Changes in Bay Shoreline Position, West Bay System, Texas

James C. Gibeaut, Rachel Waldinger, Tiffany Hepner, Thomas A. Tremblay, William A. White
With assistance from Liying Xu

A Report of the Texas Coastal Coordination Council pursuant to National Oceanic and Atmospheric Administration Award No. NA07OZ0134
GLO Contract Number 02-225R

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Scott W. Tinker, Director
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

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Contents

Introduction

This report presents long-term rates of shoreline change along the bay shorelines of the West Bay system of the Galveston Bay system (Fig. 1). In addition to West Bay, the smaller secondary bays of Drum, Christmas, Bastrop, Chocolate, Jones, and Halls Lake are included in this report. The successive positions of historical shorelines are combined in a linear regression model that provides the average annual rate of shoreline change. Based on previous years, therefore, these rates indicate how the shoreline is expected to advance seaward or retreat landward during the next several decades, making this information useful for coastal planning. The Bureau of Economic Geology is currently updating shoreline change rates for most of the Texas coast under the Texas Shoreline Change Project. All data, including what is presented in this report, are being placed in a web-based Geographic Information System (ArcIMS) on the Bureau's Texas Shoreline Change Project web site (http://www.beg.utexas.edu/coastal/intro.htm. The public can use this web site to create custom maps and download data.

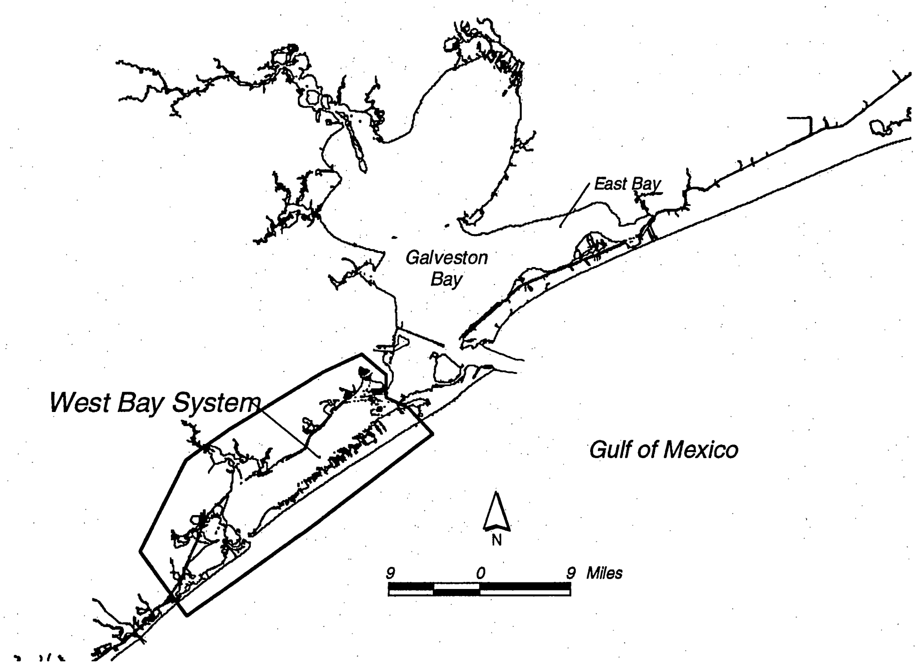


Figure 1. Location of West Bay System study area.

Previous Work

Scientists at the Bureau of Economic Geology have been mapping historical shorelines and determining shoreline change rates since the early 1970's. Paine and Morton (1986) determined historical rates of shoreline change by comparing shorelines from topographic surveys conducted by the U. S. Coast Survey from 1850 to 1852 and aerial photography from 1930 and 1982. The 1930 and 1982 shorelines originally mapped by Paine and Morton (1986) were digitized and used in this report. Paine and Morton's work covered the entire Galveston Bay System including Trinity, Galveston, West, and East Bays. They determined shoreline change from the 1850's to 1930, from 1930 to 1982, and from the 1850's to 1982. Lengths of retreating, stable, and advancing shorelines were determined and average rates of shoreline change were calculated at transect locations spaced 4,000 to 5,000 ft alongshore. This report differs from the previous work in several significant ways: (1) only West Bay and it's secondary bays are included; (2) the 1850's shorelines are not used because of accuracy concerns and the desire to measure the effects of more recent processes on shoreline change; (3) average annual rates of change are computed by a linear regression of shoreline positions from 1930, 1956, 1982, and 1995; (4) rates are determined at transects spaced 25 m (82 ft) alongshore; and (5) rates are matched with detailed information on shoreline type.

Methods

Historical Shoreline Mapping

The rate of shoreline change is determined by comparing the positions of historical shorelines. Shorelines from 1930, 1956, 1982, and 1995 (Appendix A) were mapped using vertical aerial photographs. The 1930 and 1982 shorelines were mapped by Paine and Morton (1986) using an optical technique. This technique is a two-step process. First, the shoreline feature is identified and traced on the photograph; second, the shoreline is transferred to a common base map using a Saltzman projector to adjust the scale of the photograph to match the base maps. The base maps were U.S. Geological Survey, 1:24,000-scale, 7.5 minute, topographic quadrangle maps. Paine and Morton made linear measurements between shorelines on the hardcopy base maps. For this study, however, we digitized the lines on the original base maps and integrated them into a Geographic Information System (GIS).

The 1956 and 1995 shorelines were also mapped from aerial photography, but digital methods were used to rectify the photographs to a common base map. The 1995 photographs were obtained as color infrared digital orthophoto quarter quadrangles (DOQQ) from the Texas Natural Resources Information System and served as base maps to which the 1956 photographs were registered. The DOQQ's are created by using camera and flight information, digital elevation models, and ground control points. The film is scanned with 24-bit color and 1-meter spatial resolution. They meet National Map Accuracy Standards for 1:12,000-scale maps (i.e., 90 percent of well-defined test points must fall within 10 m (32.8 ft) of their real location), but our field tests have shown them to be accurate to within 5 m (16.4 ft).

The 1956 photographs are 1:24,000-scale mosaics scanned at 1,000 dots per inch and imported into Earth Resource Mapping's ER Mapper software, version 6.2, for rectification. Rectification involved the establishment of ground control points that linked each image to its corresponding aerial coverage on a DOQQ. Points were chosen on the image that matched points on the DOQQ. Road intersections and other cultural features are preferred as reference points rather than natural features. However, in many cases cultural features are lacking and features such as trees, shrubs, and the edges of water bodies were used. Where possible, points were evenly spaced across the image, with special emphasis on the edges of the image, and on areas near the shoreline. The number of ground control points used for each photomosaic varied depending on how distorted it was and on the availability of suitable reference features. The average range was approximately 80 to 100 points per photo mosaic.

Once all the ground control points are established for a photograph, the image is rectified using ER Mapper's implementation of Delaunay Triangulation. Once the rectification is complete, the image is made semitransparent and overlain on the DOQQ. In some areas a "double image" occurs, indicating that either more ground control points are needed, or one or more existing ground control points have been placed incorrectly. In these cases, images were reprocessed to correct any remaining distortion. The rectified 1956 photographs and the1995 DOQQ's were imported into ArcView GIS software and the shoreline was digitized at a scale of 1:3,000.

The shoreline features used in the 1930 and 1982 photographs was the land-water boundary (water line) (Paine and Morton, 1986). For the 1956 and 1995 shorelines we used the boundary between wet and dry sediment (wet/dry line) if it was evident. This boundary represents the upper reach of the wave swash during the preceding high tide and is less susceptible to daily changes in bay water levels, which are not related to shoreline changes, than the water line. Often, however, the wet/dry line is not distinct from the water line, and the mapped shoreline may follow the visible water line or the scarp of an erosional shoreline. Where there is no beach, the shore and vegetation lines will coincide, and because of tidal and meteorological changes in water levels and gently sloping bay margins, the vegetation line in places is more closely related to average water level than the wet/dry line. Because of the low tide range (~0.15 m), the differences in shoreline positions based on various shoreline features is small within the context of computing shoreline change rates over a period of 65 years.

Geographic Information System (GIS)

All shoreline data were compiled into ArcView GIS software. Shorelines that were transferred onto hardcopy base maps from the historical photographs were digitized. Once in the GIS, the shorelines were compared against each other for consistency. They were also overlain on the 1995 DOQQ's to help determine proper registration. The historical shorelines are available for viewing and download on the Texas Shoreline Change Project Web site (http://www.beg.utexas.edu/coastal/intro.htm).

Calculation of Average Annual Rate of Shoreline Change

Shoreline data were processed by the Shoreline Shape and Projection Program (SSAPP) developed by the Bureau of Economic Geology. SSAPP automatically draws a segmented baseline that follows the trend of the historical shorelines. Transects that intersect the shorelines are constructed perpendicular to this baseline. Distances between the shoreline positions along each transect are determined, and in this study, a linear regression model was used to calculate the average annual rate of shoreline change. The baseline segment length varied between 50 and 400 m so that shoreline curvature could be adequately followed. Transect spacing was 25 m. Shoreline change rates were computed for only those transects where all four historical shorelines (1930, 1956, 1982, and 1995) are available. A GIS point file was generated with shoreline change rates and shoreline types (see below) as attributes. This point file may be viewed and downloaded at the Texas Shoreline Change Project Web site (http://www.beg.utexas.edu/coastal/intro.htm).

