ERDC/CHL TR-06-17

Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
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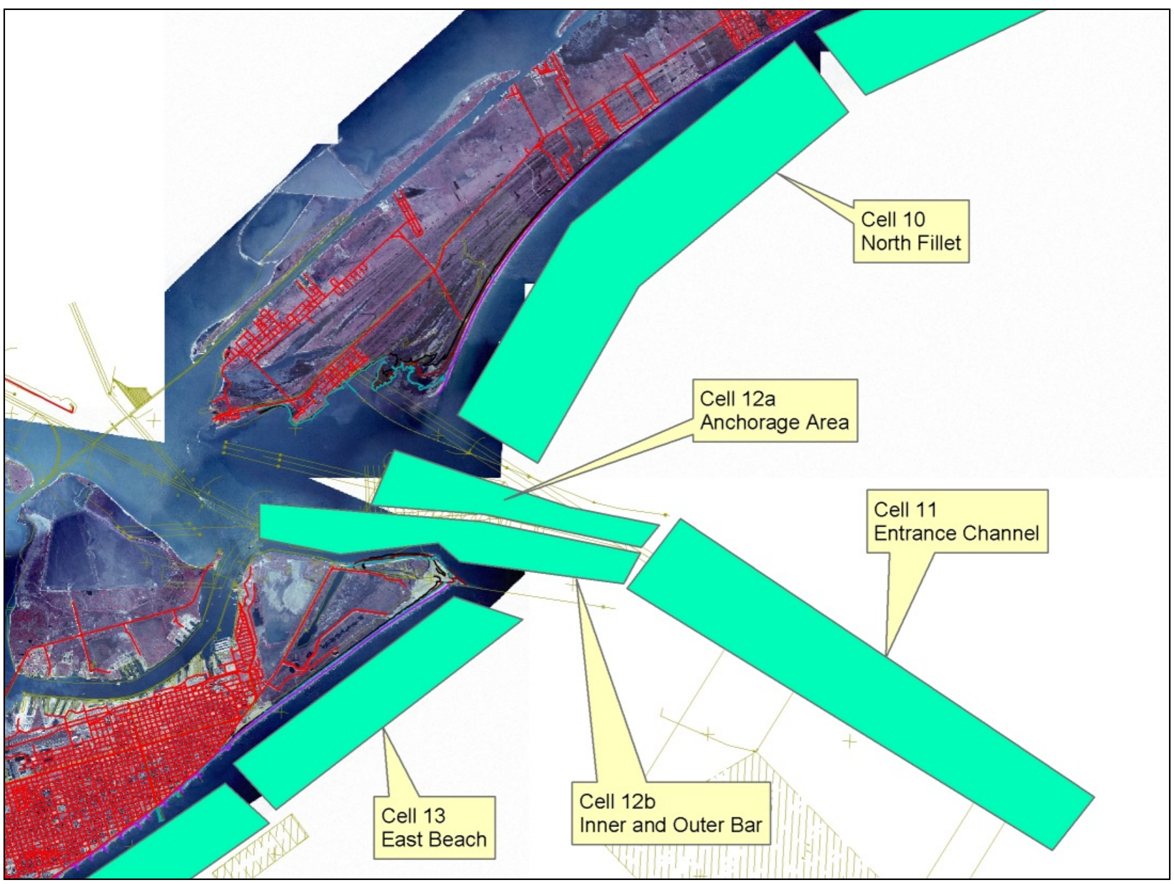
North Texas Sediment Budget

Sabine Pass to San Luis Pass

Andrew Morang

September 2006



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Sabine Pass to San Luis Pass

Andrew Morang

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Final report

Prepared for U.S. Army Engineer District, Galveston
2000 Fort Point Road
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Abstract: The North Texas sediment budget was developed to support the U.S. Army Corps of Engineers, Galveston District's Sabine Pass to Galveston Bay, Texas, Shoreline Feasibility Study. Data sources included dredging data from the 1970s to the present, beach fill quantities, sediment grain size statistics, aerial photographs, shoreline data, and information from the literature and historical sources.

For this study area, 23 sediment cells have been defined based on prominent morphologic or man-made features. In general, longshore sediment movement is from east to west, although reversals occur east of Sabine Pass, south of Rollover Pass, and south of Galveston entrance. Sabine Pass is heavily dredged, but material from the jetties and further landward is disposed on land. Therefore, the pass is primarily a source of fine-grain material, which disperses over the shoreface. At Galveston entrance, about 25 percent of the sediment in the channel is fine-grained material from Galveston Bay, with the remainder supplied from littoral sources from north and south of the jetties. The quantity of sand entering Galveston harbor via the south jetty or by aeolian transport is about 300,000 cu m/year. To balance the budget at Galveston entrance, significant onshore transport must occur on both sides. A sediment node occurs off the Galveston seawall, with material moving to the northeast towards East Beach and to the southwest along the island, eventually to San Luis Pass.

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Preface

During 2003 and 2004, the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, conducted engineering studies for the U.S. Army Engineer District, Galveston, in support of their study of shore erosion problems along the upper Texas coast between Sabine Pass and San Luis Pass. This report describes the development of a sediment budget for the reach between Sabine and San Luis Passes. Dr. Andrew Morang, of the Coastal Engineering Branch (HN-C), conducted this portion of the study and wrote this report.

The author wishes to thank many coworkers and colleagues who provided data and advice including:

- U.S. Army Engineer District, Galveston: Ms. Laura L. Vera, Messrs. James M. Kieslich, Timothy Bamer, Robert G. Hauch, Arthur J. Martin, Robert C. Thomas.
- U. S. Army Engineer District, Mobile: Ms. Rose Dopsovic.
- Coastal and Hydraulics Laboratory, Vicksburg: Drs. David King and Trimbak M. Parchure, Mr. William R.Curtis, Dr. Jeffrey P. Waters, and Ms. Julie Rosati.
- Bureau of Economic Geology, University of Texas: Dr. James C. Gibeaut.
- Texas General Land Office: Mr. E. Ray Newby.
- Shiner Moseley and Associates: Mr. Neil McLellan.
- Texas A&M University: Dr. Billy L. Edge.
- Mr. Ty Wamsley, CHL, and Lynn Vera, Galveston District, reviewed this report.

The study was conducted under the general supervision of William Curtis, CHL, Principle Investigator of Sabine Pass to Galveston Bay, Texas Shoreline Erosion Feasibility Study; Dr. Yen-hsi Chu, former Chief, Coastal Engineering Branch, CHL; Dr. William D. Martin, Deputy Director, CHL; and Thomas W. Richardson, Director of CHL. Dr. James R. Houston was Director of ERDC, and COL Richard B. Jenkins was Commander and Executive Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
short tons	0.9078	tons (metric)
yards	0.9144	meters

1 Introduction

During 2003, the Engineer Research and Development Center's (ERDC's) Coastal and Hydraulics Laboratory (CHL) conducted technical analysis and numerical modeling to support the U.S. Army Engineer District, Galveston's (hereafter, Galveston District) comprehensive engineering analysis of the north Texas coast, a program known as the Sabine Pass to Galveston Bay, Texas – Shoreline Erosion Feasibility Study. King (in preparation) describes the wave and beach processes numerical modeling. This report, a companion to King (in preparation), describes the examination of sediment movement, geomorphology, and historical data for the purpose of computing a coastal sediment budget. The first draft of this budget was submitted to the Galveston District in November 2003. Based on review comments pertaining to sediments in Galveston Harbor, the author examined additional sediment statistics from the 1950s to the 1980s and modified the budget.

Study objectives

The objectives of this study were to:

a. Identify sources and sinks of sediment in the coastal system.
b. Compute quantities.
c. Determine direction of movement using morphologic evidence.
d. Identify additional data needed to refine the budget.
e. Provide results to other researchers involved in the North Texas feasibility study.

Products and deliverables

This effort will supply the Galveston District two products: (a) final report describing the study procedures, data used, assumptions, and results and (b) the sediment budget in the form of an Excel spreadsheet that can be changed and modified in the future based on new data or additional findings.

2 Study Area

The study area encompasses the Gulf of Mexico shore between Sabine Pass, at the Louisiana-Texas border, and San Luis Pass, at the southwest end of Galveston Island. This 147-km section of the north Texas coast lies in Jefferson, Chambers, and Galveston counties, and includes both barrier island terrain (Galveston Island) and low-lying Chenier Plain. This area includes undeveloped beaches, wildlife refuges, residential communities, and the Galveston urban area, with its well-known 15.7-km seawall. The beaches from Sabine to near High Island have limited sand, often showing outcroppings of muddy organic sediments, while further west, especially beyond Rollover Pass, the beaches contain more sand. Morton (1997); Morton and Peterson (2005); and Morton et al. (2004) provide a description of the morphology and coastal characteristics.

Four inlets (known as passes) influence sediment dynamics of this coast. Listed from east to west, they include:

- Sabine Pass. This deep-draft navigation channel is maintained by the U.S. Army Corps of Engineers to allow oceangoing ships to reach Beaumont, Port Arthur, and Sabine Lake. Total traffic in 2001 for the Sabine-Neches Waterway, (including Beaumont, Orange, Port Arthur, and Sabine Pass Harbor, TX) was 128,900,000 short tons, making this one of the United States' top 10 entrances in terms of tonnage (Navigation Data Center 2001). Petroleum products were the main cargos, along with chemicals and agricultural products. Twin jetties protect the entrance.
- Rollover Pass, TX. This is a non-navigable inlet artificially cut in 1954-1955. Both sides of the channel have been lined with steel sheet pile. A significant volume of sand enters the pass and is deposited in Galveston Bay immediately to the west and in the Intracoastal Waterway (Parchure et al. 2000). The adjacent beaches have eroded and were nourished in 2003.
- Galveston Entrance Channel. Galveston entrance is stabilized with twin jetties, some of the longest in the nation. This is one of the world's busiest harbor entrances, and the U.S. Army Corps of Engineers must regularly dredge the channel. In 2001, total shipping passing through the Galveston entrance to or from Houston, Texas City, Dickinson, Cedar Bayou, and Galveston was 258,200,000 short tons (Navigation

Data Center 2001). Much of this cargo consists of petroleum, petroleum products, and agricultural goods. Houston is one of the Nation's leading ports in terms of foreign trade (Morang and Chesnutt 2004).

- San Luis Pass. This is a natural, nonjettied inlet with stable overall location but dynamic shoals and inlet margins. The inlet is believed to be a significant sediment sink.

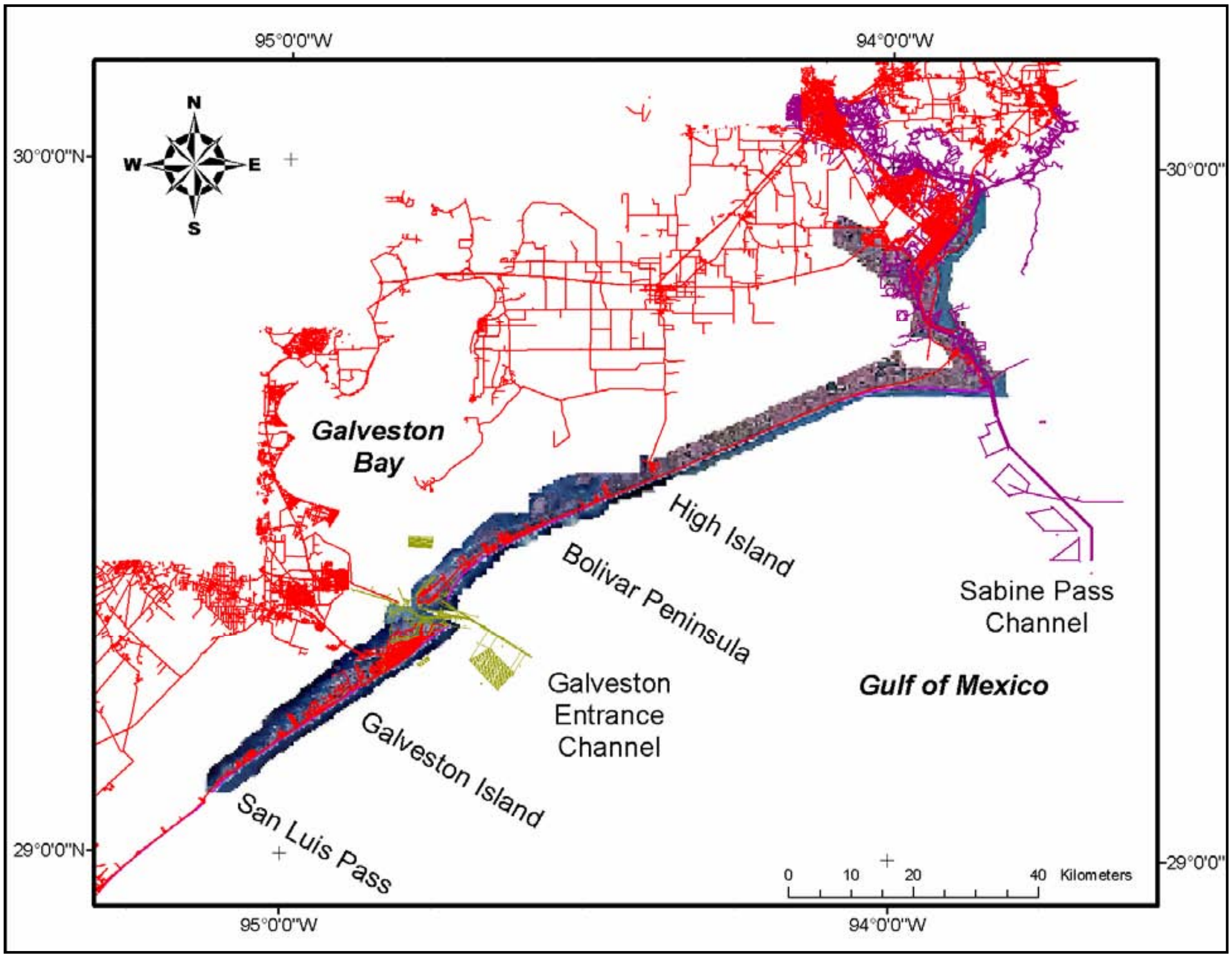

Figure 1. Study area, Sabine Pass to San Luis Pass, TX.

