CHAPTER 158

Thirty Year Erosion Projections in Florida: Project Overview and Status

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Abstract

A project to analyze historic shoreline erosion and to predict future erosion in Florida is discussed in this paper. Information is given concerning the data base and the methods of analysis. Some examples are provided illustrating the use of various analysis tools. The utility of numerical modeling as a newly developed analysis tool is discussed in particular. Some of the general results of the study are noted, as well as conclusions and opinions concerning the effectiveness of the program.

Introduction

Since 1985, the Florida Department of Natural Resources (DNR), Division of Beaches and Shores, has been required to consider thirty year erosion projections in the regulation of coastal construction. Certain types of major structures are prohibited seaward of the thirty year projection of the "seasonal high water line" (SHWL). This elevation contour is defined by rule to be a function of the mean high water (MHW) elevation and the mean tide range at a site. In many areas of the state the SHWL corresponds well with the vegetation line or the base of the dune escarpment. The SHWL is assumed to move in close correspondence with the MHW line in the longer term.

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There are approximately 1250 km (780 miles) of sandy beaches in Florida for which thirty year erosion projections must eventually be made. Due to staffing limitations, first priority is given to analyzing and making erosion projections for areas where there are frequent applications for construction permits. The second priority is completion and updating of the historic data base. The third priority is to perform regional analyses.

The author works for the Division as a coastal engineer assigned to build and maintain the historic shoreline data base, and to analyze the data. In effect, the author acts as a consultant in recommending to the engineering staff and management which erosion rates to apply as thirty year erosion projections. Any of the staff engineers may elect to perform their own analyses. The author's recommendations in a case are subject to acceptance or not, per the judgment of the staff engineers and managers. This allows for useful scientific debate. The party making the final thirty year erosion determination in a case is responsible for its' defense. The following is a description of the DNR historic shoreline data base, and the author's analysis methods and opinions.

Data Base

In order to have a reasonable chance of predicting the future, it is helpful to have a reasonably good understanding of the past. Therefore the author's methods of analysis are based on obtaining a high quality, reliable data base, and a working understanding of the coastal processes controlling long term shoreline changes in Florida.

In the initial data acquisition phase, all the U.S. Government historic coastal topographic survey maps of Florida from the 1850's to the 1980's were precision digitized by skilled personnel on state-of-the-art equipment. This was done for the Department at Florida State University, primarily by Dr. S. Demirpolat. The results include an atlas of historic mean high water (MHW) change maps, which are computer-generated map overlays on a common coordinate system. Paper copies on standard scales of 1:24000 and 1:2400 are available. Digital copies which can be used with several computer assisted design (CAD) or geographic information system (GIS) software packages are now becoming available. An example historic shoreline change map is shown as Figure 1.

