CHAPTER 154

SEAWALL EFFECTS ON HISTORICALLY RECEDING SHORELINES

Bryan N. Jones[1] and David R. Basco[2]

ABSTRACT

This paper presents the results of a study using 15 years of beach profile data to determine how the presence of seawalls influences the existing erosional trends of the beach at Sandbridge, Virginia (USA). Three analysis methods using historic and seasonal time scales were used to answer three questions about the possible effects seawalls may have on adjacent nonwalled beaches. The results show that, statistically, there is no difference in the erosion rates of walled and nonwalled beaches. Seasonal variability of volume is greater for walled profiles. Seasonal recovery rates for both profile types are similar. Finally, the claim that the erosion of landward volumes at nonwalled beaches is increasing due to the presence of nearby seawalls is not supported by the evidence at Sandbridge beach.

INTRODUCTION

Great debate has arisen over the long term impacts seawalls may or may not have on the erosion rate of an historically receding shoreline. An obstacle to the formation of definite conelusions about seawall and beach interaction is the lack of long term physical data, which must be collected prior to and following seawall construction. Kraus (1988), and Kraus and McDougal (1996), summarize the state of knowledge on seawall and beach interaction.

Sandbridge is a coastal residential and commercial community within the City of Virginia Beach, Virginia. Sandbridge is located 25 km south of Cape Henry at the entrance to the Chesapeake Bay and 25 km north of the Virginia-North Carolina border. The historical shoreline recession rate over the past 140 years varies linearly from -1.1 m/yr on the north end to -2.9 m/yr at the south end of the study area (Everts, et al., 1983; Dolan, 1985). The first seawalls were built at Sandbridge around 1978, with a peak construction period between 1987 and 1989. At present, about 62 percent of the study

[1]Project Engineer, Collins Engineers Inc., 745 Bluecrab Road, Newport News, VA 23606.

[2]Professor, Coastal Engineering Program, Old Dominion University, Norfolk, VA 23529.

area is walled and 38 percent is nonwalled. The length of the study area is 7.7 km.

This paper presents a statistical analysis of subaerial beach profile data collected over the past 15 years in an effort to determine how the seawalls influence the existing erosional trends of the beach at Sandbridge, Virginia (USA). To achieve this goal, this study addresses the following three questions:

Question 1: Is the sand volume seaward of walled profiles disappearing at a faster rate than a similar volume defined at adjacent nonwalled profiles?

This question can be answered by analyzing the long term and seasonal trends for the volume of sand located seaward of the walls at walled and nonwalled profiles. A statistical analysis of profile data was performed to show any differences between the rate of change of these volumes. If the seawalls are responsible for increasing beach erosion, the trends should show that the volume seaward rate of change for the walls is greater than that for the nonwalled profiles.

Question 2: Are the seawalls responsible for delaying beach recovery during the seasonal transitions?

Another way in which seawalls may detrimentally affect beaches is by interfering with the processes responsible for the natural recovery of sand volumes with the change in seasons. This question can be answered by looking at when thc walled and nonwalled profiles make their seasonal transitions.

Question 3: Following seawall construction, does the volume landward of an adjacent nonwalled profile erode at a faster rate than was previously recorded before the construction?

Because upland sand trapped by the seawalls is essentially removed from the littoral system, less sand is available to replace that removed by natural long-term erosion processes. If seawalls are increasing the erosion rate of the beach, then there should be evidence of an increase in the erosion rate of sand for the nonwalled profiles after the seawalls were built. This question is addressed by using 15 years of profile data divided into time intervals before and after construction of nearby walls.

DATA COLLECTION AND ARCHIVES

In August 1990, Old Dominion University began collecting subaerial beach profile data at 28 locations along a 7.7 km study area at Sandbridge. Surveys were made at these locations monthly and following significant coastal storms. Other agencies, including the City of Virginia Beach, have contributed profile data collected over the past 15 years at Sandbridge. At present, 13 of the ODU profiles are located at walled sections and 15 are located at nonwalled (dune) sections. The current data set contains more than 2700 profiles taken at 53 different locations over 15 years (October 1980 to September 1995). The 15 year data set includes several years before and after a boom in seawall construction during the late 1980's.