3 Sediment Budget Methodology

Sediment budget definition

A sediment budget is a tally of sediment gains and losses, or sources and sinks, within a specified control volume (or cell), or in a series of connecting cells, over a given time (Dopsivic et al. 2002). The algebraic difference between the sediment sources and sinks must equal the rate of change of sediment volume occurring in each cell, accounting for possible engineering activities such as placement or dredging. Expressed in terms of variables:

$$\sum Q_{source} - \sum Q_{sink} - \Delta V + P - R = Residual \qquad (1)$$

where

Q_{source} and Q_{sink}	=	sources and sinks to each cell
ΔV	=	net change in sediment volume in each cell
P and R	=	material placed or removed
Residual	=	the degree to which each cell is balanced

For a balanced cell, the *Residual* must equal zero. If it is not, then one of the inputs or losses has not been computed correctly, or some other unknown factor is contributing to a change in volume.

When a budget is being prepared for an extended length of coast, a number of cells are created. Each will represent a length of shore with uniform geomorphic and energy conditions. A cell may be hundreds or thousands of meters long. For a region consisting of many contiguous cells, the budgets of each individual cell must balance to achieve a balanced budget for the entire regional system.

A sediment budget has to reflect a particular time interval. Geologists sometimes examine a major feature like a river delta and compute a budget representing centuries of deposition. Occasionally, the timing of a budget is matched to a particular event, such as the construction of long jetties, in the attempt to determine how local sediment dynamics have been changed by the structures. A budget that only covers a few years can be unduly influenced by atypical physical events such as unusually severe winter storms or the El Niño-Southern Oscillation. A sediment budget covering the last three or four decades is a reasonable compromise for several reasons:

- Coastal areas in much of the industrial world (and even remote continents) have been profoundly affected by coastal construction, dams, sand mining, river diversion, and dredging. Therefore, littoral sediment movement today may be drastically different than the patterns only a century ago. For example, we know that the 1900 construction of the Galveston Seawall drastically changed the morphology and dynamic resonse of Galveston Island.
- In the United States, trustworthy topographic and bathymetric data become increasingly rare before the 1930s (the introduction of acoustic bathymetry), and vertical aerial photographs are largely unavailable before the 1930s (Morang 2003).
- Wave data are only available since the 1980s.
- For the Sabine Pass to Galveston Bay, Texas – Shoreline Erosion Feasibility Study, the budget described in this report represents a 25-year period. This coincides with the time span used by the Texas Bureau of Economic Geology (BEG) to compute shoreline change statistics.

Study procedure

The mathematics of balancing sediment budget cells is trivial. The computations can be done with a speadsheet program or the USACE's SBAS software, which runs as a plugin to ArcView© Geographic Information System (GIS) software. The challenge is determining the various inputs, losses, and volume changes for each cell. Obtaining these data requires searching for historical dredging, engineering and geomorphic data, and making numerous assumptions. The more background data that can be assembled, the more likely the budget will reflect actual field conditions. Confidence in the budget increases with greater background information.

The Sabine Pass to San Luis Pass sediment budget included the following steps:

- Review technical literature, engineering reports.
- Find and organize data.
- Assemble GIS project, import data.
- Check for overlap of historical and recent cross-shore profiles.
- Tabulate dredging and fill statistics.
- Create budget cells along coast.
- Tabulate sources and sinks.

4 Analysis of Geomorphic and Engineering Data

Data sources

Texas state agencies, universities, and the Galveston District provided historical and contemporary geomorphic and engineering data. Table 1 lists these data, and the following sections describe how the data were used in this project.

Table 1. Data sources.

Type of data	Source	Notes
Beach profiles 1966 to 1980	Texas Coast Inlet Studies, Galveston District (SWG)	Digitized from 11x17-in. paper plates at SWG, supplied as ASCII XYZ and BMAP software files. Coverage near Sabine and Galveston Passes only
August-September 2002 cross-shore profiles	Texas A&M University (TAMU)	Beach topography and offshore lines every 820 m (½-mile) along the shore. Data supplied in UTM Zone 15, NAD83, elevations in NAVD 88
Shoreline change statistics	Texas Bureau of Economic Geology (BEG)	Analysis completed in 2002 based on three aerial photography dates (Jun 1974, Jun-Jul 1982, Jan 1995) and one LIDAR topography date (May 2000). Statistics computed at 50-m spacing along shore.
Project and navigation channel maps	SWG	Supplied as MicroStation .dgn files in State Plane coordinate system, Texas South Zone, NAD27.
Dredge statistics	SWG	Excel file based on SWG in-house database
Sediment grain size statistics	SWG and TAMU	Samples in navigation channels in Galveston and Sabine channels and at select locations on 2002 cross-shore profiles
Beach-fill data	Shiner Moseley and Associates (Houston) and BEG	MS Word table (Shiner Moseley) and misc. verbal communications with specialists at BEG
February 2002 aerial photograph mosaics	Texas BEG	Three mosaics from Sabine to San Luis Passes. Supplied as ER Mapper compressed .ecw files, coordinate system UTM Zone 15, NAD 83
Longshore drift directions	King (in preparation)	Based on wave hindcast statistics and limited buoy data
Rollover Pass sediment losses	Parchure, Brown, and McAdory (2000)	Excess dredging volumes from Gulf Intracoastal Waterway. Additional information from Parchure (personal communication, 2003)
Trinity and Sabine Rivers sediment load	Phillips and Musselman (2003)	Additional information from Phillips (personal communication, 21 August 2003)

Contemporary cross-shore beach profiles

Texas A&M University conducted the surveys during August and September of 2002 under contract to the Galveston District. Profiles were spaced at one-half-mile intervals (approximately 800 m) and were oriented perpendicular to the local shoreline (Figure 2). They extended from the dune or a prominent man-made feature (e.g., seawall or building) to approximately the 10 m water depth.

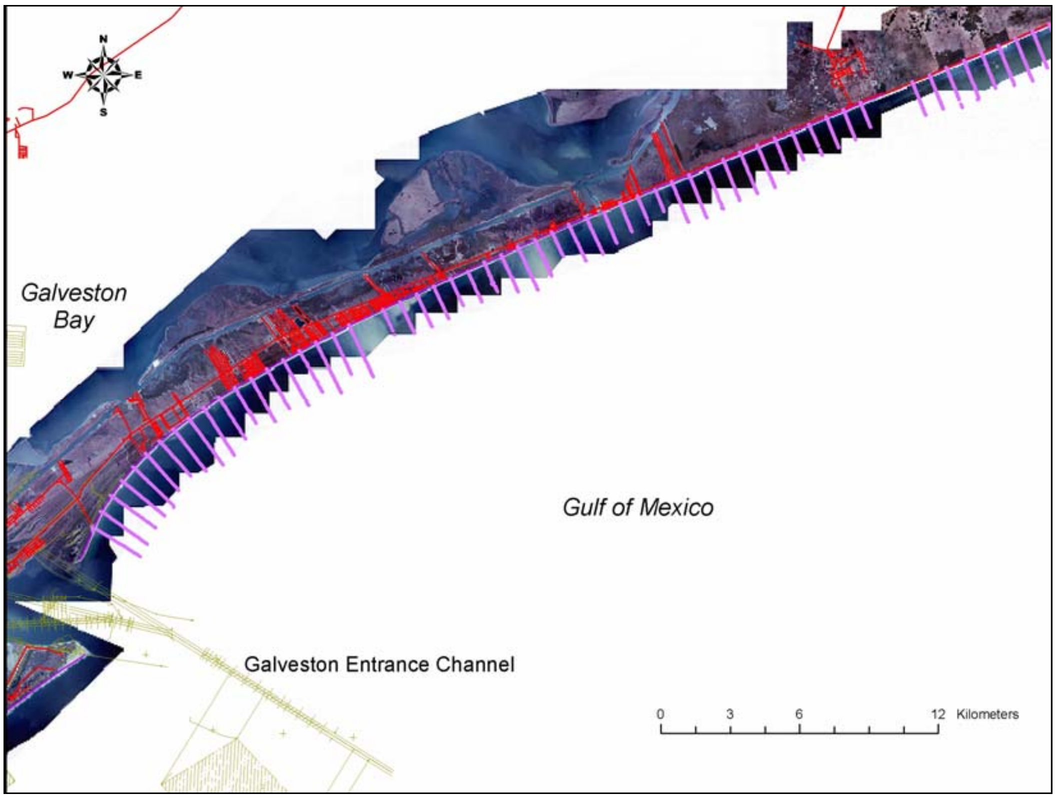

Figure 2. August-September 2002 profiles along Bolivar Peninsula and High Island area, TX.

Shoreline change statistics and beach volume change

The Bureau of Economic Geology (BEG) of the University of Texas computed shoreline change statistics for the north Texas shore between Sabine Pass and San Luis Pass. These shorelines were based on three aerial photography flights and one LIDAR topography survey (Table 2). In addition to plotting the four shorelines, BEG computed shoreline change statistics at 50-m intervals along the shore (Figure 3). The locations, marked by a symbol, can be queried in the ArcGIS software, revealing a table that lists the linear advance or retreat at each station (Table 3 shows a sample of the database). King (in preparation) discusses differences between these shorelines and ones developed by other researchers.

Table 2. Sources for BEG Shoreline Data.

Date & Time	Type	Scale	Area
9/5/1974	Black & White	1:24,000	Sabine Pass to 5 miles west
6/28/1974	Black & White	1:24,000	5 miles west of Sabine Pass to San Luis Pass
7/9/1982	Color Infrared	1:24,000	Sabine Pass to Galveston Entrance Channel
6/10/1982	Color Infrared	1:24,000	Galveston Entrance Channel to San Luis Pass
1-2/1995, 1-2/1996	Color Infrared	1:40,000 photos, 1:12,000 DOQQ's	Sabine Pass to San Luis Pass
5/23-24/ 2000	LIDAR topography and intensity	N/A	Sabine Pass to San Luis Pass
From King (in preparation) DOQQ = Digital Ortho Quarter Quadrangle LIDAR = Light Detection and Ranging			

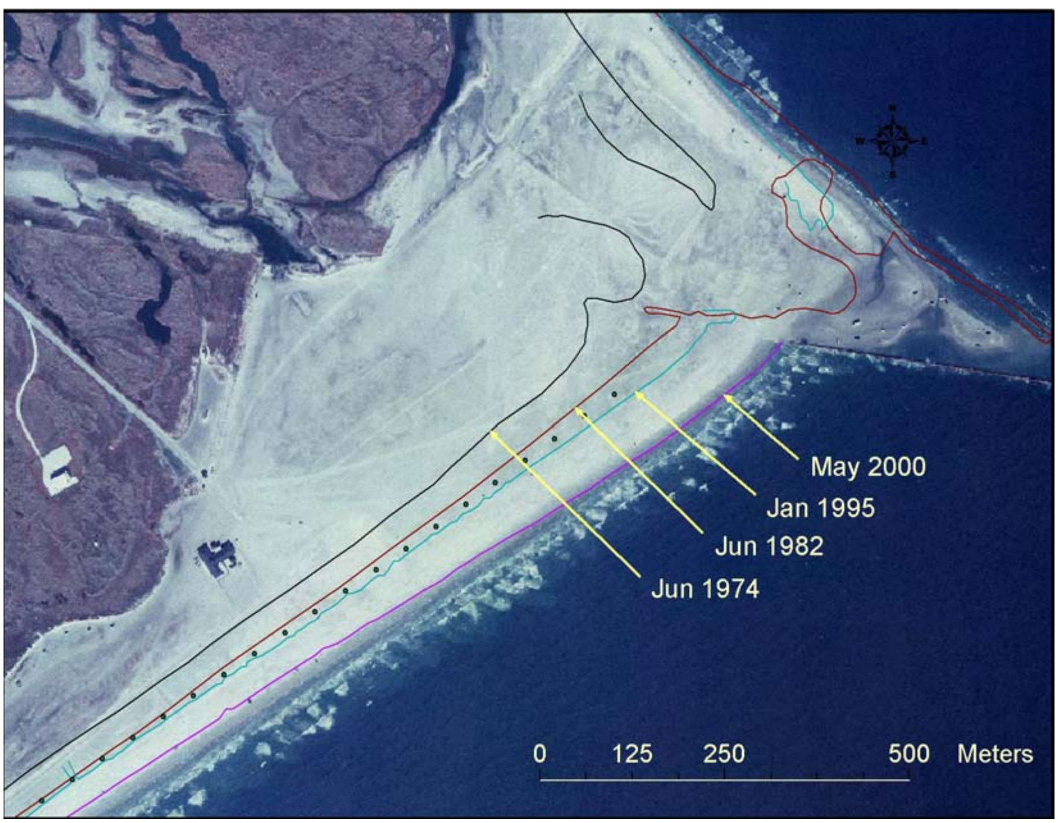

Figure 3. East Beach, Galveston Island. Example of historical shorelines interpreted by Texas Bureau of Economic Geology. Points on shore are at 50-m spacing and are locations of shoreline change transects.

Table 3. Shoreline change statistics (sample).

