Biennial Report of Sand Beaches; Harrison County, 2001

Keil Schmid

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S. Cragin Knox
State Geologist

Mississippi Department of Environmental Quality
Energy and Coastal Geology Division

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This work has been checked and approved for publication by the following Mississippi Registered Professional Geologist –

Jack Moody

Director of Energy and Coastal Geology Division

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The goal of this report is to identify and quantify areas of shoreline change. In addition, the occurrence or lack of shoreline change is compared to physical properties of the beach and surrounding structures. Detailed analysis of site-specific conditions that create shoreline erosion is beyond the scope of this report; this is meant to be a step toward that important goal.

From 1992 to 2000 the Harrison County Beach was maintained to a uniform, but continuously decreasing beach width. Volume changes, which more accurately portray beach change, indicate that sediment has generally moved from the "dry" beach to the submerged "wet" portion of the beach. No estimates were made on the loss of sediment onshore to Highway 90. Although there is an overall trend of erosion, shoreline retreat of more than 1 m/yr (3.3 ft/yr) occurs on only 27% of the beach. Overall, shoreline retreat increases toward the west; specifically it is concentrated on the ends of the beach and at locally occurring hot spots. Regional volume changes do not follow an easily recognized pattern. They do, however, suggest that about 10,000 cubic yards of sediment are lost yearly from the beach system, which includes the nearshore platform. If only considering loss on the dry (above mean low water) portion of the beach, nearly 30,000 cubic yards are lost annually to the nearshore platform and some onshore to Highway 90. The long length of the beach and extensive nearshore platform reduce sand loss from the system. Before the latest renourishment (2000-2001), flattening of the beach by maintenance equipment, while maintaining a wider width, had, in most cases, lowered the beach elevation and restricted dune growth, which are both important for storm protection. This practice will continue following renourishment, but the process should be examined in terms of protecting against short duration, high-energy events (hurricanes, extra-tropical lows).

The renourishment in 2000-2001 contributed an estimated 1.2 to 1.3 million cubic yards of sand to the beach from borrow pits located about 600 to 700 m (1/3 of a mile) offshore of the beach. After a short period for the beach to equilibrate with the wave conditions, the average beach width had been increased 17 m (55 ft) from the 2000 width. The beach was widened most at the critically eroding hot spots, and thus beach width increase between 2000 and 2001 is also a good measure of where shoreline retreat is problematic. The data included in this report are available at many different scales and in digital format from the Mississippi Department of Environmental Quality, Office of Geology.

Introduction

The Harrison County Beach (Figure 1) is a valuable asset to residents and visitors alike. Beaches are vital environmental, cultural, recreational, and economic resources; they help maintain the health and productivity of adjacent coastal waters and provide for diverse cultural and recreational activities. Moreover, in Mississippi, they are important in limiting infrastructure damage and protecting the 75 year old seawall. Thus, with an increase in development along the Mississippi Gulf Coast, the beaches are becoming an even more valuable asset. For these reasons, the Mississippi Office of Geology will continue to update local communities on the state of their sand beaches.

This is the second interim report (see Schmid, 2000a for the previous report); it is meant to update coastal governments on the state of their beaches from a coastal geology perspective and highlight areas that may require more resource allocation. More in-depth analyses, including surface and subsurface geology, sand bar morphology, and total-sand-volume calculations are in progress. The data presented here include GPS shoreline surveys and beach profiles along the beach from Henderson Point to the end of the renourished beach in Biloxi; this study encompasses the years of 1992 to 2001. Changes during the period between 1992 and 2000 are used to analyze the longer-term trends. Analyses of changes between 2000 and 2001 are mainly to document the beachwide renourishment beginning in November 2000 and ending in July 2001. In this case, changes will be monitored to better understand how the beach equilibrates itself and where the sediment is transported to and lost from.

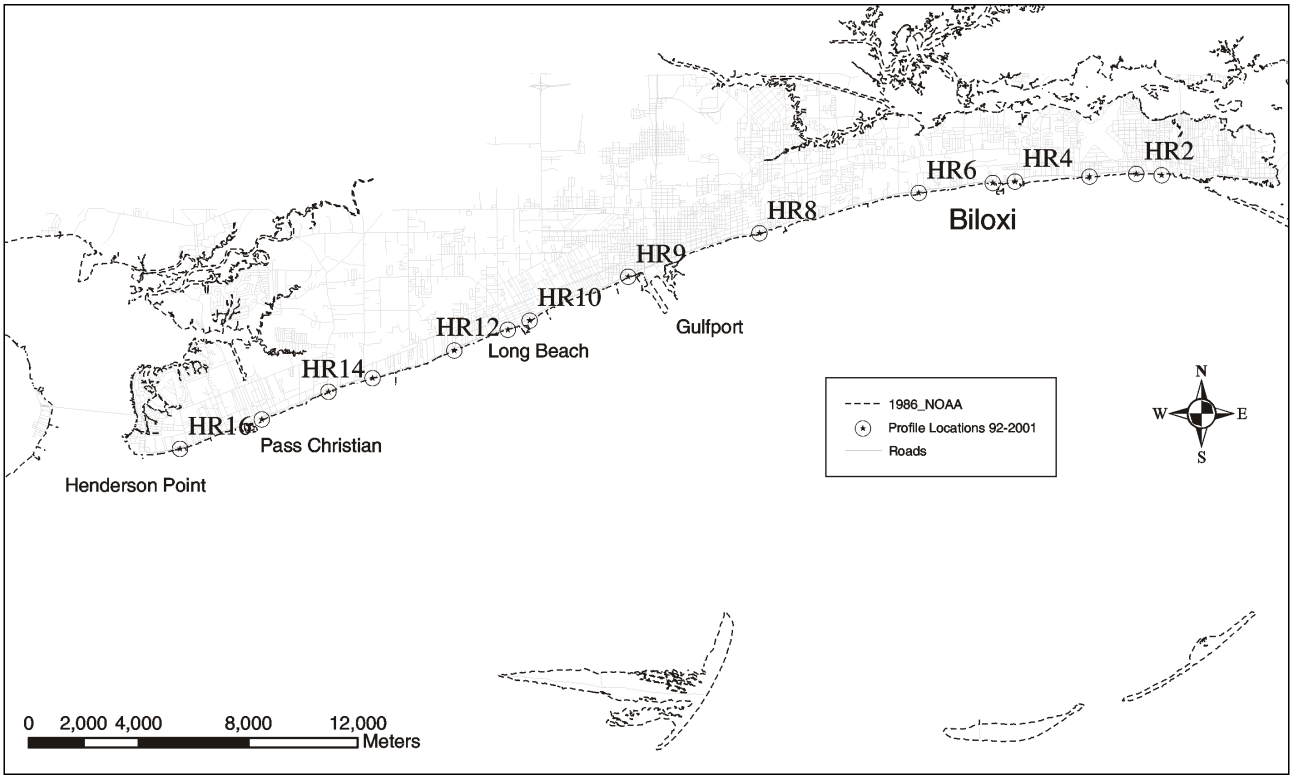

Figure 1. Harrison County base map with profile locations.

Methods

Two methods were used to map and describe beach change, both above and below sea level. Shoreline surveys of the mean high water (MHW) line were carried out using backpack style GPS (Global Positioning System) receivers with an accuracy of 1-2 meters (3-6 ft.). To supplement the data, beach profiles with accuracies of inches are used to measure volume changes and beach shape. To analyze the survey data within the bounds of the physical setting, aerial photography in the form of Digital Ortho Quarter Quads (DOQQ's) were used in a Geographic Information System (GIS) as a base map. These data files were downloaded from the Mississippi Automated Resource Information System (MARIS).

The MHW line has been chosen as a repeatable datum for the GPS shoreline surveys, which were done in the summer and spring months. The error in determining the high tide line is, based on comparison of multiple surveys of the same beach area, on the order of 1-3 meters (3-10 ft.). Thus, the overall accuracy of the method is generally about 2-5 meters (6-16 ft.) (Hutchins and Oivanki, 1994). GPS surveys of the high tide position were carried out in 1993, 1994, 1996, 1998, 1999, 2000, and 2001.

To examine areas with significant shoreline change a buffer analysis was performed using a Geographic Information System (GIS). The technique highlights any portion of the shoreline with retreat or accretion (change) of more than a predetermined value. Two values were chosen to highlight moderate and high change. These values were based on the total change from 1993 to 2000 and are similar to the value (1.2 m/yr) classified by Otvos (Otvos, 1976) as critically eroding. In an effort to summarize the shoreline and its spatial characteristics it was broken into individual 50m segments. The spatial characteristics were then compared to the shoreline change to examine relationships between shoreline angle and proximity to structures to shoreline behavior.

Proximity to culverts and shoreline angle were computed for each segment and compared to shoreline change. Culvert locations were digitized from obvious departures in shoreline patterns from 1993 to 2001, located by visual inspection of orthophotos, and taken from previous databases with culvert locations. Some of the smaller culverts may have been missed; an earlier study (Schmid, 2000b) demonstrated that shoreline response is affected mainly by larger diameter culverts.

These GPS surveys and analysis techniques do not show the extent of storm-related or astronomical high tides. In many locations wind tides can advance the shoreline several tens of meters (50+ ft.) beyond the mapped shoreline. During these events the shape or elevation of the beach is critical in protecting infrastructure and limiting erosion. In addition, beach maintenance and storm water runoff from the coastal roads are periodic events that can obscure local trends. Therefore, the GPS surveys, though largely representative of erosion and accretion, are augmented by higher accuracy beach profiles.

Beach profiles are performed using traditional survey grade instruments giving accuracies on the order of one inch. They have been taken since 1991 on the Harrison County beach; the data for this report come mainly from 1992, 2000, and 2001 surveys. Unfortunately, beach profiles are time consuming and therefore only performed at set locations along the shore. Spacing between beach profiles is determined by structures (e.g., harbors), access, degree of change based on GPS surveys, and change in beach morphology (e.g., dunes).

Beach profiles are aligned at right angles to the shoreline, beginning at the seawall, and ending at depths around –4 feet (up to chin of survey personnel), which typically corresponds to the sand/mud boundary. Elevations are based on benchmarks or station elevations along the seawalls that reference National Geodetic Vertical Datum 1929 (NGVD-29). Beach profiles encompass nearly the whole beach system, from seawall to the start of deeper water and the change from a sandy to a muddy bottom. It is, thus, a more accurate technique to describe changes that take place. Beach profiles, while representing changes caused by beach maintenance, wind loss, storm runoff, and high tides, are not compromised because of them.