Volumetric beach parameters were defined to quantify changes in space and time, as shown in Figure 1. For profiles at walled locations, the volume of sand located seaward of the wall and above MLW is called the volume seaward (V_S). Volume landward (V_L), therefore, is the volume of sand located behind the wall, down to the MLW elevation. For profiles at nonwalled locations, an imaginary partition is extended from adjacent walls parallel to the shoreline. This imaginary partition becomes the boundary separating V_S and V_L for the nonwalled profiles. The volumetric parameters (V_S and V_L) are the best indicators of long-term beach erosion trends for this study, using volume loss with time as the key variable of interest (Basco, et al., 1996).

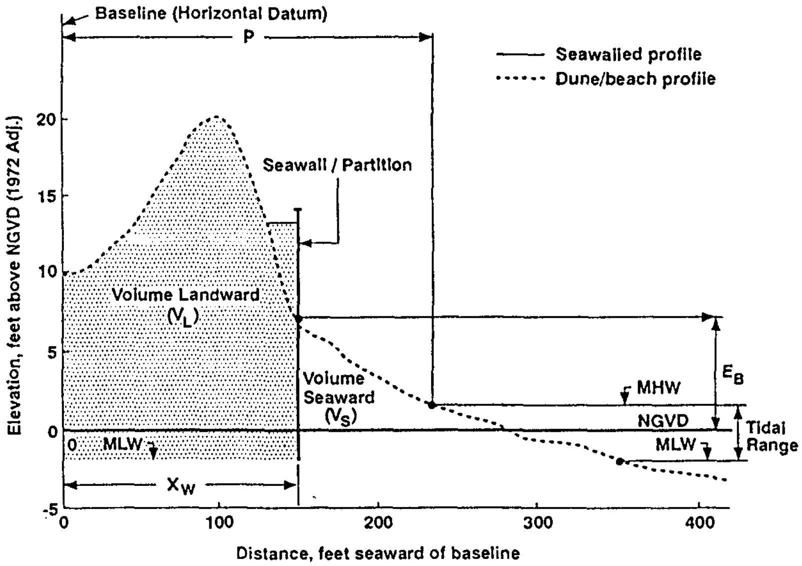

Figure 1. Beach Parameter Definitions.

The measured volumetric beach parameters are known to vary with the seasons. In general, subaerial beach sand is dragged offshore onto bars during frequent storms in the winter months (October to March), and is pushed back onto the beach by the long swells of the summer (April to September). The seasonal variability was modeled as a sinusoidal wave with a period of one year. The seasonal amplitude of the sinusoidal wave was found using the value that produced the least variance between the measured parameter and the calculated seasonal signal. A linear regression analysis using the method of least squares was performed to estimate the annual rate of change for each profile parameter and each profile type. The null hypothesis test was performed to determine if one parameter's slope was statistically greater than the other.

ANALYSIS METHODS

Over the five-year ODU monitoring study, three methods were developed to analyze the observed changes in V_S and V_L. These methods included the Weighted Average Method (WAM), the Sectional Weighted Average Method (WAMSECT), and the Individual Profile Method (IPM).

The WAM method used only the 28 ODU profile locations surveyed since October 1990, and was useful to characterize generalized beach change for the entire study area. The 28 profiles were grouped into two sets by type, walled or nonwalled (dune). Each profile was assigned a representative length of beach which was assumed to represent the walled or nonwalled conditions along that particular length of shore. For each profile, the volumetric parameters were multiplied by that profile's representative length. All of the wall profile products were then summed for each parameter, then divided by the total wall length. The result was a set of weighted averaged parameters (V_S and V_L) for each survey that singularly represented the walled profiles at Sandbridge. A set of weighted average nonwalled profile parameters were found in the same manner, using different representative lengths of nonwalled beach.