TRAN	LR_M_YR	LR_FT_YR	EASTING	NORTHING
-231	0.04	0.13	276354.72	3203337.63
-230	-0.16	-0.51	276382.69	3203379.08
-229	-0.19	-0.63	276410.66	3203420.52
-228	-0.40	-1.31	276438.63	3203461.97
-227	-0.58	-1.89	276466.60	3203503.41
-226	-0.66	-2.16	276494.57	3203544.86
-225	-0.77	-2.51	276522.54	3203586.30
-224	-0.73	-2.39	276550.51	3203627.74
-223	-0.73	-2.39	276581.14	3203667.27
-222	-0.65	-2.14	276611.76	3203706.79
-221	-0.50	-1.63	276642.39	3203746.31
-220	-0.62	-2.03	276673.01	3203785.84
-219	-0.59	-1.95	276703.64	3203825.36
-218	-0.66	-2.15	276734.26	3203864.88
-217	-0.68	-2.22	276764.89	3203904.41

Notes:
Statistics developed by Bureau of Economic Geology, University of Texas (Dr. James C. Gibeaut).
Original table contains approx. 3,300 transects.
Based on 1974, 1982, and 1995 aerial photographs and 2000 LIDAR topography.
TRAN = transect (station number).
LR_M_YR = linear change in m/year.
LR_FT_YR = linear change in ft/year.
EASTING, NORTHING = coordinate of transect in UTM Zone 15, NAD83, metric.

The BEG shoreline statistics provided the underlying basis to project the cross-shore profiles and compute changes in sediment volume for each littoral cell. First, a series of sediment cells along the shore had to be created. These were based on:

a. Change in direction of shoreline movement (advance, retreat, stable) based on the BEG statistics.
b. Dredging zone (for navigation channels). Using the BEG values from each 50-m station, compute a simple arithmetic mean for the shoreline change for each cell along the coast.

Computing the volume change required a series of steps:

a. Import the 2002 profiles into the Beach Morphology and Analysis Package (BMAP) software (Sommerfeld et al. 1994).
b. Obtain an average profile based on all the profiles in each cell (Figure 4).

c. With the translation tool in BMAP, translate the average profile the appropriate distance seaward (shoreline advance) or landward (retreat) (Figure 5).

d. Multiply the area under the curve (computed by BMAP) by the length of the cell to obtain a total sediment volume in cubic meters (ΔV in Equation 1). This study used a depth of 4 m as the active zone in most cells (the black box in Figure 5).

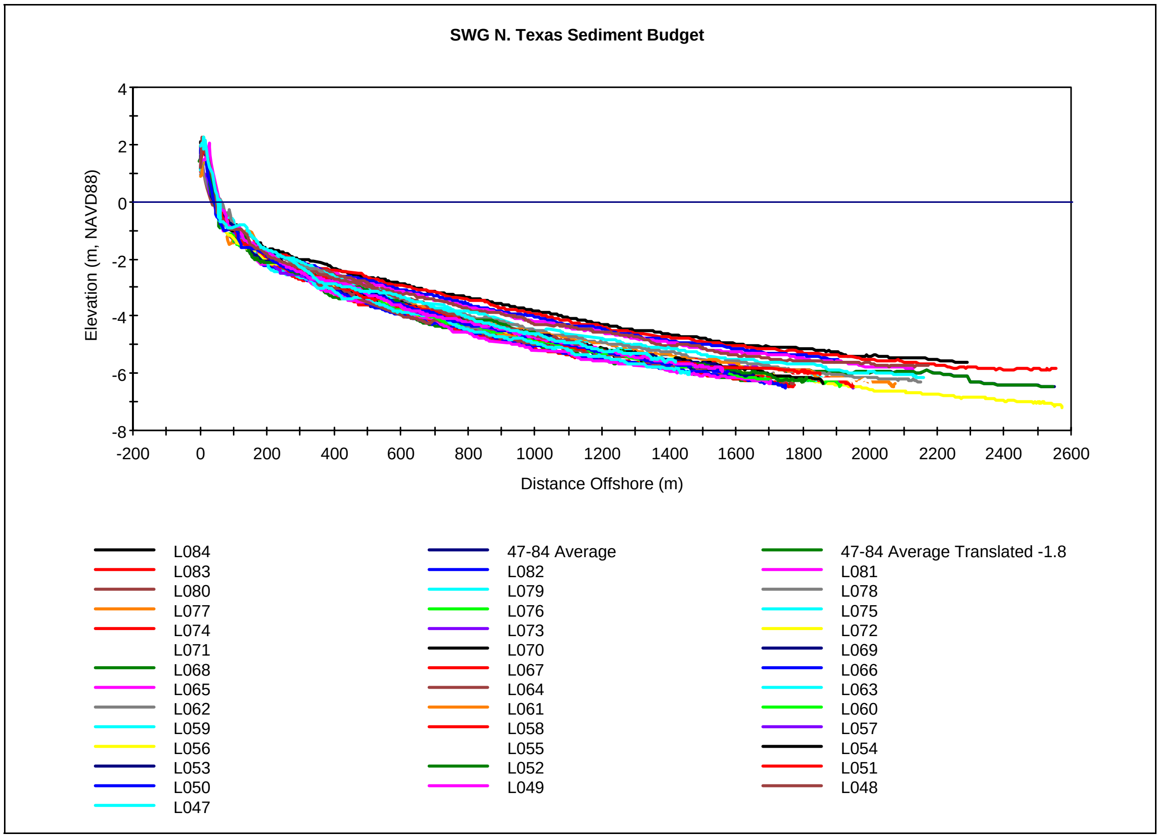

Figure 4. Profiles from cell 4 (High Island to McFadden Wildlife Refuge area).

Project maps

The Galveston District supplied 1992 project maps for the Federal navigation projects at Sabine Pass and Galveston Harbor in the form of MicroStation computer-aided-design (CAD) files (Figures 6 and 7). The geographic coordinate system of these files was State Plane, Texas South Zone, NAD27. The CAD files were imported into the master GIS project and were converted to UTM Zone 15 coordinates, NAD83. This allowed navigation features to be superimposed with other data and aerial photographs. The project maps identified the USACE station numbering along the channels and outlined areas of offshore disposal.

Plotting the locations of 1950s and 1960s sediment samples proved to be more difficult because full-size charts showing channel stationing from that era were no longer available. However, some charts had been reproduced onto microfiche. A 1955 chart on microfiche was mosaiced to rebuild charts of the inner bar and outer bar channels. The charts were orthorectified using fixed features such as jetty tips and survey monuments. With the 1955 chart imported into ArcGIS software, it was possible to plot the older sediment locations in their correct state plane coordinates.

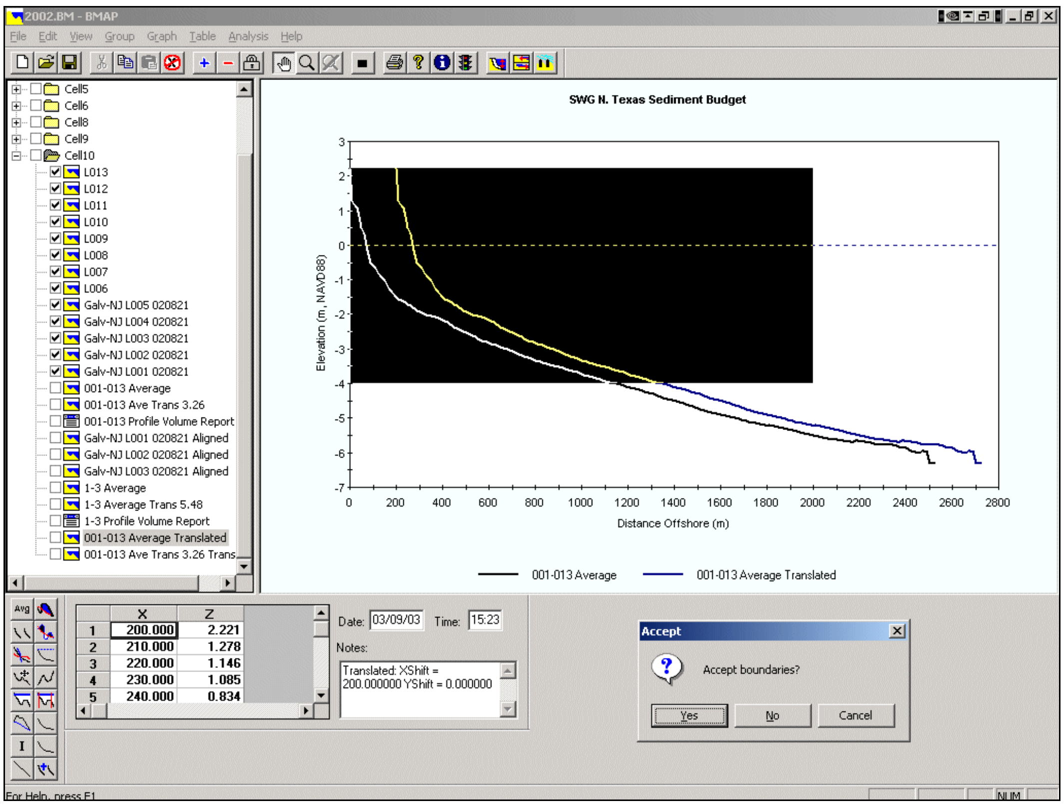

Figure 5. Example of procedure to compute area under curve for two profiles using BMAP software. These are average profiles for a specific cell, and one profile has been translated an amount equal to average shoreline change (retreat or advance) for that cell.

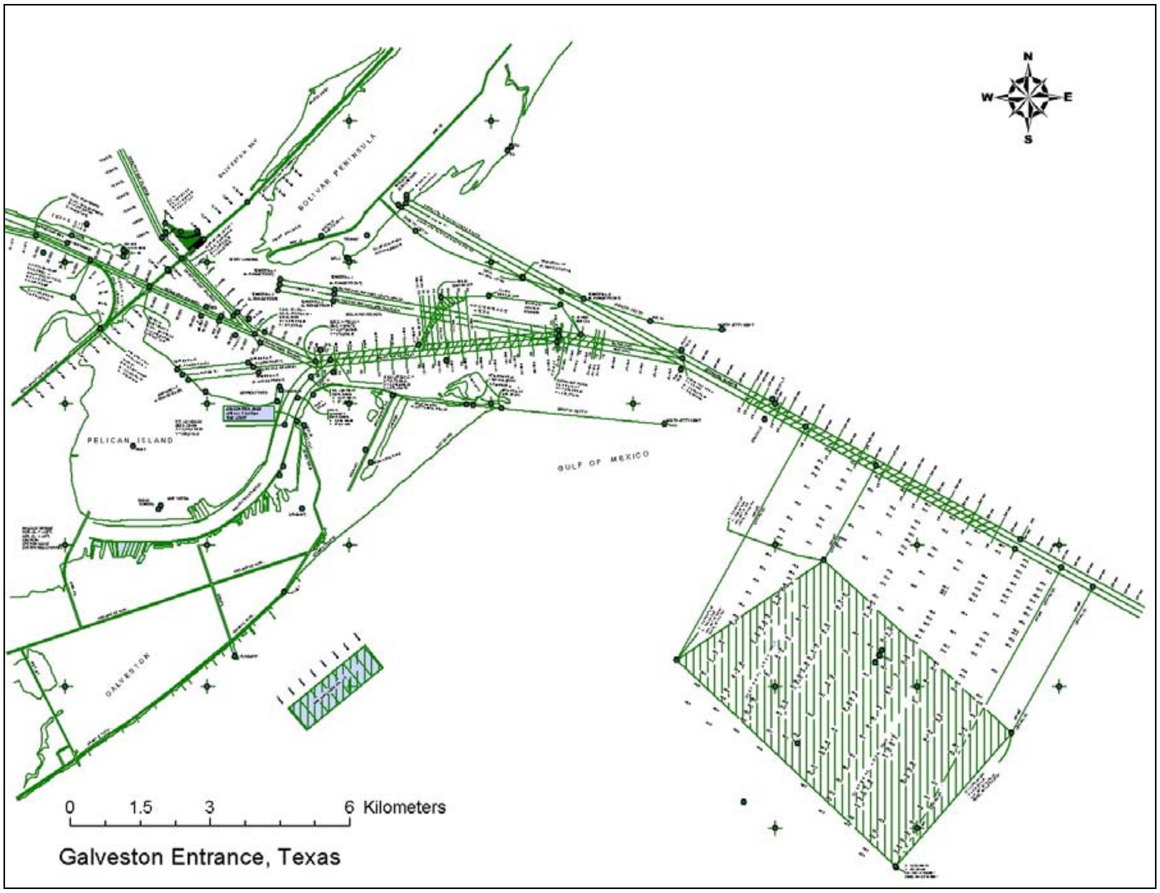

Figure 6. 1992 Federal navigation project features at Galveston entrance and Bolivar Roads. Annotations showing channel stations and coordinates are barely visible at this scale but are fully readable at higher magnification in ArcGIS.

Figure 7. Project features for Sabine waterway. Sabine Lake and inland channels are north of this figure. The polygons show offshore disposal sites. The street grid at top of figure is Port Arthur.

Dredge statistics

The Galveston District maintains a database of dredging that can be searched for information by project location, date, and contract number.

The database uses station numbering to indicate channel dredging locations for a particular contract. To better visualize the details, polygons were plotted around the section of channel listed for each contract and saved as shape files in the ArcGIS software (Figure 8). The shape files were superimposed to determine which channel section regularly needed maintenance. The Galveston-Bolivar Roads area was divided into four dredging regions (volumes listed in Table A1):

- Bolivar Roads channel.
- Galveston entrance channel (Figure 9).
- Galveston anchorage area (Figure 10).
- Inner and outer bar channels (within jetties and into back bay; Figure 11).

Dredging locations in the Houston Ship or Texas City Channels and other areas in Galveston Bay that were not influenced by sediments from the open coast were not plotted.

