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EDITORIAL

What Might Happen to America's Shorelines if Artificial Beach Replenishment is Curtailed: A Prognosis for Southeastern Florida and Other Sandy Regions Along Regressive Coasts

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SUMMARY

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Beach replenishment in Florida consumes about one-third of what the federal government spends nationally on battling coastal erosion. Recent proposals from Washington are to cut the federal share of hurricane and storm surge protection, inlet maintenance, sand bypassing, beach restoration, and periodic renourishment projects in Florida. Although Florida has more beach erosion control projects than all the other states combined, erosion is still a problem for some 700 km of shore and has reached "critical" levels along 370 km of Florida beachfront where development or recreation are threatened. Of 215 km of erosion that have been studied, 140 km have been restored; the remainder has been abandoned because erosion rates are too high. If the average federal 50% cost-share for coastal protection is eliminated, local governments will have to support future projects at a minimal rate of $20–40 million per year. The annual cost of shore protection is modest compared to income generated by beach-related activities in Florida which overall bring in about $1.5 billion in annual sales. Alternative proposals to forego beach renourishment altogether, because it is "too expensive," suggest that new lines will be drawn in the sand for construction control and erosion setbacks.

Due to relative sea-level rise (which includes land subsidence), natural background shoreline recession rates for the Florida Atlantic coast now average between 0.3–0.4 m a^{-1}. Accelerated rates of coastal erosion are associated with beaches backed by seawalls and coastal segments lying downdrift from stabilized inlets. Because jetties are littoral drift blockers, they are responsible for about 85% of Florida's beach erosion problem. Erosion fronts, which migrate downbeach from jetties at a rate of about 1 km a^{-1}, can quickly impact long coastal segments in a few years. Just south of the Port Everglades inlet, for example from DEP monuments R86-R91, beach fill placed in 1989 eroded 60 m in 6 years for an annual shoreline recession rate of 10 m a^{-1}, or a volume loss of 10 m^3 m^{-1} a^{-1}. Additional erosion hot spots occur downcoast from other trained (jettied) inlets and elsewhere along the coast. With the present total annual net loss at 3–5% by volume of beach sand in Broward County, about two-thirds to one-half of the Atlantic dry beach width will remain within a decade, by around 2007. This new line in the sand will reflect loss of both artificially replenished beaches and natural beaches alike. Without replenishment, the volume of eroded beach sand in Broward County alone will probably amount to something on the order of 5.2 × 10^6 to 8.6 × 10^6 m^3. This magnitude of unrecovered decadel sand volume loss translates into future problems of greater magnitude than exist today. Salient among them is the prospect that fewer tourists will visit narrower, eroded beaches and the Florida economy will realize significantly less income from a major but declining economic resource. A management policy of 'no new beach replenishment activities' will in the first decade: (1) cause accelerated loss of beaches, (2) place a larger proportion of the coastal population at risk from flooding, (3) increase vulnerability of coastal infrastructure to floods and inundation, (4) decrease revenue from tourism, and (5) result in higher costs for future shore protection. The proposed federal policy would be environmentally shortsighted, fiscally irresponsible, and negligent of proper methods of beach management. It is perhaps ironic to note that America has no national shore protection policy, that sand has become a restorrative resource of choice (opposed to hard, structural stabilization methods), and at a time when sand resources on the outer continental shelf may become available for beach renourishment, the Clinton Administration is proposing to put the brakes on soft shoreline stabilization.