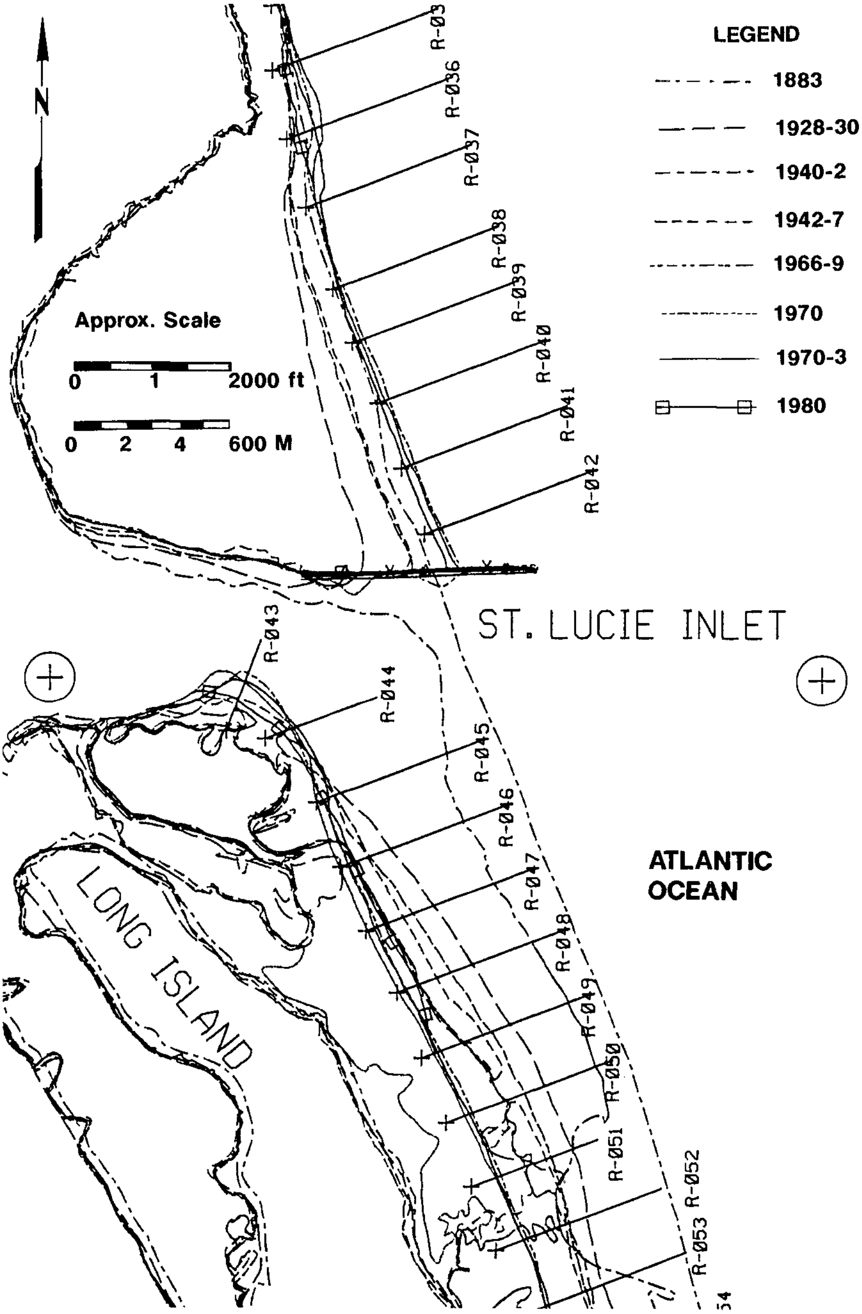

Figure 1. Example, Historic Map

The maps provide the basis for files of tabulated MHW locations referenced to fixed DNR survey points ("R" monuments) at approximate 300 m (1000 ft) intervals along the Florida coast. Beach profiles from these points have been surveyed semi-periodically since the early 1970's. The MHW data from the field surveys is systematically being added to the historic data tables. As new surveys are taken, the data base is continually updated. Strict data quality control is necessary, although this requires a large investment of time and effort. In the past when similar projects have proven unreliable, it was usually because of poor data quality control. The data base is supplemented with sets of controlled and uncontrolled aerial photographs, bathymetric maps, bathymetric profiles, full beach profiles, and access to university and Division libraries.

The accuracy of the historic map data is estimated to be +/- 10-15 meters, or better. The field derived data is +/- 3 meters, and usually better. Not all data are equal. The process of comparing the historic shorelines with physical reality during the analysis helps to determine data of questionable reliability.

Analysis

A methodology has been developed and tested over several years which works well in analyzing this data set. A useful graphic tool is the distance versus time plot. To illustrate, an example of an enlarged portion of a shoreline change map is shown as Figure 2a. The distances from reference point "R-1" to the various historic shoreline locations, along a fixed, approximately shore-normal direction, are plotted versus time in Figure 2b. A downward sloping line indicates erosion. An upward sloping line indicates accretion. The greater the slope, the more rapid the rate of change. The advantage of the distance versus time plot is simply to give a perspective on the rate of change, which is not readily discernable from the plan view maps. Plots for several adjacent reference points, as shown on the left side of Figure 3, may be combined onto one graph, as shown on the right side of Figure 3. The advantage of the single graph with multiple plots is simply to show that the plots, when viewed in sequence, are related in a pattern.