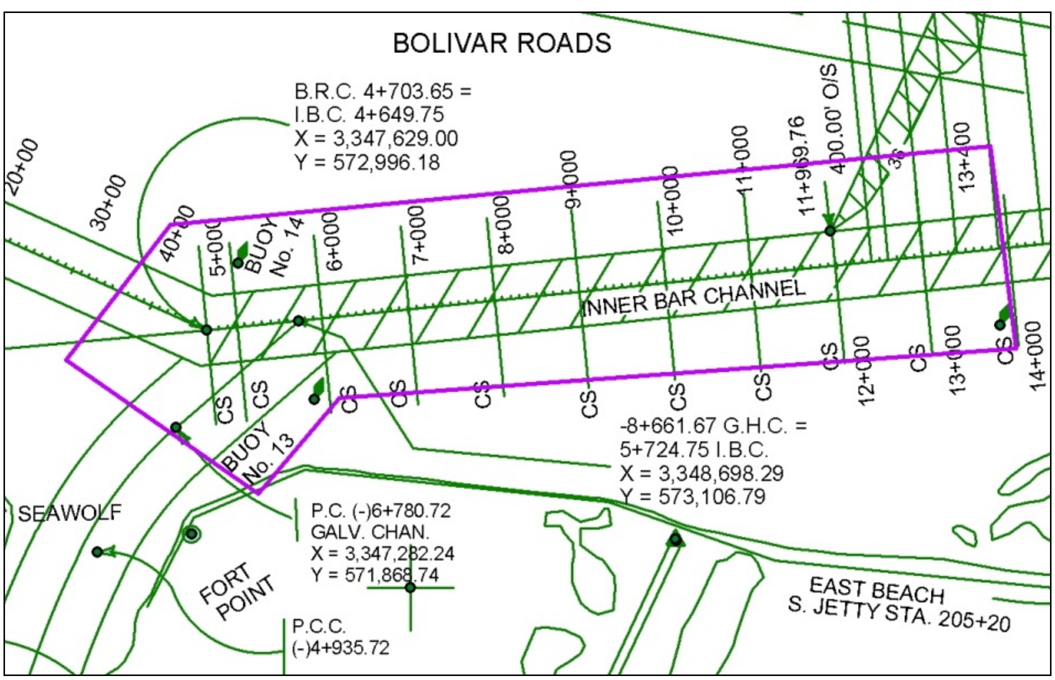

Figure 8. Example of polygon outlining a channel section dredged during a particular contract. The project annotations (stationing, coordinates, etc.) are from Galveston District CAD files.

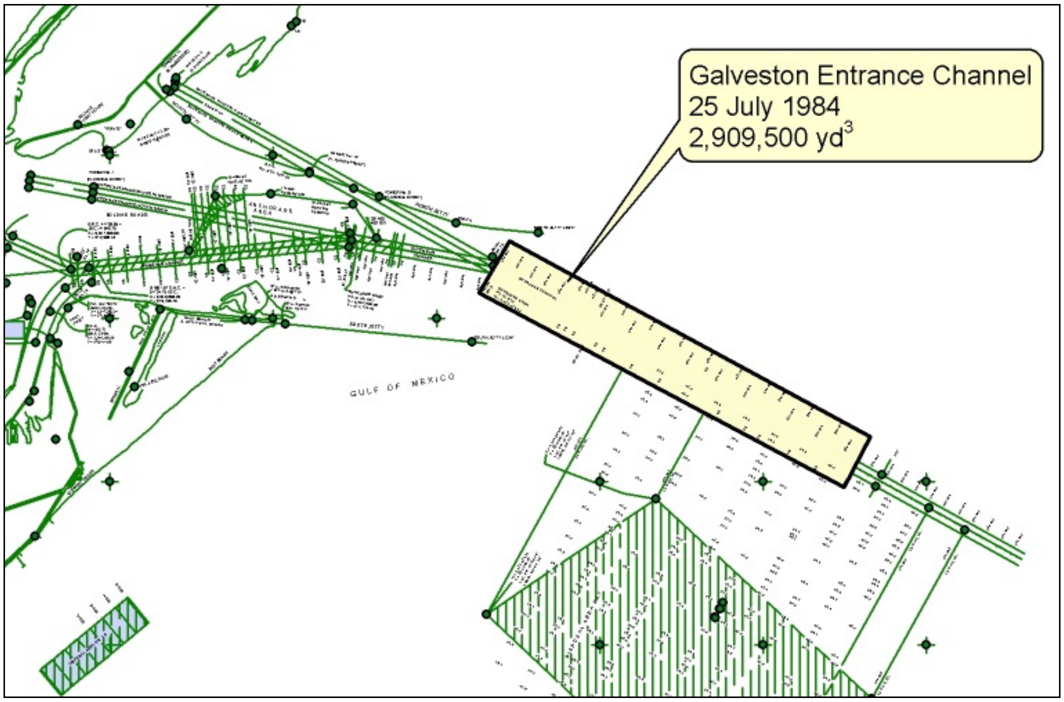

Figure 9. Galveston entrance channel. North is to top.

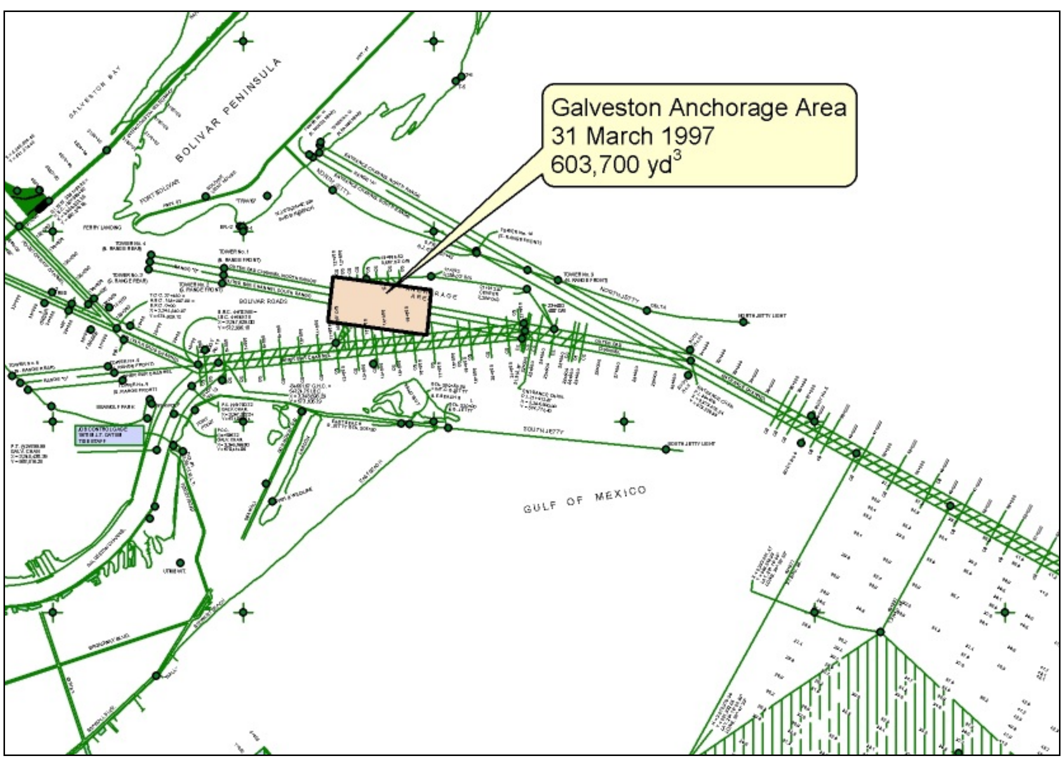

Figure 10. Galveston anchorage area.

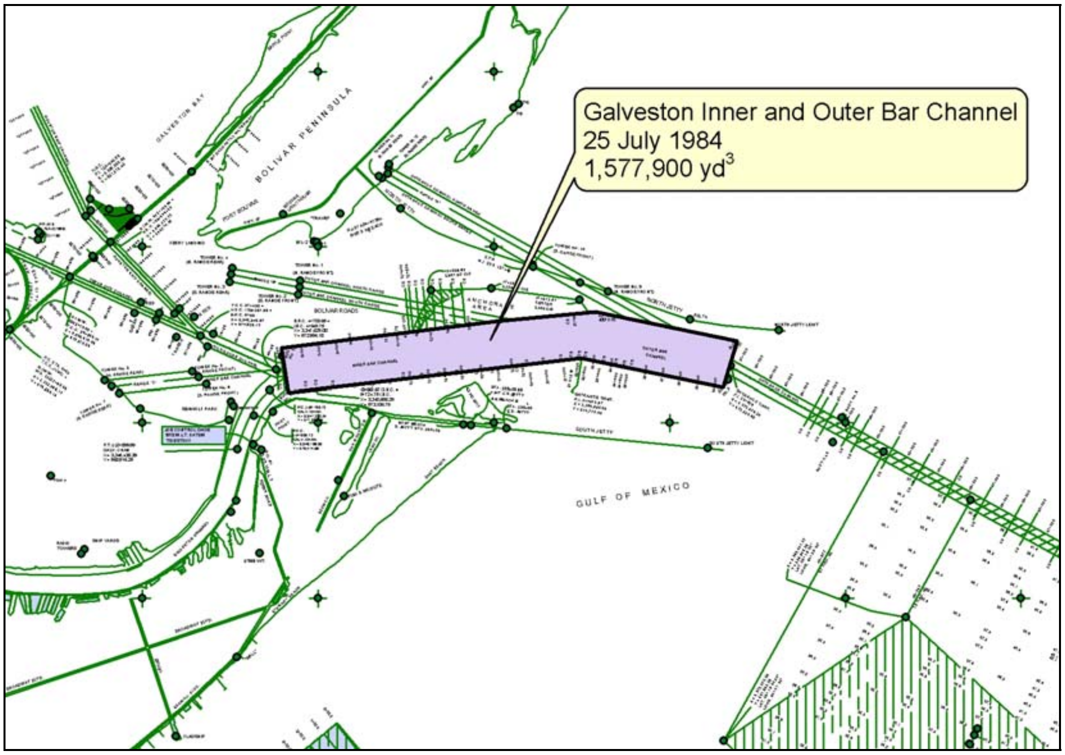

Figure 11. Galveston inner and outer bar channel. Big Reef is the sand body that projects into channel between the jetty and navigation channel.

The Sabine-Neches Waterway includes four dredging regions at or near the Gulf coast:

- Sabine Bank channel (Figure 12).
- Outer bar channel (Figure 13).
- Entrance jetty channel (Figure 14).
- Pass channel (Figure 15).

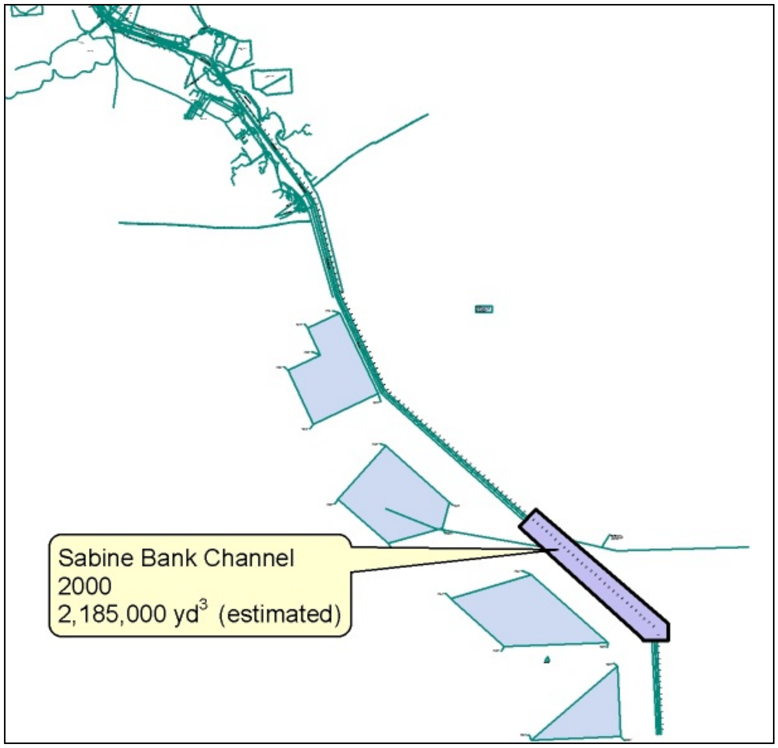

Figure 12. Sabine Bank channel. North is to top.

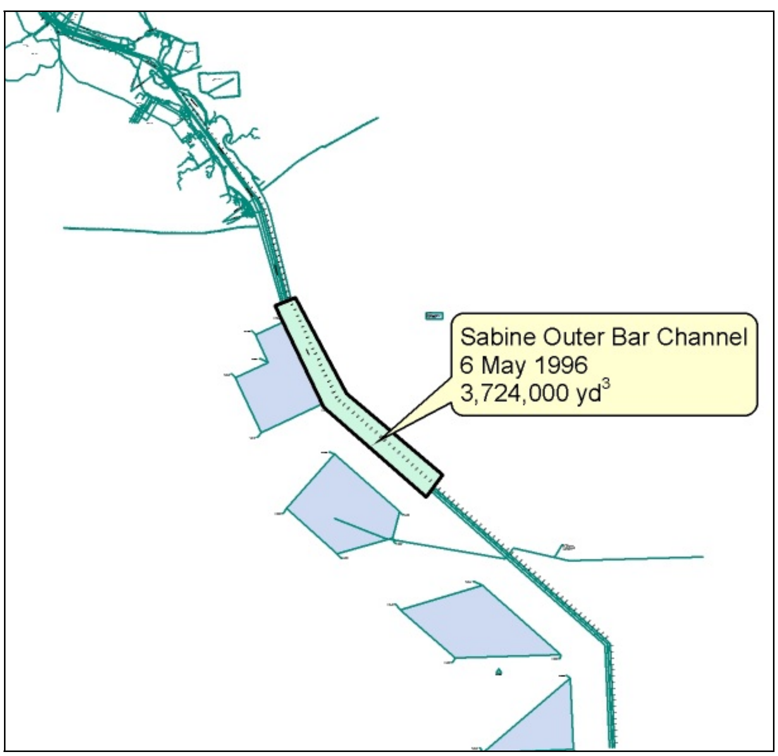

Figure 13. Sabine outer bar channel (seaward of jetties).