The Sectional Weighted Average Method (WAMSECT) divided the Sandbridge study area into three distinct reaches (North End, Middle Section, South End) to recognize differences in barrier island elevation and historic shoreline erosion rates. As with the WAM, weighted averages were employed for each type (walled or nonwalled) based on the lengths of walled and nonwalled beach in each section.

Differences in the parameter change rates before and after seawall construction were studied using the individual profile method (IPM). Beach profiles taken prior to October 1990 varied in location, and were not sufficient in number to permit accurate use of the WAM or WAMSECT averaging methods. The volumetric beach parameters were calculated for all surveys dating back to October 1980 for each profile, thus permitting the profile history to be analyzed beyond the five years of ODU monitoring. Parameter rates of change could then be compared for the periods of time before and after wall construction, but only for each individual profile location. The results of this analysis could then be used to form conclusions regarding Question No. 3.

RESULTS

Seasonal trends are best identified by plotting the WAM and WAMSECT results for the volume seaward difference (ΔV_S) for the five full wave years of ODU profile data. The initial value of each parameter is taken as the regression line intercept for October 1, 1990. The differences, therefore, represent the change in time over five years. Comparisons of the trends between walled and nonwalled profiles were made in an attempt to find supporting evidence for Questions No. 1 and No. 2. Transition from winter to summer was defined by when the ΔV_S parameter passed from below to above the regression line for each profile type. Likewise, the summer to winter transition was said to occur once the ΔV_S parameter moved below the regression line.

WAM Results

Using the WAM, Figures 2 and 3 show the long term change in ΔV_S for the walled and nonwalled profiles, respectively. The negative regression slopes in these figures demonstrate the imbalance of the seasonal cycle, which is caused by the chronic long term erosion rates at Sandbridge. Volume seaward from the walled and nonwalled profiles is disappearing at yearly rates of 1.58 m^3/m and 1.80 m^3/m, respectively. This difference in the change rates of the two profile types is not statistically significant, as determined from the null-hypothesis test.

It is apparent from Figures 2 and 3 that the winters of 1992-1993 and 1994-1995 were the most severe. Volumes seaward in each of these years were below the mean decreasing value for each profile type. By comparison, the winters of 1990, 1991 and 1993-1994 were very mild. The summer beach rebuilding periods also demonstrate variability from year to year. With the exception of the 1994-1995 wave year, the walled profiles recovered to about $\Delta V_S = +7$ m^3/m during each summer, which was the summer value prior to October 1990. In contrast, the nonwalled sections continued to fall below the seaward volume present during the summer of 1990.

A comparison of seasonal transition times showed that the walled profiles recovered in the summer of 1991 first. The dunes made the summer transition first in 1992. Both profile types recovered simultaneously in 1993 and 1994. In 1995, the severely eroded beach never quite recovered in front of the walls while the dunes eventually did recover near the end of the summer season. The summer to winter transitions occurred at the same time for both types in 1990, 1992, 1993, and 1994. In 1991 and 1995, the winter transition was observed earlier for the dune sections.

WAMSECT Results

Figures 4 and 5 show the trends in the North End seaward volumes for walls and dunes, respectively. Similar plots were generated for walled and nonwalled profiles in the Middle Section and South End. Differences in the rates of change and seasonal variation amplitudes between each WAMSECT subsection are apparent. The results of the WAMSECT linear regression analysis of volumetric change rates are summarized in Table 1.

