COASTAL HAZARDS AND ECONOMIC EXTERNALITY: IMPLICATIONS FOR BEACH MANAGEMENT POLICIES IN THE AMERICAN SOUTHEAST

A HEINZ CENTER DISCUSSION PAPER

MAY 2002

Warren Kriesel
Department of Agriculture and Applied Economics
The University of Georgia

Robert Friedman
The H. John Heinz III Center for Science, Economics and the Environment

This Discussion Paper provides the technical basis for a shorter paper by the same authors that has been submitted to *Shore and Beach.* This Discussion Paper was peer-reviewed by *Shore and Beach,* and this version reflects the authors' response to that review. The Heinz Center makes this longer version available here as a service to scholars and others interested in the details of the findings. The views expressed are those of the authors and not necessarily those of the Heinz Center.

THE H. JOHN HEINZ III CENTER FOR SCIENCE, ECONOMICS AND THE ENVIRONMENT
1001 Pennsylvania Avenue, N.W., Suite 735 South, Washington, D.C. 20004
Telephone (202) 737-6307 Fax (202) 737-6410 www.heinzctr.org

ABSTRACT

To better understand the community-wide implications of coastal erosion and erosion management measures to minimize its impacts, we analyzed data on about 1200 properties in nine southeastern U.S. counties. Not only is erosion responsible for hundreds of millions of dollars of property damage each year, the threat of erosion, that is, merely being located in an erosion-prone area, significantly lowers property values as well. Both beach nourishment and shoreline stabilization can help waterfront property owners protect the sales value of individual properties. However, when analyzed at the scale of a community, the implications of the two approaches are quite different.

Beach nourishment increases property values for both waterfront properties and for non-waterfront properties a few rows inland. Thus the total benefits to the community may be substantially greater than estimated for waterfront properties alone, as is typically the case. In contrast, shoreline stabilization appears to lower property values a few rows inland. Thus, while it is beneficial for each individual waterfront property owner to stabilize his shoreline, non-waterfront property owners lose value as a result of the actions of near-by waterfront owners. Moreover, as more and more waterfront property owners rely on shoreline stabilization, waterfront property values decline as well. The first few property owners to stabilize their shoreline achieve significant benefits, but as more and more of their neighbors follow suit, property values drop to about where they started.

INTRODUCTION

Leatherman, Merrell, and Friedman (2001) have summarized the results of The Heinz Center "Evaluation of Erosion Hazards", a major analysis of coastal erosion and its impact on the National Flood Insurance Program (Heinz Center 2000a.) That study concluded that during the next 60 years, coastal erosion may claim one out of four houses located within 500 ft of the U.S. shoreline. Nationwide, over the next 60 years, coastal erosion may be responsible for the loss of about 1,500 homes per year--costing coastal property owners about $500 million per year, including both damage to structures and loss of land.

However, two key assumptions were made in The Heinz Center study. First, the damage estimates above assume no additional shoreline stabilization or new beach nourishment projects over the next several decades. Because we had no way of estimating the likelihood of new projects, we simply assumed that historical rates of change (including the effects of nourishment during the applicable time frame) continue into the future. To the extent that coastal communities choose to nourish their beaches during the next 60 years or stabilize their shores, fewer homes will be lost.

The estimates above also do not include damage to structures not yet built. Growth in erosion-prone areas is, in part, under the control of states and local communities. We had no way of determining how many communities might avoid such growth by instituting, for example, erosion setbacks. But absent changes in policy, some growth will occur in erosion-prone areas, and the estimate of the number of homes lost over the next 60 years will be low.

In this paper, data collected on about 1200 properties is analyzed to better understand the economic implications of beach nourishment and shoreline stabilization on both waterfront properties and properties several rows inland. Such information will be helpful to state and local officials facing coastal protection and development decisions. Both methods of protection offer advantages to waterfront properties when considered alone. However, when actions are taken and analyzed at the scale of a community, that is, when many waterfront properties in a community opt for shoreline stabilization or when a substantial stretch of a community's beachfront is nourished, the economic implications can be quite different.

Our results indicate that beach nourishment increases property values both for waterfront properties and for non-waterfront properties. Thus the total benefits to the community may be far greater than estimated for waterfront properties alone, as is typically the case.

In contrast, shoreline stabilization appears to lower property values for non-waterfront properties. Thus, while each individual waterfront property benefits, non-waterfront properties lose value as a result of the actions of nearby owners. Moreover, as more and more waterfront properties rely on shoreline stabilization, waterfront property values decline as well. The first few property owners to stabilize their shoreline achieve significant benefits, but as more and more of their neighbors follow suit, property values can drop to about where they started.