Shoreline Types

Shoreline types were mapped by Morton and White (1995) for the purpose of oil spill response and contingency planning. The digital shoreline was derived from U.S. Geological Survey 7.5 minute quadrangle maps and was classified under the Environmental Sensitivity Index (ESI) system developed by Research Planning, Inc. The ESI system ranks shoreline types in relation to their sensitivity to damage by oil spills and difficulty in removing oil. The shoreline was classified using vertical and oblique photography and low-altitude oblique video. The classification is a detailed characterization of shoreline types and includes all types occurring in the West Bay system. The shoreline change rate point file was coded with the shoreline type attribute of the polygon file from the ESI mapping. An automated routine and manual editing was used to accomplish this. Some shorelines have undergone significant modification through dredging, dredge spoil disposal, filling for land development, and emplacement of erosion control structures. A shoreline modification attribute, therefore, was added to the shoreline change rate point file so that statistics and causes of shoreline change could be determined separately for natural and unnatural shoreline settings.

Beach Profiles

On January 30 and 31, 2002, topographic ground-survey transects were conducted at 5 locations (Fig. 2) along the bay sides of Galveston and Follets Islands. The transects are oriented perpendicular to the shoreline and extend from upland environments to approximately 2 ft (0.61 m) water depths. Two of the transects (WST-04 and BEG-12) span the entire barrier island from the Gulf to the bay. Transects, or "beach profiles," provide data for checking the accuracy of shorelines mapped from photography. They also provide data on the geomorphology and sediment and vegetation characteristics. The ground surveys can also be repeated frequently to detect short-term shoreline changes.

Transect locations were selected based on shoreline types, energy level, rate of historical change, and accessibility. At each location, an existing feature was used as a datum point, or if that was not possible, a temporary marker consisting of a steel pipe with a piece of flat stock welded on the end was buried with about 30 cm of the pipe above ground. The datum point of each profile was surveyed using precise differential Global Positioning System (GPS) techniques. Geodetic Trimble 4000ssi GPS receivers were used to collect GPS data at each profile. The Galveston CORS (Continuously Operating Reference Station) site (GAL1) served as the reference station. GPS data were post-processed using phase differencing techniques to provide positions of the datum markers accurate to within a few centimeters. All survey data are provided in the NAD83 datum. Vertical measurements are expressed as heights above the reference ellipsoid (HAE). Using the Geoid99 model, HAE heights were converted to orthometric heights relative to NAVD 88, which approximates mean sea level. A local mean sea level correction was than applied to the orthometric height based upon vertical information from the bayside Pier 21 tide gauge in Galveston.

Beach profiles were measured using a Sokkia Set 5W Electronic Total Station and a reflecting prism. Vegetation, sediment type, and geomorphic features were noted along each transect line. Navigation back to the marker locations will be possible using real-time differential GPS. Data tables and graphs are provided in Appendix B.

Results

Figure 2 is a map showing the distribution of the rate of shoreline change in the West Bay system. A total of 6,490 transects were measured spaced 82 ft (25 m) alongshore for a total measured shoreline length of 100.8 miles. Shoreline length is actually longer than this because not all shoreline segments were measured. The map shows that the smaller, low-energy bays have overall lower rates of retreat than in West Bay. The effects of dredging on retreat and spoil disposal on advance are also apparent.

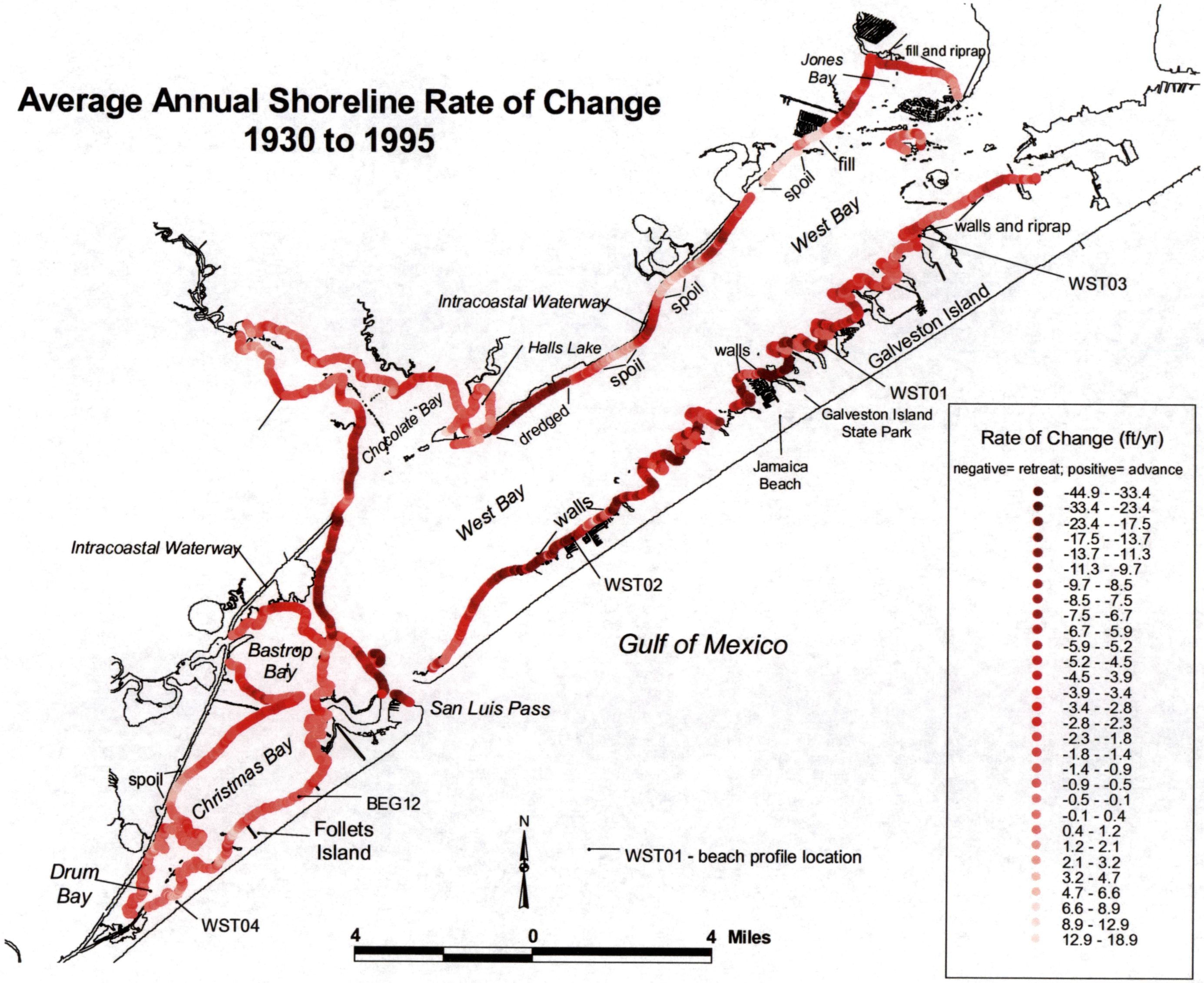


Figure 2. Shoreline change map of the West Bay system.

Figure 3 is a series of pie charts showing statistics for each bay and natural versus unnatural shorelines. Shorelines are classified as retreating if the change rate, as determined by the slope of a linear regression line through the 1930, 1956, 1982, and 1995 shoreline positions, is less than -2 ft/yr (-0.61 m/yr). Advancing shorelines have rates greater than 2 ft/yr (0.61 m/yr) and stable shorelines have rates between -2 and 2 ft/yr (±0.61 m/yr). The selection of ±2 ft/yr (±0.61 m/yr) as the interval for stable shorelines is based on a conservative estimate of the mapping accuracy of the shoreline positions and the limitations of quantifying a continuously varying geologic process with 4 data points over 65 years time. The shoreline positions in this study need to be accurate to within approximately 50 ft (15.2 m) to reliably measure change with an accuracy of 2 ft/yr (0.61 m/yr). Comparisons of shorelines and DOQQ's show that the shoreline positions are accurate to within 50 ft (15.2 m). Furthermore, natural geologic processes that cause relatively high-frequency shoreline shifts in the West Bay system are expected to be much less than 2 ft/yr, thus inadvertently sampling a shoreline shifted by a short-term process is not problematic.

Overall, 87 % of the shoreline is considered natural and not *directly* affected by anthropogenic activities. Half of these natural shorelines are retreating with the greatest percentage of retreat occurring in West and Jones Bays (Figs. 2, 3). Drum Bay and Halls Lake, which is actually a bay, are sheltered from waves and have only 5 and 15 %, respectively, of their shorelines naturally retreating. The moderately exposed bays of Christmas, Chocolate, and Bastrop have 28 to 40 % of their shorelines naturally retreating. West and Jones Bays are relatively exposed to wave activity with much of their shorelines facing long fetches. These bays have the highest percentages of naturally retreating shoreline with West Bay at 57 % and Jones Bay at 69 %. Table 1 list natural shoreline change rates by bays and shoreline type.