At the North End, the linear regression analysis showed that the ΔV_S rates of change for dunes and walls are negative and statistically equivalent. In addition, the amplitudes of the calculated seasonal variation are also equivalent. Beach recovery following the winter season occurred simultaneously for both profile types from 1990 to 1993. The walled profiles recovered first in the 1993-1994 wave year. Wave year 1994-1995 was characterized by two hurricanes along the mid-atlantic coast (Gordon, Nov. 1994 and Felix, Aug. 1995) in addition to a stronger wave climate generated by hurricane activity in the Caribbean. While the nonwalled profiles eventually recovered, the data shows ΔV_S for the walled profiles never recovered above the regression line for this section. Both profile types made the transition from "summer" to "winter" characteristics (seasonal erosion) around the same time for the first four years of the

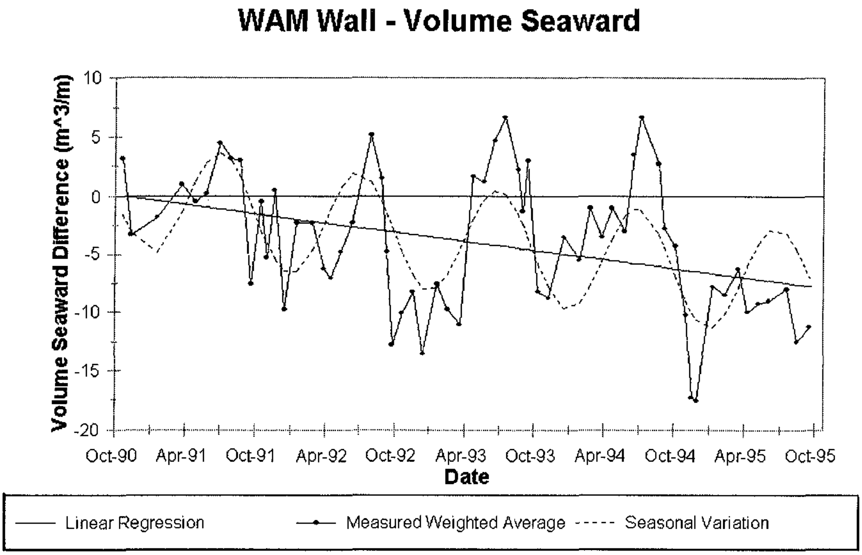

Figure 2 WAM seasonal variations in volume seaward for walled profiles.

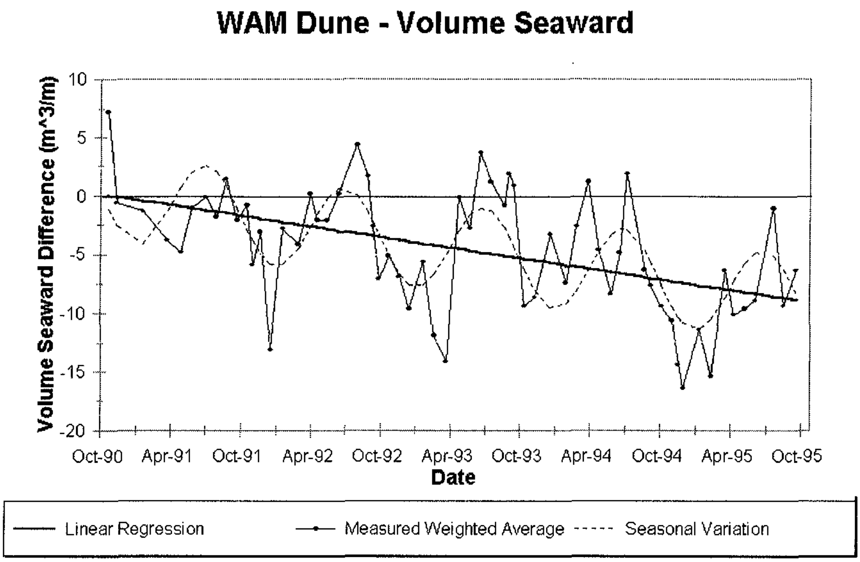

Figure 3 WAM seasonal variations in volume seaward for nonwalled profiles.