An example of a non-linear erosion pattern in the historic data is shown in Figures 4a and 4b. The example is the downdrift (south) side of St. Lucie Inlet, in southeast Florida. In a graph such as Figure

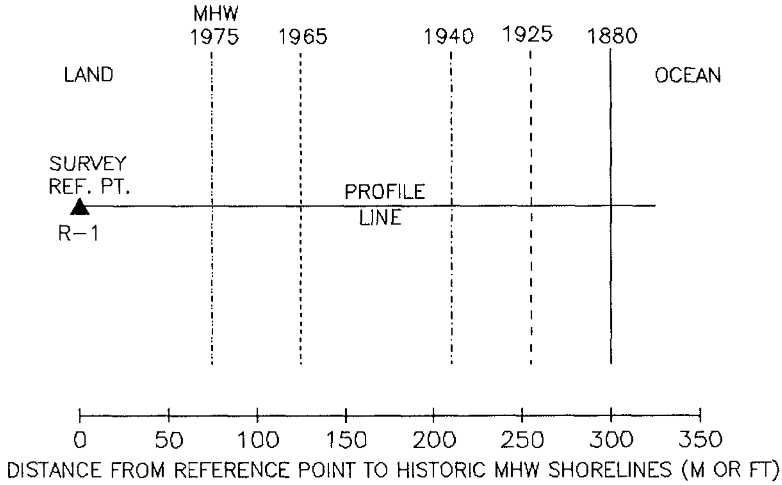

Figure 2a. Example, Enlarged Map Area

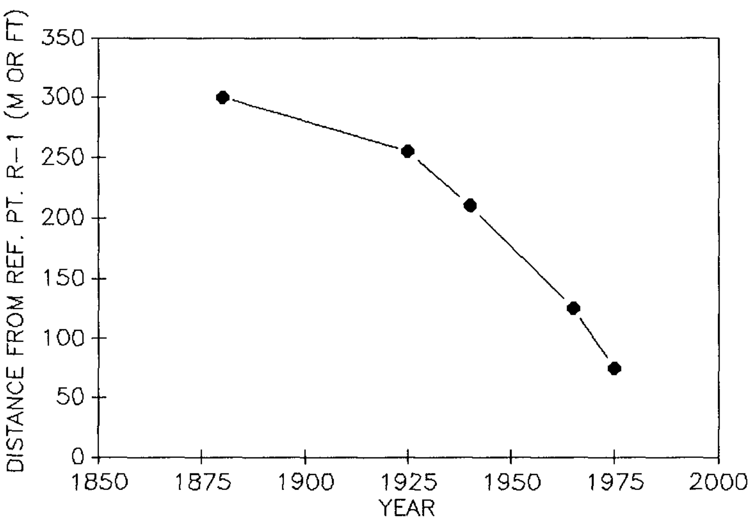

Figure 2b. Example, Distance vs. Time Plot

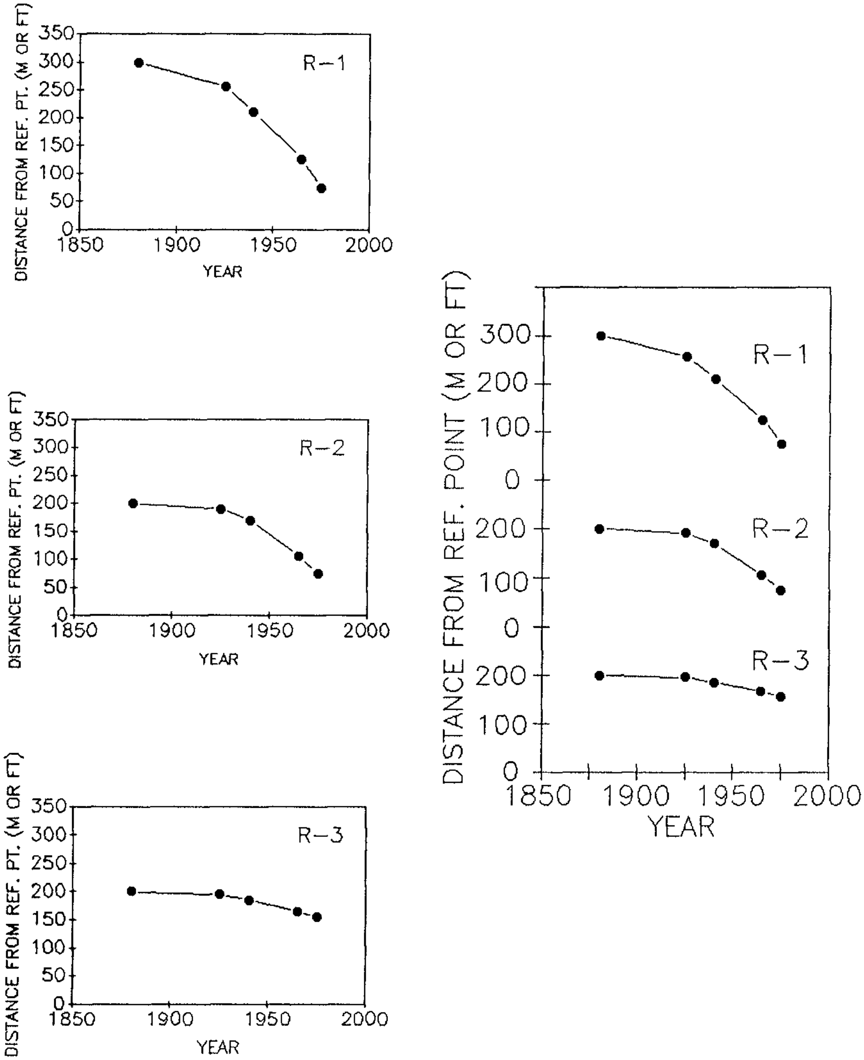

Figure 3. Combining Distance vs. Time Plots

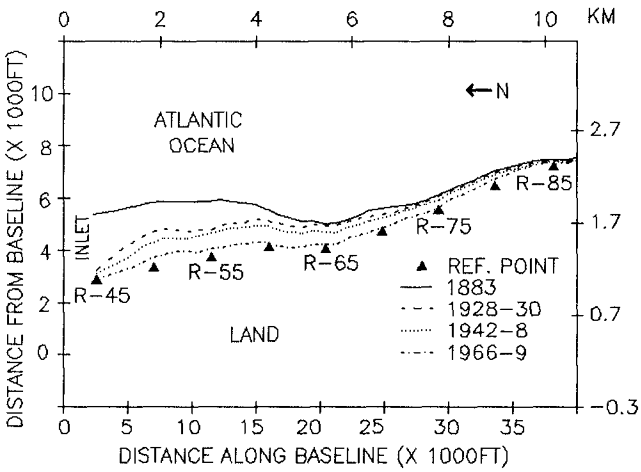