These findings have important implications for communities grappling with the threat of coastal erosion. Shoreline stabilization can lead to a classic "tragedy of the commons" (Hardin, 1968). While it may be attractive to an individual, the property values within the community as a whole will suffer if it allows too many property owners to rely on this method. Though questions still remain about the environmental consequences of beach nourishment (NRC, 1995), a community's major concern is likely to be about cost. Our results imply that property prices will rise as a result of beach nourishment—for both the waterfront and non-waterfront properties. Thus communities may have been underestimating their ability to pay for beach nourishment themselves. Few communities have undertaken large-scale nourishment projects by themselves, rather they have waited until the majority of funds could be obtained from the federal government.

DATA AND METHODS

The Heinz Center report's conclusions are based on detailed field measurements and mail survey information collected on approximately 3 percent of the buildings located within 500 feet of the shore. The Heinz Center sent field survey teams to measure and photograph 11,450 structures in 18 coastal counties. Additional information on the surveyed structures was obtained from county assessor and similar offices, and detailed questionnaires mailed to the owners. The research team intensively studied 120 miles of shoreline, or about 1 percent of the U.S. coastline outside of Alaska and Hawaii. The additional analyses presented in this paper used a subset of the data, the ten Atlantic and Gulf of Mexico coastal counties only.

The effect of beach management options on property value was estimated by analyzing the primary components of coastal property values (e.g., house size, ocean view, neighborhood, etc.) and then comparing typical properties with and without beach nourishment, shoreline stabilization, and along naturally stable and eroding shores. The statistical technique used to estimate these relationships was a type of regression analysis called "hedonic price analysis" (see Freeman, 1993). The method is commonly used not only to estimate such relationships, but also to predict how certain changes (such as building a bulkhead) may lead to other changes (for example, in property value).

Hedonic price analysis uses market sales prices of houses in a given area as the dependent variable. Many independent variables can be included, for example, structural characteristics such as number of bedrooms and square footage that affect the value (and therefore the sales price) of a house. Neighborhood characteristics are usually included as well (such as distance from an urban center). Environmental factors can also affect the sales price (see MacDonald, 1987). For research on coastal hazards, such factors include whether the property is ocean or lakefront; the house's elevation above the forecast height of a one-percent chance flood; and the distance from, and erosion rate of, the shore. Hedonic price analysis allows researchers to estimate the relative contribution of the independent variables to the house sales price, which, in turn, implies the value of those factors to consumers.

Once such an analysis is conducted, the model can also be used to predict how housing prices will change given a change in one of the independent variables. For example, if erosion rates increased by 1 foot per year, how would housing prices be expected to change? Or, if beaches are nourished, what will happen to housing prices?

Detailed descriptions of data collected and methods used are presented in a set of appendices to the original study (Heinz Center, 2000b).

EMPIRICAL SPECIFICATION OF THE HEDONIC MODEL

Both flooding and erosion risks affect the price of coastal properties. Buyers can protect themselves from flooding by purchasing a house that is built on land or piles elevated above potential flood waters or they can purchase flood insurance. All susceptible properties in the sampling frame for this study have the opportunity to buy flood insurance underwritten be the

NFIP, except those properties in the Coastal Barrier Resources System (and we account for these separately). Physical flood protection is measured with the variable *Elevation*, the height of the first floor compared to the "base flood elevation", i.e., the expected height of one-percent chance flood. If buyers suspect incomplete compensation for losses from NFIP (as suggested by MacDonald, Murdoch and White, 1987), then *Elevation* should have a positive effect on price.

Buyers can also reduce risk of loss if they purchase a house that has been constructed under FEMA's mandated building codes. *Built Post-FIRM* is a dummy variable that provides a measure of a given structure's resistance to flood damage. It is set to '1' if the house was constructed after the community's acceptance into the Regular insurance program, when more stringent building codes were first required. According to Davison (1993), large reductions in storm losses have resulted from the construction standards that include hurricane wind resistance and the use of pilings that elevate a building above flood waters. Therefore, houses built under these standards should be more valuable, after accounting for the house's age, and the regression coefficient for *Built Post-FIRM* should have a positive sign.

A lower rate of shoreline erosion probably will have a positive effect on property values, assuming many buyers are aware of the increased risk from erosion. In some—but by no means all—areas, property-specific erosion information is available to prospective buyers.

As suggested by Kriesel, Randall and Lichtkoppler (1993), it is likely that buyers will tolerate some erosion if risk to the property is buffered by a sufficient distance separating the building from the water. Assuming that buyers are indifferent between the source of their erosion protection, these two risk-reducing effects can be combined into one variable, *Geotime*. *Geotime* is defined as the expected number of years until the buffering distance is zero, given the property's historical erosion rate. For example, consider a building which was 200 feet from the water when purchased. If the historical erosion rate is 4 feet per year, then *Geotime* is equal to 50 years until the water is likely to threaten the building.

