

## Beach Nourishment on United States Coasts

Coastal areas are some of the most popular and sought-after places for human activities. Those with sand beaches are especially desirable for recreation and attract tourism. For this reason, such beaches are important to economies worldwide. This has led to a great deal of development on beaches, especially on the Atlantic and Gulf coasts of the United States, and has prompted measures for protecting them against erosion, such as putting structures on or near them to inhibit wave erosion (“hard” shoreline protection) and replenishing the sand that gets washed away (“soft” shoreline protection).

Sand beaches are also unique ecosystems that can be disrupted by excessive human activity, including the measures used to protect them against erosion. Beach replenishment, also called beach nourishment, is less overtly disruptive to shoreline ecosystems than other measures, but still causes damage, some known and some that has yet to be determined. The economic and political incentives to continue beach nourishment in these areas are many, however, and proponents exist everywhere from owners of beachfront property to developers to the federal government.

While there are several good reasons to continue the practice of beach nourishment in the short term, it is questionable whether it is a sustainable practice in the long term both economically and environmentally. The enormous cost of federal beach nourishment projects, as well as the increasingly temporary effectiveness of the practice as climate change and sea level rise reshape coastal areas on a global scale, raises the moral and practical question of whether it is wise for humans to continue using coasts as intensively as we do currently. Solutions exist to

make coastal living more tenable, but the demands of coastal development as it exists now, including large-scale beach replenishment, make it largely impractical.

### **Background on Shoreline Protection**

Humans have been protecting coastal areas from erosion and inundation for centuries. Shore protection has been well-documented in Europe, revealing that dikes and sea walls have been used in what is now the Netherlands since at least the 8<sup>th</sup> century to protect low-lying areas from flooding (Charlier, Chaineux, & Morcos, 2005). A dune belt was put in place along the present-day Belgian coast sometime between the 9<sup>th</sup> and 13<sup>th</sup> centuries (Charlier et. al., 2005). To protect sandy coasts against erosion, small-scale sand dune stabilization was being practiced in various locations during the 13<sup>th</sup> century, with large-scale dune stabilization common by the 18<sup>th</sup> century (Schlacher et. al., 2007). Major shoreline protection projects began during the 20<sup>th</sup> century, coinciding with an exponential increase in the intensity of coastal development (Schlacher et. al., 2007, p. 557). The first beach replenishment project in the United States took place on Coney Island, beginning in 1922 (Landry, 2002). Many types of beach protection have been implemented over the past 1000 years, including ditches, sea walls, groins, jetties, breakwaters, dune protection, and beach nourishment (Charlier et. al., 2005). Several of these measures are widely used along the Atlantic and Gulf coasts of the United States today, with varying effects and levels of success.

“Hard” shoreline protection measures consist of engineering physical structures that are then placed on or near the beach. The main purpose of this type of shoreline protection is to interrupt longshore currents that cause sand to drift along the beach, so that sand is forced to accumulate in a desired way (Christopherson, 2007, chap. 13). Types of hard shoreline protection include jetties, structures that are placed perpendicular to the coast to block sediment

from collecting in harbor entrances; groins, which are similar in appearance to jetties but serve to slow the drift of sand along beaches; and breakwaters, structures that are placed seaward from the coast and parallel to the shore to create an area of still water at the coastline (Christopherson, 2007, chap. 13). There are problems associated with this type of shoreline protection, however, since disrupting natural coastal drift patterns results in replenishment of sand in some areas and increased erosion in others. Groins, for example, cause increased deposition of sediment on the side impacted by the longshore current and increased erosion on the opposite side.

“Soft” shoreline protection consists of either stabilizing present coastal features, such as sand dunes, or by artificially adding sand to the beach. The latter measure is referred to as beach replenishment, or beach nourishment. This type of shoreline protection, instead of “hardening the shoreline” and redistributing sediment, adds sediment temporarily to the beach and extends it seaward (Peterson & Bishop, 2005). Because it does not interrupt the littoral drift of sediment, it is generally considered the form of shoreline protection that is the least invasive and damaging to the functions of the beach. Unlike groins that cause erosion of downdrift beaches, beach nourishment usually does not adversely affect adjacent areas of shoreline (Dean, 2002).