Figure 4a. Plan View, Historic

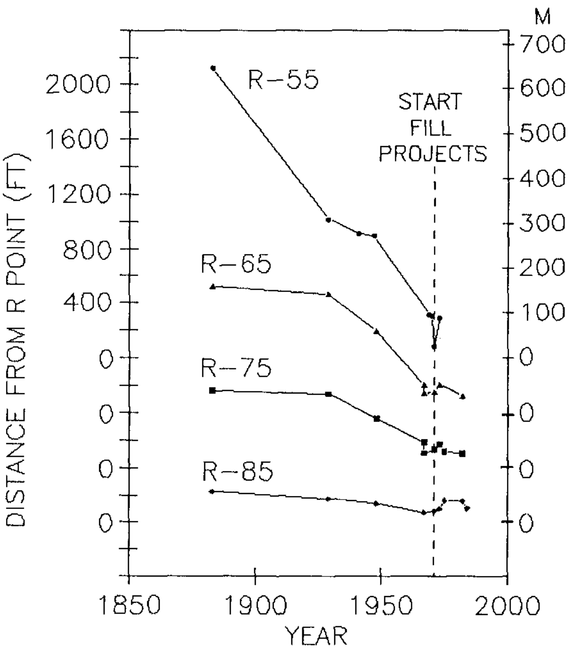

Figure 4b. Time Plot, Historic

4a, the historic shoreline locations at the reference points can be plotted in a connect-the-dot manner, in any coordinate system. The vertical and horizontal scales can be used to exaggerate the longshore features as desired. The time history of shoreline change along a sequence of selected reference points is given in Figure 4b. Note that the erosion pattern was interrupted by renourishment projects in the early 1970's.