Geotime, *Elevation*, and *Built Post-FIRM* are the primary measures of flooding and erosion risk. There are other factors that also affect risk, such as the beach width, beach nourishment and erosion control structures. However, these factors also affect the property's amenity value. For example, consider the distance separating the building from the water, defined as the variable *Distance to Water*. Greater *Distance to Water* reduces the ocean view and beach access, thereby decreasing the property's value. However, greater *Distance to Water* reduces risk of storm damage, through the physical distance and through *Geotime*, thereby increasing the property's value. Therefore, it is possible that the *Price-Distance to Water* curve would have a bell shape. If the hedonic also contained a dummy variable for waterfront property, then price could be lowest at the beach. Houses slightly inland would increase in price in response to the risk-reducing feature of *Distance to Water*, but only to the point where they are no longer vulnerable to hazards. Price would be at a maximum at this point and it would thereafter decline as the amenity value is lost. To capture this nonlinearity in the price gradient, a specialized functional form for the hedonic equation is employed.

The double log functional form was applied successfully to similar research by Kriesel, Randall and Lichtkoppler (1993). The functional form should also reflect how waterfront properties are most affected by the presence of erosion protection, while non-waterfront property owners (i.e., those 500 or 1000 feet back) face a very low prospect of erosion damage. To add more flexibility to the model the square of the natural logarithm of *Geotime* was included as an argument. Thus, the functional form used was:

$$\ln \textit{Property Price} = \beta_0 + \beta_1 \ln (D/E) + \beta_2 [\ln (D/E)]^2 + \beta_3 \ln D + \dots + \beta_k X_k$$

where ln indicates the natural logarithm of a variable, the ∃s are regression coefficients, D is the *Distance to Water*, E is the historical erosion rate measured in feet lost per year, and the other variables X_1 through X_k are entered the natural logarithm of their value. This functional form permits the concavity hypothesized for the price gradient with respect to distance[1].

Coastal properties possess other characteristics which simultaneously offer protection and amenity value. *Beach Width* is one of these factors because a wider beach reduces the strength of storm waves. Simultaneously, a wider beach presents more spaciousness for residents and visitors to enjoy. Therefore, the variable *Beach Width* should have a positive impact on property values.

Properties at the waterfront will be worth more because of the better view, shorter walk to the beach, etc. If the risk aspects of proximity are captured by *Distance to Water, Geotime* and

---

[1] It can be shown that the second order sufficiency condition for maximizing the property price, P, with respect to distance is $P/D^2 \{2 \beta_2[1-\ln(D/E)] - (\beta_1 + \beta_3)\} < 0$.

Elevation, the net effect of being waterfront should be positive. The dummy variable *Waterfront* should capture this effect.

The effect of shoreline stabilization is more ambiguous. The types of stabilization reported by survey respondents included rip-rap, seawalls and groins. Stabilization protects property on the waterfront from the disappearance of land and damage to the buildings, and this is a beneficial effect on prices for risky waterfront (but not non-waterfront) property. However, stabilization may also decrease property prices due to degradation of beach amenities such as recreation, aesthetics and natural habitat. If buyers value these beach amenities, and if stabilization significantly degrades them, then stabilization would reduce property prices.

Waterfront property buyers probably desire the assurance of safety that stabilization lends to the property (a positive effect on price). This effect is represented by a dummy variable *Waterfront Stabilization,* defined as 1 if the property was on the waterfront and had hard stabilization, and is zero for other properties.

On the other hand, non-waterfront property owners may care little about erosion protection for their waterfront neighbors. Their property may experience little if any beneficial effect from stabilization. For them a net negative perception of stabilization would be expected, since they may regard the seawall or rip-rap as unsightly and it can impede their beach access (a negative effect). This differential effect is captured by *Percent Stabilization,* defined as the percent of waterfront properties within a community which reported that they were protected by stabilization. If the stabilization is the type that degrades such beach amenities as recreation and natural habitat, and if non-waterfront property buyers care about these amenities, then *Percent Stabilization* would have a negative effect on property prices.

A similar situation may exist for large-scale beach nourishment projects. Nourishment can maintain some beach amenities that would be lost otherwise to erosion. Furthermore, coastal property buyers probably recognize that they do not pay the full costs of nourishment. Large projects are typically financed from federal or state government sources. Since nourishment may cost the buyers little or nothing, houses at nourished beaches should be worth more. *Beach Nourishment* is a dummy variable that equals 1 if the property is in a community whose beach has been renourished periodically, and it is zero otherwise. In our sample of coastal communities, some “0” beaches were nice and natural but the majority were armored with rip-rap, groins, etc. We think that within this sample nourishment would be preferred, so its effect upon price should be positive.