Beach nourishment is carried out by obtaining large volumes of sand from one area, either from offshore or a more distant source, and placing it on the beach. Sand from offshore is obtained mainly through dredging, which is either carried out by a floating dredge connected to a pipeline which pumps the sand onshore or by a ship equipped with dredge pumps that pulls sand from the bottom onto its deck and then dumps it near the shore, where it can be pumped onto the beach from there (Dean, 2002). In order for the environmental impacts of beach nourishment to be fully assessed, effects on both the beach and the dredge site need to be determined.

## **Environmental Effects of Beach Nourishment**

As with any human modification of the environment, beach nourishment must be carried out with full knowledge of the coastal ecosystem that it is affecting. Sandy beaches are unique ecosystems that provide habitats for several animal species, including shorebirds, sea turtles, benthic invertebrates like oysters, clams, and sea anemones, and other marine life such as fish and crabs (Peterson et. al., 2005). Beaches also perform valuable ecosystem functions such as filtering seawater, supporting coastal fisheries, and recycling nutrients (Schlacher et. al., 2007). Animals living on sandy beaches are dependent on the physical attributes of the beach, such as sediment grain size and composition, chemical composition of sediments, and wave properties (Schlacher et. al., 2007), all of which are affected by beach replenishment.

Evaluations of the effects of beach nourishment on coastal organisms have produced varying, uncertain, and sometimes contradictory results. Several short-term studies have determined that beach nourishment can in fact be beneficial to certain species' shoreline habitats. A study to determine the effects of beach nourishment in the Chesapeake Bay on the habitat of the Northeastern beach tiger beetle concluded that the nourishment projects within the study area provided favorable habitats for the beetles, evidenced by increased numbers of adults and larvae on the beaches after nourishment than before (Fenster, Knisley, & Reed, 2006). This was because the particle size and compaction of the beach resulting from the addition of sand for replenishment was ideal for this particular species, and because nourishment increased the beach to a favorable width (Fenster et. al., 2006). Some literature on beach nourishment practices has identified potential environmental benefits of the practice, such as providing improved nesting sites for sea turtles and certain species of birds (Dean, 2002). Clearly beach nourishment has

some positive environmental effects, but these findings need to be examined in the context of all the possible environmental impacts.

Much of the scientific study on beach nourishment has revealed several potential detrimental effects on coastal wildlife populations. One such effect involves the issue of mismatched sediments and its impact on marine life. When sand for replenishment is brought in from a distant source, a common occurrence as offshore borrowing sites are being exhausted by repeated nourishment projects, care must be taken to ensure that it matches the sand already on the beach in terms of chemical composition and physical properties (Christopherson, 2007, chap. 13). If it does not, disruption of marine life at the coast may occur. For example, sediments that are coarser than the existing sediment may remain on beaches and become concentrated in the biologically important swash zone, where they can modify the natural community composition and abundance of marine invertebrates for years (Peterson et. al., 2005). Beach nourishment also tends to increase the fraction of fine-grained sediments on the beach, which erode more quickly due to wave action and can coat coral reefs or hard-bottom habitats with a veneer of finely-ground sediment that would not have resulted from erosion of the natural sediment and can continue to impact communities in those habitats for 3-10 years (Peterson et. al., 2005). Proper monitoring has not yet been done to determine the extent to which mismatched sediments affect organisms living on the sites of beach replenishment projects, nor has the length of time added sediments affect replenished areas been properly measured (Peterson et. al., 2005).