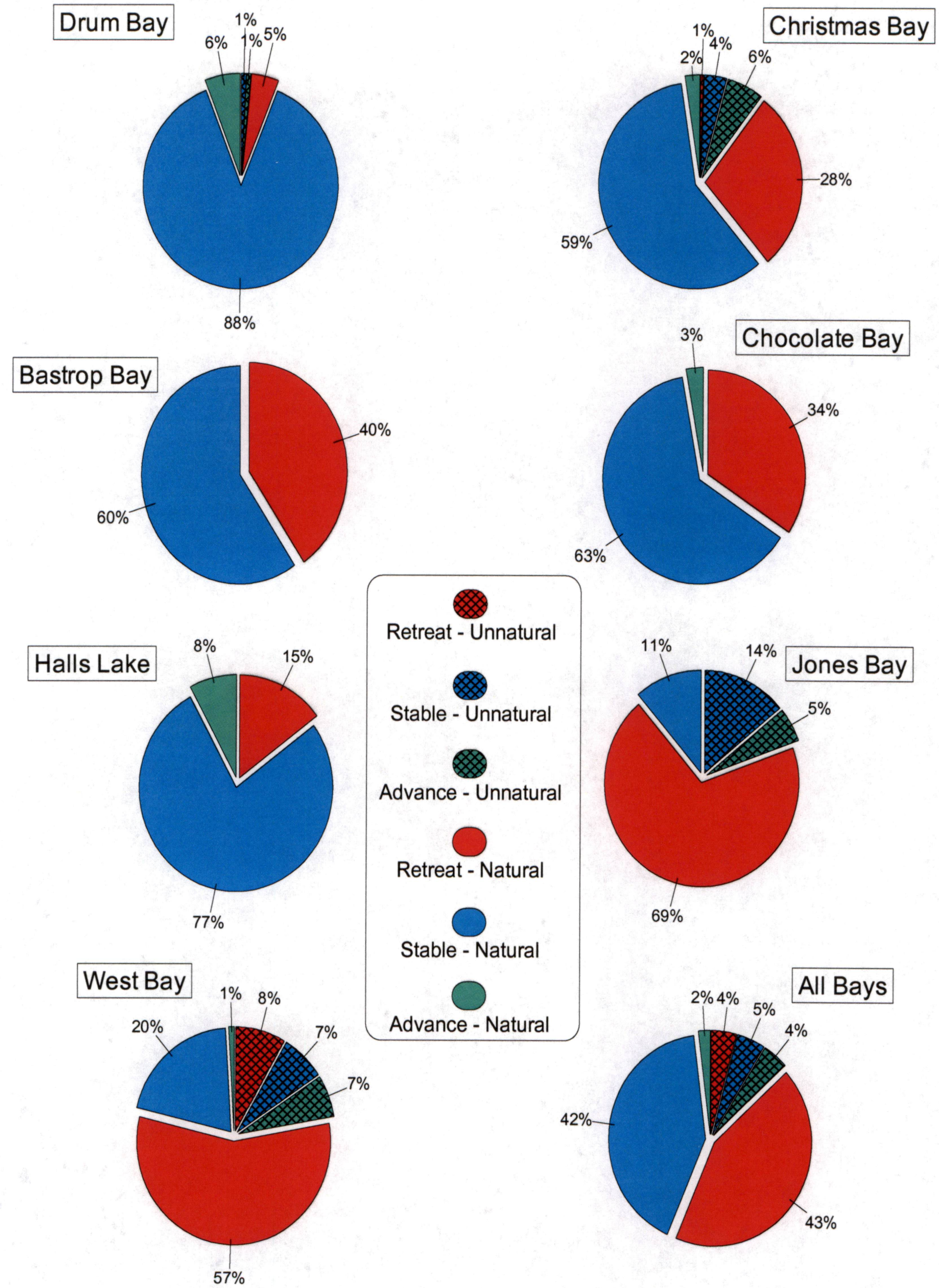


Figure 3. Rate of shoreline change according to bay and naturalness of shoreline. Stable shorelines are classified as having change rates equal to or less than 2 ft/yr. Retreating and advancing shorelines have change rates of more than 2 ft/yr.

Table 1. Shoreline change rates by bay and shoreline type for natural shorelines.

Scarps and Steep Slopes in Clay - Natural Shorelines Only

			retreating		stable		advancing					
Location	length (mi)	% of bay length	length (mi)	% of type	length (mi)	% of type	length (mi)	% of type	mean	std. dev.	min.	max.
Drum Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Bastrop Bay	0.42	5.4	0.00	0.0	0.43	100.0	0.00	0.0	-1.1	0.6	-1.9	0.4
Christmas Bay	1.60	13.3	0.80	49.5	0.82	50.5	0.00	0.0	-2.3	0.9	-4.7	-0.6
Chocolate Bay	2.14	14.2	0.65	29.7	1.53	70.3	0.00	0.0	-1.8	1.6	-7.1	1.7
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.37	9.3	0.17	45.8	0.21	54.2	0.00	0.0	-2	0.4	-3	-1.4
West Bay	1.21	2.4	0.71	57.7	0.50	41.0	0.02	1.3	-2.4	2.5	-6.6	2.2
All Bays	5.75	5.7	2.33	40.0	3.49	59.7	0.02	0.3	-2	1.6	-7.1	2.2

Fine-Grained Sand Scarps, Steep Slopes, and Beaches - Natural Shorelines Only

			retreating		stable		advancing					
Location	length (mi)	% of bay length	length (mi)	% of type	length (mi)	% of type	length (mi)	% of type	mean	std. dev.	min.	max.
Drum Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Bastrop Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Christmas Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Chocolate Bay	1.86	12.3	0.84	44.2	0.93	49.2	0.13	6.7	-2.1	2.3	-7.8	5.2
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
West Bay	3.18	6.4	2.15	66.3	1.04	32.2	0.05	1.5	-4.3	3.9	-19	2.9
All Bays	5.05	5.0	2.98	58.2	1.97	38.5	0.17	3.4	-3.5	3.5	-19	5.2

Mixed Sand and Gravel (Shells) Beaches - Natural Shorelines Only

			retreating		stable		advancing					
Location	length (mi)	% of bay length	length (mi)	% of type	length (mi)	% of type	length (mi)	% of type	mean	std. dev.	min.	max.
Drum Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Bastrop Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Christmas Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Chocolate Bay	0.20	1.3	0.09	46.2	0.11	53.8	0.00	0.0	-2.7	2.2	-5.5	-0.1
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.23	5.8	0.06	26.7	0.17	73.3	0.00	0.0	-1.4	0.8	-2.6	0.1
West Bay	3.01	6.0	2.48	80.9	0.58	19.1	0.00	0.0	-4.1	2.5	-16	1.2
All Bays	3.45	3.4	2.63	75.2	0.87	24.8	0.00	0.0	-3.8	2.5	-16	1.2

Gravel Beaches (Shell) - Natural Shorelines Only

			retreating		stable		advancing					
Location	length (mi)	% of bay length	length (mi)	% of type	length (mi)	% of type	length (mi)	% of type	mean	std. dev.	min.	max.
Drum Bay	0.05	0.5	0.00	0.0	0.05	100.0	0.00	0.0	-0.2	0.2	-0.4	0.1
Bastrop Bay	0.11	1.4	0.03	28.6	0.08	71.4	0.00	0.0	-1	1.1	-2.2	0.6
Christmas Bay	1.15	9.5	0.63	54.1	0.54	45.9	0.00	0.0	-1.8	1	-3.3	0.2
Chocolate Bay	0.02	0.1	0.00	0.0	0.02	100.0	0.00	0.0	-1.9	0	-1.9	-1.9
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.03	0.8	0.00	0.0	0.03	100.0	0.00	0.0	-0.2	0.2	-0.3	-0.1
West Bay	0.68	1.4	0.19	27.3	0.32	45.5	0.19	27.3	-0.4	3.4	-9.1	4
All Bays	2.03	2.0	0.85	41.2	1.03	49.6	0.19	9.2	-1.2	2.2	-9.1	4

Table 1. Continued

Exposed Tidal Flats - Natural Shorelines Only

Location	length (mi)	% of bay length	retreating length (mi)	retreating % of type	stable length (mi)	stable % of type	advancing length (mi)	advancing % of type	mean	std. dev.	min.	max.
Drum Bay	0.53	5.7	0.00	0.0	0.43	79.4	0.11	20.6	0.3	1.9	-2	4.3
Bastrop Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Christmas Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Chocolate Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
West Bay	1.21	2.4	1.23	100.0	0.00	0.0	0.00	0.0	-5.8	2.9	-13	-2.2
All Bays	1.74	1.7	1.23	69.6	0.43	24.1	0.11	6.3	-3.9	3.8	-13	4.3

Sheltered Scarps - Natural Shorelines Only

Location	length (mi)	% of bay length	retreating length (mi)	retreating % of type	stable length (mi)	stable % of type	advancing length (mi)	advancing % of type	mean	std. dev.	min.	max.
Drum Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Bastrop Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Christmas Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Chocolate Bay	0.42	2.8	0.02	3.7	0.41	96.3	0.00	0.0	-0.6	1	-2.3	1.3
Halls Lake	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
Jones Bay	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0				
West Bay	0.16	0.3	0.02	10.0	0.14	90.0	0.00	0.0	-0.9	0.9	-3.4	-0.5
All Bays	0.57	0.6	0.03	5.4	0.55	94.6	0.00	0.0	-0.7	0.9	-3.4	1.3

