Utilization of Remote Sensing Methods for Management of Florida's Coastal Zone

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ABSTRACT: Natural erosion processes and construction influences constantly change Florida's coastal zone. Monitoring shoreline changes is the most crucial element in managing the coastal zone, and historically this has been accomplished by surveying the nearshore bathymetry and shoreline topography at one thousand feet intervals using traditional hydrographic and leveling practices. Aerial photography has been used in conjunction with the surveys to monitor structural changes in the coastal zone. Comparison of new and old data is made possible by all surveys and photography being referenced to a state plane coordinate system and vertical control linked first order. Because of time and cost to survey using conventional methods and to maintain control points, only three to four counties' coastlines were surveyed each year.

Recent technology advancements in remote sensing methods provide new tools to monitor larger areas each year at a lower cost without sacrificing the accuracy provided by traditional methods. LIght Detection And Ranging (LIDAR) provides dense, accurate hydrographic and topographic data simultaneously along the beach. The US Army Corps of Engineers Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system has been used successfully to cost effectively collect nearshore bathymetry and shoreline topography along Florida's coast. Kinematic Global Positioning System (GPS), linked to Florida's High Accuracy Resolution Network (HARN), was used for horizontal and vertical data positioning. Because the historical and new data are linked to the HARN, data are compared quickly and easily without conversions. Digital orthometric photography, also linked to the HARN, was taken at the same time as the lidar data. This digital photography provides engineers a method of monitoring structural changes in the coastal zone. The combination of these tools will allow monitoring of the entire state's coastal zone every two years.

Other benefits to coastal zone management come from dense lidar data and digital orthometric photography. Post-storm data can be collected within days following a storm event and compared to pre-storm data for damage assessment. These data may be used to develop new three-dimensional erosion prediction models to supplement or replace existing two-dimensional models. These data will be loaded into a Geographic Information System (GIS) as bathymetric, topographic and photography layers to assist the coastal zone management process.

Better representation of the coastal zone is obtained by combining lidar hydrographic and topographic data with digital orthometric photography. Utilization of these methods will result in less effort spent maintaining survey control, more frequent monitoring, and improved coastal zone management.

1.0 Introduction

The Florida Department of Environmental Protection’s (FLDEP) Bureau of Beaches and Coastal Systems continuously monitors and manages Florida’s coastline. The tremendous length of shoreline coupled with human and nature-influenced dynamics make this an enormous and ongoing process. With a greater consciousness for spending and resources, traditional methods of data collection to support shoreline management are being revised and augmented by technologies which provide a more comprehensive approach. However, these technologies offer improvements in all aspects of shoreline management from data collection to data analysis, and beyond. Data, information and tools are now available which allow the FLDEP to manage the coastline as

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contiguous regions rather than individual segments. This regional approach provides a more comprehensive analysis of the coastline and a better understanding of the dynamics of the shoreline.

The FLDEP is responsible for monitoring and managing approximately 680 miles of Florida's coastline. This includes the state's entire coastline except for Monroe County (Florida Keys) and Federal sites. These management efforts are the result of two contributing factors. In addition, nature constantly changes the shoreline through normal coastal processes and occasional storm events. Other shoreline changes result from mans engineering activities associated with ports and harbors and shoreline stabilization. The FLDEP must identify and quantify these changes and manage the coastline to preserve Florida's most important natural resource – its beaches.

2.0 Traditional Management Tools

Conventional survey methods employed by the FLDEP have produced a very comprehensive data set for coastline management. Historically, the coastal monitoring has been based on cross sections surveyed at one thousand foot intervals. These cross sections include both the subaerial (topographic) and nearshore (hydrographic) areas. The topographic data extends from the water line to an established baseline marked by survey monuments. Measurements are taken at fifty feet intervals and at points of slope change along these cross sections. The nearshore survey extends from the waterline to either the 30 ft contour line or 2,400 ft from the shoreline, whichever is closer. Survey monuments on the baseline are maintained so that subsequent surveys may be taken in the same locations providing a common reference point to allow comparisons. Because of the time required to collect these data, only three to four counties' shorelines are surveyed each year using this technique. Aerial photography is taken in conjunction with the surveys to provide visual record and supplement the coastline management process.