Excess sand compaction and the burying of animals is another detrimental effect of beach nourishment on coastal habitats. Burial of the animals directly inhabiting the replenishment area is a common short-term effect (Dean, 2002), but long-term evaluations of the effect of repeated burial of organisms have yet to be conducted (Nordstrom, 2005). Excess sand compaction

resulting from beach nourishment has been found to have longer-term detrimental effects. Nourished beaches tend to be harder and more compact than natural beaches, and therefore provide a less suitable habitat for nesting sea turtles (Dean, 2002).

Other characteristics of beach replenishment that can adversely affect coastal species include different color properties of sand brought in for replenishment and the formation of steep erosion scarps on the higher-elevation beach resulting from the addition of sand. The survival rate and sex of sea turtle eggs is dependent to a large extent on the temperature of the sand around them. Sand temperatures between 32 and 34 degrees Celsius will cause most of the eggs to be female, while temperatures between 24 and 28 degrees will produce more males (Dean, 2002, p. 198). If the sand added during replenishment is darker or contains a higher percentage of silt than the natural sand, it will absorb more solar radiation and become warmer, resulting in more females or a lower survival rate in general, depending on how much the temperature is raised (Landry, 2002). Slopes of nourished beaches also tend to be steeper than natural beaches. In order to protect against flooding, federal standards require the replenished beach to be higher than a natural beach. This restricts the movement of water onto the beach and creates erosion scarps that can make it difficult for fauna such as sea turtles to get onto the beach (Nordstrom, 2005). These effects can be controlled for to some degree, but others, such as differential sand bleaching properties, can persist over the long term (Dean, 2002).

The conclusions reached by the above studies and others convey a large sense of uncertainty regarding the environmental effects of beach nourishment. Both positive and negative impacts were found, as well as many areas in which more research is needed before the effects of beach nourishment can be determined. Some causes for the current uncertainty regarding the environmental impacts of beach nourishment are incomplete monitoring of dredge

and fill sites, poor scientific practice in many of the monitoring reports that do exist, and conflicts of interest between the researchers and the agencies that fund them.

Most of the beach nourishment projects carried out in the United States are federally funded and carried out by the US Army Corps of Engineers (USACE). As a result, monitoring the onshore and offshore effects of these projects is overwhelmingly conducted through government agencies, which often do not invest in funding the rigorous scientific investigation necessary to determine the complex environmental responses to beach nourishment (Peterson et. al., 2005). Nordstrom (2005) pointed out that most monitoring practices are concerned with making sure sand stays in the fill areas, and that studies to evaluate adverse effects on marine life are rare. When such studies are conducted, comparably simplistic means such as documenting fish populations as indicators of environmental stress are often used. This is problematic because it does not reveal impacts on the many other animals living in coastal environments, and is purely observational, lacking the use of more sophisticated scientific tools such as modeling (Peterson et. al., 2005). Other factors were left out of several monitoring studies, such as habitat topography at dredge sites, which is significant because deeper pits caused by dredging leads to finer sedimentation and slower recovery of marine invertebrates (Peterson et. al., 2005).

Poor scientific method also plagues many of the monitoring studies. One example of this is, when comparing nourished beaches with natural ones, the “natural” beach sites that are used as control sites are often contaminated with sediment that has drifted over from the nourished area, or else they had been nourished at some point in the past (Peterson et. al., 2005). This was the case in a beach nourishment study of a North Carolina beach that was mentioned in the article on the beach tiger beetle discussed earlier. The North Carolina study had determined that detrimental effects on beach fauna could not be attributed to beach nourishment because the

effects were documented beyond the nourishment site (Fenster et. al., 2006). However, the movement of sediment from nourished areas through littoral drift could have easily contaminated that study's control site, which could possibly explain why some of the effects extended beyond the initial nourishment site.

Another way in which many of the studies violate common rules of scientific practice is that they are not peer reviewed by anonymous scientific organizations (Peterson et. al., 2005). Peer review is essential to ensure that studies claiming to be based on sound science reached their conclusions in an objective and repeatable manner. Many of the monitoring studies, however, are reviewed by private contractors rather than people in the scientific community, and such contractors often are proponents of beach nourishment (Peterson et. al., 2005). Putting the review of studies determined to evaluate the effects of beach nourishment in the hands of those biased in favor of it does not help to ensure that the study is evaluated based on its objectivity, and instead makes it likely that any positive biases in the study will be overlooked.