In this report, beach profiles are used to calculate sand volume change over the studied periods, highlight areas of erosion and accretion, and document the evolution of sediment transport features (i.e., megaripples and sand waves). Unfortunately, in the longer term analysis (1992 to 2000) there are some gaps in the survey dates, such that in some years certain profiles were not measured and others were. To correct for this, and to account for the different survey length (to standardize loss per foot of 'beach') a yearly or decadal change rate was computed for the average 1050 feet wide beach system (250 feet of dry beach and 800 feet of nearshore platform).

In addition to standardized volume change at each location, volume change per linear foot of beach width was also computed to provide real numbers of sand loss or gain. Volumes include the dry beach (above 0 elevation) as well as the beach below sea level to about -4.0 feet. Values from the most recent profile surveys (2000 and 2001) were taken to document the volume of sediment pumped onto the beach and lateral changes in renourished sediment, and to separate future change patterns from quick changes that occur on newly renourished beaches as they adjust to achieve a state of semi-equilibrium.

Harrison County Results – 1992 to 2000

As the Harrison County Beach is significantly long, this report has been broken up into three sections: West, Central, and East Harrison County. The total average change (both erosion and accretion) over the entire 40.25 km (25 mile) surveyed shoreline (there are some small stretches with no data coverage) from 1993 to 2000 is between 5 and 7 m (0.71 to 1.0 m/yr). Since 1 m/yr change is an easily relatable value and is consistent with the level of retreat considered critical by Otvos (1.2 m/yr, Otvos, 1976), buffer widths for the 1993 to 2000 analysis are based on this value. Areas with less than 7 m (23 ft) of change in the seven-year period are treated as stable or effectively maintained as such. Areas with 7 to 14 m of change are considered retreating (eroding) or advancing (accreting) and areas with more than 14 m (2 m/yr; 6.5 ft/yr) of change are considered highly retreating or highly advancing. For each section the profile results are separated into standardized change, total volumes, and profile geometry.

Western Harrison County (Henderson Point to Long Beach)

Western Harrison County has several harbor structures and one of the most highly eroding stretches of beach on the coast. As it is also the downdrift end of one of the longest man-made beaches, the trends are important for understanding the entire beach system and potentially where sediment ends up.

GPS Shoreline Surveys

Shoreline values

Comparison of the 1993 and 2000 GPS shoreline surveys provides a long-term average of where and how much shoreline retreat and advance are occurring. Of the 14.1 km (8.75 miles) in this section, about 40% of the shoreline is retreating at more than 1 m/yr (Table 1); only 6% is advancing at more than 1 m/yr. Clearly this shows a net trend toward erosion, which is typical of most beaches in the Gulf of Mexico and around the world. Given this erosional trend, sections that erode the quickest are an even more important problem and are a weak link in the beach. Areas with more than 2 m/yr of erosion (double the average rate) are considered highly eroding. These areas are the most costly as more work must be done to move sand or, alternatively, they create a situation where it is necessary to renourish more often. Eight percent (8%) of the shoreline along this stretch is classified as highly eroding.

Table 1. Shoreline statistics in Western Harrison County

Total Shoreline (m)	7-14 m erosion (m)	> 14 m erosion (m)	> 7 m accretion (m)
14115	4048	1069	855
Percentage %	29	8	6

Shoreline trends

Locally, the highest levels of retreat were to the west of Pass Christian harbor and near HR-12. Another location, west of Long Beach harbor, also had very high retreat; however, given that this was a known erosion 'hot spot', a project was undertaken in 1999 to scrape sand from offshore and place it on the beach. This widened the beach and thus masked the highly erosional pattern in the short term. Two of the three locations with high levels of shoreline retreat are downdrift (west) of harbor structures. Shoreline change appears to be grouped; shoreline retreat typically occurs in lengths that average about 100 m (330 ft).

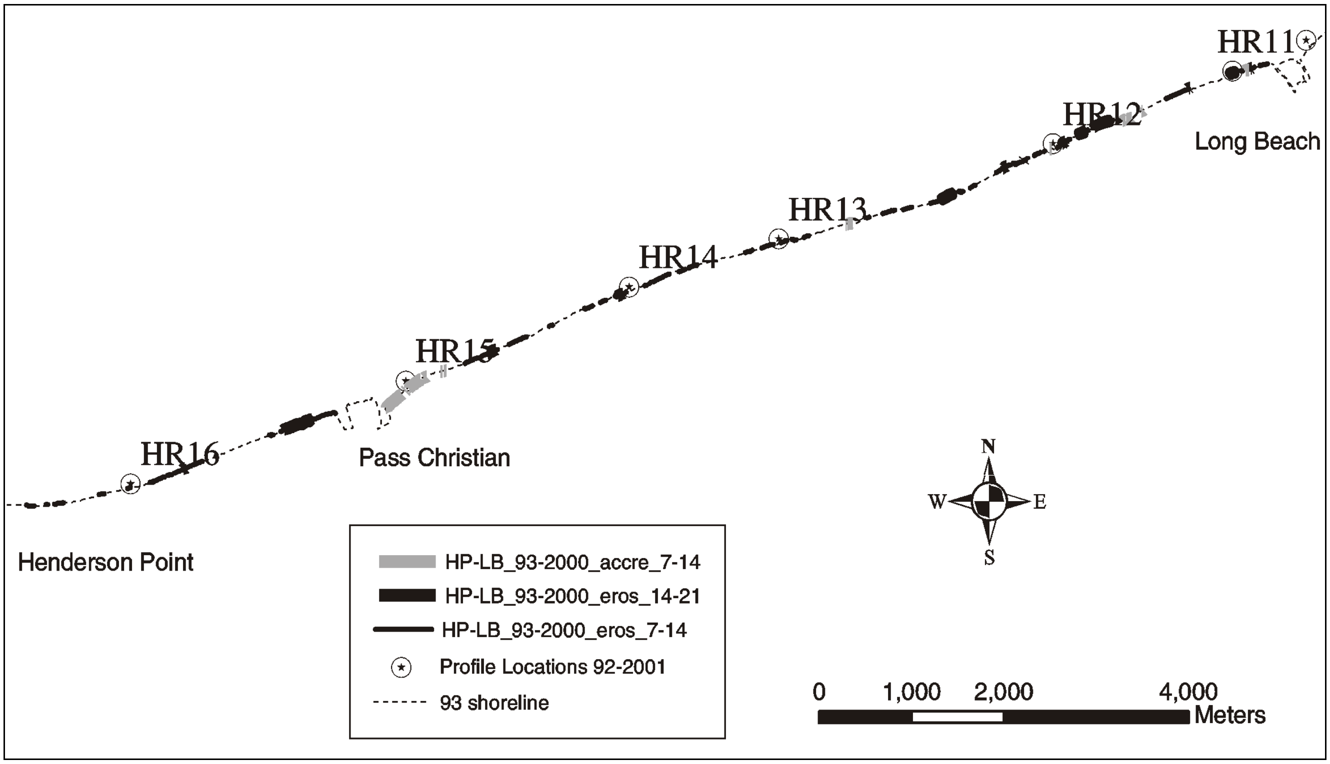

Figure 2. Shoreline advance and retreat from Henderson Point to Long Beach.

To determine the association with culverts, all of the shoreline segments within 20 m of erosion were selected and then compared to segments that are also within 20 m of culverts. There were 180 50 m-segments (9000 m) within 20 m of the eroding shoreline (Table 2). The value (64%) is larger than the overall retreating shoreline (40%) because, even if there is a 1 m eroding segment within 20 m, the entire 50-m segment was classified as eroding. This 64% can be looked at as a baseline, such that a higher percentage value would suggest that there is a factor (culverts in this case) increasing the amount of erosion; a lower value would suggest that there is a factor decreasing the amount of erosion.

Of the total eroding segments, 50% were within 20 m of a culvert (Table 2). The total shoreline (50 m segments) within 20 m of a culvert was 6,850 m and about 66% was classified as eroding. In both erosional segments near culverts / total erosional segments (50%) and erosional segments near culverts / shoreline near culverts (66%), the values were basically at or lower than the baseline (64%). Thus, this comparison of eroding shoreline near culverts and the total percentage of eroding segments suggests that culverts as a whole on this stretch of beach do not concentrate erosion. This does not mean that culverts are not factors in causing erosion, as different size (diameter) culverts have distinctly different effects on beach response (Schmid, 2000b) and in specific locations they are certainly large factors. A closer look at culvert sizes and shoreline retreat is necessary to better quantify the process, but at first look, culverts as a whole do not appear to be the controlling factor in shoreline retreat patterns.

Table 2. Culvert shoreline statistics in Western Harrison County

Total Shoreline (m)	Culvert Shoreline (m)	Erosional Segments (m)	Eros Segments near Culverts (m)
14115	6850	9000	4500
Shoreline near Culverts (%)	Eros Segments/Total shoreline (%)	Eros Segments near Culverts/ Eros Segments (%)	Eros Segments near Culverts/ Culvert Shoreline (%)
49	64	50	66

To determine if erosional segments show any relation to the shoreline angle, the shoreline orientations of all 50 m segments were compared to the orientation of 50 m segments within 20 m of erosion. In both, the average shoreline orientation (direction facing the sound) was 161 degrees; however, the difference in percentage of each total within the five-degree interval (Table 3) suggests that the interval from 155 to 165 degrees has a slightly higher percentage of erosional segments. In contrast, shoreline segments with the most easterly orientation have fewer occurrences of erosion and are probably the outcome of accretion on the updrift sides of culverts and structures.

Table 3. Shoreline angle and shoreline retreat in Western Harrison County. Negative difference values indicate lower erosion percentage; positive values indicate higher erosional occurrence.

Shoreline Angle	135	140	145	150	155	160	165	170	175	180	185	190	195	205
# of total segments	2	2	7	21	30	85	58	41	16	16	6	5	3	1
% of total	0.7	0.7	2.4	7.2	10.2	29.0	19.8	14.0	5.5	5.5	2.0	1.7	1.0	0.3
# of eros. segments	0	0	2	11	20	61	37	22	8	10	1	4	2	1
% of total	0.0	0.0	1.1	6.1	11.2	34.1	20.7	12.3	4.5	5.6	0.6	2.2	1.1	0.6
Difference %	-0.7	-0.7	-1.3	-1.0	0.9	5.1	0.9	-1.7	-1.0	0.1	-1.5	0.5	0.1	0.2

Accretion is basically confined to the areas updrift (east) of Pass Christian harbor, where there is a nearly continuous 450 m stretch of accretion. The shoreline orientation here is among the most easterly and is a product of sand being trapped by the harbor structure. The shoreline angle, like culverts, does not in and of itself appear to control erosion, but may be a result of it.