3.0 New Surveying Tools

Advancements in survey technology have provided new tools for gathering data to manage the coastline. Airborne lidar is one such advancements. Lidar is an acronym for LIght Detection And Ranging. Lidar works similar to radar, but a laser is used instead of radio waves for distance measurements. Each laser pulse is transmitted from the airborne platform to the surface below. Some of the light energy is reflected from the water surface and detected by onboard optical sensors. The remaining energy continues through the water column, is reflected from the bottom and is detected by the onboard sensors. The time difference between the two energy returns indicates the water depth (Guenther, Thomas and LaRocque, 1996).

The U.S. Army Corps of Engineers' Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system is an airborne lidar system capable of measuring nearshore depths and subaerial elevations. The system is mounted on a Twin Otter DeHaviland DHC-6, shown in Figure 1, that operates "at an altitude of 300 to 500-m and at speeds up to 70 m/s" (Parson, Lillycrop and McClung, 1999). Sounding densities vary from four to eight meter horizontal grid spacing, depending on the altitude, swath width and speeds used during data collection.

Figure 1: Twin Otter DeHaviland DHC-6 Aircraft Used as SHOALS Platform

The FLDEP has established a program to utilize SHOALS to support its monitoring of Florida's beaches and to date has utilized SHOALS to survey in the panhandle and southwest regions of Florida in 1998 and along the east coast in 1999. SHOALS collected shoreline data from Panama City to Alligator Point and from Anna Maria Key to Captiva Island (Figure 2). By traditional methods these areas would have required close to two years to survey, but though the use of airborne lidar the areas were surveyed in approximately one month producing data on an 8m by 8m grid spacing as opposed to the historic 1,000 ft cross sections. The

Figure 2: Areas Surveyed by SHOALS

speed and cost effectiveness of SHOALS will enhance FLDEP's ability to "resurvey more beach areas on a more frequent basis" (Green, 1998).

4.0 Regional Shoreline Management

Effective management of the coastline relies on an accurate quantification of regional over time. Three major efforts are involved in the management process. First, collect data over regional scales to accurately quantify conditions. Next, compare the conditions from various time periods to identify areas of change. Finally, determine the cause and rates of change through detailed analysis of the data and apply coastal engineering analysis and prediction tools.

4.1 Regional Data Collection

The FLDEP objective is to survey the state's coastline every two years. Approximately half of the state's shoreline will be surveyed in alternating years to accomplish this goal. Elevations from approximately 500m landward of the water line to 750m seaward are collected at 8m spacing. Survey control is established along the coastline using high accuracy Global Positioning System (GPS). GPS data are collected on the airborne platform and at the control stations as SHOALS lidar data are being collected.