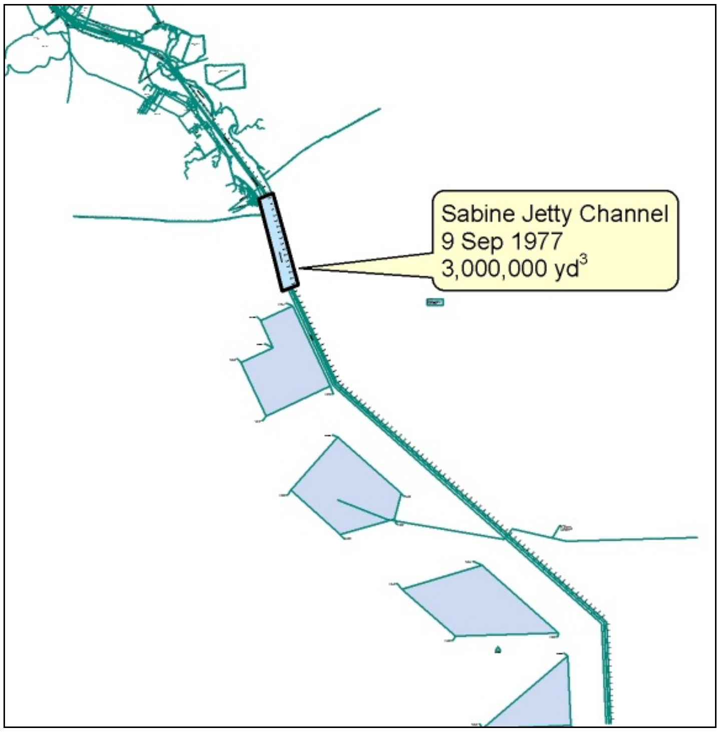

Figure 14. Sabine jetty channel.

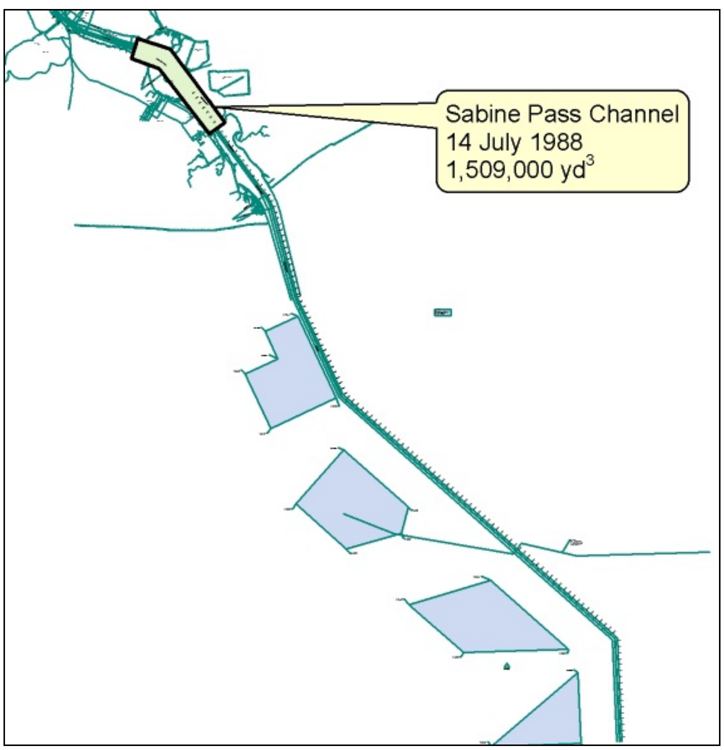

Figure 15 Sabine Pass channel. Dredged material, which is mostly fine-grain clay and silt, is disposed on land.

Sediment grain size statistics

The Galveston District collected sediment samples in select locations of dredged channels and disposal areas. Samples from the 1990s to the present have been analyzed (percent sand, silt, and clay) and the statistics listed in the Galveston District dredging database. Plotting the sample locations in the GIS project provided a convenient way to visualize the types of materials in different portions of the channels. Figures 16 and 17 show sand percentages in Sabine and Galveston waterways. The 1950s to 1980s samples consisted of cumulative grain size curves. For these, it was necessary to interpret the percentages of gravel, sand, silt, and clay.

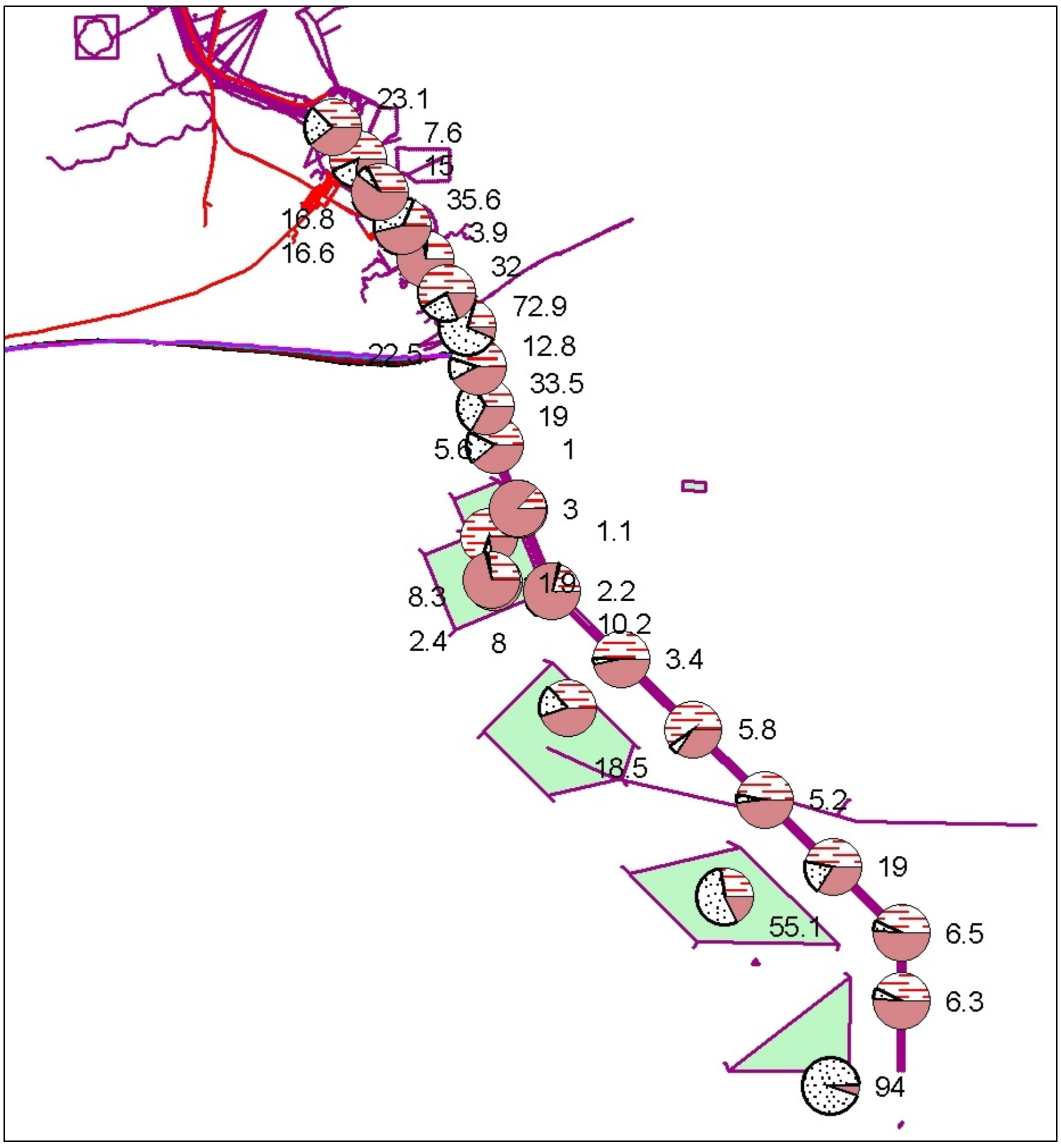

Figure 16. Sand percentage of samples collected in Sabine waterway. Note low proportion of sand in system, demonstrating that this is largely a muddy/silty environment. The two southernmost samples are on Sabine Bank, a relict sandy shoal. Numbers = sand percentage. Dotted pattern = sand; striped pattern = silt; solid = clay.

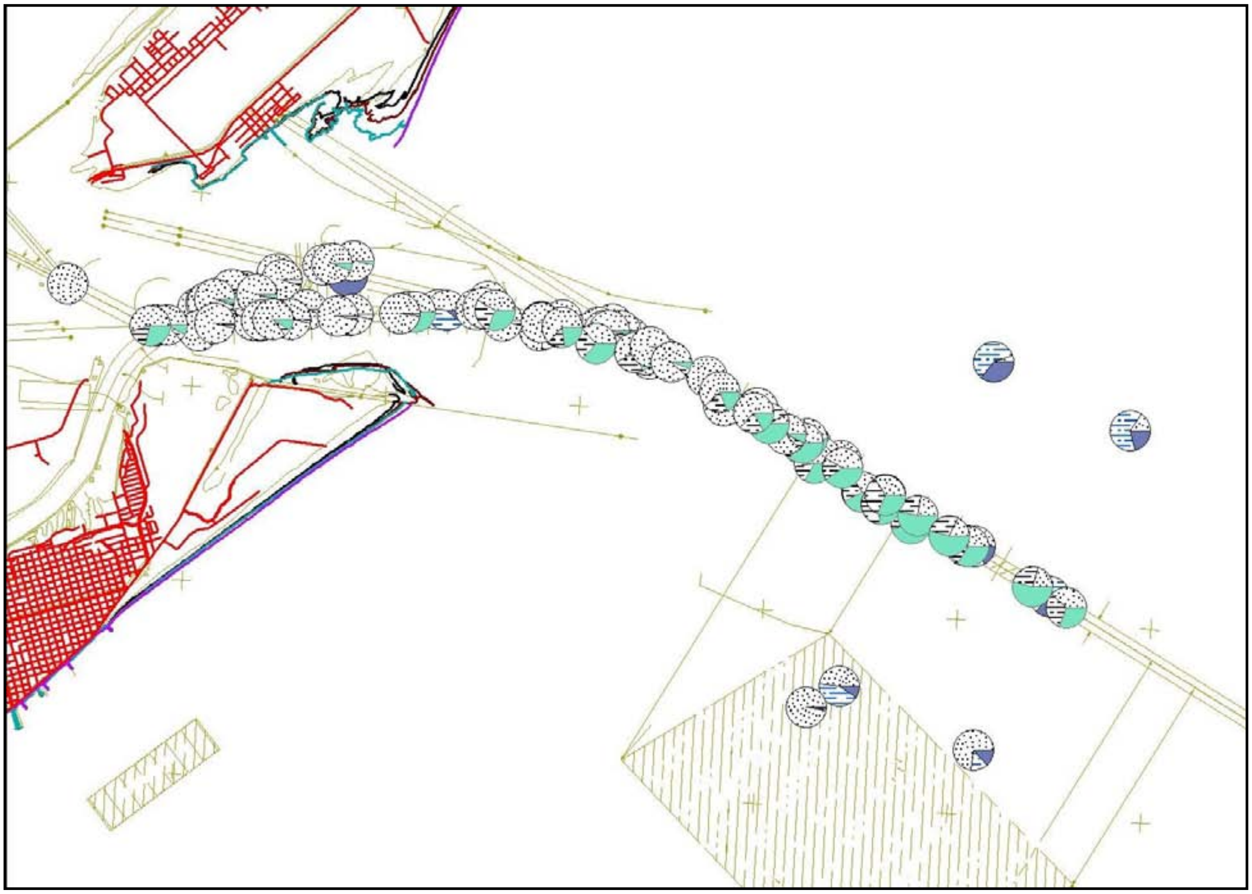

Figure 17. 1950s to 1990s sediment samples in Galveston channels. Dotted pattern = sand; striped pattern = silt; solid = clay. Samples between jetties and in inner bar channel consist of mostly sand (north is to the top.

Historical cross-shore profiles

Between 1964 and 1980, the Galveston District annually collected cross-shore profiles at many Texas inlets. Every year, a report was produced which contained 11×17-in. plots of the profiles, along with descriptions of the jetties and limited geographic coordinate data[1] (Figure 18). The original velum or Mylar sheets from which the report plates were reproduced have disappeared. Therefore, the profiles were digitized from the paper plates at the Galveston District. The X-Y-Z data were converted from state plane coordinates into UTM Zone 15 and imported into the master GIS project.

Deciphering the vertical control of the historical profiles was a challenge. The sheets listed "Sea Level Datum" as the vertical datum, but no written

[1] Texas Coast Inlet Studies, Beach Profiles, Jetty Condition Survey and Mid-Point Surveys, Department of the Army, U.S. Army Corps of Engineers, Galveston, Texas. Authorship anonymous, issued annually from 1964 to 1980 with gaps, distribution unknown.

description can be found. After conversations with surveyors at the Galveston District and experiments with plotting the new and old profiles, the Galveston District concluded that Sea Level Datum was meant to be NGVD 1929[2]. In the Galveston area, NGVD 1929 is essentially equal to NAVD 1988, so no additional vertical adjustments were necessary.