In addition, waterfront property buyers probably recognize that nourishment is a type of risk reduction against erosion damage. Given a choice, most waterfront property buyers would prefer the house whose protection is renewed periodically, especially if the government pays for it. Another dummy variable, *Waterfront Nourishment* can capture whether nourishment has a different effect on the value of waterfront versus non-waterfront houses. *Waterfront* and *Beach Nourishment* should have a positive coefficient. We also expect that *Waterfront Nourishment* is positive, that is, beach nourishment increases the value of a waterfront property more than a non-waterfront property.

Table 1 lists the variables with each one's hypothesized effect on price. The seven structural characteristics are fairly standard property descriptor variables found in the literature. All of these variables are entered in logarithmic form and should have a positive influence on the quality of the property and, therefore, its price. Exceptions that should be negative are the two variables associated with time: *Age of House,* a measure of depreciation, and *Age of Transaction*, whose coefficient can yield an estimate of the average annual price appreciation rate for coastal property. All of the variables are measured as they existed at the time of the last purchase. In the regression, the location of each property is indicated by a dummy variable for the property's county. They are not reported here to conserve space.

EMPIRICAL RESULTS

Starting from the full FEMA data set, we decided to focus on the Southeast United States. Most of the FEMA study counties were in this region and the uniform geological character of this coast facilitates lumping the counties together for a large study. The represented counties on the Atlantic coast are Sussex, DE, Dare and Brunswick, NC, Georgetown, SC, Glynn, GA, and Brevard, FL. Counties on the Gulf of Mexico are Lee, FL, and Galveston and Brazoria, TX. Fifty coastal communities are contained in these nine counties. Within the 9 counties, 1,262 residential properties had data complete enough to be included in the analysis.

Table 1 lists the summary statistics of the 20 variables in the regression analysis of property prices. The sale price was $179,390 for the average property purchased twelve years prior, in 1987 (in 1999, this average house was priced at $570,000). This average property contained about 13,000 square feet of land, or slightly more than a quarter acre lot. The average house had 1,860 square feet, 3.5 bedrooms, and was 26 years old. Each of the dummy variables is entered with 1-0 values, and as such their means represent the proportion of properties that possess a characteristic. For example, the mean of the *Fireplace* variable is 0.43, which means that about 43 percent of the houses had a fireplace.

Table 2 lists the regression results. The model performs well with 67 percent of property prices' variation explained by the variables in the regression.[2] Of the 20 independent variables, the associated null hypothesis is rejected at the five percent level for 16 of the variables. Surprisingly, the *Waterfront Nourishment* variable was negative (and smaller in absolute magnitude than *Beach Nourishment*.) This implies that beach nourishment increased the value of both waterfront and non-waterfront properties, but the value of non-waterfront properties increased more.

The first column lists the regression's beta coefficients. Since all continuous variables are expressed as natural logarithms, the beta coefficients can be interpreted as elasticities. For example, the coefficient for *House Size* is 0.55. This says that when a property's square footage increases by one percent, its price increases by 0.55 percent. Similarly, the coefficient for *Distance to Water* is -0.024, indicating that a house that is one percent further from the beach is priced 0.024 percent less.

Another way to interpret the regression results is listed in Table 2 as the marginal effects column. A marginal effect states how price, measured in dollars, would change in response to a one-unit change in an independent variable. For example, the marginal effect for *House Size* is 53.65. This means that an additional square foot increases property price by $53.65. The marginal effects do not apply to the dummy variables.

To interpret the dummy variable coefficients, consider the coefficient for *Built Post-FIRM* of 0.204. This is the amount by which the natural logarithm of property price changes for a house constructed in compliance with newer, more stringent building codes compared with the

[2] White's generalized test was applied to the model and no evidence of heteroscedasticity was found. The condition index was somewhat high at around 125, but the model displays no effects of damaging multicollinearity, i.e. wrong signs on coefficients, low t-ratios, etc.

base situation, i.e. a house built prior to the code changes. To find the percent change in price, apply the simple formula:

$$\text{percent change in price} = (e^{\beta} - 1) \times 100.$$

The antilog of 0.204 is 1.226, so that buyers value a house built under the FEMA building code 22.6 percent more than a comparable house.

The variables that describe coastal hazards—*Geotime*, *Elevation*, and *Built Post-Firm*—are all significant predictors of property prices. This implies that property buyers recognize that flooding and erosion are real threats to their financial well-being and that risk-prone properties are discounted in the coastal real estate market. The fact that this discounting occurs even though the risk is insurable through the NFIP implies that property buyers do not believe that they would be fully compensated by insurance in the event of damage. Indeed, the NFIP maximum coverage of $250,000 is well below the current price of many coastal properties. Therefore, buyers seek to protect their assets by purchasing property that is less risk-prone and the prices of these properties are bid up, as demonstrated by this regression analysis.