Beach Profile Surveys

Standardized change

Standardized change is used to describe volume changes in terms of absolute values regardless of how wide or narrow a profile is. Maps 1 (standardized onshore volume change) and 2 (standardized nearshore volume change) detail the standardized change for the entire beach system. The western section is between HR-16 and Long Beach Harbor. Nearshore (offshore) standardized volume change (Map 2) indicates that offshore loss is restricted to the areas updrift of Pass Christian Harbor (HR-14 and HR-15), and that in general the nearshore platform is gaining (Map 2) on this section of beach. The onshore change (Map 1) is negative across most of this section. The highly negative onshore change downdrift of Long Beach harbor (HR-11) is consistent with a local and aforementioned ‘hot spot’. The other ‘hot spot’ (HR-14) is dominated by a trend of both negative onshore volume change and a negative offshore change. The remaining profile segments have a balance between onshore and nearshore volume change.

The onshore and offshore profile changes suggest several possible scenarios for sediment transport. Sediment transported in the swash zone (above low tide elevation) is likely directed offshore and downdrift between Long Beach and Pass Christian Harbors. The downdrift direction is typically east to west; however, there is also a west to east component especially in the summer months (Schmid, 2000b). As a result, east of Pass Christian Harbor (HR-15) the sediment is trapped and moved more onshore. In contrast, west of Long Beach Harbor there is no sediment moving in the swash zone from the east and it ends up a sediment-starved area. West of Pass Christian Harbor sediment transport in the swash zone appears to have a higher offshore component that in conjunction with a lack of a western sand source leads to high onshore loses.

The offshore transport regime is more difficult to detail. The general trend is for sediment to move from onshore to offshore except at HR-14 and HR-15. As mentioned, the sediment is probably moved more in an onshore fashion at HR-15. The offshore loss at HR-14 is problematic and represents a ‘hot spot’ that needs further study.

Volumes

Volumes were not adjusted for the beach width; they are the raw changes in cubic yards. Based on the longest records available for the six profiles on this stretch of beach, a total of 3,500 cubic yards are lost per year (onshore + offshore). The largest loss is at the HR-11 profile (-1.5 cubic yards/ft); the largest gain is at the HR-16 profile (+1.5 cubic yards/ft). This trend is consistent with the longshore drift direction toward the west, which would tend to move sediment toward HR-16 from the entire beach. However, an important but unanswered question remains – how much sand is moving to the west of HR-16.

The most important trend from the profile volume analysis is the 25,000 cubic yards per year lost from only the onshore portion of the beach over this section of Harrison County, which is about 80-85% of the total Harrison County onshore loss. Unfortunately, it is difficult to assign a cause for the overwhelming percentage of onshore sediment loss on this section of beach given the wide spacing of profiles. Future work should be done here to verify the results and identify potential causes.

Beach Profile Surveys: Beach Geometry

The beach geometry or geomorphology is an important factor in determining how susceptible a portion of the beach is to flooding and storm events. Looking at the geometry through time also aids in determining how sediment is moving and where it is going. In response to a sea level rise in the absence of new sediment from rivers, eroding cliffs, or scarps, the shoreline retreats and the profile adjusts (Figure 3). In large part, the evolution of profiles subject to increasing sea level fit the Bruun Rule (Bruun, 1962) (Figure 3). Profiles from Long Beach to Henderson Point (Figures 4 and 5) are no exception; however, the profiles are also the product of beach maintenance practices and, thus, not totally representative of natural processes. This is evident in the lowering of beach elevation above the zero elevation (Figures 4 and 5) instead of an increase (Figure 3). The two profiles represent the difference between profiles with an overall positive volume change (Figure 4) and an overall negative volume change (Figure 5). Notice in both cases that the shoreline position (location of profile at roughly 1 foot elevation) retreated.

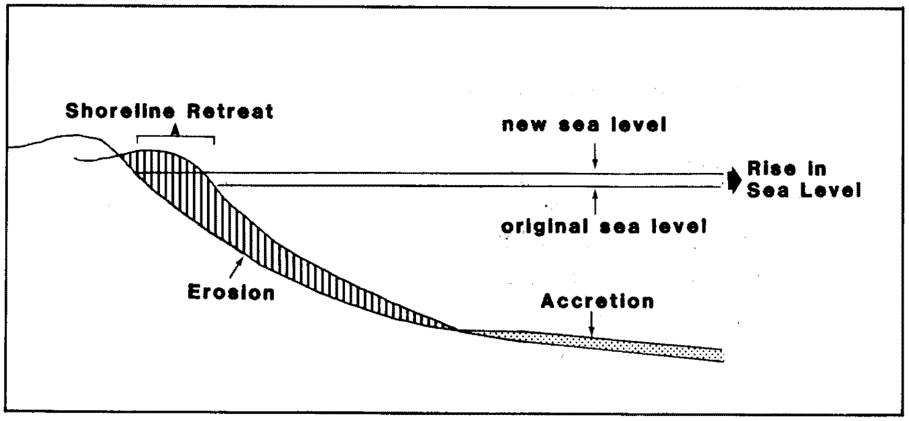

Figure 3. Generalized Bruun rule sea level rise (from Bruun, 1962).

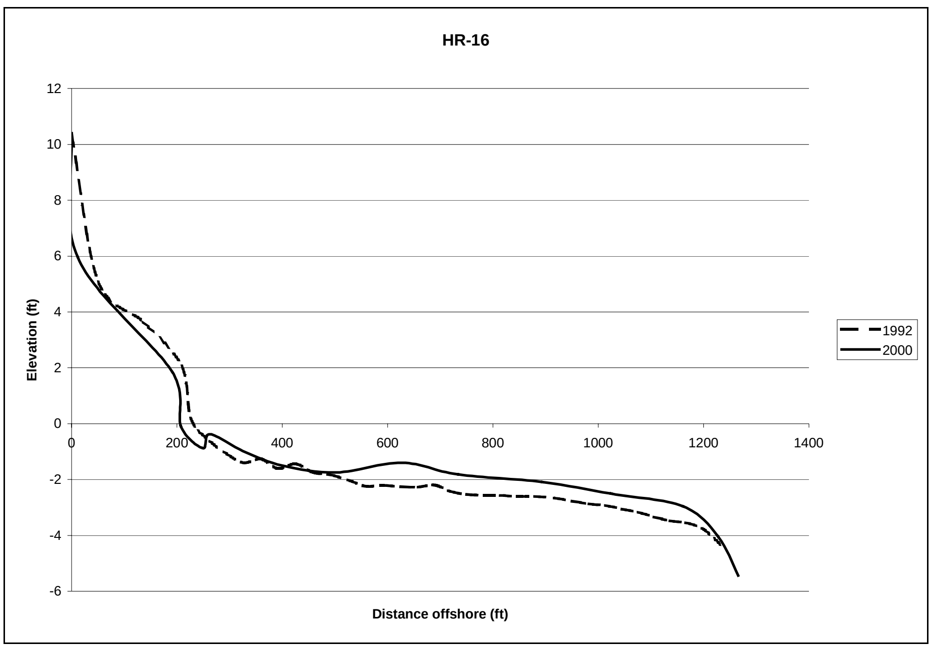

Figure 4. Profile at HR-16.

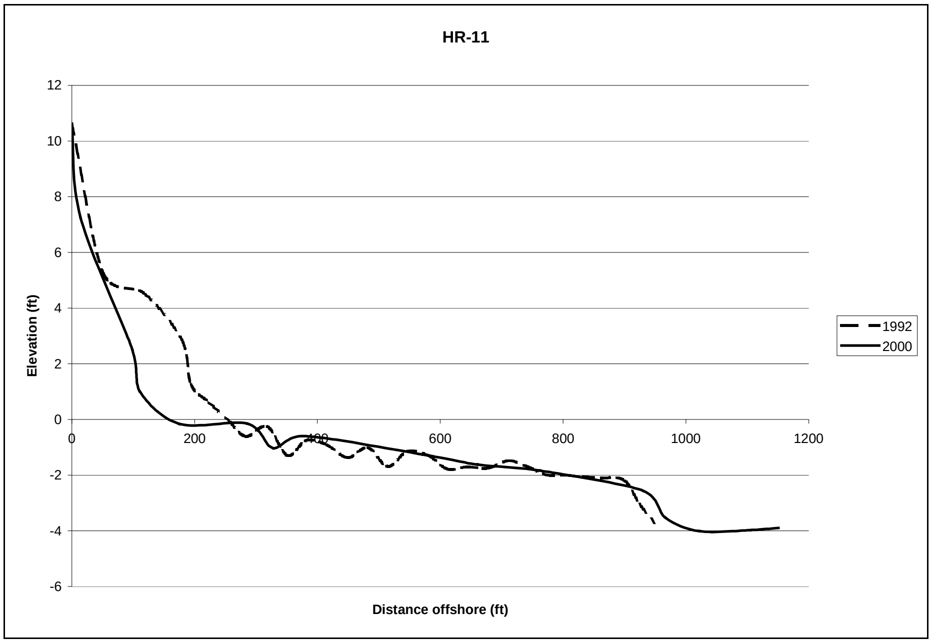

Figure 5. Profile at HR-11.

Local hot spots

Based on shoreline and volume changes the hot spots in this beach section are at HR-14 and HR-11. HR-11 has a dramatic loss of onshore volume, such that sediment is rapidly being moved seaward; its proximity and location downdrift of Long Beach Harbor are some important factors. HR-14 is removed from harbor structures but still shows a higher than normal trend toward shoreline retreat and volume loss. Both areas should be monitored more closely, and/or preferentially maintained to promote shoreline stability.

Central Harrison County (Long Beach – Gulfport – Western Biloxi)

This portion of the Harrison County shoreline is dominated by harbor structures; there are three such structures: Long Beach Harbor, Gulfport Harbor, and the Pier at Courthouse Road. Profile locations are widely spaced on this section of beach and therefore interpretations based on the data are tentative.

GPS Shoreline Surveys

Shoreline values

Comparison of the 1993 and 2000 MHW shoreline positions on this 14.8 km (9.1 mi) stretch indicates that, unlike the previous section, shoreline change is nearly balanced between retreat and advance. In all, more than a quarter of the shoreline is retreating at more than 1 m/yr; of that, 5% is retreating at more than 2 m/yr (Table 4). Shoreline advance of more than

1 m/yr occurred on almost 20% of the shoreline; of that, more than 6% was advancing at more than 2 m/yr. The high level of shoreline advance is likely a product of the harbor structures, similar to the shoreline advance updrift of Pass Christian harbor in the previous section, and beach maintenance.