The erosion pattern is easily recognized by comparison to a modeled idealized case, shown in Figures 5a and 5b. A one-line, two-season, longshore numerical (finite difference) model was used to illustrate what theoretical erosion pattern to expect downdrift from a jettied inlet. Note the essential similarity of the non-linear erosion curves in Figure 5b to those of Figure 4b, exclusive of the renourishment period.

Once the erosion pattern is recognized, the task is to resolve the pattern into time segments during which the rate of shoreline change is approximately linear. Three rate calculation methods are then applied to each approximately linear time segment to achieve a consensus estimate, thereby avoiding the potential bias of any individual rate calculation method. Rate estimates are generally averaged alongshore with a floating six or seven point averaging technique, unless there is reason not to do so. Longshore averages are usually rounded upward to the nearest -0.15 m/yr (-0.5 ft/yr) as a conservative practice. The data base and analysis methods are described in greater detail by Foster and Savage (1989a).

A case study where the same numerical model as previously mentioned was calibrated with the entire record of historic data is described by Foster (1991a). The location of the case study area and some of the results of that work are shown in Figures 6a and 6b, respectively. Note that the historic data and the model data match reasonably well. There are two physical equations on which the model is based: a version of the longshore transport equation and an equation for volumetric continuity. The primary factors causing shoreline erosion in this case were indicated by the very limited range of parameters in the model which resulted in a match with the historic data. In addition, the model indicated that the erosion process is non-linear and far from completed, both observations that were not necessarily intuitive.

It must be noted that it is not at this time usually practicable to do calibrated modeling for most