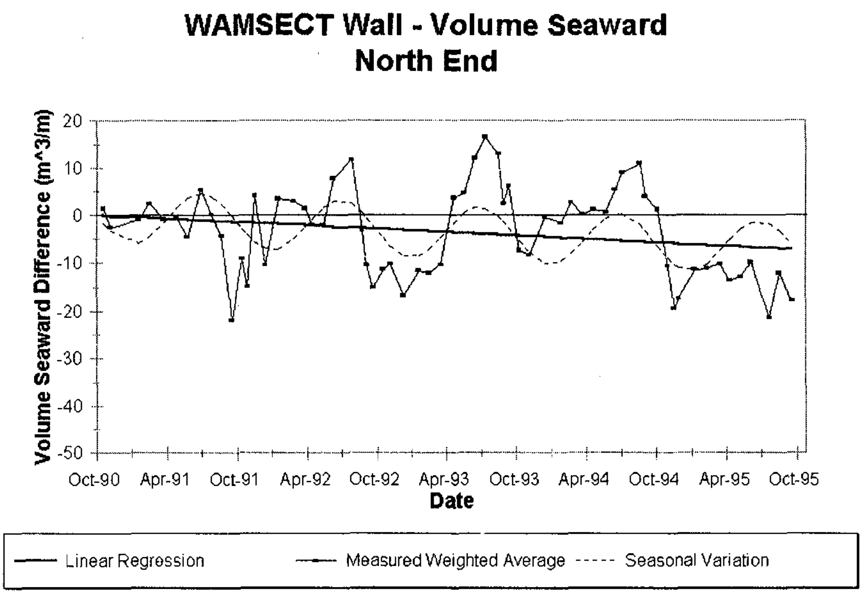

Figure 4 North End WAMSECT Seasonal Variations in Vs for walled profiles.

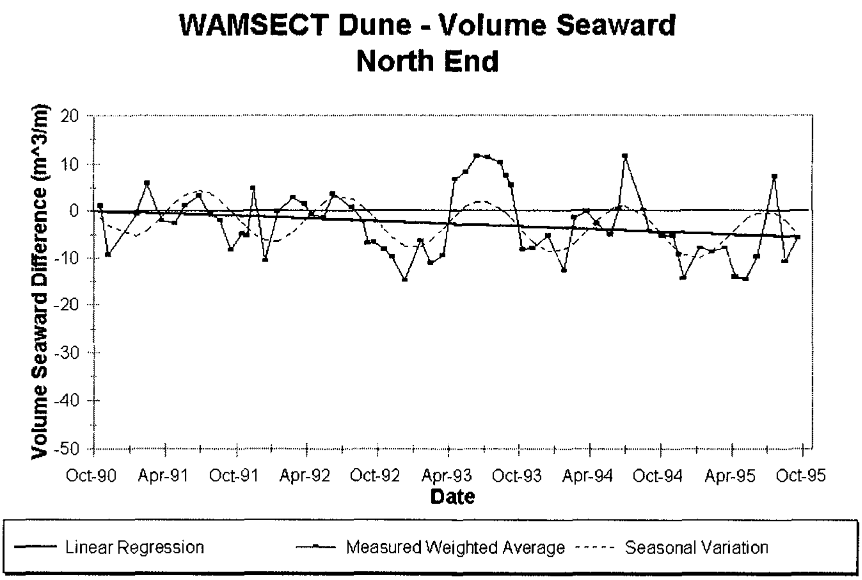

Figure 5 North End WAMSECT seasonal variations in Vs for nonwalled profiles.

Table 1. WAMSECT volumetric rates of change.