Table 4. Shoreline statistics in Central Harrison County

Total Shoreline (m)	7-14 m erosion (m)	> 14 m erosion (m)	> 7 m accretion (m)
14800	3034	720	2715
Percentage %	21	5	18

Shoreline trends

Accretion on the eastern side of harbor structures and an increase in shoreline retreat to the east of Gulfport are the most obvious spatial trends. In the cases of Long Beach and the Pier at Courthouse Road (just east of HR-8), this is accompanied by retreat on the downdrift (western) side of the structures. At Gulfport Harbor, the downdrift side is advancing, which is atypical given the westward longshore transport. It appears that the harbor is large enough to not only block longshore sediment transport, and create the updrift accretion, but also to reverse or negate the dominant longshore direction for about 1 km (0.6 mi) to the west of the harbor. This acts to move sediment toward the harbor from the west and/or lessen the movement of sediment to the west (away from the harbor). In response to the longshore drift modification, however, there is a segment with high erosion very close to where the apparent node point lies; it suggests that this is the area where shoreline erosion is being caused by the harbor structure. It is interesting to note that the node point is about as far from the harbor as the harbor extends seaward. In addition to the actual harbor structure, there is a deep channel that precludes sediment transport from the east, effectively ending the transport cell.

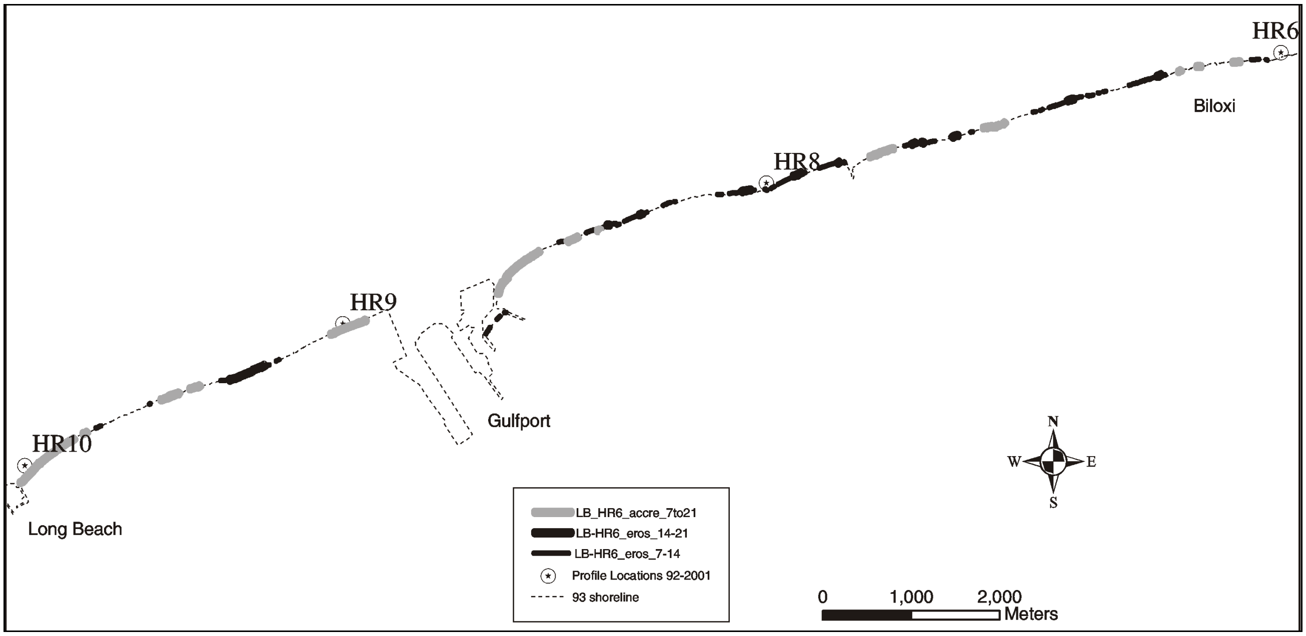

Figure 6. Shoreline retreat and advance from Long Beach to West Biloxi.

Culverts, like harbor structures, may be an important factor in shoreline response. Erosional 50-m segments constitute 47% (Table 5) of the section's shoreline. Of the 6,900 m of erosional segments, 57% were within 20 m of a culvert. Additionally, 7650 m of shoreline is within 20 m of a culvert and over half was classified as erosional. Using 47% as a baseline, comparison of total percent erosional segments to both erosional segments near culverts (57%) and erosional segments to culvert shoreline (52%) suggests that culverts play a role in concentrating shoreline retreat, as they are both higher than the baseline. Here again, the differences in culvert diameters probably play a big role in determining shoreline effects.

Table 5. Culvert shoreline statistics in Central Harrison County

Total Shoreline (m)	Culvert Shoreline (m)	Erosional Sements (m)	Eros Segments near Culverts (m)
14800	7650	6900	3950
Shoreline near Culverts (%)	Eros Segments/Total shoreline (%)	Eros Segments near Culverts/ Eros Segments (%)	Eros Segments near Culverts/ Culvert Shoreline (%)
52	47	57	52

Shoreline orientation of erosional segments shows a slight trend toward erosion on more southerly exposures (Table 6). This is probably a result of accretion on the eastern sides of harbors and culverts, which creates a more easterly shoreline orientation on the updrift side and a more south to southwest exposure on the downdrift side. The highly erosional segments (2 m/yr) show an even greater trend toward southerly exposures. In broader shoreline trends, the section from Gulfport Harbor to Long Beach Harbor is oriented more easterly (155 degrees) than the section from Gulfport to HR-6 (162 deg) and has less erosion (13% vs. 30%).

Table 6. Shoreline angle and shoreline retreat in the Central Harrison County section. Negative difference values indicate lower erosion percentage; positive values indicate higher erosional occurrence.

Shoreline Angle	120	130	140	150	160	170	180	190	200	210
# of total segments	7	6	11	24	99	87	45	10	3	1
% of total	2.4	2.0	3.8	8.2	33.8	29.7	15.4	3.4	1.0	0.3
# of eros. segments	1	2	1	8	44	45	24	7	2	1
% of total	0.7	1.5	0.7	5.9	32.6	33.3	17.8	5.2	1.5	0.7
Difference %	-1.6	-0.6	-3.0	-2.3	-1.2	3.6	2.4	1.8	0.5	0.4

Beach Profile Surveys

Standardized change

Onshore standardized volume changes west of Gulfport harbor are positive, such that there has been an increase in beach volume above the low tide line (Map 1). The nearshore (below low tide line) portion (Map 2), however, differentiates the two segments (HR-9 and HR-10); the segment updrift of Long Beach Harbor has a positive offshore volume change, the segment downdrift of Gulfport Harbor has a negative offshore volume change. This suggests that an onshore and east to west sediment transport regime is present between Gulfport and Long Beach harbors, which is consistent with the low level of shoreline retreat found here.

To the east of Gulfport Harbor the two profiles are widely spaced, limiting sediment transport interpretations. In both profiles onshore volume changes are minimal (slightly negative); however, offshore changes are distinctly different. Sediment was lost from the nearshore (underwater) portion of the HR-8 profile; the nearshore portion of the HR-6 profile gained volume. It is possible that sediment from the nearshore platform near HR-8 is feeding the eastern flank of Gulfport Harbor, where the shoreline has prograded significantly (10-20 m; 33-66 ft) during the seven-year period.

Volumes

Volumes were not adjusted for the beach width; they are the raw changes in cubic yards. Based on the longest records available for the four profiles on this stretch of beach, a total of 17,000 cubic yards are lost per year. The biggest loss is at the HR-8 profile (-2.6 cubic yards/ft); the biggest gain is at the HR-6 profile (+2.13 cubic yards/ft). Trends from volumes indicate only that Long Beach Harbor (HR-10) is effectively trapping sediment and that HR-8 is a 'hot spot' area that needs careful analysis in the future.

Beach Profile Surveys: Beach Geometry

Of the three profiles with negative nearshore volume change in the entire study area, two were within this section (HR-8 and HR-9). The HR-9 profile (Figure 7) is an example of this case. There is evidence that the sediment is moving offshore, creating a wider nearshore, instead of growing vertically.

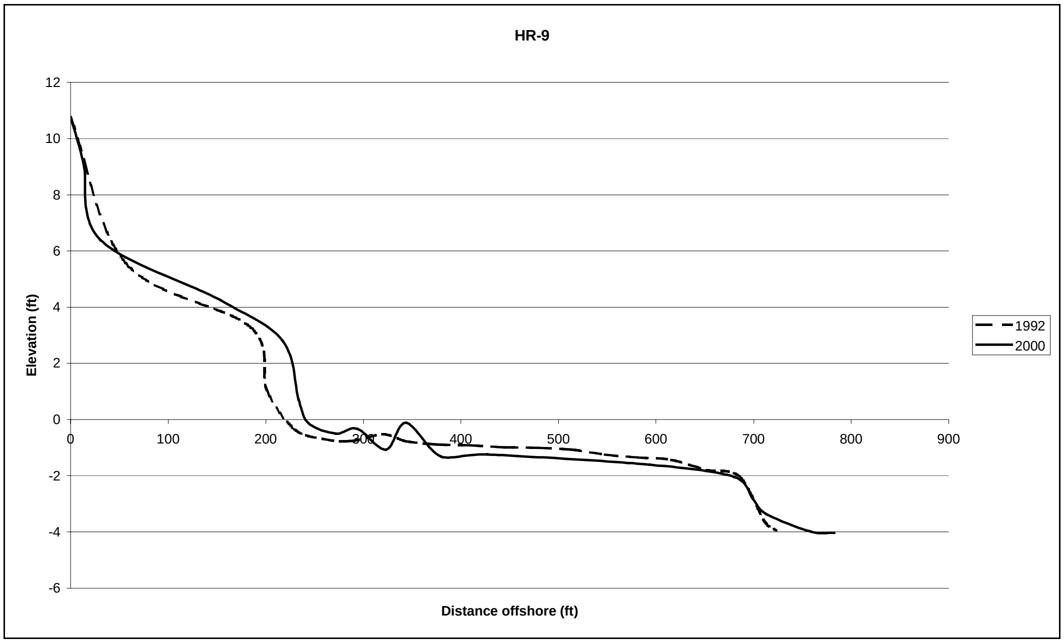

Figure 7. Profile at HR-9.

Local hot spots

The high shoreline retreat and negative volume change at HR-8 make it a local erosion hot spot. The area is a slight promontory, has a large open culvert structure updrift, and is also downdrift of the Courthouse Road pier. The size of the area represented by only one profile is problematic in ascertaining the trends along this area of the beach, as it has the highest volume change value. More profiles have been added here since 1999. This area was also targeted as a trial site for movement of offshore sediment onto the dry beach. The lack of favorable weather conditions hampered the experiment, so only modest gains in shoreline stability were realized.

Eastern Harrison County (Biloxi)

This section of the beach includes the highly developed Biloxi shoreline and is composed of the nearly continuous beach from the Biloxi Lighthouse to the Edgewater Mall and the short beach section sheltered by Deer Island. This is also the updrift end of the beach system and, thus, given the general lack of natural sediment input has a lower potential to receive longshore sediment.