ADDITIONAL INDEX WORDS: *Shore erosion, beach renourishment, coastal management, storm protection.*

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PROPOSAL TO CURTAIL FEDERAL PARTICIPATION IN BEACH PRESERVATION IN AMERICA

In a recent 1996 budget proposal, the Clinton Administration has proposed legislation to eliminate beach projects from the U.S. Army Corps of Engineers funding and responsibility. This reasoning is partly based on budgetary constraints and the idea that the Corps should only be involved in those projects that have interstate or 'national significance.' Although no specific proposals have yet been submitted to Congress for approval, the spirit of the proposals milling around clearly points to prohibition from participating in the majority of existing or proposed projects. In cases where participation might continue, Congress is calling for increased cost-benefit ratios from the present 1:1 to at least 2:1 while the federal cost-sharing would decrease from 75% to 25%. In brief, the future role of the Corps of Engineers would be limited to participating in commercial navigation, 'interstate' flood control, technical assistance to the States and Tribes, and environmental restoration. The "Continuing Authorities Program" would be eliminated. Such re-orientation of federal participation would place a greater burden on states and local communities.

These proposals represent a real and grave threat to beach preservation. Beaches are a commonly accepted 'symbol of area,' an image so powerful that for many tourists "Florida equals beaches" just as the Empire State Building and the Grand Canyon respectively represent New York and Arizona. Although there are some popular notions that beach renourishment benefits only oceanfront property owners with federal dollars, the concept is ill-conceived. Beaches, perhaps more than any other environment, provide for multiple uses including storm surge protection, flood control, recreation, and habitat for endangered species, among others. Most beaches have adequate public access and are often used to capacity. Beaches are dynamic natural features that are not confined by administrative boundaries between states, counties, or municipalities. Parts of all beaches on tidal costs belong to state or federal governments and therein lies some responsibility for proper management of a public natural resource. Beaches occurring within national parks and marine sanctuaries are, however, clearly federal responsibilities. Beaches lying downdrift from federally maintained inlets may also come under federal responsibility if it can be demonstrated that the improved (stabilized) navigational entrance contributes to downcoast beach erosion.

IS FLORIDA'S GREATEST NATURAL RESOURCE AT RISK?

When it comes to beach renourishment, the state of Florida is a major player on a national basis. Florida beaches comprise a quarter of America's sandy shores and about 56% of the Corps' South Atlantic Division. Additionally, about 25% of the beach nourishment projects in Florida occur in Palm Beach, Broward, and Dade counties.

In Florida, beaches retain all of these attributes and are additionally the basis of an economy that is largely dependent on tourism and coastal recreation. Florida is only one state among 30 coastal states but the positive economic benefits of beaches on this state's economy are representative of a larger reality.

Because the possibility of federal cost sharing for beach nourishment projects is very real, it is perhaps worth considering what might happen if these proposals were enacted. At first glance, some might agree that these proposals will save money and that curtailing beach management will somehow serve the budgetary rescission process in Washington. Federal dollars will not be spent on our nations beaches to provide protection from hurricanes, frontal (cyclonic) storms, storm surge, nor coastal flooding. Such being the case, one may well wonder why tax payers in coastal states will have a portion of their tax dollars sent to interior states ravaged by earthquakes, river flooding, tornadoes, blizzards, droughts, and so on? Inhabitants of coastal zones are equally entitled to environmental protection with federal cost-sharing dollars. For inlanders, there is a real danger in parachial thinking, that beaches are expendable and not worth managing. Today, about 75% of the US population lives within an hour's drive of the coast and there is a constant drang to the shore from the heartland. Citizens living in one sector of the country should not be pitted against those living in other environments, nor should they have to choose which geophysical hazard areas they will attempt to protect.

If the coastal areas are to be abandoned by the federal government and the Corps not allowed to participate in proper beach management practices, then they also should be restricted from participating in river flood control projects in the con-