	Profile Type	WAMSECT Subsection					
		North End Oct 90 - Sept 95		Middle Section Oct 90 - Sept 95		South End Oct 90 - Sept 95	
		Rate of Change	Seasonal Amplitude	Rate of Change	Seasonal Amplitude	Rate of Change	Seasonal Amplitude
ΔV_S (m^3/myr)	Wall	-1.44	-5.6	-0.61	-6.8	-3.2	-2.5
	Dune	-1.14	-5.2	-1.50	-3.6	-4.0	-3.9
Sectional make-up (by length)		75% walled		44% walled		73% walled	
		25% nonwalled		56% nonwalled		27% nonwalled	

ODU study. During the stormy 1994-1995 season, the dunes made the transition first.

The results for the Middle Section showed the rates of change for ΔV_S were statistically equivalent for both walled and nonwalled profiles. Seasonal amplitudes in ΔV_S were greater for the walled profiles in this region. Beach recovery occurred simultaneously for both profile types in the first three years (1990-1993). The walled profiles recovered before the nonwalled profiles in the 1993-1994 summer season. Like the North End, the walled profiles never recovered above the regression line following the stormy 1994-1995 season. Transition from summer to winter levels occurred first for the walled profiles in 1990-1991. Both profile types changed at the same time in the three years between 1991-1994. The nonwalled profiles eroded to winter levels before the walls in the turbulent 1994-1995 wave year.

As in the North End and Middle Section, the rates of change for ΔV_S in the South End are statistically equivalent for both walled and nonwalled profile types. The greater historic erosion rates for the South End are clearly demonstrated by the greater change rates in Table 1. The walled profiles recovered first during the summer beach rebuilding season for the first two years of the study (1990-1992). In the 1990-1991 season, however, the nonwalled profiles did not recover above the ΔV_S regression line. In the remaining three years of the study, both profile types recovered simultaneously. Seasonal transition from summer to winter occurred at the same time for walled and nonwalled profiles for 1990-1994. The 1994-1995 season showed that the walls eroded to winter levels before the dunes, conflicting the trends observed for this wave year in the North and Middle regions.

IPM Long-Term Rates of Change

Comparisons of the volume rates of change for each of the profiles used in the IPM were made in three groups (North End, Middle Section, and South End) to recognize the regional differences in physical characteristics. The key variable is V_L of the seawall or partition. A large decrease in the V_L after adjacent wall construction meant that Question No. 3 was supported, i.e., at one profile location, the volume of sand retained behind nearby walls is unavailable, causing adjacent, nonwalled locations to erode at a faster rate. Profile 1 is a good example as shown in Figure 6. For eight years (October 1980 - July 1988) and for 24 surveys, V_L "before" nearby wall construction was +0.8 $m^3/m/yr$. Seawalls were built during the spring of 1989 about 30m south of Profile No. 1 so that for five years (July 1989 - June 1994) with 54 surveys the rate became -9.0 $m^3/m/yr$. Unfortunately, the lot owner at Profile No. 1 leveled the dune in June 1994, so that some question remains as to how much affect the adjacent wall really has at this location.

By this same method of comparison for other profiles in the North End, supporting evidence does exist for Question No. 3. However, this is not true for the Middle Section or South End. A conflicting example in the Middle section lies at Profile 161. Figure 7 shows a similar eight year period (October 1980 - October 1988) for this profile. After 50 surveys, V_L "before" nearby construction was -2.2 $m^3/m/yr$. Seawalls were built during 1989 starting 30m south so that after 5 years and 70 surveys, the "after" rate became -0.8 $m^3/m/yr$. This evidence, and many other examples in the Middle section does not support Question No. 3. The South End includes both supporting, nonsupporting and inconclusive results so that it must be concluded that the evidence is inconclusive for this region.