Salt and Brackish Water Marshes - Natural Shorelines Only

Location	length (mi)	% of bay length	retreating length (mi)	retreating % of type	stable length (mi)	stable % of type	advancing length (mi)	advancing % of type	mean	std. dev.	min.	max.
Drum Bay	8.54	92.3	0.43	4.9	7.81	90.0	0.44	5.1	-0.4	1.3	-7.9	5.9
Bastrop Bay	7.22	93.2	3.15	43.0	4.18	57.0	0.00	0.0	-1.9	1.6	-7.3	1.3
Christmas Bay	8.05	66.8	2.03	24.9	5.84	71.4	0.30	3.7	-1.1	1.9	-4.7	10.8
Chocolate Bay	10.49	69.3	3.68	34.5	6.66	62.5	0.32	3.0	-1.9	3.1	-9.8	18.9
Halls Lake	2.75	100.0	0.41	14.7	2.16	77.4	0.22	7.9	-0.5	1.4	-4.3	3.4
Jones Bay	2.58	64.6	2.57	98.2	0.05	1.8	0.00	0.0	-4.1	1.2	-9.1	-1.4
West Bay	29.20	58.5	21.80	73.5	7.62	25.7	0.24	0.8	-5.6	6	-45	3.6
All Bays	68.83	68.3	34.07	48.7	34.31	49.1	1.51	2.2	-3.2	4.7	-45	18.9

Unnatural shorelines comprise 13% of the total length of measured shorelines, and most of the unnatural shoreline is in West Bay (Figs. 2, 3). In West Bay, unnatural shorelines are equally distributed among the retreating, stable, and advancing categories reflecting the various effects of dredging, spoil disposal, land filling, and structuring. In Christmas Bay, however, most of the unnatural shorelines are a result of dredge disposal from the Intracoastal Waterway (ICW) in the western corner of the bay (Fig. 2). Thus unnatural shorelines are stable or advancing there. In Jones Bay, land filling and riprap have caused the unnatural shorelines to be stable or advancing in the eastern corner of the bay. West Bay is bounded by the ICW on the north, and dredging and spoil disposal have caused retreat and advance, respectively. Along the bay shoreline of Galveston Island, the unnatural shorelines are comprised of shoreline stabilization structures such as bulkheads and riprap protecting houses and small-boat channels.

The West Bay system is bordered mostly by natural marsh shorelines. Natural shorelines comprise 87 % of the total length of measured shorelines, and 79 % of the natural shorelines are salt- and brackish-water marshes. This means that 68% or 69 miles of the 101 miles of shoreline are natural marsh. Table 2 is a tabulation of shoreline change according to shoreline types and naturalness. Half of the natural marsh shorelines (33.55 mi) are retreating. The shoreline classes with the next greatest length of retreating shoreline are natural fine-grained sand and mixed sand and gravel beaches, but only 5.53 mi are retreating in these categories combined. The retreating fine-grained beaches are concentrated in the western portions of West and Chocolate Bays, and the retreating natural mixed sand and gravel beaches are along the northern shoreline of West Bay. Retreating natural scarps and steep slopes in clay cover 2.3 mi of shoreline scattered along the northern part of the bay system. Retreating unnatural shorelines of this type cover 2.22 mi and are concentrated along the northern shoreline of West Bay where dredging along the ICW has occurred. All other shoreline categories have less than 1.5 miles of retreating shoreline.

Table 2. Shoreline Change and Shoreline Types

			retreating		stable		advancing					
	length (mi)	% of bay length	length (mi)	% of type	length (mi)	% of type	length (mi)	% of type	mean	std. dev.	min.	max.
Exposed walls and other structures made of concrete, wood, or metal	2.19	2.2	0.99	45.4	1.09	49.6	0.11	5.0	-3.4	5.1	-22.3	6.6
Scarps and steep slopes in clay - Natural	5.75	5.7	2.30	40.0	3.43	59.7	0.02	0.3	-2	1.6	-7.1	2.2
Scarps and steep slopes in clay - Unnatural	4.09	4.1	2.22	54.4	0.87	21.3	0.99	24.3	-4.3	6.3	-14.3	8.6
Fine-grained sand scarps, steep slopes, and beaches - Natural	5.05	5.0	2.94	58.2	1.94	38.5	0.17	3.4	-3.5	3.5	-18.7	5.2
Fine-grained sand scarps, steep slopes, and beaches - Unnatural	0.11	0.1	0.11	100.0	0.00	0.0	0.00	0.0	-13	3.3	-17.5	-8.6
Mixed sand and gravel(shells) beaches - Natural	3.45	3.4	2.59	75.2	0.85	24.8	0.00	0.0	-3.8	2.5	-16.2	1.2
Mixed sand and gravel(shells) beaches - Unnatural	1.80	1.8	0.05	2.6	0.47	25.9	1.29	71.6	4.6	5.6	-21.1	12.0
Gravel(shells) beaches - Natural	2.03	2.0	0.84	41.2	1.01	49.6	0.19	9.2	-1.2	2.2	-9.1	4.0
Gravel(shells) beaches - Unnatural	0.61	0.6	0.11	17.9	0.08	12.8	0.42	69.2	1.3	6.8	-16.0	7.4
Exposed riprap structures	1.80	1.8	0.39	21.6	1.40	77.6	0.02	0.9	-2	3.5	-12.7	2.2
Exposed tidal flats - Natural	1.74	1.7	1.21	69.6	0.42	24.1	0.11	6.3	-3.9	3.8	-12.9	4.3
Exposed tidal flats - Unnatural	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0	0	0.0	0.0
Sheltered solid structures such as bulkheads and docks	0.36	0.4	0.14	39.1	0.17	47.8	0.05	13.0	-2	3.6	-9.7	4.1
Sheltered scarps - Natural	0.57	0.6	0.03	5.4	0.54	94.6	0.02	2.7	-0.7	0.9	-3.4	1.3
Sheltered scarps - Unnatural	0.31	0.3	0.00	0.0	0.06	20.0	0.25	80.0	4	2.7	-0.4	9.1
Sheltered tidal flats - Natural	0.12	0.1	0.09	75.0	0.03	25.0	0.00	0.0	-3.2	1.2	-5.4	-1.7
Sheltered tidal flats - Unnatural	0.05	0.0	0.05	100.0	0.00	0.0	0.00	0.0	-6.6	0.7	-7.1	-5.9
Salt- and brackish-water marshes - Natural	68.83	68.3	33.55	48.7	33.79	49.1	1.49	2.2	-3.2	4.7	-44.9	18.9
Salt- and brackish-water marshes - Unnatural	1.96	1.9	0.19	9.5	0.62	31.7	1.15	58.7	2.2	2.7	-8.7	6.0
All	**100.82**	**100**	**47.80**	**47.4**	**46.77**	**46.4**	**6.26**	**6.2**	**-2.9**	**4.71**	**-44.9**	**18.9**

Discussion and Conclusions

Forty-eight percent of the shoreline in the West Bay system is retreating, 47 % is stable, and 6 % is advancing. The average rate of change since 1930 has been -2.9 ft/yr (-0.88 m/yr) (Table 2). Most of the retreat has occurred along natural marsh shorelines because this type of shoreline makes up 68 % of the bay system and 49 % of the marsh shoreline is retreating. Rates of retreat are lower in the smaller, more sheltered bays indicating that exposure to wave energy is a primary cause of shoreline retreat. Only 6 % of the shoreline in Drum Bay and 15 % in Halls Lake retreated, and the average rate of change was only -0.5 ft/yr (-0.15 m/yr). These bay shorelines are more than 90 % natural marsh and have been subjected to relative sea-level rise since the 1930's but very low-energy conditions. This indicates that relative sea-level rise is perhaps less important than erosion by waves and currents in causing shoreline retreat in the bay system as a whole.

To show the distribution of areas with relatively high retreat rates, locations with change rates more than one standard deviation less than the mean change rate were mapped (Fig. 4). These areas have retreat rates greater than 7.61 ft/yr (2.3 m/yr) and occur along the west side of San Luis Pass where there are strong tidal currents, along the western shore of West Bay where there is a long fetch exposing the shoreline to east and southeast winds and waves, and along western Galveston Island that has exposure to northerly winds and waves. Areas where dredging for the ICW affected shoreline change along the north shore of West Bay also have high retreat rates. Only a few places in the smaller bays experienced these relatively high rates of retreat.

References

Morton, R. A. and White, W. A., 1995, Shoreline types of the upper Texas coast: Sabine-Galveston-Freeport-Sargent Areas. Final Report, Prepared for the Texas Natural Resources Inventory Program, TGLO, TNRCC, TPWD, and MMS, The University of Texas at Austin, Bureau of Economic Geology, 42 p.

Paine, J. G. and Morton, R. A., 1986, Historical shoreline changes in Trinity, Galveston, West, and East Bays, Texas Gulf Coast. Geological Circular 86-3, The University of Texas at Austin, Bureau of Economic Geology, 58 p.