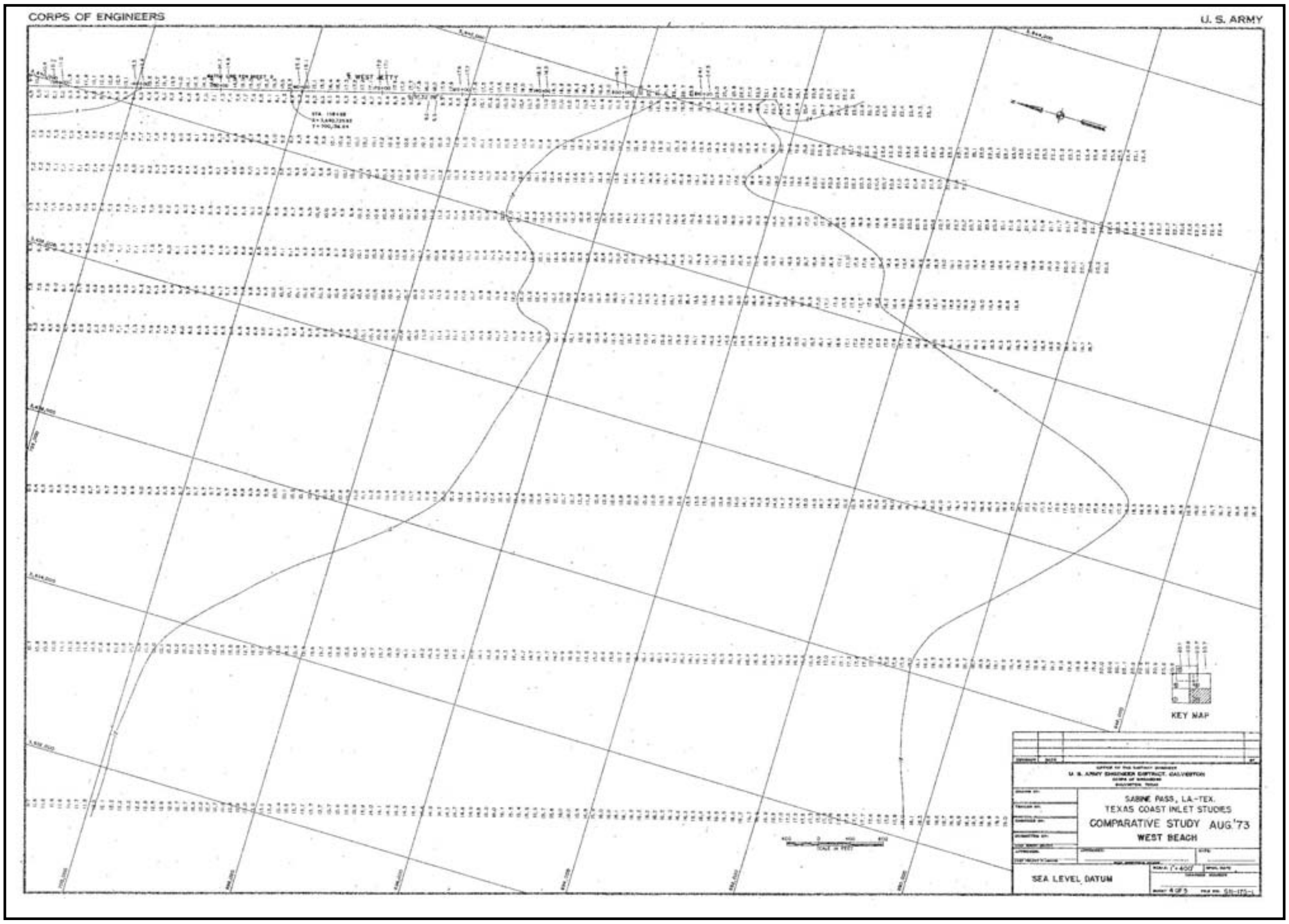

Figure 18. Example of Texas Coast Inlet Studies profiles from Sabine Pass west, 1973. These 11×17-in. sheets were digitized at Galveston District using MicroStation software.

The 1960s and 1970s profiles were closely clustered next to Sabine and Galveston Passes (Figure 19). Unfortunately, the Sabine profiles did not overlap with any of the 2002 profiles, and at Galveston, there was only limited overlap at East Beach and on the Bolivar Peninsula. However, when historical and modern profiles were plotted together, the resulting volume changes were unrealistically low at East Beach and too great along the Bolivar Peninsula (procedure illustrated in Figure 5). As a result, the historical profiles were not used in this study.

2 Personal communication, 21 August 2003, Mr. Arthur J. Martin, District survey coordinator, U.S. Army Engineer District, Galveston.

The historical data may have errors from a number of sources:

a. The reproduction from velum to 11x17 inch paper may have induced random error.
b. Digitizing the paper sheets induced error.
c. The original navigation may have been to reconnaissance (USACE Class 3) standards only.
d. The vertical datum control may be faulty.
e. The original data points may have been smoothed or adjusted.

Comparing the old surveys with each other should be valid, and possibly they may be used in conjunction with the modern profiles if some documentation on survey methods and processing can be found.

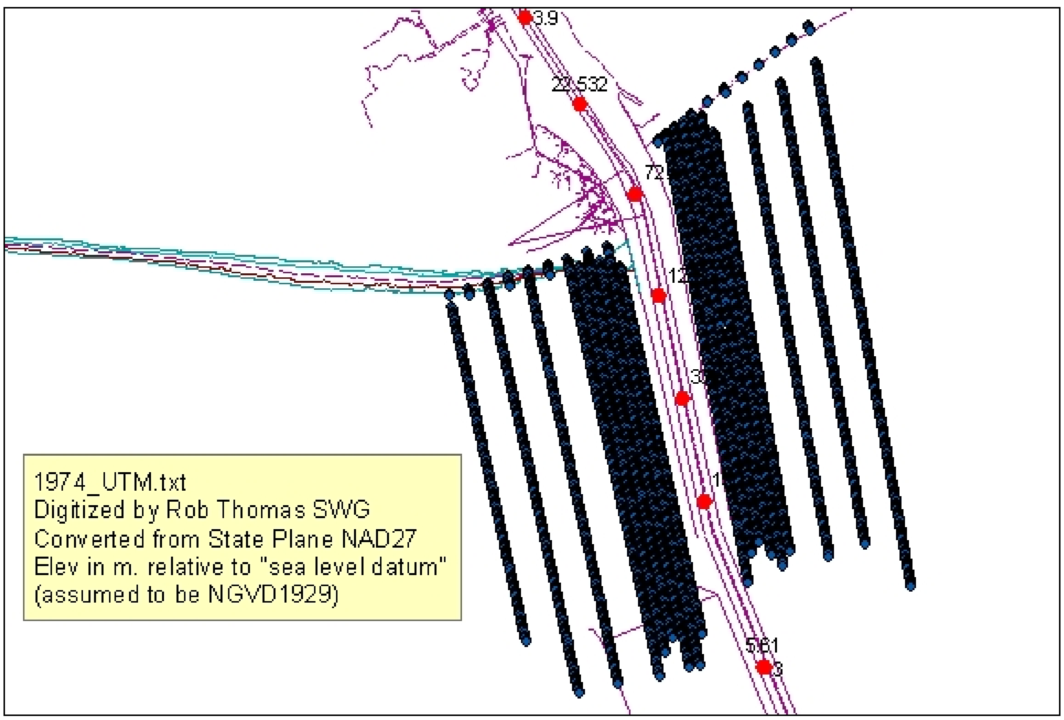

Figure 19. 1974 profiles at Sabine Pass. Data digitized from Texas Coast Inlet Studies 11x17-in. plates. In Sabine area, historical profiles did not overlap with 2002 profiles. Markers in channel indicate sediment samples.

5 Sediment Budget Cells

Cell selection

Sediment budget cells are based on the following criteria:

a. Prominent engineering features (Sabine jetties, Galveston jetties).
b. Geomorphic features (passes).
c. Dredging regions.
d. Shoreline change statistics. Locations where a section of the coast changed from shore advance to retreat defined the boundary of a cell.

Figure 20 shows 23 cells in the overall study area. The following paragraphs describe each cell and list assumptions and observations. Table B1 lists the inputs and outputs (the terms in Equation 1) for each cell in units of 1000 cu m/year. Table B2 lists the east and west coordinates of each coastal cell and the average shoreline change value used to compute the beach volume change (ΔV).

Sabine 1, Pass Channel

This cell includes the Sabine Pass channel located landward (north) of the entrance jetties (Figure 21). Annual dredging is approximately 450,000 cu m/year. This material is placed on land in a confined disposal facility (CDF) and is no longer available to the littoral system. Total bed load is approximately 660,000 cu m/year, based on the quantity removed by dredging and the computed balance with the next cell to seaward.

Assumption 1: Little sand reaches the open coast from the Sabine and Neches Rivers because Sabine Lake is an efficient sediment trap and most coarse material from the Sabine River is deposited in the lake (Mason 1981; USACE 1971). Recent studies have verified that most of the river sediment, in particular the bed load, is trapped in the lower alluvial reaches of the river[3]. But, samples from the Entrance Channel do contain sand, and there are no obvious local sources because the banks of the channel are low mudflats. Because the dredged material is removed from the system, some mechanism must be replenishing sand. Sand may be

[3] Personal communication, 21 August 2003, Dr. Jonathan Phillips, Professor, Department of Geography, University of Kentucky.

delivered to this portion of the channel during periods of unusually high runoff.

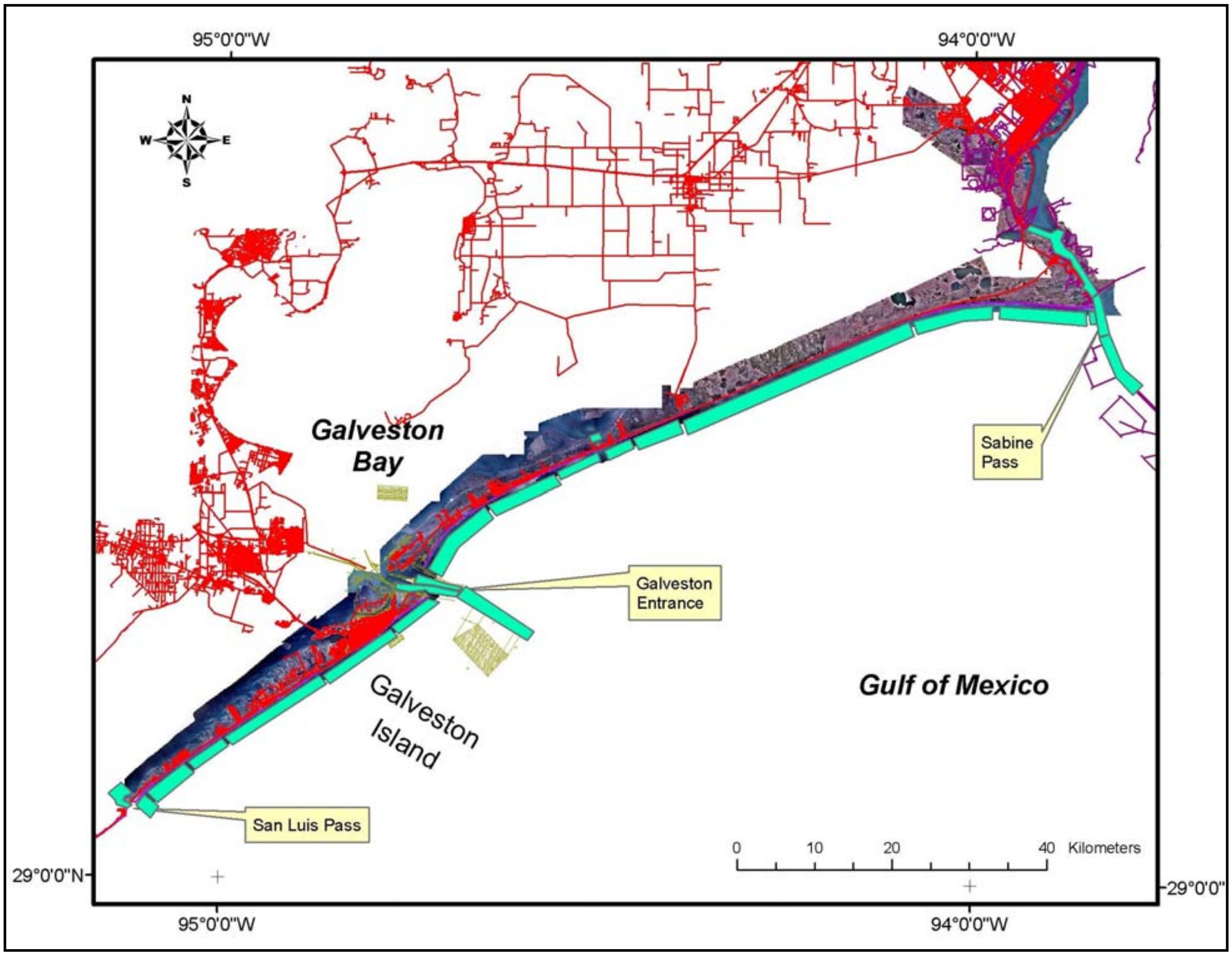

Figure 20. Sediment budget cells, Sabine Pass to San Luis Pass.

Assumption 2: Negligible material from the littoral system enters the channel and moves upstream.

Observations: Clearly some, possibly much, fine-grain material exits the pass because plumes of muddy water can be seen in satellite images. However, this material disperses over the continental shelf and does not contribute to the littoral budget. The percentage of the total transport that is suspended material is not known.