tinental interior. Part of the reasoning here is that rivers are commonly regarded as having interregional importance and there are numerous riparian rights laws that protect downstream users. Application of the same philosophy to the coast has resulted in beaches being referred to as 'rivers of sand.' The idea here is the same as water flowing down a river valley. Beach sand migrates (flows) continuously downcoast from one coastal segment to another. On the southeast coast of Florida, for example, it is possible to trace the provenance (source) of sand grains to the Appalachian Mountains along the Mid-Atlantic coast. These grains have traveled long distances and are clearly interstate migrants having arrived on Florida beaches from Georgia, the Carolinas, or even as far north as Virginia. It is unfortunate that there are few legal conventions that treat the migration of beach sands along coasts. Further, as sand supplies become limited there are bound to be more "sand wars" between communities. It is estimated that Dade and Broward counties have enough offshore sand resources to complete one more major round of beach nourishment from a 10–15 year reserve. Although there are about 2.6 $\times$ 10^6 m^3 of sand from inlets on the east coast that is available for nourishment, very little of this reserve is present in southeastern Florida.

IMPACTS OF 'NO NEW BEACH RENOURISHMENT PROJECTS': THE EXAMPLE OF FLORIDA

The possibility of no more beach renourishment may sound reasonable from a superficial point of view. More responsible consideration, however, raises the specter of potential environmental degradation, loss of natural habitat, larger human populations at risk, and economic decadence. Rather than focus on environmental issues, which are important, it is perhaps more poignant to focus on some socio-economic issues. Everyone understands the power of the dollar and the issues that surround the well being of local communities and states. The process ultimately impacts the federal government because the buracuracy feeds off the local economic base.

SOCIO-ECONOMIC ASPECTS OF BEACH EROSION, A NATURAL PHYSICAL PROCESS

But first, before we can estimate damage costs we need to look at the beach erosion problem itself, mainly from a purview of shoreline rate of retreat and sand volume losses. Beach erosion results in coastal land loss due to (1) current transport of sediment (alongshore, cross-shore), (2) wind erosion from the berm, and (3) relative sea-level rise. Beach erosion typically shows secular trends as well as areas of accelerated activity, such as occur downdrift from jetties or in association with bathymetric irregularities in the surf zone causing so-called erosional "hot spots."

The *background erosion rate* related to relative sea-level rise in southeastern Florida falls in the range 1–4 mm a^{-1}. For a coastal slope of about 1:400 this translates into a maximum shoreline recession rate of about 1.6 cm a^{-1}. The sea level component of shoreline recession in the *short (annual) term* is thus of minor importance (see also discussion by Fairbridge, 1989). Over the longer term, the rate becomes progressively more important however. For all of the Florida Atlantic coast the rate of shoreline regression is estimated to be on the order of -0.3 to -0.4 m a^{-1} (Dolan *et al.*, 1983).

Using Broward County as a representative sample on a decadal time scale, the gross shoreline recession is the sum of retreat due to (1) sea-level rise (16 cm), (2) "hot spot" erosion (4 m), and (3) overall background regression (4 m) for a total of 8.16 m over much of the active coastline. This is the gross (background plus hot spot) rate of shoreline regression for natural beaches. For renourished beaches, the rates of shoreline retreat are even greater. Just south of the jettied Port Everglades navigational entrance, for example, the beach renourished in 1989 eroded 60 m in 6 years for an annual rate of 10 m a^{-1}. Aside from isolated sites of hot spot erosion, the average net volume loss of beach sand in Broward is about 3–5% per year. Thus, every decade there is a cumulative 30–50% loss of beach volume. Without natural or artificial replenishment, these beaches will largely disappear in a few decades. That is, the shoreline will retreat to condominium bulkheads and other hard structures.

My analysis of aerial photos (1:100 scale) show dry beach widths in Broward in 1989, for example, shows that 43% of beach widths range between 200 and 300 feet, 34% between 300 and 400 feet, and 56% between 200 and 400 feet (Table 1). Only about 2% of dry beach widths range from 400 to 500 feet. These widths expressed as a percentage of total beach length (22 miles) were compiled by measuring beach widths at DEP range markers every one-thousand feet along the shore. Dolan