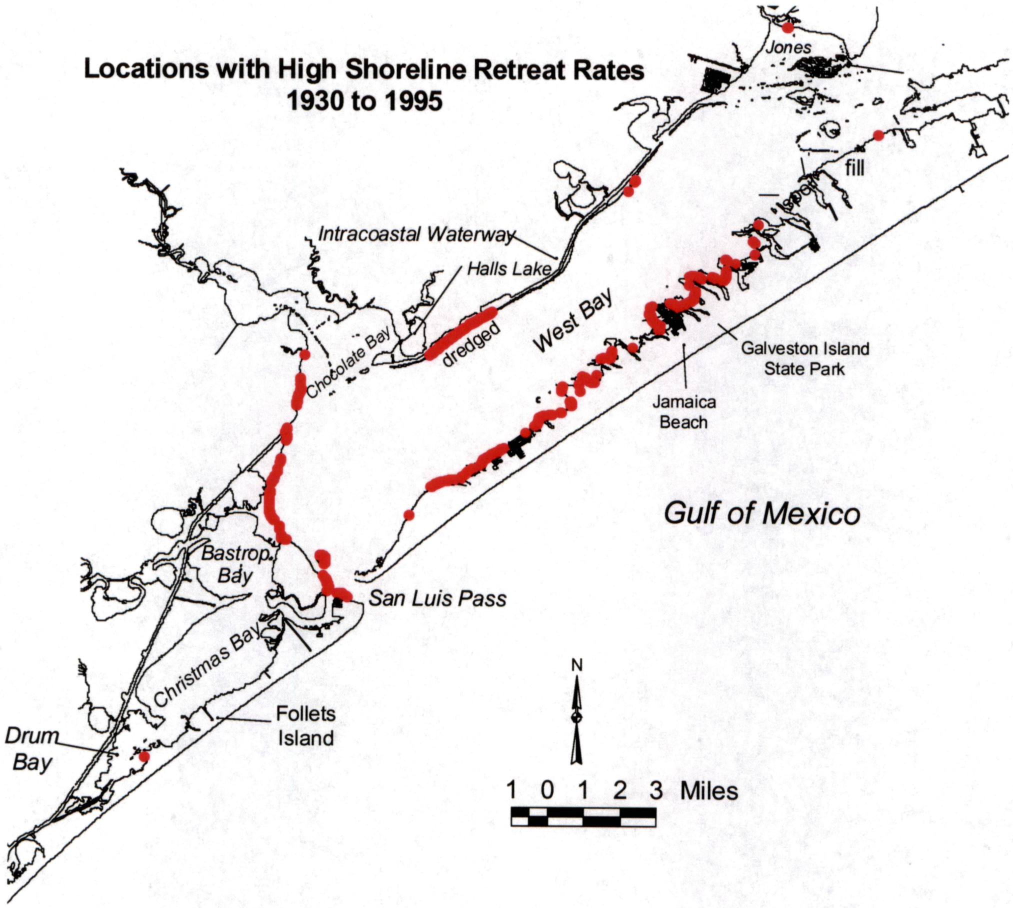


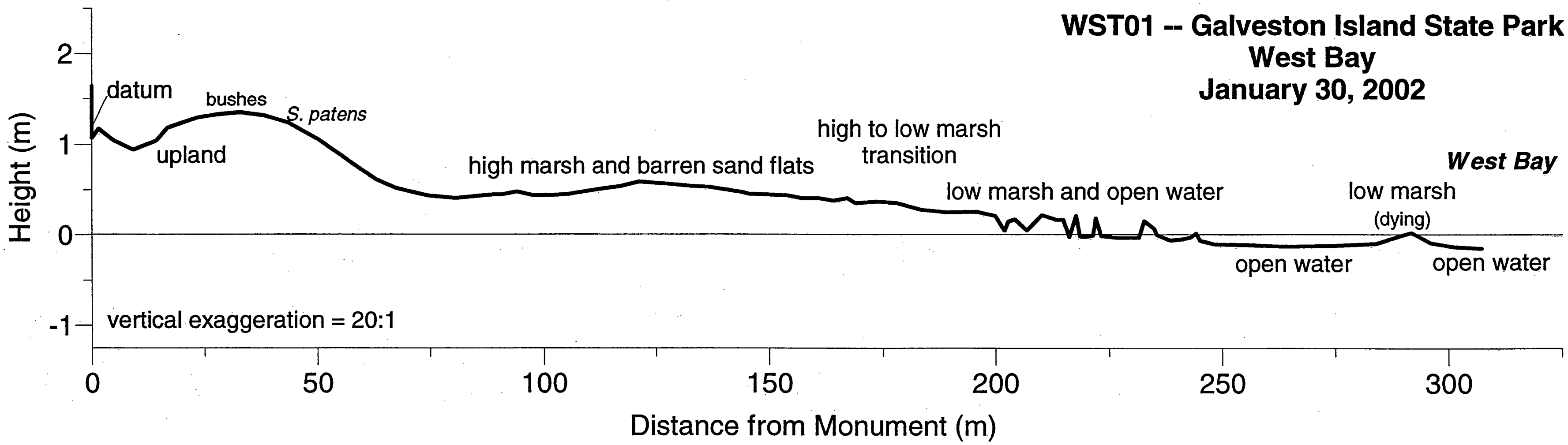
Figure 4. Map showing locations where the shoreline is retreating at a rate of more than 7.6 ft/yr, which is the rate that is one standard deviation from the average rate of change for the bay system.

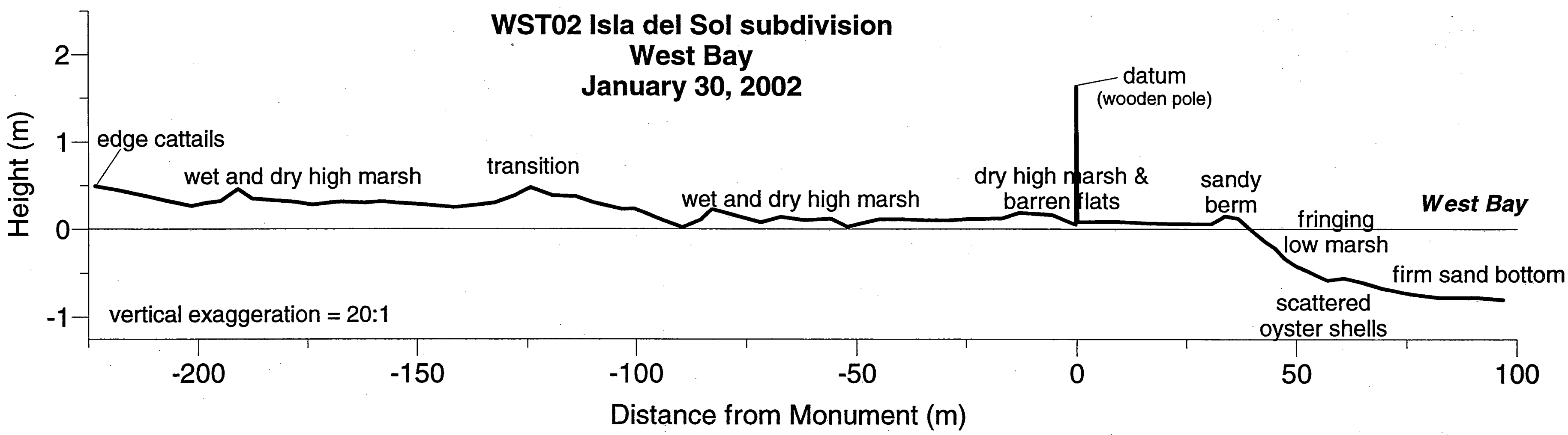
Appendix A: Vertical aerial photographs used for shoreline mapping.

Date	Scale	Type	Source
1930, April to November	1:24,000	Black-and-white mosaics	Tobin Research, Inc.
1956, August	1:24,000	Black-and-white mosaics	Tobin Research Inc.
1982, June and July	1:24,000	Color-infrared	Texas General Land Office
1995, January	1:24,000	Color-infrared digital orthophoto quarter quadrangles	Texas Natural Resources Information System

Appendix B: Beach profiles.

Plots of beach profiles and data tables. Plots are relative to local mean sea level.


WST01 -- Galveston Island State Park
West Bay
January 30, 2002
datum
bushes
S. patens
upland
high marsh and barren sand flats
high to low marsh
transition
low marsh and open water
West Bay
low marsh
(dying)
open water
open water
vertical exaggeration = 20:1
Height (m)
Distance from Monument (m)
2
1
0
-1
0
50
100
150
200
250
300