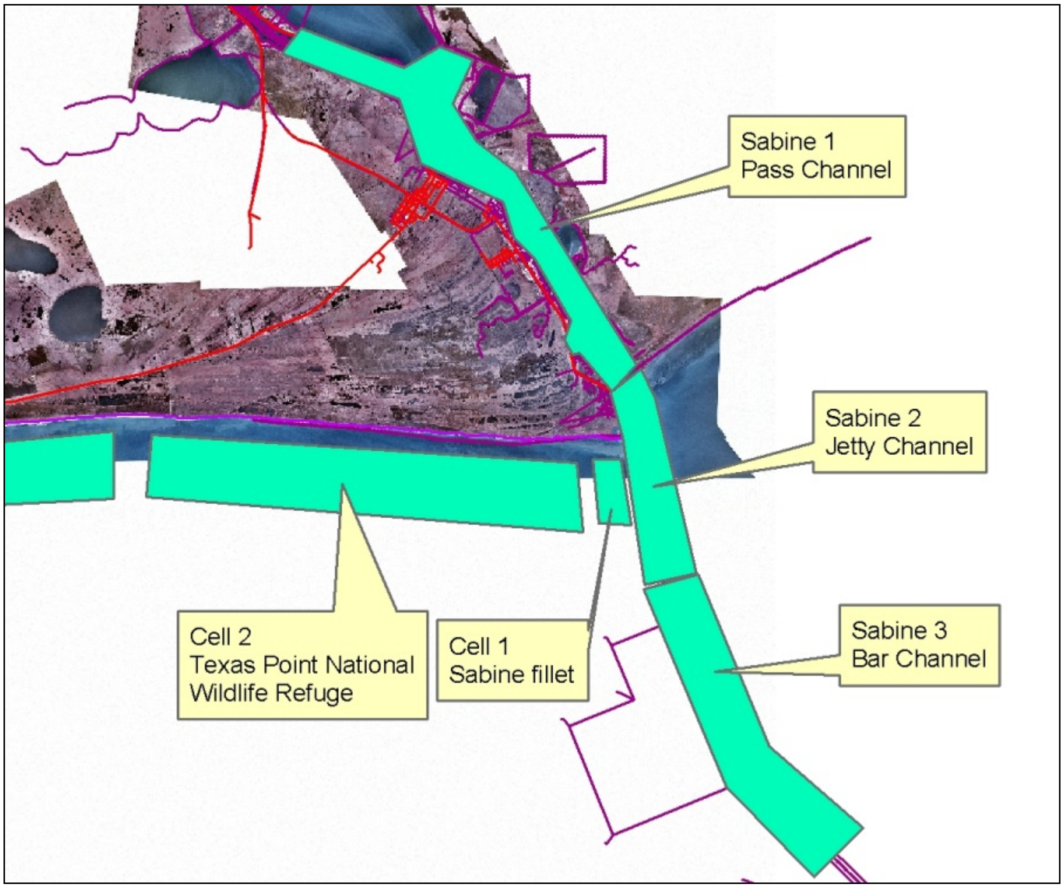

Figure 21. Sabine 1, 2, and 3 and coastal cells 1 and 2.

Sabine 2, Jetty Channel

This cell consists of the portion of the channel that extends from the east shoreline intersect (the Louisiana side) to the seaward mouth of the jetties. Dredging averages 220,000 cu m/year but is only needed on an irregular basis. The channel appears to be self-scouring for years at a time.

Assumption 1: Sedimentation in the jetty channel is the result of a combination of silt and some sand delivered by the Sabine Channel along with a minor contribution from the littoral system. Although most of the coast west of the jetties is eroding, the narrow cell immediately to the west (cell 1, Figure 21) has accreted since 1974, indicating some eastward transport.

Assumption 2: No material enters the channel from the east (Louisiana) side, where there is no evidence of a fillet against the east jetty.

Observations: During high runoff episodes, it is possible that significant amounts of mud and silt are transported down the channel. But, because of the jetting action caused by the jetties, little of this material should settle in the jetty channel. Therefore, a riverine flux greater than that estimated for the Sabine 1 cell should not materially change the budget of this cell.

Sabine 3, Bar Channel

The bar channel cell extends from the mouth of the jetties to beyond the first bend in the navigation channel (Figure 21). Based on the balance of material entering Sabine 2 versus what is removed by dredging, it appears that little material moves from Sabine 2 into Sabine 3. Annual dredging is in the range of 1,400,000 cu m/year.

Assumption: Material dredged from Sabine Outer Bar and Sabine Bank channels does not come from the littoral system. The offshore disposal areas are immediately southwest of the outer bar channel. With the predominant wave direction being from the south and southeast, the most logical scenario is that sand and silt placed in the disposal areas rapidly migrates back into the channel[4].

Cell 1, Sabine Fillet

This cell consists of the fillet west of the Sabine west jetty (east of profile transect 879). Much of the low, muddy coast west of the jetties is severely eroding, but the shoreline data show that a small fillet has formed against the jetty. This material is silt and mud.[5] Sediment accumulation in the fillet ($\Delta V \approx$ 8,000 cu m/year) was based on translating the measured profiles seaward equivalent to the average annual shoreline advance. Q_{LST} (longshore transport) is minimal, about 11,000 cu m/year.

Assumption 1: Net littoral transport is west to east. Although most references state that littoral transport on the north Texas coast is east to west, the small fillet against the jetty lends morphological evidence of occasional eastward transport in this region.

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[4] Material placed in the disposal areas does not form permanent mounds. Soon after dredging ends, the seabed becomes flat again, indicating rapid dispersal of the material (Personal communication, August 2003, Mr. James M. Kieslich, Chief, Operations Division, U.S. Army Engineer District, Galveston).

[5] Personal communication, 14 November 2003, Dr. Billy Edge, Professor, Civil Engineering Department, Texas A&M University.

Assumption 2: The accumulated volume was based on an active depth of -1.8 m (-6 ft).[6]

Cell 2, Texas Point National Wildlife Refuge

This area has suffered steady erosion over the last 40 years, with shoreline retreat of up to 350 m between 1974 and 2000. The shore is flat, with a muddy substrate covered by a thin, discontinuous sand veneer (Figure 22). The annual volume change is -332,000 cu m/year.

Assumption 1: The active depth used to compute the eroded shore wedge = -2 m. Varying this elevation has a major effect of the volume of sediment removed from the shoreface (see Figure 5 for the method used to compute the volume). Additional profiles over time can help refine this depth.

Assumption 2: The bulk of the eroded material is fine-grained (mud and silt), but there may be a minor proportion of sand. A veneer of sand appears to move back and forth across the shoreface, but there must be a local source to replenish the sand or littoral transport to the west removes it from the area.

Assumption 3: Forty percent of the eroded material is lost offshore, 35 percent is lost to overwash, 20 percent moves west to cell 3, and the remaining 5 percent moves east to cell 1. The 20 and 5 percent values were based on the need to balance the adjoining cells, while the overwash proportion was based on the opinion of an experienced field observer.[7]

[6] Personal communication, 14 November. 2003, Dr. Billy Edge, Professor, Civil Engineering Department, Texas A&M University.

Figure 22. Cell 2, Texas Point National Wildlife Refuge, west of Sabine channel. The muddy shore is partly covered with a thin veneer of sand (photo courtesy of Dr. Billy Edge, Texas A&M University).

Cell 3, Sea Rim State Park

In contrast to cell 2, this cell covers an accreting section of the coast, with ΔV = 90,000 cu m/year (Figure 23). The beach consists of sand and shell fragments, probably underlain by mud. Sediment samples from the profile lines have a D_{50} of 0.1 to 0.14 mm.

Assumption 1: This cell is a convergence zone with littoral material coming from the west and east.

Assumption 2: The active depth used to compute the accreted volume = -2 m.

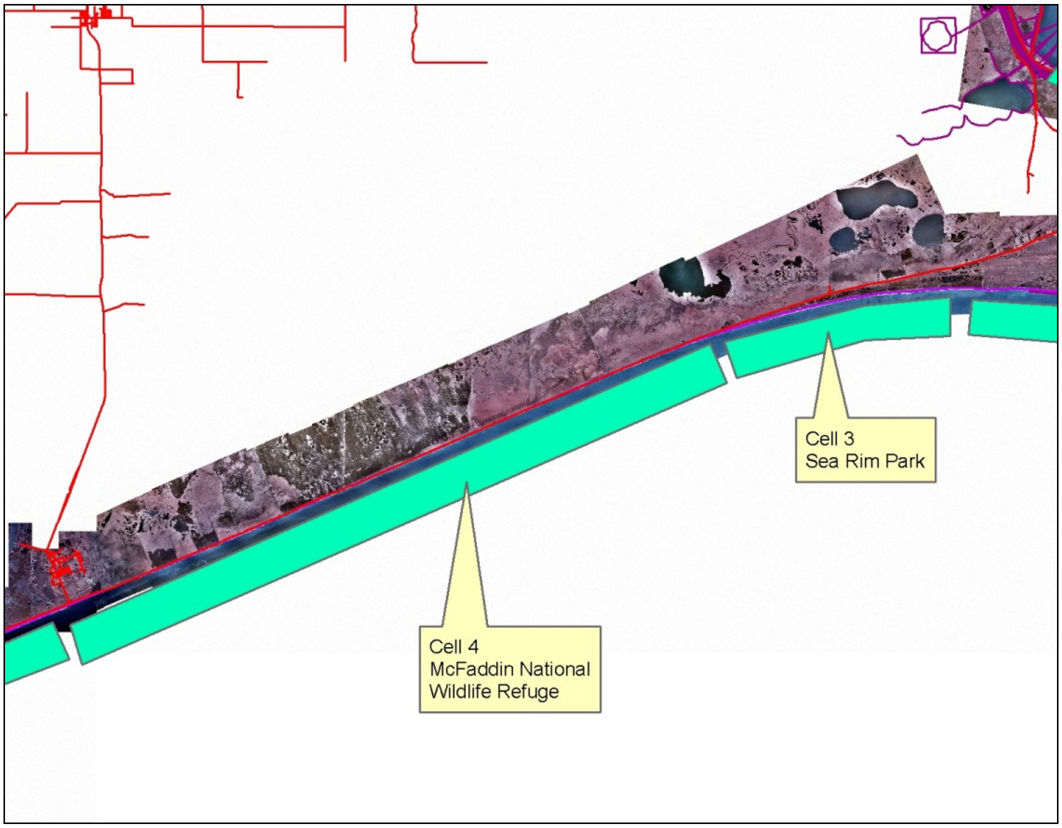

Figure 23. Cells 3 and 4, along north Texas shore between High Island and Sea Rim State Park.

Cell 4, McFaddin National Wildlife Refuge

At 32 km, this is the longest cell in the study area (Figure 23). The west end of the cell is at the High Island highway junction, while the east end is about 1.6 km west of the border of Sea Rim State Park. The terrain is low and flat, consisting of coastal plain and marsh. The McFaddin National Wildlife Refuge (NWR) occupies much of this cell. Access to this part of the coast is difficult because a long stretch of State Highway 87, which formerly ran from High Island to Sea Rim State Park, has been closed since 1989. Much of the roadbed has been destroyed by erosion, and because of the refuge, there is no room to relocate the road farther landward (Figures 24 and 25). Shore erosion has averaged about 260,000 cu m/year.

The east end of the cell is mostly cohesive, but the shoreface becomes sandier to the west. The amount of sand in the environment is not known. At times, the above-water beach is completely sand-covered (Figure 24), while at other times, broad expanses of mud are exposed. Most field workers believe that the sand consists of thin sheets or patches that move back and forth over the shoreface. However, some sand must be lost to overwash during storms and, therefore, there must be some source of replenishment. Possibly there are offshore sand deposits or sand may be winnowed from the Pleistocene mud banks.

Assumption 1: About 40 percent of the eroded material is lost to overwash, 40 percent is lost offshore, and littoral transport moves 10 percent to east and to west. According to King's (in preparation) modeling work, this cell is a divergence zone.

Assumption 2: Active depth used to compute the eroded shore wedge = -3 m. Note that a different depth would greatly affect the amount of material lost from erosion.

Figure 24. Broken pavements, remnants of State Highway 87, near west end of McFaddin NWR. Day this image was taken, beach was completely covered with sand, shell hash, and gravel (19 February 2003).

Figure 25. Mud outcrops on shoreface at McFaddin NWR. At times, entire beach is exposed mud, but on this day (19 February 2003), shore was largely sand-covered. Blocks are destroyed roadbed.

Cell 5

This cell covers a stable section of the coast west of High Island (Figure 26). The 25-year shoreline change statistics indicate that the shore has neither retreated nor advanced to a significant degree. As a result, $\Delta V = 0$.

Assumption. The amount of littoral material moving through the west end of this cell equals the quantity entering the east boundary.

Cell 6, Rollover East

This cell consists a 4,300-m section of eroding beach northeast of Rollover Pass (Figure 26). Some of the dunes have recently been protected with sand-filled fabric tubes and other materials (Figure 27). The beaches on both sides of Rollover Pass have eroded over the last 40-50 years after the pass disrupted littoral transport. The amount of sand that moves into Galveston Bay is controversial, and the reported volumes vary widely (King in preparation). This budget used the quantity computed by Parchure et al. (2000), who examined dredging records and determined the excess siltation in the Intracoastal Waterway adjacent to the pass compared to siltation in areas further away. They computed that the excess siltation was 11,800 cu m/year.