One of the biggest impediments to clear scientific evaluation of beach replenishment projects is the fact that many of the studies meant to monitor the success of federal beach nourishment projects are funded by the Army Corps Engineers itself. This creates a conflict of interest, which can often result in the underreporting of negative effects of a project if the funding agency has an interest in portraying the project in a positive light. The findings of the beach tiger beetle study, while they seem to be based on sound science, are somewhat compromised by the fact that the study was funded in part by the USACE and the US Fish and Wildlife Service, which had both "developed agreements that would permit nourishment at these two sites if deposition minimized the effect on the beetle habitat" (Fenster et. al., 2006, p. 1134). Since the USACE authorized and carried out the beach nourishment project, it was in its best

interest for the study to reveal that the beetles were not negatively affected so as to retain its credibility as a protector rather than a destroyer of the environment. Because the study that the USACE itself funded showed beach nourishment to be beneficial to the beetle community, it raises questions as to what extent the funding agencies' agendas influenced the findings of that study, as well as the findings of other monitoring studies.

While beach nourishment is arguably less detrimental to the natural environment than measures of "hard" shoreline protection, is it not entirely devoid of adverse environmental effects. Studies evaluating the effects of beach replenishment have revealed both positive and negative impacts, as well as many uncertainties that still exist regarding the long-term effects. From evaluating the environmental studies on the effects of beach replenishment, it has become clear that there is a strong bias in favor of the practice that is held by certain actors, including the federal government. The way this relates to the practice of beach nourishment reveals the many human factors that influence beach replenishment, as well as the impacts of the practice on human populations. These topics will be the focus of the next section.

### **Human Issues Related to Beach Replenishment**

Beaches in the United States are highly valued for their role as destinations for recreation and tourism. Sand beaches, like the ones that line the Atlantic and Gulf coasts, are the most highly used type of seashore in the world, attracting millions of visitors each year (Schlacher et. al., 2007). Because they attract so much human activity, these types of beaches also are highly important for coastal economies. Ocean City, Maryland, whose shoreline is its main attraction, brings in over \$85 million in state revenues each year (US Army Corps of Engineers, 1993). As sand beaches are such a desirable destination for tourism and vacation housing, many of them are highly developed, with millions invested in infrastructure to facilitate tourism such as hotels,

stores, roads, and vacation homes. But due to the nature of beaches as dynamic features, there is a constant risk of property loss for infrastructure along the coast (Peterson et. al., 2005). Fixed human structures block the natural migration of beaches inland, resulting in apparent erosion and narrowing of the beach (Nordstrom, 2005). To protect these structures and the millions invested in them against loss, huge amounts of money are spent on erosion mitigation measures, including beach replenishment. One replenishment project in Ocean City in 1988 cost \$13.5 million (US Army Corps of Engineers, 1993). The way beach nourishment projects are funded along U.S. coastlines is an issue of some controversy.

As mentioned, the US Army Corps of Engineers is responsible for most beach nourishment projects on U.S. shores. This has been the case since the first federally funded project was conducted in New Jersey in 1962, after a storm destroyed many of the state's beaches (Landry, 2002). Since then, the Army Corps of Engineers has spent increasing amounts on beach replenishment, spending \$40 to \$70 million annually by the early 1990s (Bagstad, Stapleton, & D'Agostino, 2007). For federal replenishment projects, 65 percent of the costs are covered by the federal government in the form of federal tax revenues, while 35 percent are shared by the state and local governments of the area being replenished (Landry, 2002, p. 185). The controversy in this method of funding involves the large share of the cost that is paid for by federal taxpayers, who share the burden equally but may not benefit equally. For example, taxpayers across the country pay to have beaches in New Jersey replenished, but only a few of them may ever go to those beaches (Landry, 2002). Someone from Pennsylvania is much more likely to visit a New Jersey beach, or any east coast beach, than someone from Kansas, even though they are both paying federal taxes to be able to enjoy those beaches.