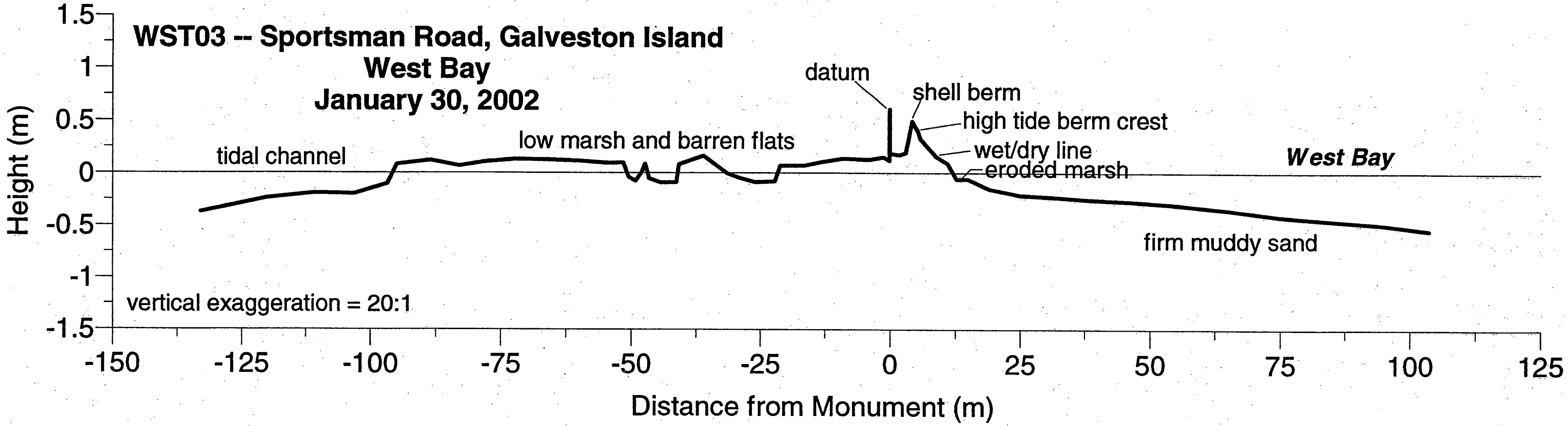

WST02 Isla del Sol subdivision
West Bay
January 30, 2002
datum
(wooden pole)
edge cattails
wet and dry high marsh
transition
wet and dry high marsh
dry high marsh &
barren flats
sandy
berm
fringing
low marsh
West Bay
firm sand bottom
scattered
oyster shells
vertical exaggeration = 20:1
Height (m)
Distance from Monument (m)
2
1
0
-1
-200
-150
-100
-50
0
50
100

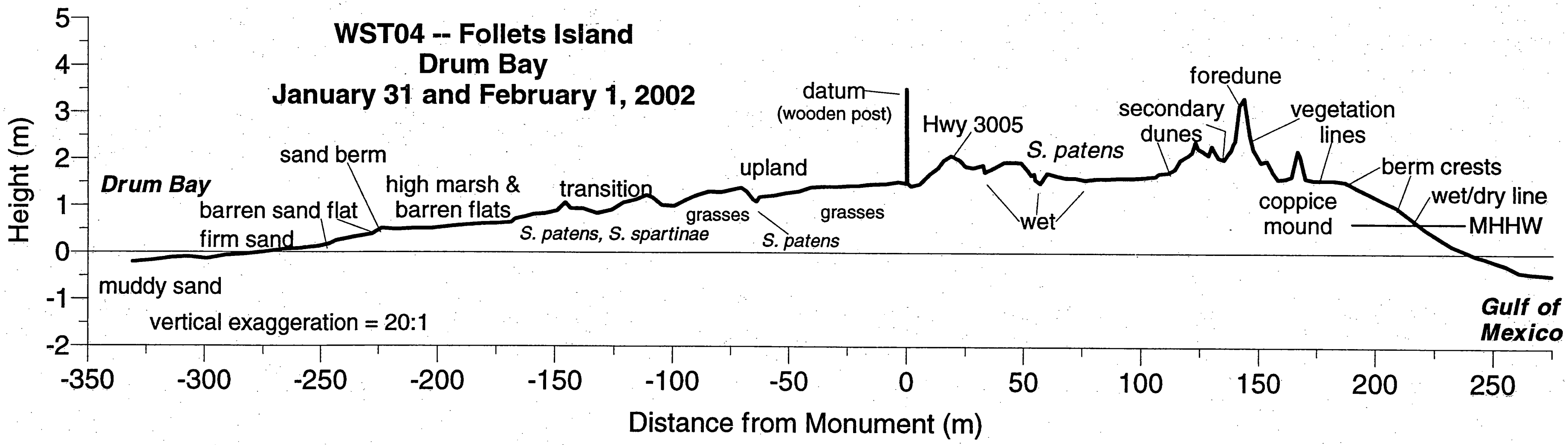
WST01 Datum Latitude: 29° 12' 44.3367" N
Datum Longitude: 94° 57' 14.5705" W
Azimuth: 280° Magnetic North
HAE: -25.012 meters
NAVD88: 1.43
Local MSL Height: 1.64 meters

X (m)	Z (m)	Beach feature	X (m)	Z (m)	Beach feature
0.00	1.64	datum, concrete box	173.89	0.368	high marsh, wet
0.03	1.071		178.20	0.349	*S. alterniflora*
1.50	1.173		183.47	0.278	low marsh
4.95	1.042		189.23	0.249	low marsh
9.17	0.943	*Spartina*	195.73	0.253	low marsh
14.26	1.041	*Spartina*	199.95	0.209	open water
16.76	1.181	bushes	202.00	0.046	open water 14cm
23.41	1.295	bushes	202.79	0.146	water/low marsh
27.46	1.328	bushes	204.27	0.17	low marsh
32.78	1.352	mowed grass	206.85	0.047	open water 15cm
38.28	1.317	mowed grass	210.23	0.218	low marsh
43.47	1.239	mowed grass	213.45	0.164	low marsh
50.26	1.05	grass/*S. patens*	214.92	0.165	low marsh/water
57.64	0.79	*S.patens*/bushes	216.20	-0.027	open water
63.04	0.611	bushes/upper flat	217.71	0.212	low marsh
67.44	0.519	sand flat	218.57	-0.02	open water
69.93	0.486	sand flat	220.13	-0.021	open water
74.47	0.431	high marsh	221.50	-0.006	open water
80.49	0.405	marsh	222.11	0.185	low marsh
88.45	0.441	sand flat	223.22	-0.012	open water
90.64	0.445	sand flat	226.70	-0.034	open water
93.96	0.477	high marsh	231.54	-0.033	open water
97.78	0.434	sand flat	232.74	0.151	low marsh
102.23	0.44	sand flat	234.84	0.072	low marsh
105.42	0.448	sand flat, algal mat	235.49	-0.001	open water
111.75	0.499	sand flat	238.35	-0.059	open water
117.14	0.537	sand flat	241.31	-0.046	open water
121.20	0.588	sand flat/high marsh	242.99	-0.027	open water
127.60	0.562	high marsh	244.14	0.017	low marsh
132.25	0.541	high marsh	245.01	-0.065	low marsh
136.64	0.525	*Monanthochloe*	248.13	-0.103	open water
143.55	0.475	sand flat	255.70	-0.112	open water
145.45	0.451	sand flat, algal mat	263.83	-0.13	open water
148.59	0.447	sand flat/high marsh	274.09	-0.122	open water
154.00	0.432	high marsh/sand flat	283.95	-0.098	open water
157.30	0.402	sand flat	289.51	-0.011	dying low mash
160.69	0.406	barran flat, algal mat	291.76	0.024	dying low mash
163.87	0.377	sand flat/high marsh	296.12	-0.088	dying low mash
166.98	0.405	high marsh	301.27	-0.132	open water
168.83	0.349	high marsh, wet	307.20	-0.147	open water

WST02	Datum Latitude:	29° 8' 22.4082" N
	Datum Longitude:	95° 3' 32.7622" W
	Azimuth:	293° Magnetic North
	HAE:	-24.947 meters
	NAVD88:	1.43
	Local MSL Height:	1.64 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
96.81	-0.8	open water	-67.32	0.141	*Paspalum*
90.54	-0.778	open water	-71.75	0.081	*Paspalum*
82.66	-0.779	open water	-76.28	0.143	*Paspalum*
76.00	-0.74	oyster bar to east	-79.70	0.19	high marsh
69.34	-0.673	open water	-82.85	0.231	high marsh
64.86	-0.609	open water	-85.33	0.112	wet high marsh
60.72	-0.558	oyster shells	-89.51	0.023	wet high marsh
56.92	-0.582	oyster shells	-93.70	0.1	wet high marsh
52.78	-0.482	oyster shells	-97.50	0.177	dry marsh
49.78	-0.415	*S. alterniflora*	-100.57	0.235	sand flat
47.49	-0.336	waterline	-103.26	0.232	sand flat
45.10	-0.215	fringing low marsh	-109.73	0.305	high marsh
42.71	-0.132	sand flat	-114.01	0.378	*Spartina*
39.05	0.025	sandy berm	-119.24	0.385	*Spartina*
36.75	0.122	sandy berm	-124.32	0.478	*Spartina*
33.73	0.152	berm crest	-126.48	0.429	*Spartina*
32.82	0.121	berm/high marsh	-127.99	0.387	transition/high marsh
30.59	0.063	high marsh	-132.61	0.304	high marsh
25.94	0.062	high marsh	-141.48	0.251	high marsh
20.45	0.065	high marsh	-149.35	0.287	high marsh
15.77	0.071	high marsh	-155.03	0.306	high marsh/transition
8.35	0.091	high marsh/sand flat	-157.96	0.321	*Spartina*
0.17	0.084	sand flat/road	-161.98	0.304	transition/high marsh
0.00	1.64	datum	-168.01	0.318	high marsh
-0.20	0.051	sand flat/road	-174.03	0.284	high marsh
-5.53	0.164	sand flat/high marsh	-177.93	0.316	*Juncus or Paspalum*
-12.97	0.188	high marsh	-187.65	0.353	*Juncus or Paspalum*
-16.85	0.127	high marsh	-190.90	0.462	*Spartina*
-24.97	0.116	high marsh	-194.89	0.323	*Juncus or Paspalum*
-28.74	0.103	high marsh	-198.26	0.303	*Juncus or Paspalum*
-34.78	0.105	high marsh	-201.54	0.267	*Scirpus*
-39.13	0.113	high marsh	-207.59	0.328	*Scirpus*
-44.81	0.118	*Monanthochloe*	-211.65	0.375	*Scirpus*
-52.22	0.031	high marsh, wet	-218.44	0.448	*Spartina*
-56.10	0.125	high marsh	-223.50	0.492	cattails
-62.07	0.104	high marsh			