Among the variables that describe the beach amenities, *Waterfront* is significant. Its coefficient of 0.32 indicates that a waterfront property is priced 37.7 percent more than a comparable non-waterfront property. *Distance to Water* and *Beach Width* are not significant.

There are four variables that describe the erosion management alternatives: *Waterfront Stabilization*, *Percent Stabilization*, *Waterfront Nourishment* and *Beach Nourishment*. These, together with the *Waterfront variable*, are used to simulate how the management alternatives affect property prices.

THE EFFECT OF SHORELINE MANAGEMENT ALTERNATIVES ON PROPERTY PRICE

We used the statistical model described above to estimate the effects of shoreline stabilization and beach nourishment on both waterfront and non-waterfront properties. The hypothetical waterfront property is located 150 ft from the shoreline. The hypothetical non-waterfront property is set back twice this distance, i.e., 300 ft inland. We have set the erosion rate for our typical eroding shoreline to 3 ft/yr, a rate commonly found in many communities along the Atlantic and Gulf coasts. Thus, unless protected, the waterfront property is likely to be destroyed by erosion within 50 years (150 ft divided by 3 ft/yr), while the non-waterfront property has an expected remaining life of 100 years. The erosion rate for a stable shoreline has been set to less than 0.1 ft/yr.

We evaluated the expected property price for six different cases of waterfront properties:

1. A waterfront property behind a stable shoreline.
2. An identical property in all respects except that it is located behind an eroding shoreline.
3. A waterfront property in a community that is nourished to deal with an eroding shoreline.
4. A waterfront property behind a stabilized, formerly eroding shoreline, but one of few stabilized shorelines in a community.
5. An identical waterfront property behind a stabilized, formerly eroding shoreline, but in a community with half of the houses behind stabilized shorelines.
6. A waterfront property behind an unprotected, eroding shoreline in a community with half of the houses behind a stabilized shoreline.

Similarly, we evaluated the property price expected for four different cases of non-waterfront properties:

7. A non-waterfront property behind a stable shoreline.
8. An identical non-waterfront property behind an eroding shoreline.
9. A non-waterfront property in a community that is nourished to deal with an eroding shoreline
10. An identical non-waterfront property in a community with half of the houses behind stabilized shorelines.

The results are presented in Table 3 and summarized below. A waterfront home with no erosion threat is valued at $640,000 (case 1). A comparable home that is threatened by an erosion rate of 3 ft/yr—again, the typical value for the Atlantic and Gulf coasts—looses about 25 percent of its value (case 2). If the community nourishes its beaches, the comparable house in case 3 can reclaim over half of this loss (a 15 percent increase over the eroding case 2.)

Interestingly, a property owner can achieve about the same gain if he is the only one to stabilize his shoreline (case 4). But if half of the community's shoreline is stabilized, everyone is back to where they started (case 5). This can be seen from the significantly negative effect that the *Percent Stabilization* variable has on sales price. And for the other half of property owners who do not stabilize their property in case 6, their property values drop to 12 percent below case 2 where everyone does nothing. We hesitate to extrapolate to a shoreline that is 100 percent stabilized because none of the communities in the data set were in that situation.

The next set of comparisons is for non-waterfront properties. A non-waterfront home near a stable shoreline is worth $499,000 (case 7), but if the nearby shoreline is receding at the 3 ft/yr, the comparable non-waterfront home is worth 23 percent less (case 8). It may seem odd that even the houses that are physically separated from the shore are affected by erosion. However, this is a result of risk-averse homebuyers reacting to prospective erosion damage, and can be seen in the magnitudes of the coefficients for the Geotime variables.

If the community's beach is renourished, housing values in the non-waterfront rows increase to just about the same as those within a community with a stable shoreline (case 9). If half of the waterfront property owners in the community stabilize their shoreline, the housing values in the non-waterfront rows are about 12 percent below the case where the shoreline is left to erode (case 10). This illustrates how the actions of threatened waterfront property owners have the unintended side effect of harming their inland neighbors, and this situation fulfills the classical definition of a negative economic externality.

These findings have significant implications for communities with many homes at risk of damage from erosion. Considering community-wide property price impacts—rather than the effects on waterfront structures alone—increases the attractiveness of beach nourishment but raises very serious concerns about widespread use of shoreline stabilization. Though shoreline stabilization can increase the value of a waterfront property, would it be wise for a community's residents to allow widespread reliance on stabilization if there is evidence that it will lead to lower property values inland?

Concerns over shoreline stabilization are not new. In the last major review in 1998, 6 of 24 coastal states surveyed prohibited new shoreline stabilization structures (Bernd-Cohen and Gordon, 1998). The remaining 18 generally allowed them if impacts were minimized, though most had regulatory language that promoted nonstructural solutions. However, it is not clear whether a recognition of any larger, community-wide negative impacts were part of the decision-making.