GPS Shoreline Surveys

Shoreline values

Of the 11 km of beach, about 20% is experiencing shoreline retreat beyond 1 m/yr; only 2% is retreating at more than 2 m/yr (Table 7). Shoreline advance of more than 1 m/yr is nearly equal to retreat. The balance is a good indicator of the high level of shoreline maintenance and an overall lack of erosion.

Table 7. Shoreline statistics in Eastern Harrison County

Total Shoreline (m)	7-14 m erosion (m)	> 14 m erosion (m)	> 7 m accretion (m)
10928	1817	231	1900
Percentage %	17	2	17

Shoreline trends

This section of beach is very nearly balanced in terms of shoreline retreat and advance. There are only subtle shoreline changes, which suggests an overall trend for lower shoreline change from the west end of the county beach (Henderson Point) to the east end (Biloxi). Of potential note, however, are the high-use shoreline sections west of the Broadwater Marina and from HR-1 to HR-2 where there are extended areas of dominant shoreline retreat. There is also a large open culvert just west of HR-3 that appears to be an important factor in shoreline advance to the east and retreat to the west. The "Natural Beach Maintenance Project" is located just to the west of this culvert. It will be interesting to see how the shoreline reacts now that the area is being left to self adjust. In the sheltered section north of Deer Island (to the east of Casino Row), shoreline retreat beyond 1 m/yr is absent; however, there has been some shoreline advance.

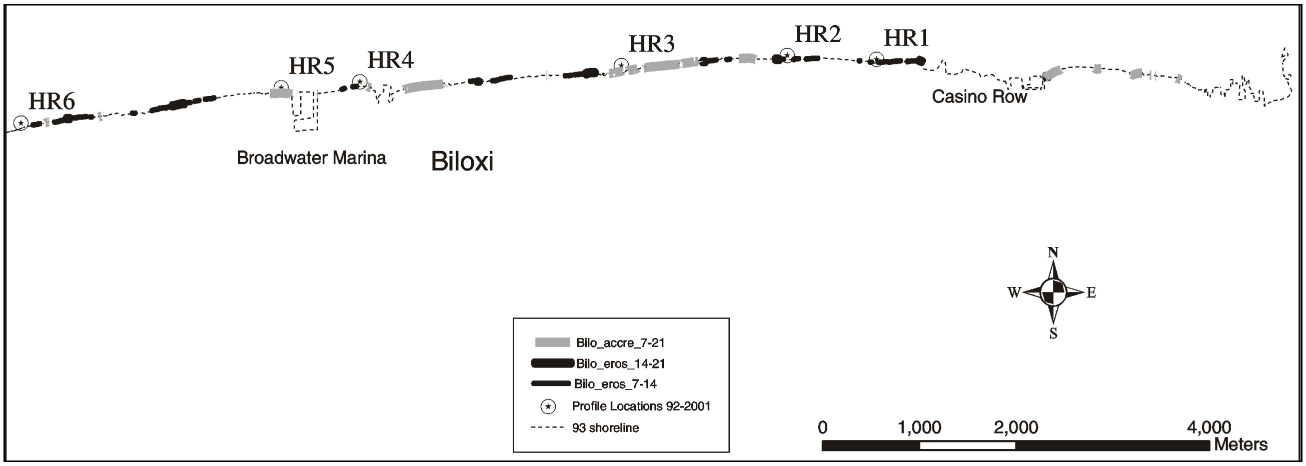

Figure 8. Shoreline change between HR-6 and the eastern extent of study area.

As in the previous beach section (Long Beach to West Biloxi) culverts appear to be a factor in shoreline retreat. The total number of 50-m segments within 20 m of shoreline retreat is about 40% of the total shoreline segments (once again this value is high due to the technique). This 40% can be looked at as a baseline, such that a higher value suggests there is a factor increasing the amount of erosion and a lower value suggests there is a factor decreasing the amount of erosion. In both erosional segments near culverts / total erosional segments and erosional segments near culverts / shoreline near culverts the values were above the baseline 40%. As both of these numbers are higher than the total erosion percentage (40%) it suggests that there is a relationship between culverts and shoreline retreat. The relationship between culverts and shoreline retreat on this section of beach may be in response to a change in shoreline orientation.

Table 8. Culvert shoreline statistics in Eastern Harrison County

Total Shoreline (m)	Culvert Shoreline (m)	Erosional Segments (m)	Eros Segments near Culverts (m)
10928	4850	4250	2250
Shoreline near Culverts (%)	Eros Segments/Total shoreline (%)	Eros Segments near Culverts/ Eros Segments (%)	Eros Segments near Culverts/ Culvert Shoreline (%)
44	39	53	46

This section of beach has the most southerly average orientation, 176 degrees, and therefore a higher propensity for westward longshore drift from the dominant southeast wind. In terms of shoreline aspect, there are a higher percentage of erosional segments between 165 and 175 deg (Table 9). This suggests that the more easterly exposed portions of the shoreline are prone to retreat, which differs from the other two shoreline sections (West and Central).

The lack of large harbor structures and generally higher percentage of erosion near culverts may have some effect on the pattern change on this section of beach.

Table 9. Shoreline angle and shoreline retreat in Eastern Harrison County. Negative difference values indicate lower erosion percentage; positive values indicate higher erosional occurrence.

Shoreline Angle	145	150	155	160	165	170	175	180	185	190	195	200	205
# of total segments	1	0	2	3	11	37	52	47	27	17	8	4	1
% of total	0.5	0.0	0.9	1.4	5.1	17.3	24.3	22.0	12.6	7.9	3.7	1.9	0.5
# of eros. segments	0	0	1	0	5	21	20	18	10	6	1	0	0
% of total	0.0	0.0	1.2	0.0	6.0	25.0	23.8	21.4	11.9	7.1	1.2	0.0	0.0
Difference %	-0.5	0.0	0.3	-1.4	0.8	7.7	-0.5	-0.5	-0.7	-0.8	-2.5	-1.9	-0.5

Beach Profile Surveys

Standardized change

Standardized yearly volume change suggests that the two ends of this section behave differently with respect to offshore volume change and to a lesser degree with onshore volume change. The easternmost profiles have a general lack of offshore aggradation (little to negative offshore volume change), whereas the western profiles (west of Broadwater Marina) have a positive nearshore sediment budget, reflecting noticeable offshore aggradation (Map 2). Onshore volume change (Map 1) is negative in all but one case, HR-4, which is located between the Broadwater Marina and Treasure Bay Casino. It is possible that the large harbor structures on either side of this beach section cause a change in wave dynamics (refraction) resulting in a more onshore-directed sediment-transport regime, which may explain the negative offshore change as well. The highest negative onshore values are on the eastern end; this trend is consistent and is a logical response to the westward-directed longshore drift. These profiles, HR-1 especially, have no updrift source of sediment in the swash zone.

Volumes

In general, the raw volume trends indicate very little overall change (Map 3); there is only a slight gain in volume from east to west. To the west there is a positive gain of about 13,000 cubic yards of sediment per year; to the east there is a loss of about 10,000 cubic yards per year of sediment resulting in a positive volume balance of about 3,000 cubic yards per year. This value is below what can be distinguished from the profiles given the spacing, so in short there is very nearly no volume loss on the section landward of the nearshore – offshore boundary, which corresponds to about -5 feet elevation. The near balance is difficult to explain given the general loss of volume on the beach as a whole. It is possible that there is an exchange of sediment from the broad nearshore platform south of Deer Island to the Harrison County mainland shoreline.

Beach Profile Surveys: Beach Geometry

Two examples are shown (Figures 9 and 10) to illustrate the differences in response between the western and eastern profiles in this stretch of shoreline. The first, HR-2 (Figure 9), is typical of a profile with offshore and onshore volume loss and shoreline retreat. This profile represents a situation with low sediment input and maintenance of a standard but decreasing onshore width. The second profile, HR-5 (Figure 10), is indicative of a higher sediment input and the effects of maintenance, which reduces the onshore elevation but keeps the beach width constant through time. Also note the highly developed set of offshore bars in the HR-5 profile; this pattern has changed little in the past six to eight years.

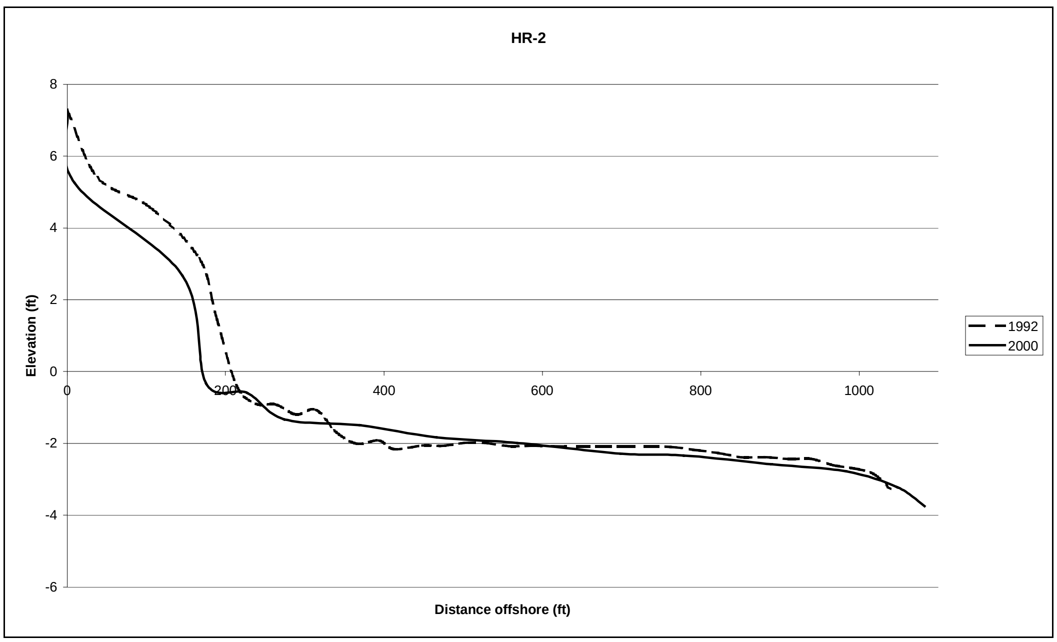

Figure 9. Profile at HR-2.