WST03 -- Sportsman Road, Galveston Island
West Bay
January 30, 2002
Height (m)
Distance from Monument (m)
tidal channel
low marsh and barren flats
datum
shell berm
high tide berm crest
wet/dry line
eroded marsh
West Bay
firm muddy sand
vertical exaggeration = 20:1


WST04 -- Follets Island
Drum Bay
January 31 and February 1, 2002
Height (m)
Distance from Monument (m)
Drum Bay
sand berm
barren sand flat
firm sand
muddy sand
high marsh &
barren flats
transition
S. patens, S. spartinae
grasses
upland
S. patens
grasses
datum
(wooden post)
Hwy 3005
S. patens
wet
secondary
dunes
foredune
vegetation
lines
coppice
mound
berm crests
wet/dry line
MHHW
Gulf of
Mexico
vertical exaggeration = 20:1

WST03	Datum Latitude:	29° 15' 18.8714" N
	Datum Longitude:	94° 55' 4.4288" W
	Azimuth:	270° Magnetic North
	HAE:	-26.086 meters
	NAVD88:	0.41 meters
	Local MSL Height:	0.61 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-132.96	-0.372	tidal channel	-13.00	0.105	low marsh
-120.25	-0.24	tidal channel	-8.99	0.139	low marsh
-110.76	-0.194	tidal channel	-4.00	0.127	low marsh
-103.14	-0.202	tidal channel	-1.19	0.151	low marsh
-96.75	-0.104	waterline	-0.08	0.12	low marsh
-94.89	0.081	*S. alterniflora*	0.00	0.61	datum
-88.55	0.119	low marsh	0.05	0.185	low marsh
-82.98	0.065	low marsh	1.77	0.174	low marsh
-78.27	0.104	low marsh	3.01	0.192	washover shells
-72.18	0.129	low marsh	4.25	0.495	crest shell berm
-65.86	0.124	low marsh	5.03	0.418	
-59.93	0.114	low marsh	5.30	0.406	high-tide berm crest
-54.13	0.094	low marsh	5.75	0.329	
-51.52	0.098	low marsh	6.84	0.268	wet/dry line
-50.50	-0.04	sand flat, flooded	8.86	0.158	shelly sand/mud
-49.18	-0.076	sand flat, flooded	10.97	0.093	eroded marsh
-48.01	0.004	low marsh	12.76	-0.062	waterline
-47.31	0.087	low marsh	14.83	-0.055	low-tide berm
-46.55	-0.053	sand flat, flooded	19.03	-0.154	slightly muddy sand
-44.28	-0.093	sand flat, flooded	25.01	-0.211	slightly muddy sand
-41.31	-0.088	low marsh	32.34	-0.23	slightly muddy sand
-40.78	0.083	low marsh	38.03	-0.251	slightly muddy sand
-36.05	0.163	low marsh	46.12	-0.271	slightly muddy sand
-31.43	-0.003	low marsh	54.10	-0.296	slightly muddy sand
-29.06	-0.049	low marsh/low flat	65.20	-0.355	slightly muddy sand
-25.98	-0.089	low flat, flooded	75.05	-0.415	slightly muddy sand
-22.21	-0.08	low marsh	83.95	-0.452	slightly muddy sand
-21.18	0.071	low marsh	94.57	-0.491	slightly muddy sand
-16.76	0.067	low marsh	103.65	-0.549	slightly muddy sand

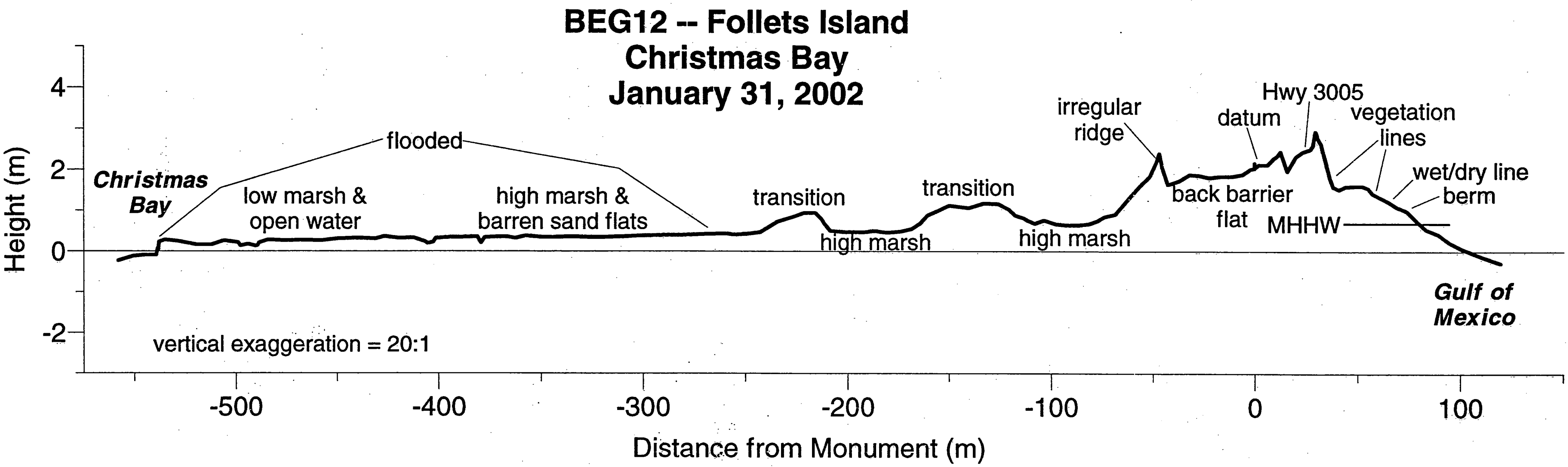
WST04

Datum Latitude: 29° 0' 23.0073" N
Datum Longitude: 95° 13' 7.2987" W
Azimuth: 135° Magnetic North
HAE: -22.963 meters
NAVD88: 3.31 meters
Local MSL Height: 3.51 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-330.86	-0.216	open water	-90.35	1.215	upland, grasses
-322.58	-0.177	open water	-84.55	1.304	upland, grasses
-314.19	-0.122	open water	-79.30	1.291	upland, grasses
-307.26	-0.104	open water	-75.55	1.334	upland, grasses
-299.08	-0.142	open water	-70.78	1.387	upland, grasses
-290.92	-0.068	open water	-68.21	1.304	upland, grasses
-283.03	-0.045	open water	-65.54	1.134	*S. patens*
-274.56	0.004	open water	-64.25	1.089	*S. patens*
-266.90	0.058	open water	-62.92	1.189	*S. patens*
-258.87	0.08	open water	-61.57	1.2	upland, grasses
-250.85	0.126	open water	-56.61	1.222	upland, grasses
-246.53	0.172	waterline	-51.37	1.275	upland, grasses
-243.37	0.248	sand flat	-46.00	1.307	upland, grasses
-234.77	0.327	sand flat	-40.60	1.398	upland, grasses
-227.82	0.387	sand berm, algal mat	-34.83	1.4159	upland, grasses
-223.75	0.51	berm/high marsh	-28.93	1.412	upland, grasses
-217.49	0.485	*Salicornia*	-24.17	1.434	upland, grasses
-209.48	0.508	high marsh/sand flat	-20.41	1.432	upland, grasses
-203.62	0.501	sand flat, algal mat	-17.24	1.456	upland, grasses
-197.59	0.538	high marsh/sand flat	-14.17	1.469	upland, grasses
-191.15	0.573	*Salicornia*	-8.32	1.478	upland, grasses
-181.58	0.608	*Monanthochloe*	-3.25	1.517	upland, grasses
-174.33	0.621	high marsh/sand flat	-0.14	1.483	upland, grasses
-168.50	0.644	sand flat/high marsh	0.00	3.51	datum
-166.89	0.714	high marsh/sand flat	0.14	1.502	mowed grass
-162.39	0.764	sand flat/transition	1.76	1.425	mowed grass
-159.12	0.814	*S.patens/S.spartinae*	5.50	1.472	mowed grass
-154.18	0.831	*S.patens/S.spartinae*	9.82	1.69	mowed grass
-149.20	0.891	*S.patens/S.spartinae*	13.11	1.817	mowed grass
-145.67	1.064	*S.patens/S.spartinae*	15.78	1.98	highway 3005
-143.48	0.943	*S.patens/S.spartinae*	18.90	2.077	highway 3006
-138.37	0.936	*S.patens/S.spartinae*	22.50	1.987	highway 3007
-132.38	0.839	*S.patens/S.spartinae*	25.00	1.851	mowed grass
-126.11	0.907	*S.patens/S.spartinae*	28.26	1.821	mowed grass
-121.13	1.066	*S.patens/S.spartinae*	32.37	1.882	mowed grass
-115.67	1.133	*S.patens/S.spartinae*	33.23	1.727	*S. patens*
-111.21	1.228	*S.patens/S.spartinae*	36.84	1.82	*S. patens*
-108.65	1.178	*S.patens/S.spartinae*	41.54	1.936	*S. patens*
-104.83	1.015	*S.patens/S.spartinae*	45.24	1.945	grass, cactus, dry
-99.44	0.995	*S.patens/S.spartinae*	48.83	1.935	grass, cactus, dry
-93.52	1.146	*S.patens/S.spartinae*	51.80	1.771	*S. patens*

WST04 continued.