The discrepancy between those who supply the funds and those who enjoy the benefits of beach replenishment extends further, however. Before a project can qualify for funding in the first place, federal regulations stipulate that its main purpose must be the protection of private and public property from flooding (Landry, 2002). This effectively limits federal beach nourishment projects to coastal areas with a great deal of development, and therefore with high economic value. Because these areas are more likely to attract tourism, they presumably bring in a lot of revenue, and therefore the federal policy acts to subsidize the wealthier areas of coast (Landry, 2002). Even though some beneficiaries of beach replenishment, such as residents of the state and local area in which the project is taking place, help pay the local areas' 35 percent share of the cost indirectly through local taxes, those who arguably benefit the most directly from beach replenishment are the owners of hotels on beachfront property. They benefit through the increase in customers that results from the hotel having sufficient beach access and space, which brings in more money for the hotels themselves. Private hotel owners thus capture a part of the federal subsidy by not having to pay a portion of the replenishment costs comparable to the monetary benefits they enjoy from it (Landry, 2002).

There are solutions that would more equitably distribute the costs of beach replenishment. The clearest one is to put funding of the projects at the local level through taxing local businesses, hotel owners, and property owners, so that those who benefit from beach replenishment are the ones paying for it. Several communities in South Carolina have done this already, as well as homeowners on Fire Island, New York, who paid the costs of the emergency beach replenishment program undertaken in 1994 (Landry, 2002; Katz, 1999). Another possible solution would be to fund beach replenishment under the National Flood Insurance Program. Since federal beach nourishment projects are currently limited to locations where they would

provide flood protection, this would only make sense, and it would more evenly distribute the economic burden of beach nourishment to those who chose to build on coastal areas since they are required to enroll in the program anyway (Bagstad et. al., 2007).

A final issue regarding beach nourishment that needs to be evaluated is the long-term effectiveness against beach erosion and its sustainability as a mitigation strategy. Many factors currently coming to light indicate that while beach nourishment may be a good short-term strategy, its effectiveness in the long term is questionable. The enormous cost of beach replenishment, usually between \$1000 to \$3000 per meter of beach (Dean, 2002, p. 1), is one concern, although many proponents of the practice point out that it is a small price to pay for the protection of their investments (Landry, 2002). But this cost must be compared to the largely uncertain but usually short lifespan of nourished beaches. The Army Corps of Engineers claims sufficiently long-lasting effects of beach replenishment projects, such as the one in Ocean City, Maryland that was said to provide 10-year storm protection (US Army Corps of Engineers, 1993), but one strong hurricane can wipe out the entire effort (Christopherson, 2007, chap. 13).

The length of time the nourished beach can be maintained also depends on the natural stability of the beach. Some can last years, but others disappear quickly, as demonstrated by a \$5 million effort to restore a beach in Ocean City, New Jersey, which completely washed away within three months (Landry, 2002, p. 188). Investigations by Duke University's shoreline development program revealed the life spans of several beach nourishment projects along the Atlantic coast to be ten times less than the USACE estimates, with more realistic estimates averaging between one and three years (Landry, 2002, p. 189). Beach replenishment is a continuous process, and the constant replenishment needed to sustain these beaches entails costs much greater than those predicted by federal and state governments.