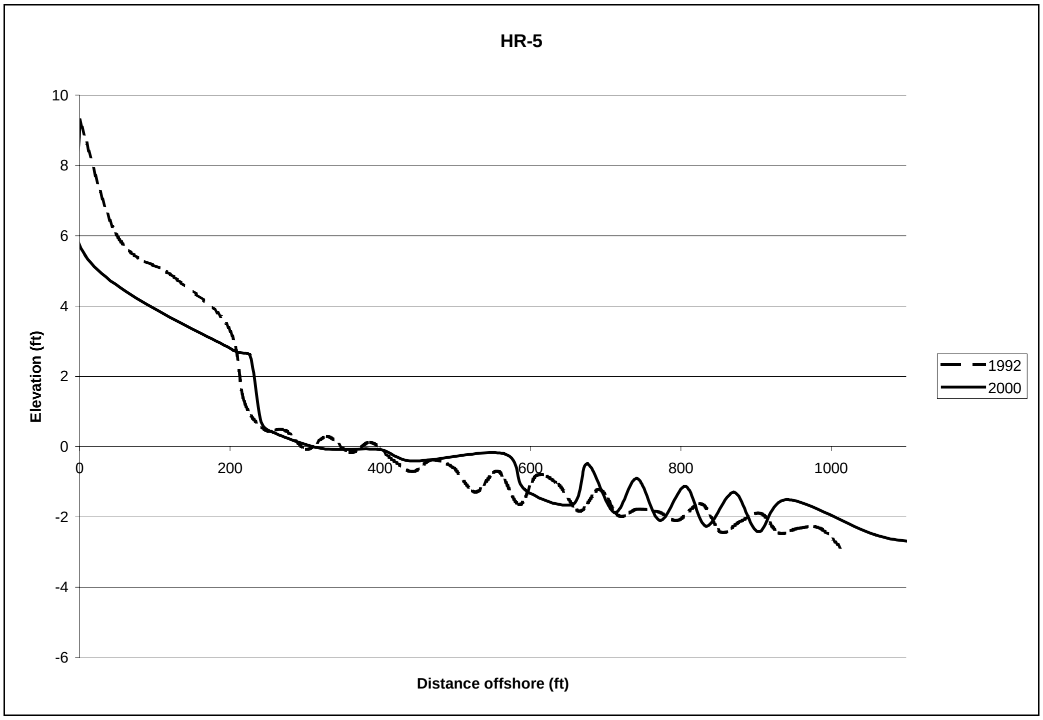

Figure 10. Profile at HR-5.

Local hot spots

The stretch between HR-1 and HR-2 is the updrift end of the renourished beach and in response does not receive much longshore sediment except during the summer months when longshore drift has a higher eastward component. Shoreline retreat is not overly high here, but there is a high volume loss on the dry beach with no associated volume gain in the offshore section. In maintaining a constant shoreline position, sediment is pushed seaward from the back part of the beach, and in response to the longshore transport characteristics little sediment is being left in the area. This stretch has a high level of use and is, thus, highly maintained.

Harrison County Beach – A Look at the Entire System

Based on GPS and profile data, the Harrison County Beach shows moderate retreat and sediment loss. However, mechanical maintenance of the shoreline position is coming at the expense, in most cases, of beach volume above high tide (dry beach) that leads to lower beach elevations. Movement of sediment to re-establish the shoreline position invariably causes some sediment to move offshore where it resides on the wide, shallow, nearshore (underwater) platform portion of the beach. If it stays on the platform it helps buffer wave attack; if it moves seaward beyond the platform it is effectively lost from the system.

The most notable regional trend is the increase in shoreline retreat from east to west. In the easternmost section shoreline retreat above 1 m/yr is only about 20%, which increases to 25% in the central section and then almost to 40% in the western section. This may be partially the result of changes in beach maintenance practices, and is consistent with the dominant longshore sediment transport direction.

Although some culverts are clearly affecting the localized shape of the shoreline, especially the large open culverts, they do not appear to be the controlling factor in causing shoreline retreat. Their quantitative role in creating shoreline retreat is still an unanswered question; however, the data indicate that they have a larger effect on the eastern end of the beach. One important factor that was not analyzed, and is being looked at, is the difference between large 48-inch diameter culverts and the smaller 24-inch culverts in creating erosion hot spots.

The orientation of the shoreline (perpendicular to shoreline angle) gradually changes from about 160 degrees in the west and central sections to 176 degrees in the eastern section. In the western and central sections, shoreline angles with more southerly aspects also had a higher percent classified with shoreline retreat (Tables 3 and 6). This relationship may be the result of shoreline accretion on the updrift (eastern) side of harbor structures and/or culverts, which creates a more easterly shoreline orientation with no erosional segments. The east section with the most southerly orientation has a slightly different trend; the more easterly shoreline angles have a tendency to be associated with shoreline retreat. The data in this section are more difficult to explain, but are also better grouped, suggesting that there is a link between shoreline angle and wave energy here.

Volumetrically, the highest loss came from the central section (Long Beach to HR-6), which also has the largest shoreline structures (harbors); however, the spacing of the profiles limits any regional conclusions or trends from the data. The total yearly volumetric change over the entire beach is less than 10,000 cubic yards; this includes both the nearshore and onshore portion of the beach. If just the onshore (dry beach) portion is considered, there were about 25-30,000 cubic yards lost per year, such that 15-20,000 cubic yards per year are deposited on the nearshore platform and 10,000 cubic yards lost either offshore, onto Highway 90, and/or past Henderson Point.

Harrison County Results – Renourishment 2000-2001

The Harrison County Beach was renourished from offshore borrow areas during the later portion of 2000 and the first half of 2001. Borrow areas were typically more than 600 m (2000 ft) from shore and in most cases from areas seaward of the earlier (1951, 1972, and 1986) borrow areas. Plans called for an estimated 1.5 million cubic yards of sediment to be removed from 24 proposed borrow areas along the beach to create/maintain a beach width of about 250 ft (75 m). In some areas this may have taken a significant amount of sediment; in others, the area would require little if any sediment. The following measurements taken before (July 2000) and after (June-July 2001) the renourishment are used to quantify and describe the actual renourishment.

Profile Data

For this sampling period, nine (9) additional profiles were established to better represent the changes along the beach; they will continue to be sampled in future surveys. Based on the 24 profiles surveyed there was an addition of 1.3 million cubic yards during the renourishment. This estimate is within 200,000 cubic yards of the planned addition; however, the spacing of the profiles precludes providing an absolute volume.

The renourishment sediment was generally concentrated (Map 4A and 4B) in areas that were highlighted as potential hot spots and areas with significant shoreline retreat (Figures 2, 6, and 8). A notable exception is the stretch from HR-8A to HR-7, where a fairly consistent trend of shoreline retreat was noted (Figure 6). This reflects the placement of the individual profiles, such that they appear to be located in specific areas that did not receive much new sediment although areas around them did. This is a weakness in using site-specific profiles, and it is thus important to look at shoreline change (new shoreline vs. old shoreline) to help augment the profile data.

Shoreline Change

Shoreline change was computed by comparing the July 2000 data to the June-July 2001 data. The data (Map 5A and B) reflect areas with little beach widening (< 15 m; 50 ft), moderate beach-width increase (15 to 25 m; 50 to 80 ft), and significant beach-width increase (> 25 m; 80 ft). Following a short period (from a couple of weeks to about 5 months depending on location from east to west) to equilibrate, the average beach width increased about 16.5 m (55 ft). There are two areas with missing data; no shoreline data are available for a 1 km (0.6 mi) stretch east of HR-8B and from HR-5A to HR-5 (1.2 km; 0.75 mi).

Beach width increases are consistent with the shoreline change data from 1993 to 2000. The most highly renourished segments appear to be from HR-11 to HR-15 and from HR-8B to HR-8. These areas were highlighted as also having high shoreline retreat in the preceding years. Areas updrift (east) of harbors received little renourishment and were also locations with shoreline advance. Although there is a trend toward increased shoreline widths from east to west, this may also reflect time of renourishment; the eastern portion of the beach was done earlier and probably exhibited significantly more natural shoreline retreat (creation of an equilibrium profile) by the time of the GPS survey.

Shoreline Change and Profile Data

Another way to estimate the total volume of sediment added to the beach is to measure shoreline change at the profile locations and compare it to the volume change. Doing this for each profile, an average volume to widen the beach by a meter was calculated (1.84 cubic yards/m of beach width increase). Using this value and the shoreline change values (Map 5A and 5B), the total volume added during the renourishment was calculated to be 1.2 million cubic yards. This value is consistent with the volume as calculated using just profiles and is again short of the projected 1.5 million.

Conclusion

In general, the shoreline from Henderson Point to Biloxi is fairly stable in the long term. There are specific areas, however, that do require more attention, and thus represent the most important areas (Balsillie and Clark, 2001) to monitor in the overall stability of the beach. These areas are costly to deal with and may hasten the need to renourish.

The renourishment project undertaken in 2000-2001 added an estimated 1.2 to 1.3 million cubic yards of sediment to the beach. Sediment was added to maintain a constant beach width and therefore hot spot areas were more highly renourished than surrounding areas. Beach sections updrift (to the east) of harbor structures received little renourishment sediment as they typically show shoreline advance.

The following conclusions can be made based on the data presented:

1) Long-term shoreline change (1993 to 2000) averaged about 1 m/yr over the entire beach. Twenty-seven percent (27%) of the beach displayed more than 1 m/yr of shoreline retreat.

2) The highest areas of shoreline change occurred on the western portion of the beach and downdrift of Long Beach and Pass Christian harbors. Shoreline retreat appears to show some dependency on shoreline angle and culvert locations, whose particular influence appears to depend on its size; the relative importance of shoreline angle changes from east (higher) to west (lower) across the entire beach system.

3) The entire beach system from the seawall to the edge of the nearshore platform (-4 ft) loses about 10,000 cubic yards/year. The subaerial beach system (above mean low tide) loses about 30,000 cubic yards/year. Thus, there are about 20,000 cubic yards/year moved from the dry beach to the nearshore platform where it either creates a wider platform or a thicker one. The existence of the extensive nearshore platform is a major factor in the stability of the beach.

4) The 2000-2001 renourishment added an estimated 1.2 to 1.3 million cubic yards of sediment to the beach from borrow pits located about 1/3 mile offshore. After a short period of shoreline adjustment the beach had been widened by about 17 m (55 ft) from the 2000 position.

5) Areas with large changes between 2000 and 2001 are areas that need to be monitored, as these are the hot spots that ultimately reduce the beach's lifespan.

Data

This report is meant to be an overview; more localized study and analysis can be done upon request. The data gathered from 1991 to present are available.