From our results, the magnitude of the difference in property values between similar properties in communities with significant stretches of stabilized shoreline and those left alone is quite striking. In communities with more than a single row of shoreline properties, community leaders faced with a permit application to stabilize a waterfront property shoreline are faced with a very difficult choice. They must either turn down a permit application by a waterfront property owner to stabilize his shoreline and thereby subject him to increased risk of damage, or approve the permit and lower the value of numerous non-waterfront property owners who collectively may have even more at stake.

Beach nourishment, in contrast, poses no such dilemma. Our analysis indicates that nourishing the beach is a plus for both waterfront and non-waterfront property values. The major question is whether it is worth the cost.

Major projects undertaken by the Army Corps of Engineers have nourished about 210 miles of the nation's shoreline. The costs to renourish these beaches average about $30 million per year (1993$) (U.S. Army Corps of Engineers, 1996.) Thus maintaining these beaches costs about $160,000 per mile per year (1999$).

An additional 26 projects, covering another 150 miles, are far enough along in the planning process to have cost estimates. (U.S. Army Corps of Engineers, 1996.) After a "surge of initial beach construction"—averaging about $45 million per year for the first 10 years—yearly costs of the planned projects are projected to be in the "$25 to $30 million per year range" (1993$). Maintaining the beaches along these proposed stretches of shoreline will thus cost at least $185,000 per mile per year to $220,000 per mile per year ($1999). However, the report also states that by 1995, estimated construction costs for planned projects had increased by about 50 percent. This suggests that new nourishment projects might actually cost closer to $280,000 per mile per year to $330,000 per mile per year (1999$).

To allow comparison to the cost of beach nourishment, Table 3 also includes the annualized equivalent of the changes in property price for each of the scenarios discussed above. For example, in case 3 a waterfront property in a community that is nourished to deal with an eroding shoreline is worth $73,000 more than a comparable property in a community that is not nourished. Annualized over 30 years at 6 percent interest, this is equal to a payment of about

$5,000 per year[3]. In case 9, the non-waterfront houses may increase in value even more, about $9,000 per year.

IMPLICATIONS OF THE ANALYSIS

The Heinz Center report (Heinz Center, 2000) concluded that of the 10 Atlantic and Gulf Coast counties analyzed, only one county could justify the cost of beach nourishment based on expected erosion damage over the next 60 years. This analysis implies a different outcome because property price increases appear to also extend to non-waterfront homes that are not likely to be damaged over the next 60 years. Therefore, the number of homes that benefit is significantly larger. All but one of the counties in the sample had housing densities within the first 500 feet of the shoreline in excess of 50 homes per mile of shoreline, a density likely to be high enough to justify the cost of nourishment from property price increases alone. Thus, if communities chose to assess both waterfront and non-waterfront properties within the first few hundred feet of the shoreline for the costs of beach nourishment, many more would be able to justify the investment.

Currently 10 of 29 states have some type of continuing funding program for beach nourishment. Nine additional states fund projects on a case-by-case basis. (Hedrick, 2000) Nevertheless, the federal government is by far the largest financier of beach nourishment projects, funding about three quarters of expenditures. (Heinz Center, 2000 summarizing data from Duke University Program for the Study of Developed Shorelines, 1998). However, this paper's findings suggest that nourishment has community-wide benefits to property owners, implying that a higher level of cost sharing by localities maybe justified.

Though nourishment appears to have fewer ecological impacts than shoreline stabilization, many environmental concerns regarding beach nourishment remain unresolved (NRC, 1995). Potential negative consequences on the beach itself include: 1) disturbance of indigenous biota living on and in the beach, which in turn may affect the foraging patterns of species that feed on those organisms and 2) disruption of species that use the beach for nesting, nursing, and breeding. Nourishment can also affect bottom habitats in the nearshore surf zone

[3] If a shorter time horizon were chosen, the annualized payment would become greater. A lower interest rate would reduce the annualized payment.

adjacent to the beach and in the borrow areas from which the sand was dredged. Additional monitoring of existing and planned projects is needed to resolve these concerns (NRC, 1995).

The Heinz Center study did not consider the effects of accelerating sea level rise due to climate change. If sea level rise over the next 50 years is 10 cm greater than over the last 50 years (IPCC, 1996), erosion rates might average 1 ft/yr faster than observed historically (Leatherman, Zhang, and Douglas, 2000). Given that typical erosion rates along the Atlantic Coast, for example, averaged 1 to 3 ft/yr over the last 50 to 100 years, this increase is not inconsequential. Many observers expect that this will lead to increased reliance on shoreline stabilization to protect increasingly vulnerable properties (e.g., Neumann et al. 2000).