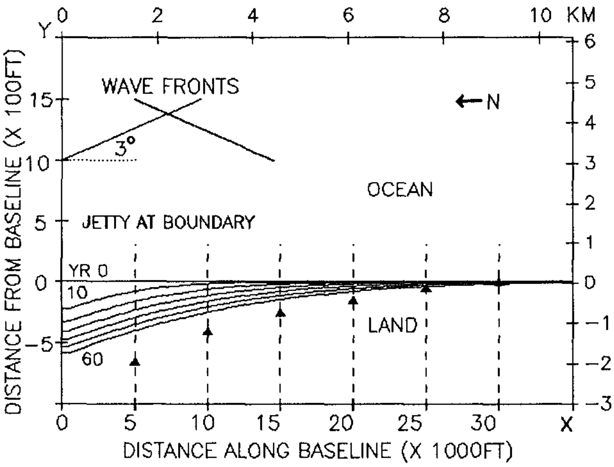

Figure 5a. Plan View, Model

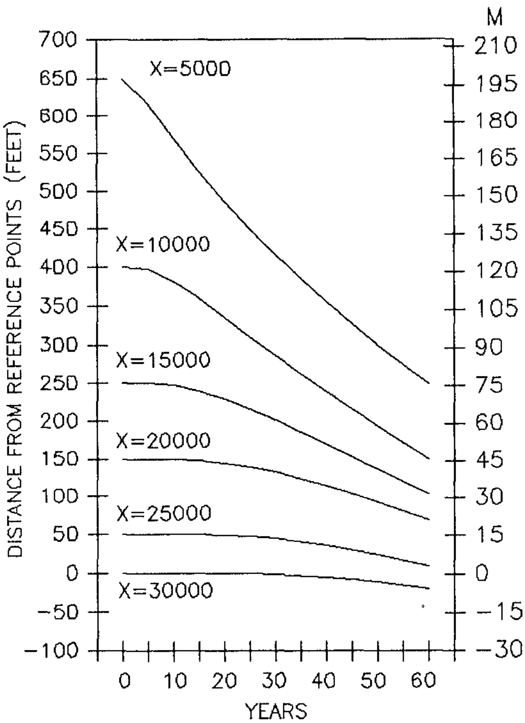

Figure 5b. Time Plot, Model

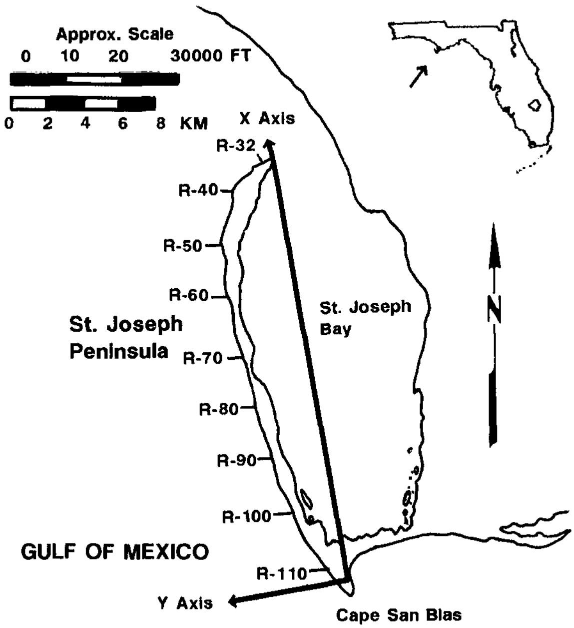

Figure 6a. Location Map

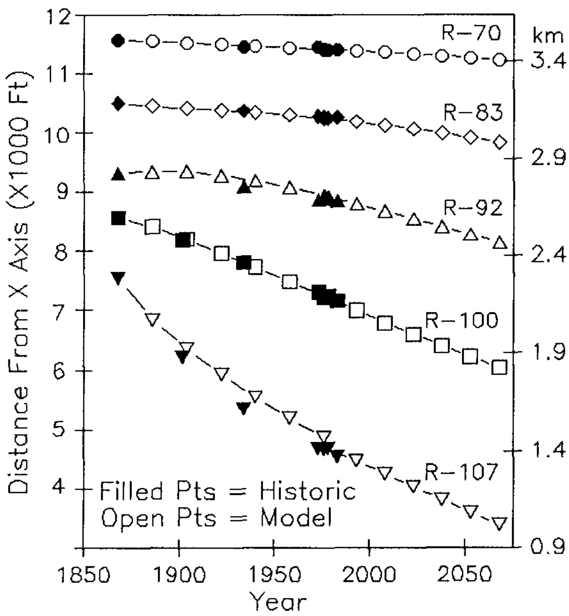

Figure 6b. Comparing Historic Data with Model Results

of the state due to applicability and workload constraints. However, it is becoming increasingly useful to perform general case modeling to help understand and explain to others some of the less obvious erosion patterns. Also, not all areas require an involved analysis for practical results. In some basically stable areas, where inlets are relatively far away, it may not be necessary to know immediately what is occurring as a process throughout the entire region. In such cases, it is usually only necessary to recognize if the historic data are within the range of beach width changes normally observed at the site, and if there is no obvious sand deficit problem. As a conservative practice, a minimum estimate of -0.3 m/yr (-1 ft/yr) is usually forecast for all historically stable areas and even for areas with accretionary trends (exclusive of uncontrolled inlet areas). The use of the minimum estimate allows for some uncertainty about future conditions in general, and about our ability to accurately measure very low levels of shoreline change.

Generally the method of forecasting has been to assume that the most recent major trend will continue linearly forward for the next thirty years. If the case warrants calibrated modeling, such may be used to help project the erosion trend forward for thirty years. However, the use of modeling is a new technique. Typically, the expected rate of change even in a non-linear system is not so rapid as to preclude use of the actual measured data to make projection rates, if the time period for the rate calculation is properly selected.