Acknowledgments

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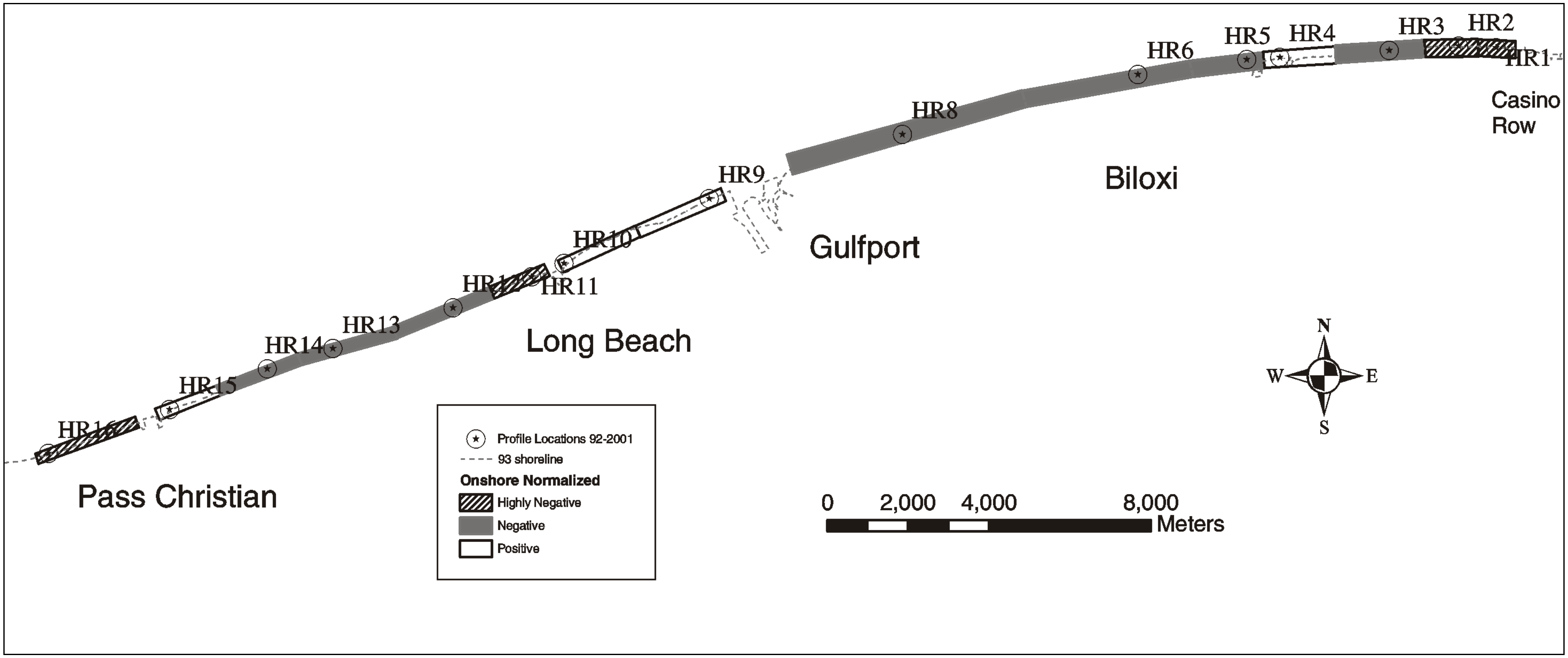
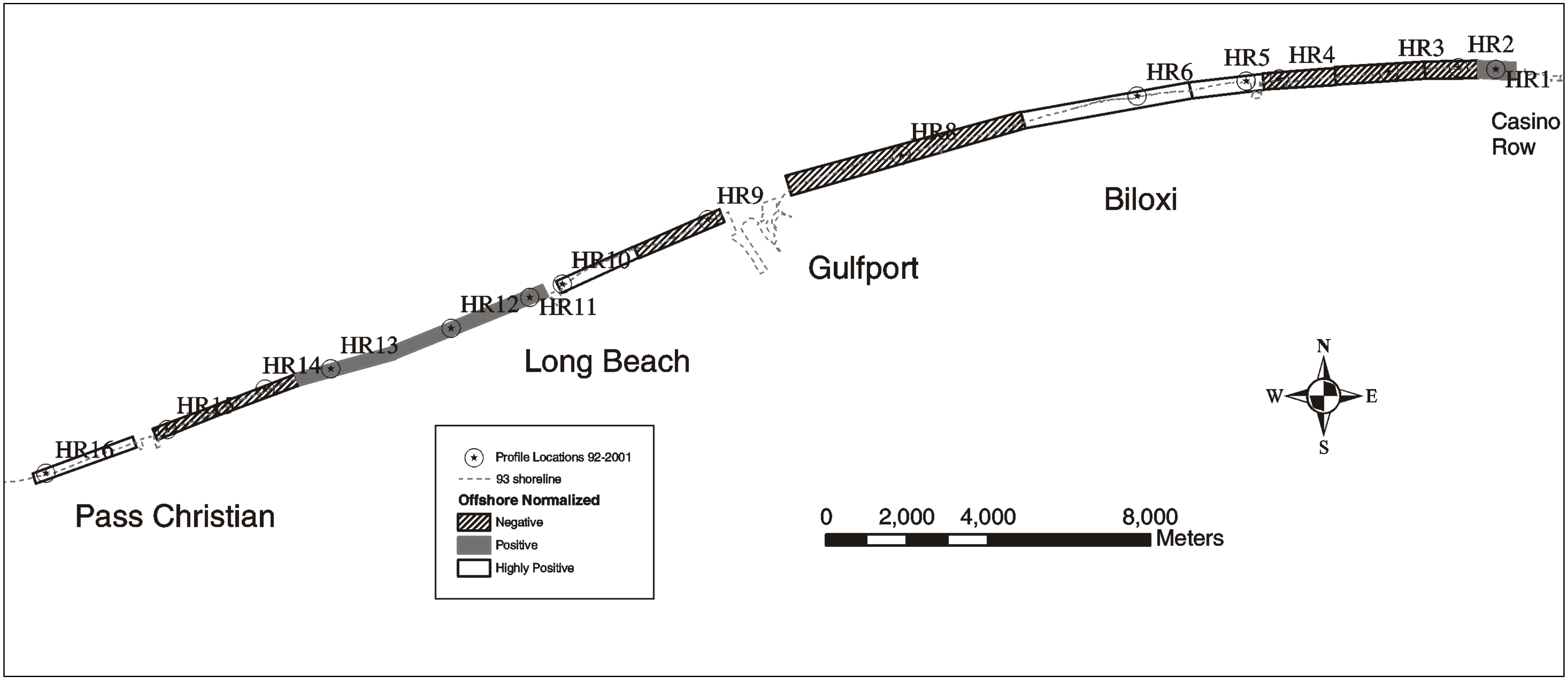
Maps

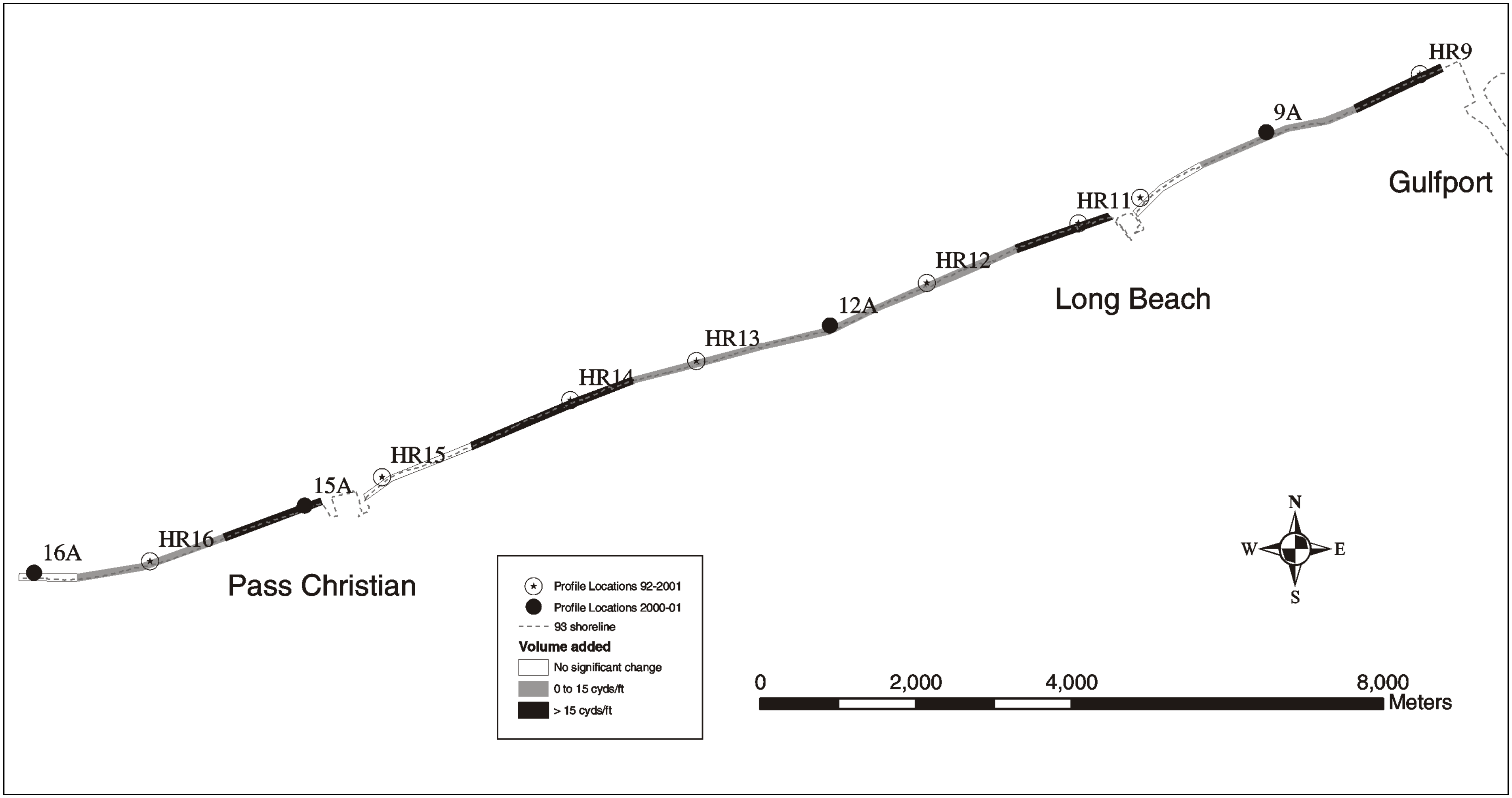


Map 1. Standardized onshore volume change.