Table 1. *Dry beach widths in Broward County, Florida, 1989.*

Dry Beach Width (in Feet) (Dune/Sea-wall to LT)	Length of Beach		% of Total Beach Length (22 mi)
	Feet	Miles	
100	1,000	0.2	0.8
200	27,000	5.1	22
300	26,000	4.9	21
400	17,000	3.2	13
480	14,000	2.7	12
520	19,000	3.6	16
600	3,000	0.6	2.6
700	4,000	0.8	3.2
800	6,000	1.2	5.2
1000	2,000	0.4	1.7
1200	1,000	0.2	0.8
1400	1,000	0.2	0.8
Total 121,000		23	100.1

Dry beach width calculated for 21 September 1989 as measured at DEP monuments spaced 1000 feet apart. Customery units were retained for ease of reference to annotated county aerial photography presented at a scale of 1 inch equals 100 feet

et al. (1983) calculated a shoreline recession rate of about 13 feet per decade for the whole of the Florida Atlantic coast. This rate is not necessarily representative of Broward County shore which differs from the average of all Atlantic coastal segments. Another point that needs to be considered when working out regression rates is the proportion of beaches that are artificially renourished. In Broward, about 60% of the total beach length has been renourished (40% of the shore is native beach). Thus, in calculation of an average rate of shoreline recession, somewhat more than half of the beaches erode about twice as fast as native beaches. Thus, to calculate recession rates, it is important to know the rates of regression for native beaches and those that are artificially replenished.

With the potential for loss of one-third to half of Broward's beaches over the next decade, there are several important questions that require consideration.

(1) What causes the shoreline to move landward and how does this happen?

We know that a relative sea-level rise is involved, but this is a relatively minor factor in the short term. Areas with accelerated rates of erosion, greater than the overall background rate, occur downdrift from jetties and bathymetric promontories. Our scale of observation thus ranges from localized hot spots to fairly long distances downcoast from jetties, that is, from hundreds of meters to some few tens of kilometers.

(2) What is the relationship between sand volume loss and rate of shoreline retreat and is one process more important than the other?

Volume loss is important but will vary from one beach to the next depending on the thickness of beach sands placed (naturally or artificially) on top of bedrock (*e.g.* the Anastasia Formation). The decrease in the *dry beach width* is, perhaps, a more relevant or practical consideration. This loss can be quantified and is visually apparent (*e.g.* Leonard, Clayton, and Pilkey, 1990).

(3) How much does a beach have to erode before adverse impacts become noticeable?

The answer to this question depends on the point of view, whether it focuses on critical natural habitat, engineering structures, *etc.* As far as economic impacts along a developed shoreline are concerned, erosion becomes critical when the number of beachgoers begins to decline, when structures are threatened or damaged, *etc.* Recreational value depends on density of use and when the dry beach area decreases and beachgoer's body space declines to a point where they are uncomfortable and go elsewhere. As a rough starting point, it seems that a loss of dry beach area on the order of 30% or so for well used beaches will probably result in a decline in the number of visitors. So the next logical question focuses on the point in time when there is a 30% decrease in dry beach area *with no beach renourishment.* For some beaches already nourished in 1989 near jetties and erosion hot spots, there is almost total (about 100%) loss of the dry beach—there is no beach today. In other areas the loss is less but it seems that a decadal time scale is also appropriate here. This is about the timing of beach renourishment schedules and it is about the time frame in which 30–50% of Broward's beach sand volume will be lost.

Comparing renourished beach lengths to natural beaches, we find that 60% of the Broward shoreline has been artificially renourished at some time in the past. Because renourished beaches erode faster than natural beaches along this intensely developed shore, by the year 2007 about 60% of Broward's beaches will be significantly more eroded than they were in 1995. Studies by Pilkey (1990) show that many replenished beach-

es along the southeast Atlantic coast will loose 50% of their volume in 4 to 5 years. Although these renourished beaches are relatively durable, compared to those in Mid-Atlantic states, it is likely that only a quarter or so of the beach will be left by 2007 without renourishment. Natural beaches are somewhat more durable but because they are sand starved downdrift from jetties they will be decreased in volume by 75–100% closest to the jetty, by 50% up to 2 km downcoast, and about 30% for several kilometers thereafter. Thus for this decadal time slice with no beach renourishment, by 2007 there will be marked declines in dry beach areas and fewer tourists. There will, on the other hand, be contemporaneous increases in coastal flooding and damage to infrastructure.

