. 1982. "The effects of structures on dune dynamics at Fire Island National Seashore." Project report to National Park Service, North Atlantic Region, Boston, MA, 70 p.

Mitchell, J. K. 1974. *Community Response to Coastal Erosion.* (Chicago: University of Chicago, Department of Geography Research Paper No. 156.)

National Oceanic and Atmospheric Administration. 1980. "Local Climatological Data, John F. Kennedy International Airport, New York, New York, 1975–1980." NOAA, U.S. Dept. of Commerce, Environmental Data Information Center, Asheville, N.C.

Nordstrom, K. F., and N. P. Psuty. 1980. "Dune district management: a framework for shorefront protection and land use control." *Coastal Zone Management Journal* 7: 1–23.

Nordstrom, K. F., and J. M. McCluskey. 1982. "The effects of structures on dune dynamics at Fire Island National Seashore." Rutgers University/National Park Service Cooperative Research Unit Report 82-1. Center for Coastal and EnvironmentalStudies, Rutgers University.

Panuzio, F. L. 1968. The Atlantic coast of Long Island. Proceedings of Eleventh Conference on Coastal Engineering. (New York: American Society of Civil Engineers), 1222–1241.

Pilkey, O. H., Jr., W. J. Neal, O. H. Pilkey, Sr., and S. R. Riggs. 1980. *From Currituck to Calabash: Living with North Carolina's Barrier Islands.* 2nd Edition. (Research Triangle Park, NC: North Carolina Science and Technology Research Center), 244 p.

Psuty, N. P. 1982. "Comparison of dune crest line position 1976–1981, Fire Island, New York." National Park Service/Center for Coastal and Environmental Studies Technical Report, December, 1982, 36 p. with appendices.

Rosen, P. S. 1979. "Aeolian dynamics of a barrier island system." In: S. P. Leatherman (ed.). *Barrier Islands: from the Gulf of St. Lawrence to the Gulf of Mexico* (New York: Academic Press), pp. 81–98.

Taney, N. E. 1961. "Geomorphology of the South Shore of Long Island, New York." U.S. Army Corps of Engineers, Beach Erosion Board, Technical Memorandum 128. 50 p. with appendices.

Town of Brookhaven. 1981. OFD Oceanfront dune district, Brookhaven Code, 10-25-81, pp. 8628.5–8628.6.

Town of Islip. 1978. Use district regulations: Oceanfront dune district AAAB, Islip Code 8-25-78, pp. 6862–6863.

Vogt, G. 1979. "Adverse effects of recreation on sand dunes: a problem for coastal zone management." *Coastal Zone Management Journal* 6: 37–68.

Book Review

Chesapeake Waters: I
ion 1607–1972, by Jo
Shivers, Jr. Tidewate
pages. $19.95.

Reviewed by Kevin Sul
Formerly Director, Ch
Studies.
Smithsonian Institutio

It is hard to imagine a
on the economy and cu
has an enormous econ
reational and commerc
industry. The symbolic
important. It is an inte
that expression of cult
tidewater Virginia, an
Bay's fishery product
"Save the Bay" bum
Middle-Atlantic states
in his State of the Un
pollution control effo
notoriety.

As state and federa
problems, it is helpful
over 350 years of
Chesapeake Waters: P
ion 1607–1972 provid
Capper, Garrett Powe
with man's attempts to
background of the eco