The findings presented in this paper call into question such conclusions about widespread shoreline protection as a likely community response to combat accelerated sea level rise due to climate change. Clearly coastal communities will grow over the coming decades. But local land use decisions will determine whether building will be discouraged within the relatively narrow strip most likely to be threatened by erosion and rising seas, or whether property owners will build with the expectation that the community will help protect their investment. It is not clear whether sand supplies are adequate to meet today's demand for beach nourishment; this becomes even more of problem when more coastal areas hope to use this method to protect their shores against accelerating erosion. Our findings about lower property values in communities that rely extensively on shoreline stabilization should give communities pause. Though most analyses of the cost of sea level rise have concluded that shoreline stabilization is a cost-effective option for many communities, (e.g., Yohe et al., 1996) the effect on property values behind stabilized shorelines were not considered. The data collected and models constructed for The Heinz Center study of erosion hazards offer a unique opportunity for a more detailed analysis of the options available to communities to anticipate the effects of accelerating sea level rise due to climate change.

Table 1: Summary Statistics for Variables in Heinz Center Study, Southeast US, 1999.

Variable	Hypothesized Effect	Mean	Standard Deviation
House Size (square feet)	Positive	1861.44	1141.21
Parcel Size (square feet)	Positive	12935.15	14309.12
Bedrooms	Positive	3.462695	1.70908
Geotime (years)	Positive	8007.19	21016.12
Geotime Squared	Negative	42.8243	41.53039
Elevation (feet)	Positive	17.70525	5.910537
Distance to Water (feet)	Negative	373.0364	287.0014
Beach Width (feet)	Positive	67.6128	170.9186
Distance to CBD (miles)	Negative	17.11568	16.29007
Age of Transaction (years)	Negative	11.83396	10.8993
Age of House (years)	Negative	26.42409	19.77951
Fireplace (1-0)	Positive	0.433918	0.572195
Brick Exterior (1-0)	Positive	0.08509	0.322129
CBRA (1-0)	Uncertain	0.023745	0.175778
Waterfront (1-0)	Positive	0.45784	0.575203
Waterfront Stabilization (1-0)	Positive	0.072478	0.29934
Percent Stabilization	Negative	19.47777	28.64174
Waterfront Nourishment (1-0)	Positive	0.183562	0.446945
Beach Nourishment (1-0)	Positive	0.427049	0.571082
Built Post-FIRM (1-0)	Positive	0.529074	0.576282
Property Price ($ 1987)	Dependent Variable	179388.9	226884.9

Statistics are for 1,262 observations representing residential properties in nine coastal counties.

Table 2: Linear Regression results for Variables in Heinz Center Study, Southeast US, 1999.*

Variable	Beta Coefficient	Standard Error	t-Statistic	Marginal Effect
intercept	6.07057	0.49823	12.18*	
House Size (square feet)	0.55269	0.04819	11.47*	53.26304
Parcel Size (square feet)	0.14318	0.03424	4.18*	1.985657
Bedrooms	0.13548	0.05398	2.51*	7018.661
Geotime (years)	0.1195	0.04407	2.71*	2.677202
Geotime Squared	-0.00831	0.00305	-2.72*	-34.81
Elevation (feet)	0.24392	0.06757	3.61*	2471.375
Distance to Water (feet)	-0.0244	0.02013	-1.21	-11.7336
Beach Width (feet)	-0.00188	0.01054	-0.18	-4.98795
Distance to CBD (miles)	-0.03271	0.01964	-1.67*	-342.831
Age of Transaction (years)	-0.46833	0.02048	-22.87*	-7099.29
Age of House (years)	-0.08495	0.03251	-2.61*	-576.709
Fireplace (1-0)	0.20376	0.03707	5.50*	na
Brick Exterior (1-0)	0.12929	0.06644	1.95*	na
CBRA (1-0)	0.01008	0.11261	0.09	na
Waterfront (1-0)	0.32831	0.05197	6.32*	na
Waterfront Stabilization (1-0)	0.14136	0.07606	1.86*	na
Percent Stabilization	-0.03142	0.0144	-2.18*	-289.375
Waterfront Nourishment (1-0)	-0.27616	0.06923	-3.99	na
Beach Nourishment (1-0)	0.53934	0.06829	7.9*	na
Built Post-FIRM (1-0)	0.20429	0.04522	4.52*	na

Dependent variable: property purchase price. All continuous variables are expressed as natural logarithms. R^2 = 67.8%, 1,262 observations. To save space, the dummy variables representing county locations are not reported. * indicates that the t-statistic is greater than the critical value of 1.645, and the one-tailed hypothesis is rejected.