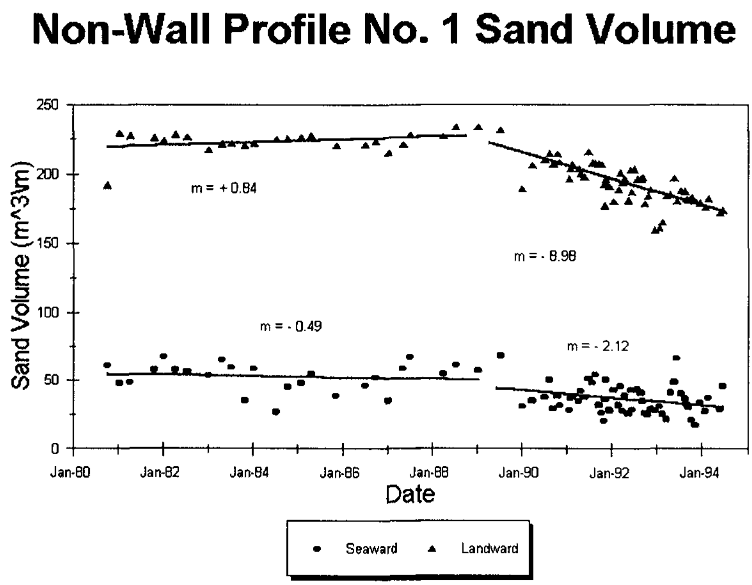

Figure 6 IPM analysis of Profile 1. Supporting evidence for Question No. 3.

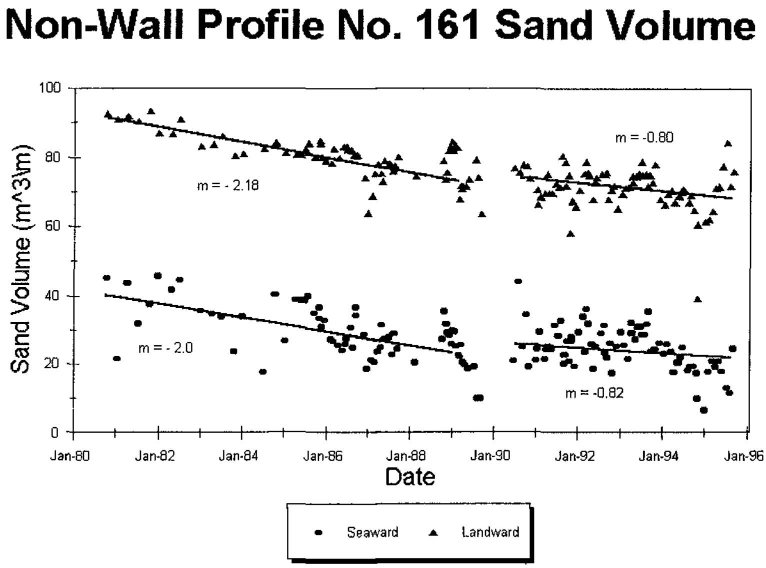

Figure 7 IPM analysis of Profile 161. Nonsupporting evidence for Question 3.

SUMMARY

The three basic methods (WAM, WAMSECT, and IPM) used in this study consider seawall and beach interaction on an increasingly more focused spatial scale. The WAM model provides trends for the Sandbridge area as a whole. The WAMSECT model concentrates on the effects of seawalls on a more localized level, and the IPM method considers each profile separately. Long-term effects are obtained from the results of all three methods using the five year ODU data set (15 years for profiles in the IPM). Seasonal variations are seen using both the WAM and WAMSECT methods.

Question No. 1: Does the sand volume seaward of the walls erode faster than a similar volume defined at adjacent nonwalled profiles?

Statistical comparison of parameter change rates (ΔV_S) using the null-hypothesis test revealed that the erosional trends are *statistically equal* for walled and nonwalled profiles. The results are the same for the WAM analysis and for each section in the WAMSECT analysis. Using five years of statistical data, there is no evidence to support the conclusion that the seaward volumes in front of seawalls is disappearing any faster than the seaward volumes in front of nonwalled profiles.