(4) What is the correlation between recreational beach use and revenue?

The Florida Department of Commerce estimates that in 1994, about 42 million tourists visited Florida. They contributed about 20% of the total sales tax ($10.2 billion) and directly supported 760,000 core employees of which 50% have full-time jobs related to beach activities. Of the total number of tourists that visit Florida each year, about half go to the beach at least once during their stay and about 14% come to Florida specifically to engage in beach-related activities. Thus, each year about 21.6 million tourists visit Florida beaches and spend about $5 billion; the "ripple effect" of beach-related activities to the economy is threefold at roughly $15 billion. Direct beach-generated sales tax in Florida amounts to about $500 million annually. Beaches have economic 'power' in that they draw tourists to the coast who provide significant tax dollars to the state.

Additionally, about 80% of the state's residents live in 35 coastal counties which provide about 50% of the state's income. There is thus no denying that beaches generate cash flow and bring in significant tax dollars to the State of Florida. Putting all of this into perspective, it seems evident that loss of tourist dollars on account of eroded beaches or no beaches at all would adversely impact the tourist-based economy of Florida.

(5) How much does it cost to maintain Florida beaches?

The total cost for maintaining Florida's beaches averages between $20 to $40 million per year. The federal share of the total cost historically averages about 50%, or $10 to $20 million. Compared to beach-generated revenues, management costs range from insignificant to minor and when expressed as a percent of total beach-related sales, direct sales, and sales tax the numbers average (based on $30M per year) 0.375%, 1.23%, and 18%, respectively (Table 2). The federal share was figured at about half of these amounts. Typically, Florida spends only about one percent (1%) of the money made from beaches to keep them in working order.

Table 2. *Total cost of beach preservation shown as a percentage of income derived from beach-related activities.*

Income from Beaches	Cost as Percent of $20M Income	Cost as Percent of $40M Income	Average of $20 and $40M Income	50% Federal Project Share
$15B Beach-Related	0.25	0.5	0.375	0.18
$4.6B Direct Sales	0.85	1.6	1.23	0.61
$164M Sales Tax	12	24	18	9

B = Billions of dollars. M = Millions of dollars. Source: FSBPA publications

Almost 27% of the state's high-energy shoreline (370 km out of 1385 km) is classified by the U.S. Army Corps of Engineers as "severely to critically eroded." To catch up on much needed repairs will require spending about 21% ($35M) of the taxes generated by beaches per year for the next ten years. Further, maintaining Florida's beaches at acceptable standards will take at least 12–24% ($20M–$40M) of the taxes generated by beaches each year (Table 2).

Because secular erosion is pervasive and effects all beaches to some degree, new projects are continually brought on line in attempts to preserve the integrity of Florida beaches. The Corps of Engineers estimates that beach preservation during the next decade will require spending on the order of $738 million for projects authorized or in the design phase (Table 3). It is significant that coastal engineers already anticipate projected cost increases for shore protection as more and more natural (non-renourished) beaches require remediation. If a do-nothing policy is adopted for the next decade, it will cost at least $1 billion (projected projects plus normal maintenance) to repair Florida beaches. After taking into account the estimated lost (reduced) income from beaches due to their degraded nature and narrower dry beach width (Table 4), the costs for proper beach management (including periodic renourishment)

Table 3. *Estimated costs for beach preservation during the next decade to year 2007.*

Projects	Cost in 1995 Dollars	Federal Share 50%	Federal Share 65%
Authorized—Await Construction Start	179,875,000	89,937,000	116,918,650
In Preparation & Engineering Design	557,859,000	278,929,000	362,608,350
Total	737,734,000	368,866,000	479,505,000