X (m)	Z (m)	Beach feature	X (m)	Z (m)	Beach feature
53.12	1.668	*S. patens*	143.71	3.33	dune crest
54.40	1.695	*S. patens*	146.04	2.548	vegetation line 1
54.82	1.58	*S. patens*	147.51	2.237	
56.95	1.488	*S. patens*	150.78	1.951	
60.09	1.713	*S. patens*	153.37	1.987	insipient foredunes
63.70	1.658	*S. patens*	155.25	1.815	
67.50	1.612	*S. patens*	155.78	1.756	old storm wrack line
72.16	1.607	*S. patens*	158.17	1.586	
76.28	1.568	*S. patens*	161.47	1.607	
80.93	1.593	*S. patens*	164.00	1.654	coppice mounds
87.10	1.603	*S. patens*	166.66	2.2	
91.41	1.617	*S. patens*	167.61	2.102	
95.68	1.607	*S. patens*	169.97	1.617	
100.99	1.624	*S. patens*	173.33	1.569	
106.06	1.652	*S. patens*	175.85	1.574	vegetation line 2
107.72	1.71	*S. patens*	181.80	1.569	
111.63	1.727	*S. patens*	187.03	1.534	berm crest
114.37	1.805	*S. patens*	192.15	1.402	
116.61	1.994	*S. patens*	197.26	1.284	berm crest
120.12	2.106	*S. patens*	202.99	1.135	
121.76	2.174	*S. patens*	208.56	1.001	
123.12	2.403	*S. patens*/dune crest	215.03	0.755	wet/dry line
124.26	2.249	*S. patens*	221.02	0.524	
126.37	2.197	interdune area	226.78	0.333	
128.68	2.102	interdune area	232.13	0.174	
129.99	2.3	interdune area	237.18	0.065	
131.02	2.204	interdune area	242.45	-0.043	
132.75	2.05	interdune area	245.44	-0.084	waterline
135.14	2.009	interdune area	250.34	-0.171	
137.25	2.17	interdune area	255.24	-0.25	
138.25	2.223	interdune area	260.91	-0.383	
138.98	2.346	interdune area	266.24	-0.418	
139.79	2.416	interdune area	270.82	-0.431	
141.72	3.171	interdune area	274.55	-0.452	



BEG12 -- Follets Island
Christmas Bay
January 31, 2002
Height (m)
4
2
0
-2
Christmas Bay
flooded
low marsh & open water
high marsh & barren sand flats
transition
high marsh
transition
high marsh
irregular ridge
datum
Hwy 3005
vegetation lines
back barrier flat
MHHW
wet/dry line
berm
Gulf of Mexico
vertical exaggeration = 20:1
-500
-400
-300
-200
-100
0
100
Distance from Monument (m)

BEG12 Datum Latitude: 29° 2' 22.8702" N
Datum Longitude: 95° 10' 9.2947" W
Azimuth: 136° Magnetic North
HAE: -24.331 meters
NAVD88: 1.96 meters
Orthometric Height: 2.16 meters

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-557.84	-0.23	open water	-362.95	0.322	*S. alterniflora*
-550.55	-0.115	open water	-357.89	0.379	*Salicornia*
-544.69	-0.092	open water	-350.08	0.353	*Salicornia*
-539.42	-0.094	low marsh fringe	-342.95	0.347	*Salicornia*
-538.57	0.076	*S. alterniflora*	-335.07	0.364	*Salicornia*
-538.27	0.05	scarp (subaqueous)	-327.81	0.346	*Salicornia*
-537.93	0.229	top of scarp	-320.16	0.343	high marsh/sand fla
-535.15	0.281	low marsh, flooded	-314.33	0.354	sand flat, flooded
-528.71	0.251	low marsh, flooded	-309.44	0.365	sand flat, flooded
-519.44	0.159	low marsh, flooded	-300.37	0.383	sand flat, flooded
-511.91	0.164	low marsh, flooded	-290.77	0.394	sand flat, flooded
-505.79	0.26	low marsh, flooded	-278.92	0.401	sand flat, flooded
-499.01	0.216	low marsh, flooded	-270.09	0.423	sand flat, flooded
-497.78	0.137	low marsh/open water	-259.11	0.436	*Monanthochloe*
-494.05	0.175	low marsh/open water	-256.24	0.412	high marsh/sand flat
-490.36	0.126	low marsh/open water	-249.23	0.429	sand flat
-489.32	0.138	low marsh/open water	-242.95	0.466	sand flat
-488.52	0.207	low marsh/open water	-239.38	0.574	*Monanthochloe*
-484.02	0.28	low marsh, flooded	-236.59	0.665	high marsh/transition
-475.19	0.265	*S. alterniflora, Batis*	-234.38	0.726	transition
-467.01	0.277	*S. alterniflora, Batis*	-226.66	0.849	*S.spartinae/S.patens*
-458.05	0.262	*S. alterniflora, Batis*	-221.55	0.94	*S.spartinae/S.patens*
-449.91	0.311	*S. alterniflora, Batis*	-216.10	0.933	*S.spartinae/S.patens*
-445.67	0.314	*S. alterniflora*	-213.26	0.793	*S.spartinae/S.patens*
-439.46	0.328	*S. alterniflora*	-211.81	0.679	transition/high marsh
-431.15	0.308	*S. alterniflora*	-208.85	0.501	high marsh/sand flat
-426.54	0.373	*S. alterniflora*	-200.92	0.468	sand flat, algal mat
-419.67	0.323	*S. alterniflora*	-191.02	0.477	sand flat/high marsh
-412.58	0.337	*S. alterniflora*	-186.73	0.498	high marsh
-407.11	0.241	low marsh/open water	-183.45	0.475	*S. alterniflora, Batis*
-405.60	0.195	open water	-180.03	0.459	high marsh/sand flat
-402.91	0.225	open water	-173.74	0.488	sand flat, algal mat
-401.62	0.324	*S. alterniflora*	-168.38	0.549	*Monanthochloe*
-395.42	0.341	*S. alterniflora*	-166.20	0.623	*Monanthochloe*
-388.35	0.348	*S. alterniflora*	-164.36	0.678	high marsh/transition
-381.40	0.358	*S. alterniflora*	-160.63	0.879	transition
-379.65	0.208	open water	-155.33	0.991	transition
-377.92	0.342	*S. alterniflora*	-150.01	1.12	transition
-372.64	0.357	*S. alterniflora*	-140.50	1.063	transition
-367.33	0.358	*S. alterniflora*	-133.26	1.175	transition

BEG12 continued

X (m)	*Z (m)*	*Beach feature*	*X (m)*	*Z (m)*	*Beach feature*
-126.04	1.16	transition	9.45	2.282	mowed grass
-120.90	1.029	transition	10.90	2.333	mowed grass
-117.79	0.884	transition	12.55	2.444	road berm
-113.75	0.81	transition	15.80	1.958	ditch
-111.43	0.748	*Monanthochloe*	19.88	2.309	Highway 3005
-108.26	0.682	*Monanthochloe*	23.27	2.436	Highway 3005
-103.64	0.761	transition	27.00	2.505	Highway 3005
-99.26	0.689	transition	28.30	2.596	road berm
-97.74	0.669	transition/high marsh	29.45	2.929	
-92.47	0.641	*Monanthochloe/Batis*	29.96	2.887	
-85.90	0.646	*Monanthochloe/Batis*	30.39	2.781	
-81.37	0.675	*Paspalum*	32.10	2.633	concrete riprap
-77.22	0.748	*S. patens, Scirpus*	34.26	2.243	concrete riprap
-73.97	0.844	high marsh/ transition	36.54	1.794	vegetation line 1
-68.62	0.908	transition	38.11	1.579	sparce veg
-61.67	1.312	transition	40.92	1.514	interdune area
-56.52	1.597	transition, grasses	44.06	1.587	sparce veg
-51.55	1.831	transition, grasses	48.43	1.604	sparce veg
-48.53	2.159	transition, grasses	52.52	1.604	sparce veg
-46.95	2.394	transition, grasses	55.32	1.539	sparce veg
-45.49	2.048	transition, grasses	57.51	1.414	vegetation line 2
-42.66	1.633	transition, grasses	62.14	1.292	
-37.26	1.72	transition, grasses	65.33	1.215	wet/dry line
-31.89	1.873	transition, grasses	69.11	1.097	
-27.25	1.852	transition, grasses	74.17	0.988	berm crest
-22.22	1.803	transition, grasses	78.75	0.751	beachface
-16.95	1.83	transition, grasses	83.49	0.539	beachface
-11.44	1.833	transition, grasses	89.50	0.418	
-5.88	1.88	*S. patens*	94.75	0.224	
-1.98	2.016	*S. patens*	100.81	0.069	
-0.04	2.037	*S. patens*	105.26	-0.02	waterline
0.00	2.16	datum/*S. patens*	110.12	-0.119	
0.02	2.045	*S. patens*	116.81	-0.235	
2.05	2.124	grasses/low bushes	119.63	-0.285	
6.30	2.12	grasses/low bushes			