Table 3: The Effect of Shoreline Management Alternatives on Property Price: Waterfront versus Non-waterfront Properties (1999 $)

Waterfront Properties		Stable Shoreline	Shoreline Eroding at Three Feet per Year				
		Case 1: Baseline	Case 2: No Action Taken	Case 3: Nourishment Project	Case 4: Property stabilized, few neighbors stabilized	Case 5: Property stabilized, 50% of neighbors stabilized	Case 6: Property not stabilized, 50% of neighbors stabilized
	Price	$640,000	$481,000	$555,000	$554,000	$486,000	$422,000
Compared to Case 1	Difference		-$158,000	-$85,000	-$85,000	-$154,000	-$218,000
	Annualized		-$11,000	-$6,000	-$6,000	-$11,000	-$16,000
Compared to Case 2	Difference			$73,000	$73,000	$5,000	-$60,000
	Annualized			$5,000	$5,000	$400	-$4,000

Non-waterfront Properties		Stable Shoreline	Shoreline Eroding at Three Feet per Year				
		Case 7: Baseline	Case 8: No Action Taken	Case 9: Nourishment Project	n.a.	n.a.	Case 10: Property not stabilized, 50% of neighbors stabilized
	Price	$499,000	$383,000	$500,000			$335,000
Compared to Case 7	Difference		-$116,000	$2,000			-$163,000
	Annualized		-$8,000	$100			-$12,000
Compared to Case 8	Difference			$118,000			-$47,000
	Annualized			$9,000			-$3,000

n.b. Annualized differences in property values are amortized at six percent interest over 30 years.

References:

Bernd-Cohen, T. and M. Gordon, 1998. State Coastal Management Effectiveness in Protecting Beaches, Dunes, Bluffs, Rocky Shores: A National Overview. Prepared for the Office of Ocean and Coastal Resource Management, National Ocean Service, NOAA. http://www.ocrm.nos.noaa.gov/pdf/efrockyshores.pdf

Davison, A. Todd, 1993. "The National Flood Insurance Program and Coastal Hazards." In: *Proceedings, Coastal Zone '93*. 1377-1391.

Duke University Program for the Study of Developed Shorelines, 1998 http://www.eos.duke.edu/Research/psds/psds_tables.htm

Freeman, A.M. 1993. The Measurement of Environmental and Resource Values. Washington, D.C.: Resources for the Future.

Hardin, G., 1968. "The Tragedy of the Commons." *Science*, 162(1968):1243-1248.

Hedrick, C., 2000. State, Territory, and Commonwealth Beach Nourishment Programs: A National Overview. OCRM Program Policy Series Technical Document No. 00-01. Office of Ocean and Coastal Resource Management, National Ocean Service, NOAA. http://www.ocrm.nos.noaa.gov/pdf/finalbeach.pdf

Heinz Center, 2000a, Evaluation of Erosion Hazards, The H. John Heinz III Center for Science, Economics and the Environment, Washington, DC, 203 pp. http://www.heinzctr.org/publications/erosion/erosnrpt.pdf

Heinz Center, 2000b, Appendices: Evaluation of Erosion Hazards, The H. John Heinz III Center for Science, Economics and the Environment, Washington, DC, 500 pp. http://www.heinzctr.org/publications/erosion/append/index.htm

Intergovernmental Panel on Climate Change (IPCC), 2001, Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge, U.K., 892 pp.

Kriesel, W., A. Randall and F. Lichtkoppler, 1993. "Estimating the Benefits of Shore Erosion Protection in Ohio's Lake Erie Housing Market". *Water Resources Research*. 29(April): 795-801.

Leatherman, S. W. Merrell, and R. Friedman, 2001. "Coastal erosion and its impact on the National Flood Insurance Program: The 'Heinz Center Report". *Shore and Beach* 69:23-27

Leatherman, S., K. Zhang, and B. Douglas, 2000, Sea level rise shown to drive coastal erosion, EOS Transactions, AGU, V. 81, p. 55-58.

MacDonald, D.N., J.C. Murdoch, and H.L. White. 1987. Uncertain hazards, insurance, and consumer choice: Evidence from the housing markets. *Land Economics* 63 (November):361–71.

National Research Council (NRC), 1995, Beach Nourishment and Protection. Washington, DC: National Academy Press.

Neumann, J., G. Yohe, R. Nicholls, and M. Manion, 2000. Sea Level Rise and Global Climate Change: A Review of Impacts to U.S. Coasts. Pew Center on Global Climate Change. Washington, DC.

U.S. Army Corps of Engineers, 1996. Shoreline Protection and Beach Erosion Control Study. Final Report: An Analysis of the U.S. Army Corps of Engineers Shore Protection Program. Special Studies, IWR Report 96-PS-1. Washington, DC.

Yohe, G., J. Neumann, P. Marshall, and H. Ameden, 1996. The economic cost of greenhouse-induced sea-level rise for developed property in the United States. *Climatic Change,* 32:387-410.