Source: FSBPA and U.S. Army Corps of Engineers, Jacksonville District

will increase significantly. A modest derease in the amount of sales tax collected (say about 10–30%) increases the proportional costs of beach repair from 12–24% to 27–35% (Table 5). This cost would have to borne by the State of Florida and local communities without the benefit of federal cost sharing or beach-derived income because tourists would probably shun degraded or "sick" (eroded) beaches. Lost income from beaches and proportional increased costs for beach preservation are summarized in Tables 4 and 5.

(6) If Florida beaches are not renourished for a decade, how much beach-generated income might be lost?

Based on beach-related income figures for 1995, several scenarios can be posited (Table 4). Although there will be fewer dollars derived from beach related activities, the pressing question focuses on the degree of loss or amount of decrease.

(7) What future risks might accrue to coastal urban environments, natural habitats, infrastructure, and tourism (recreation) if Florida beaches are not renourished for a decade?

It is estimated that about 20% of the residents

Table 4. *Scenarios for reduced income from beach-related activities due to erosion and loss of dry beach area.*

1995 (BAU)	Reduction in Income 10%	30%	50%	75%
$15B Beach-Related Income	13.5B	10.5B	7.5B	3.75B
$4.6B Direct Sales	4.14B	3.22B	2.3B	1.1B
$164M Sales Tax	147.6M	114.8M	82M	41M

Source: FSBPA and State of Florida documents

Table 5. *Cost to repair eroded beaches in year 2007 expressed as percentages of reduced income from beach-related activities due to no beach renourishment for the preceeding decade.*

Income	A	B	C	D
Beach-Related	2.96	3.81	5.33	10.66
Direct Sales	9.66	12.5	17.39	36.5
Sales Tax	27	35	50	99

A = 1995 Income reduced by 10%. B = 1995 Income reduced by 30%. C = 1995 Income reduced by 50%. D = 1995 Income reduced by 75%

in coastal counties are at risk from coastal flooding by the weakest hurricane (Category 1 storm event on the Saffir-Simpson Scale). In 1992, there were 1.97 million people at risk of coastal high hazard flooding from a Category 1 hurricane. By 2010, it is estimated that 2.31 million people will be at risk from Category 1 hurricane storm surge flooding in Florida. It is thus not surprising to note that Floridians hold 40% of the policies in the National Flood Insurance Program.

AND THE BIG PICTURE?

Although we have visited just one small coastal sector along the Atlantic shore of Florida, it is perhaps worth looking at the big picture to gain a global perspective. Such comparisons may help to emphasize the seriousness of the Clinton Administration's proposal to forego shore protection not only in Florida but along all of America's shorelines.

On a global scale, the coastal zones cover 5×10^6 km^2 (Weber and Gradwohl, 1995). While this represents only 3% of the Earth's land surface, it is equivalent in collective area to half of the United States. Coastal zones are now home to well over 1 billion people with a total population rise projected to at least 3 billion by 2025 (Sadik, 1994). Due to rapid urbanization which attracts migrants from hinterlands, numbers of people in coastal zones are increasing faster than those in other communities. Nearly 20% of coastal zone dwellers live in a city; 9 in 10 of the world's largest cities are coastal, and of the 50 largest, 33 are coastal. Yet coastal zones are increasingly unable to support their human communities and more and more people are being subjected to risk by migrating to these dynamic zones.

The vulnerabilities of large coastal populations, fragility of coastal zone socio-economic infrastructures, and susceptibilities of expensive physical plant in Florida must not be perceived as

some sort of local or specialized problem. These concerns are part of a much larger network of coastal risks that affect all thirty-five coastal states. Should these federal proposals become policy, more Americans will, in the coming decades, become more vulnerable to coastal hazards than anytime before in history.

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