Seasonal variations in seaward volume were modeled using the five-year WAM and WAMSECT data. The WAM results show the amplitude of the seasonal variation in V_S is greater for walled profiles. Because seawalls provide an impermeable barrier for cross-shore transport, sand is piled up against the walls by long period swells during seasonal recovery, resulting in larger relative seaward volumes for walled profiles during the summer. Likewise, winter erosion removes more sand from in front of the walls, since sand located landward of the partition is readily available to replenish sand removed seaward at the nonwalled profiles.

In the North End, the seasonal amplitudes for V_S were found to be the same for both profile types. Seasonal amplitudes in V_S were highest for walls in the Middle Section. The results indicate that the five-year seasonal variations in V_S are greater for the nonwalled profiles in the South End. Because not as much sand is available to replace that removed from in front of the walls during seasonal transitions, we might expect the walled profile variations to be less for the South End than in the North End and Middle Section.

Question No. 2: Do seawalls delay beach recovery during seasonal transitions?

Seasonal beach recovery was studied using the WAM and WAMSECT results over the five-year ODU monitoring period. Using the WAM, seasonal transitions generally occurred about the same time for both walled and nonwalled profiles. During the abnormally high erosion experienced by storm activity in the 1994-1995 wave year, the nonwalled sections eventually recovered while the walled sections did not. Continued monitoring for 1995-1996, however, shows that the walled profiles have recovered.

The North End WAMSECT trends indicate that seasonal beach recovery occurred simultaneously for both profile types in three of the five years studied. In 1995, the walled profiles never recovered above the regression line. In the Middle Section, seasonal recovery also occurred simultaneously for both profile types in three of five years. As in the North End, the walled profiles did not recover above the regression line in 1995. As for the South End, seasonal beach recovery for walls and dunes occurred at the same time for the last three years of this study.

Question No. 3: Does seawall construction increase the natural erosion rate of the sand volume landward of the walls at adjacent nonwalled locations?

After a seawall has been built, the sand trapped behind the wall is no longer available for transport to adjacent beaches during storms. This reduction in sediment supply is thought to place additional erosional pressure on beaches adjacent to walls. The IPM was the only method which provided enough long term data to form conclusions regarding Question No. 3. Linear regression was used to determine trends in the nonwalled V_L parameter before and after seawall construction. The individual profile results were compared according to region (North End, Middle Section, South End).

In the North End, evidence exists to support Question No. 3. None of the Middle Section profiles demonstrated an increase erosion rates, in fact, each of the profiles compared showed evidence to argue that erosion rates *decreased* following the nearby addition of seawalls. The IPM results for the South End are inconclusive and include two instances where no significant change was noted, one instance where the change rate decreased, and one where the rate increased.

CONCLUSIONS

Seawalls are not responsible for the erosion problem at Sandbridge, they are a result of it. Three different spatial and time scales have been used to analyze fifteen years of subaerial beach profile data. While the results clearly show differences in short term coastal processes between walled and nonwalled beaches, the long-term and seasonal effects are very nearly the same.

With regard to Question No. 1, the results from the five-year WAM and WAMSECT trends clearly indicate that volumes seaward of walls *are not* eroding faster than volumes in front of nonwalled profiles. These results are consistent with the conclusions made by other researchers reviewed in Kraus (1988), and Kraus and McDougal (1996). The results do show that seasonal variation in volume is greater for walled profiles, however, these variations are temporary.

The results for Question No. 2 show that seawalls *do not* inhibit seasonal recovery for either profile type. The five-year seasonal recovery trends using both the WAM and WAMSECT methods yielded the same results.

Despite the use of over 15 years of profile data, no clear conclusions can yet be made regarding Question No. 3. Comparison of change rates before and after seawall construction yielded supporting evidence in the North End, nonsupporting evidence in the Middle Section, and inconclusive results for the South End. The results for the study area as a whole, therefore, must be considered inconclusive for Question No. 3.

The study at Sandbridge is continuing. As the ratio of volume trapped behind the seawalls to that remaining on the subaerial beach increases, some evidence to support Question No. 3 may be found in the future.

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