In addition, costs of beach nourishment will likely increase dramatically in the future. The first reason for this is the diminishing onshore and near-shore supplies of sand that can be dredged (Drucker, Waskes, & Byrnes, 2004). Huge costs are associated with transporting sand from increasingly distant dredge sites, an act that could cause jurisdictional conflicts as well (Dean, 2002). The increased storminess and sea-level rise due to climate change will have significant impacts on coastal areas, and will certainly increase rates of beach erosion over the next century. This poses an increasing threat to human developments along the coast, which in turn will create more demand for shoreline protection measures such as beach replenishment, the cumulative long-term effects of which are currently unknown (Peterson et. al., 2005; Schlacher et. al., 2007). Moreover, frequent replenishment makes it difficult to determine the beach's natural rate of erosion, which is necessary in order to predict how the beach will behave once the nourished portion is washed away and allow development risk to be assessed (Morton, Miller, & Moore, 2005). This may provide developers with a false sense of security that the beach will remain stable over the long term.

Coastal erosion is certain to become more of an issue in the foreseeable future. The short-term solution of using beach replenishment or other shoreline protections to battle the effects of natural coastal processes is virtually always chosen over longer-term strategies like gradually moving infrastructure away from the coast (Schlacher et. al., 2007). Such strategies may eventually be the only practical solutions, and may include stricter land use controls, pushing back new construction projects from the coast, and retreat policies involving the relocation of existing structures away from high erosion areas (Nordstrom, 2005). The conversion from short-term to longer-term strategies will involve not only a change in policy, but a change in human views toward nature as well.

## **Conclusions and Analysis of Moral Issues Regarding Beach Nourishment**

The issue of beach nourishment is a complex one, with many stakeholders who stand to gain from the practice and varying degrees of environmental effects. In terms of environmental consequences alone, there does not yet seem to be enough information to conclude that the practice is overtly harmful and needs to be stopped. Evidence does reveal several real and potential detrimental effects on coastal animal populations, however, and many studies conclude that more investigation needs to be done to determine the extent of the impact beach nourishment projects have on marine life. The fact that the US Army Corps of Engineers continues beach replenishment efforts unhindered despite the lack of sufficient long-term environmental impact studies raises questions as to whether leaving the majority of beach nourishment projects to a federal agency is the most responsible way to go about it.

The practice of beach nourishment as a short-term solution to coastal erosion is not negative per se, as long as the costs and benefits are distributed equitably. Many of the economic concerns surrounding beach replenishment become irrelevant when projects are funded at the local level by those who are going to benefit from it. The methods used to fund federal projects are of questionable fairness, as it places part of the burden for funding beach replenishment on federal taxpayers who may never see the benefits.

The biggest concern that beach replenishment and other methods of artificial shoreline protection raise goes beyond concerns for the immediate environment and fairness of cost distribution. Such measures bear similarities to other human efforts to conquer the environment, and raise the moral question of whether it is right for humans to be so presumptuous as to think we can control nature. The way that actors involved in beach nourishment view beach movement and climate change as an inconvenience, or something that needs to be mitigated in

order for them to continue living as they please, is very short-sighted. Their willingness to allow millions to be spent on temporary solutions to keep their beachfront property instead of moving to more hospitable locations slightly inland, their support of beach nourishment practices without the full knowledge of their environmental effects, and their indifference to the fact that they are impeding natural processes all suggest a certain amount of greed on the part of beach nourishment proponents. The view of environmental processes like coastal erosion as impediments to human progress without considering the opposing view is a mindset that ultimately does not lead to sustainable interaction with the natural environment. Even use of the term “erosion”, which tends to have a negative connotation, is relative, as the natural landward movement of beaches would not be characterized as a problem if it weren’t putting human structures at risk. Beach nourishment is not a terrible thing, but it can provide people a false sense of security regarding their ability and mandate to control the natural environment.

In conclusion, beach nourishment is the least invasive of all shoreline protection measures, but it is not without environmental effects. It is also a very costly procedure, which has fueled some controversy as to the fairest way to fund it. In the short term it appears to be a reasonable shore protection measure, but in the long term it may not be practical in the face of increasing erosion from storms and sea-level rise. Over the long term it may be wise for people to rethink the intensive development of coastal areas, and move toward more permanent measures of beach protection such as building structures farther away from the coast.

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