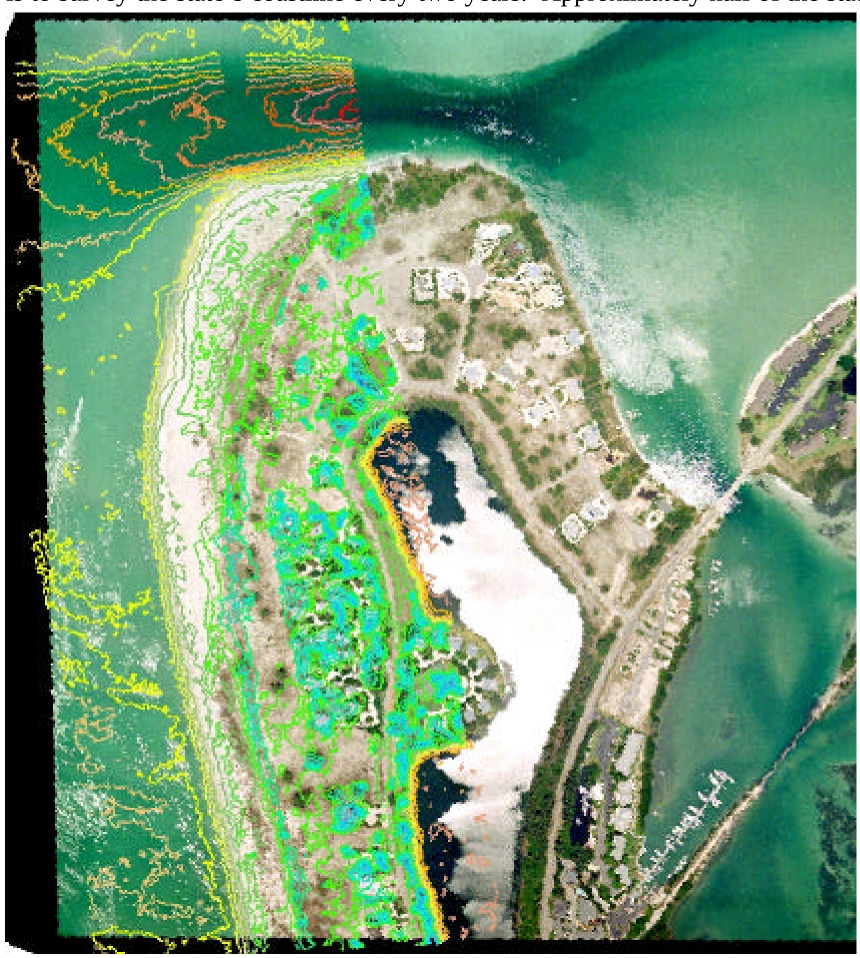

Figure 3: SHOALS' Contours and Aerial Photography at Gasparilla Island, Florida

Each lidar measurement is positioned by dual-baseline post-processed kinematic GPS (KGPS). This provides each lidar measurement a horizontal accuracy of ?1m. SHOALS data are fused with aerial photography and overlaid in a GIS for presentation and analysis. Figure 3 shows an example of the seen when SHOALS' high-density data are overlaid and used in conjunction with aerial photography. Computer generated contours of lidar data collected at Gasparilla Island, Florida accurately overlay features shown in the photography. Such features include shorelines, vegetation, roads, buildings, beaches and dunes, as well as the bathymetry indicating channel location, nearshore bars and beach erosion hot spots.

4.2 Multiple Survey Comparison

Surveying the coastline every two years adds to the historic data collected by FLDEP since the 1970's and allows for comparison of data which shows general and detailed changes in an area. Figure 4 illustrates the comparison of subsequent lidar surveys showing the migration of the thalweg at New Pass, Florida over multiple

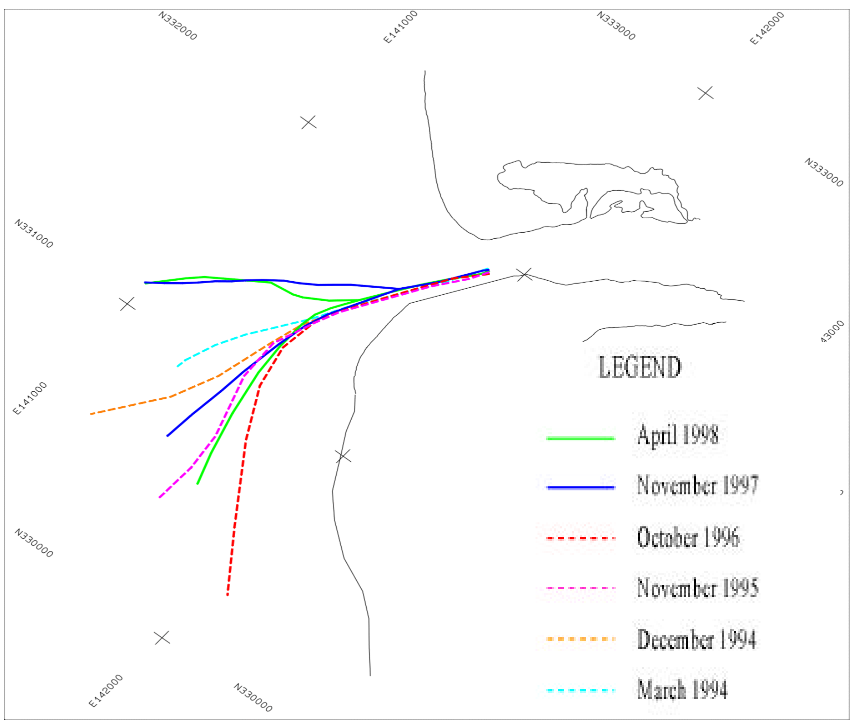

Figure 4: Thalweg Migration, New Pass, Florida

years. The thalweg migrated southward from April 1994 through October 1996 (Irish and Lillycrop, 1997). After October 1996 the U.S. Army Corps of Engineers dredged the channel and the correct thalweg location is shown farther north in November 1997 than in October 1996. Although this is one small project it illustrates the utility of SHOALS data for conventional coastal analysis as well as quantitative volumetric changes throughout entire regions.