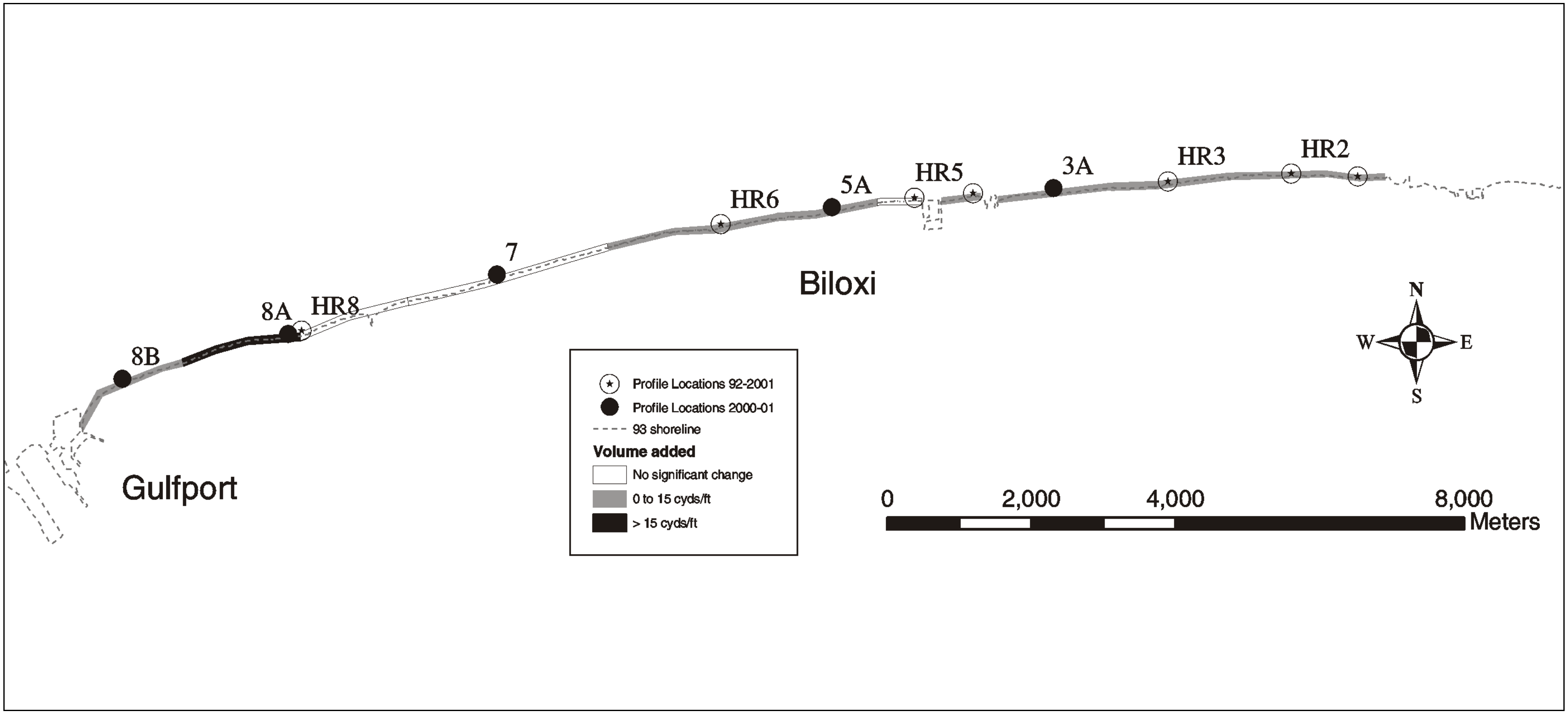


Map 2. Standardized offshore (nearshore) volume change.

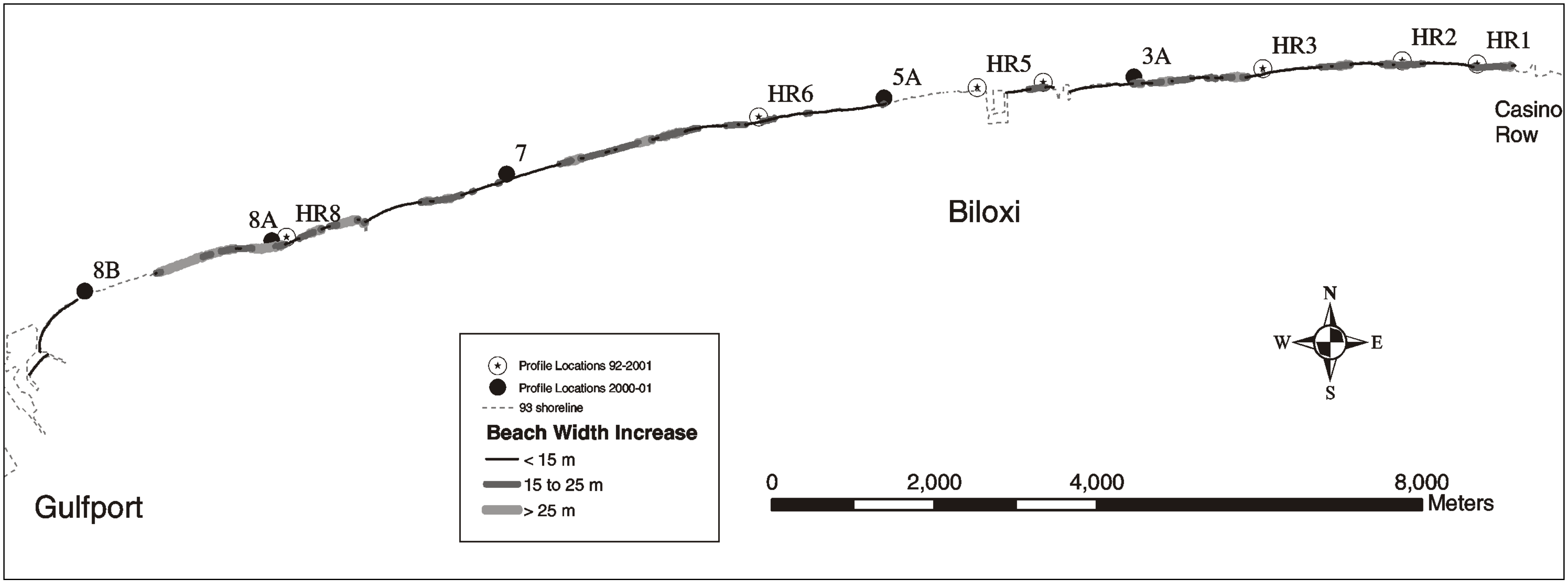
Map 3. Overall volume changes between 1992 and 2000 for most profiles. The exceptions are HR-8 (1992 for onshore, 1999 for offshore), HR-4 (1994), and HR-1 (1993).



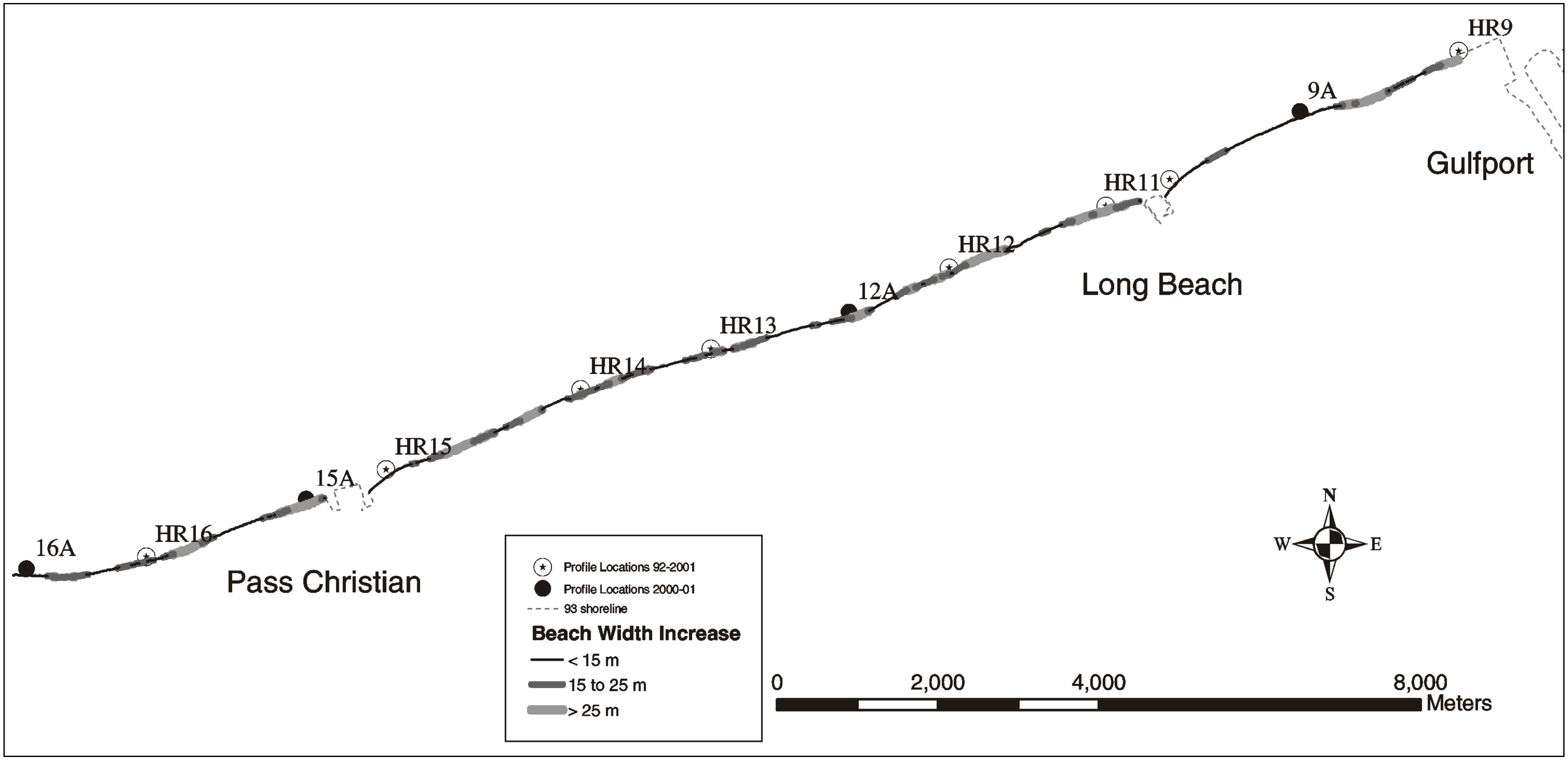
Map 4A. Volume added during 2000-2001 renourishment at profile locations in Western Harrison County.



Map 4B. Volume added during 2000-2001 renourishment at profile locations in Eastern Harrison County.



Map 5A. Beach width increases from the 2000 – 2001 beach renourishment project on the eastern half of the study area.



Map 5B. Beach width increases from the 2000 – 2001 beach renourishment project on the western half of the study area.