It is advisable to test the analysis methods and results versus on-site observations and new surveys after several years. If such observations are not consistent with expectations, a review is in order. In our program, preliminary analyses were performed for several regional areas in 1986-89 which are expected to be tested in upcoming years with new regional survey data. Site surveys submitted with permit applications are also used on a daily basis to test previous erosion projections. Another simple test is to ask whether or not the analysis method would have successfully predicted the erosion of the last decade or so, if only data prior to that time were available. If not, the analysis method or the level of understanding about the coastal process is lacking.

The question of the potential effect of sea level rise requires some comment. The historic data necessarily includes the effects of all causes of shoreline change over the last 100+ years, including any sea level rise and any land subsidence or emergence. Land movement is not believed to have been significant in Florida over the last 100+ year record. The effect of sea level rise appears to be entirely obscured in the data by accuracy limitations, the effects of storms and littoral barriers, and the longshore movement of sand. For the time being, erosion projections will continue to be based on the historic record of change and the observed longshore processes.

Results

Descriptions of the general findings for some regional areas have been published in various conference proceedings (Foster 1989b, 1991b). However, most of the results exist as in-house reports, pending verification and time to prepare items for publishing.

The historic shoreline maps and data reveal that Florida's sandy beaches have changed in systematic, progressive patterns over the historic record. The shoreline changes appear to be occurring in patterns dictated by the longshore sediment transport equation. The primary factors appear to be the local sand supply situation, the prevailing wave climate, and local geographic features such as rock and peat exposures, nearshore reefs, and man-made littoral barriers. In some areas, the coast is dominated for many kilometers by nearshore rock/reef. It is necessary to account for these features if a thorough understanding of the historic record is to be obtained.

There is certainly randomness in the short term due to seasonal changes, storms, and yearly climatic variations, but these tend to average out over a longer time period. Major storms such as hurricanes also inject an element of randomness by occasionally altering the local conditions, particularly at inlets. In the situation of an uncontrolled inlet, although we may have some understanding of what is occurring, it is not generally a very predictable process.

Problems

There are several problems which eventually need to be better resolved. At the current staffing level it will necessarily take many years of persistent, careful work to update the data base and to complete the analysis of the state.

One technical issue involves the analysis of areas with existing coastal armoring, including seawalls, revetments, and groinfields. Some of these areas have been armored for most of the historic record, and the condition of the structures varies tremendously. Another technical issue involves setting a thirty year erosion limit in the vicinity of uncontrolled inlets, where large beach width changes are frequent and random. Yet another technical problem involves predicting erosion in the several large areas of the state which have been controlled by repeated beach renourishments over several decades. There is usually insufficient monitoring data for these areas, as well as the complications of varying fill placement volumes, locations, and sand quality. Better monitoring and the use of modeling should help in this situation.

In most areas there is a lack of information regarding nearshore and subsurface geologic features such as rock, peat, and reef formations. The effects on the MHW of dune/bluff recession and overtopping caused by storms are not fully understood at this time. There is also insufficient information to prepare a reliable volumetric budget for many areas.

Beyond the technical issues, there is the human problem of dealing with preconceived, simplistic assumptions about erosion. The data and physics indicate that shorelines are very often not changing at a constant rate, contrary to popular belief and the desire for convenience.

Conclusions and Recommendations

A high quality, reliable, updated historical shoreline data base, necessarily including ground truth data, is a worthwhile investment. The data should be related to observed coastal processes in order to reach a basic understanding of cause and effect. The analysis methods and results should include projections of future changes, regardless of whether there is a legal need, and these should be tested over time. In Florida, the shoreline changes are very often non-linear, i.e. not occurring at a constant rate. However, the patterns of shoreline change appear to be very consistent with the physics of the longshore sand transport equation. Longshore models are useful and will probably become necessary in the analysis of many cases.

In the opinion of the author, it is now possible for an analyst to develop a basic understanding of longshore coastal processes for most areas of Florida based on reliable data and physics, rather than subjective judgments. Many problems remain, but a reasonably good start has been made.

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