4.3 Data Analysis

Application of coastal engineering analysis and prediction tools to determine the causes of and manage erosion is the final step in effectively managing the coastline. Digital terrain modeling (DTM) software quickly makes depth and volume change calculations over large areas. Three dimensional computations are more accurate when based on high density data, such as the 8m by 8m data provided by SHOALS, because small shoreline changes affecting the volumes are detected by dense data. Profile lines surveyed on 1,000 ft intervals often miss features critical to accurate volume calculations (Irish, Lillycrop, and Parson, 1996). For instance, Figure 5 provides an excerpt of SHOALS data from Longboat Key, Florida where the multiple bar system paralleling the shoreline merges into one bar in a historically high erosion area, or "hot spot" (Irish and Truitt, 1995). For the purpose of computing volumes, the region can be divided into smaller areas and sediment budgets can be monitored. Trends in sediment movement are determined through comparison of volume computations from multiple temporal data sets (Irish and Lillycrop, 1997).. However, erosion and accretion contours made from

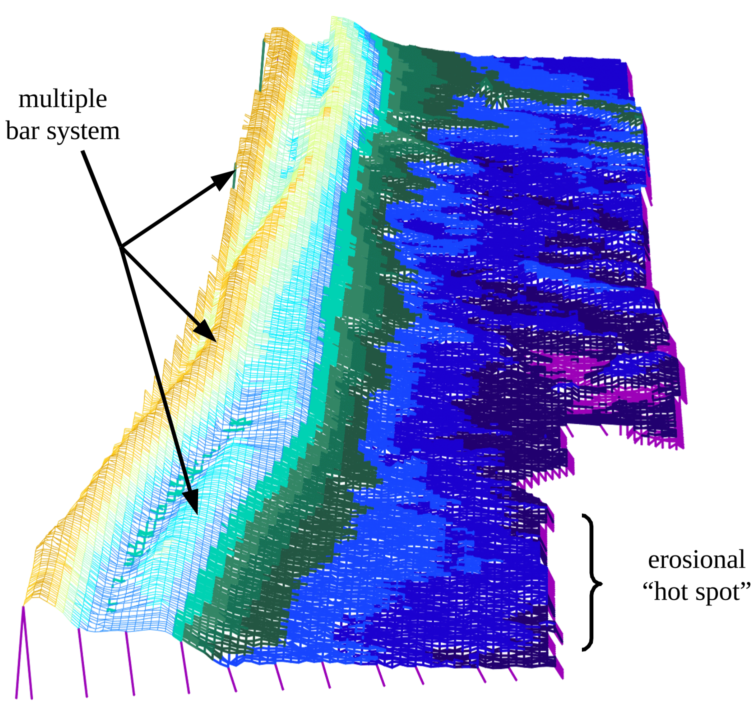

Figure 5: Erosion Hot Spots, Longboat Key, Florida

depth change calculations must also be examined because material may be moved within an area over which a net volume change is negligible. Only after areas and causes of change have been defined can effective management of the coastal zone occur.

5.0 Conclusion

The combination of regional mapping, comparing and analyzing regional temporal data provides a valuable tool for managing Florida's coastline. Even though SHOALS is a new technology for data collection, data are easily and accurately matched with the historical profile data, because both are referenced to Florida's State Plane Coordinate system. These data may be merged through the use of Geographic Information System (GIS) software, which allows both digital survey data and digital photography to be overlaid with one another. The methods of data collection and type of data being collected are both planned toward use in the GIS software.

SHOALS provides fast, cost efficient data coverage allowing Florida's coastline to be mapped on a more frequent basis than by using traditional survey methods.

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