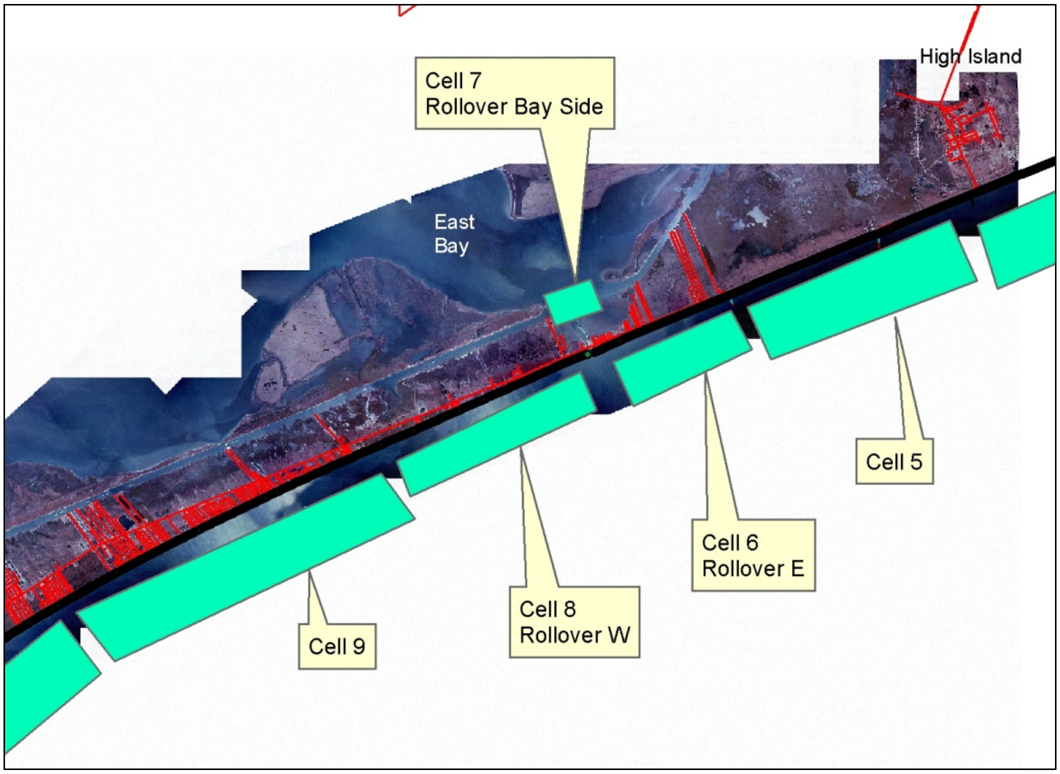

Figure 26. Cells 5-9, near Rollover Pass.

Figure 27. Dune protection north of Rollover Pass (19 February 2003). These interlocking concrete units have been placed over sand-filled fabric tube.

Assumption 1. An equal amount of material enters Rollover Pass from the cells east and west of the opening. Littoral material lost from each cell is approximately 5,900 cu m/year.

Assumption 2. Beach placement data are incomplete. One placement of 104,000 cu yd was reported for 2003, possibly preceded by a 2000 nourishment. This quantity was divided by 3 to obtain an estimate of 26,500 cu m/year.

Cell 7, Rollover Pass Bay Side

This cell covers the Galveston Bay side of Rollover Pass and the Intracoastal Waterway from Sections 2166 to 2136. Dredging averages 48,000 cu m/year. If littoral input is 11,800 cu m/year, as computed by Parchure et al. (2000), then the normal siltation from bay sources is 36,000 cu m/year. The total sand entering the pass may be greater because some is probably deposited in the nondredged areas of the bay. However, because the Intracoastal is much deeper than the surrounding bay floor, it is likely to be a sink for a majority of the incoming sand.

Cell 8, Rollover West

This cell covers a 6,300-m section of eroding beach southwest of Rollover Pass. Along much of this cell, the dunes have been protected with sand-filled fabric tubes. Beach nourishment between 1997 and 2002 averaged about 85,500 cu m/year (Figure 28). Some of the fill was pumped from the Intracoastal Waterway, but the records are incomplete. ΔV = -32,500 cu m/year, based on translating 2002 profiles -0.8 m. Considering the littoral input from cell 6, beach erosion, and placements, longshore transport to the south is about 186,000 cu m/year.

Assumption 1. Because of the sandy environment, the active depth used to compute the lost volume wedge is -4 m.

Assumption 2. Approximately 5,900 cu m/year of littoral material is transported out of this cell and into Rollover Pass (the same as cell 6).

Figure 28. Sand-filled fabric tubes protecting dunes and homes west of Rollover Pass (19 February 2003).

Cell 9

This section of the shore has been more stable than the zone just west of Rollover Pass, with ΔV = 14,500 cu m/year for this cell, based on an average shore advance of 0.22 m/year. Sand may have been placed on the beach near some of the cottages, but records are incomplete. Most of the littoral material entering the northeast side of the cell is transported out the southwest end ($Q_{LST} \approx$ 172,000 cu m/year).

Cell 10, Galveston North Fillet

Cell 10 is the last cell north of the Galveston north jetty[8]. This cell, the ones in the channel, and cell 13 (East Beach) are interconnected with a complex pattern of sediment exchange (Figure 29).

The area north of the north jetty has accumulated a significant quantity of sand since the jetties were built in the 1880s. Even since 1974, the beach has advanced, indicating that sand input exceeds sand losses through the

[8] In this area, the shoreline orientation changes to northeast-southwest. By local convention, Galveston's jetties are known as the north and south jetties rather than east and west.

porous jetty. Whether sand passes south through the jetty is not immediately obvious from the beach morphology. Just north of the jetty is a marshy, open water area rather than a traditional fillet built up against the structure. A comparison of 1952 and 2002 photographs shows that the open water area has existed for 50 years (Figures 30 and 31). Two reasons may account for the lack of infilling:

a. Wave energy in this area is low because of the shadow effect of the jetty. Therefore, littoral currents lose most of their load a few kilometers north of the jetty.

b. Sand moves through the porous jetty at a rate sufficient to prevent the accumulation of a fillet directly against the structure.

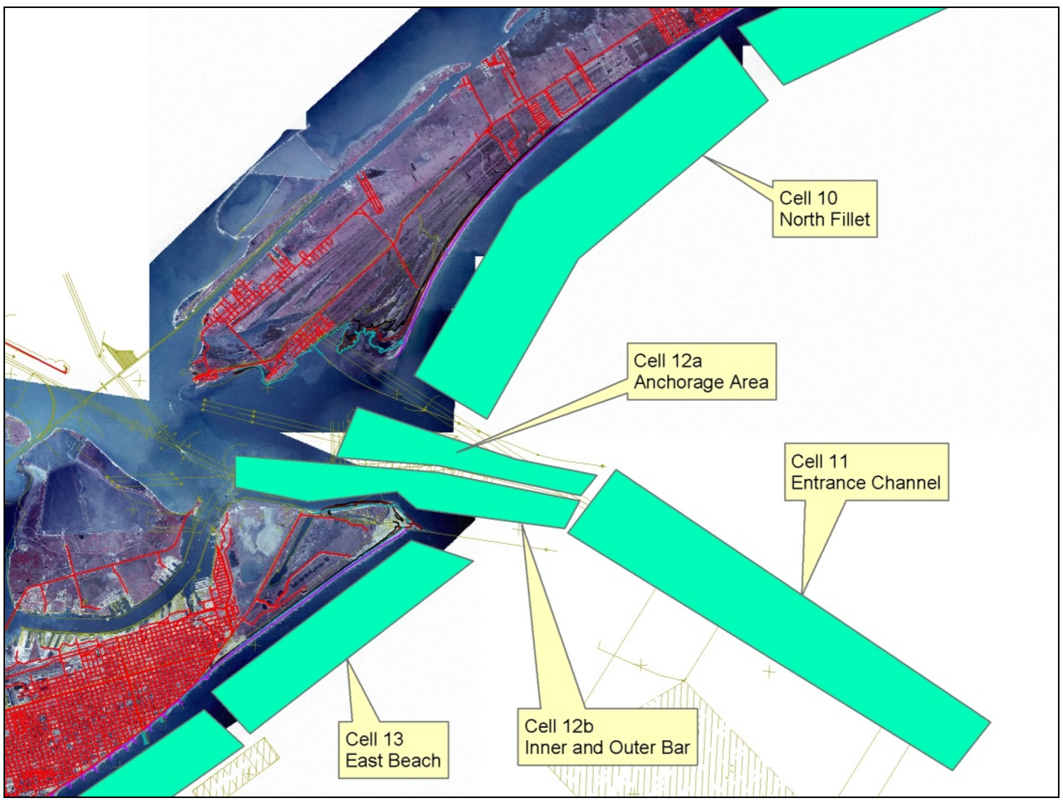

Figure 29. Galveston and Bolivar Roads cells. Cell 12a and 12b encompass inner and outer bar channels and anchorage area.

Figure 30. Bolivar Peninsula, January 1952. North jetty is in lower right, with open water on both sides of structure. North is to top (photograph from USACE Beach Erosion Board archives).

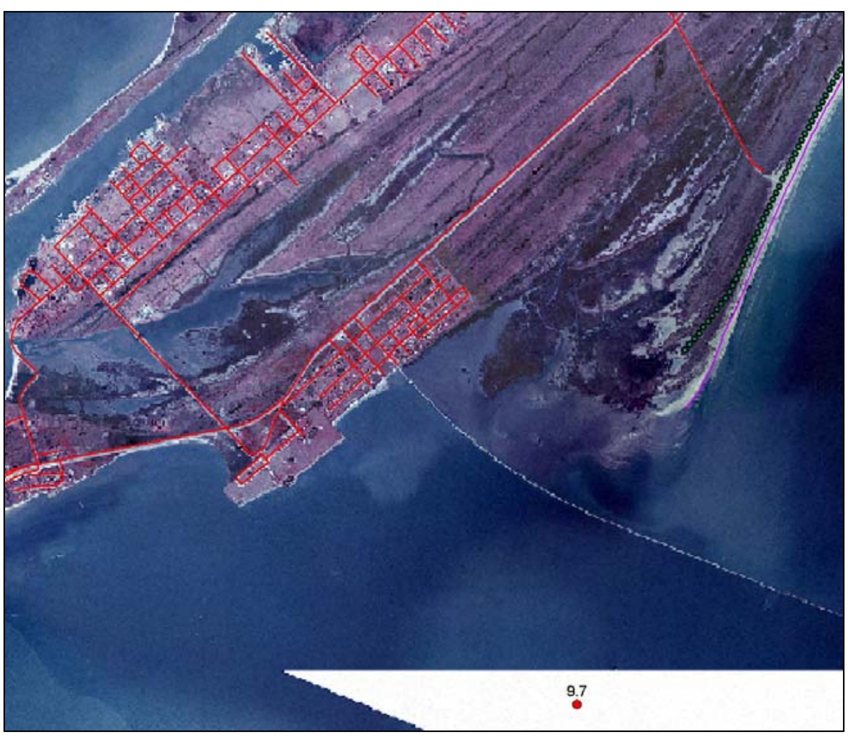

Figure 31. Bolivar Peninsula, January 2002. Despite growth of beach updrift of the jetty, there is still a marshy, open water area immediately north of structure. Boat cut cannot be seen in this image (photograph courtesy Texas Bureau of Economic Geology).

A study is underway at the Galveston District to examine the 1960s and 1970s cross-shore profiles to determine if the offshore topography shows evidence of southward sand movement. An opening was cut in the north jetty in 1964 to allow the passage of small boats. Historical profiles do show that the seafloor became deeper in a semicircle around the cut over the following years, indicating sand loss into the channel.[9] Whether sand passes through the jetty away from the cut is less clear. The 1960s radioactive tracer studies showed that following release of tracer material at 3- and 6-ft depths north of the jetty, samples were detected south of the structure. The authors concluded that some material may pass through the porous structure, but the movement patterns indicated that most passed through the small boat opening (Ingram et al. 1965).

Based on translating the 2002 profiles by 3.26 m/year, ΔV = 243,500 cu m/year. Some of the 1970s and the 2002 profiles did overlap, but a test to determine the shoreface volume change over the 30-year span produced an unrealistically large value. There appear to be errors with the horizontal positioning of the historical profiles or with their vertical datum, and until resolved, they cannot be compared directly with the contemporary profiles.

Assumption 1. Sand movement through the jetty into the Galveston anchorage area equals 156,000 cu m/year. This is based on the total volume dredged from the anchorage area (cell 12A) multiplied by the average sand percentage of 60 sediment samples from the inner and outer bar channels (88 percent).

Assumption 2. Onshore sand movement equals 227,000 cu m/year. This is the only way to balance the cell considering fillet growth, loss through the jetty, and littoral input.

Cell 11, Galveston Entrance Channel

This cell covers the portion of the channel from sta 31+000 seaward past the ends of the jetties. Average 1980-1997 dredging was 460,000 cu m/year.

Assumption. The majority of the material that fills the dredged channel comes from Galveston Bay. Some material may come from the ebb shoal

[9] Personal communication, 12 November 2003, Mr. Robert C. Thomas, U.S. Army Engineer District, Galveston.

during storms. Tests of radioactive tracers in the 1960s showed that material released near the outer end of the north jetty moved quickly around the north jetty and thence into the navigation channel (Ingram et al. 1965). Surveys using sidescan sonar might be able to resolve bedform patterns to determine whether the ebb shoal contributes material to the channel.

Cell 12a, Anchorage Area[10]

The anchorage area is north of the inner and outer bar channels. Dredging from 1988 to 1997 averaged 178,000 cu m/year.

Assumption 1. This cell is the source of half of the material that moves out to cell 11 (Entrance Channel) = 230,000 cu m/year.

*Assumption 2***.** Littoral input is 156,000 cu m/year. Based on five 1990s samples, the material removed from the anchorage area averaged 45 percent sand. However, 1950s samples from the former navigation channel contained 95 percent sand. Tidal action, dredging, and ship motion probably stir the sediments thoroughly on the harbor bottom between the jetties. Therefore, the sediment budget is based on the average sand percentage of over 60 samples, which equals 88 percent. It is possible that these samples, taken during dredging operations, might be biased towards coarser grain sizes. One reason is that the cutter head, as it moves across the bottom, stirs up the fines, which dissipate. Also, the overflow from the hopper carries away many fines. However, without some other geotechnical data, such as a sampling grid consisting of bottom grabs and box cores, the percentages must be used as provided from the 1950s to 1990s USACE dredge reports. For cell 12a, the only likely source of sand is littoral material passing through the north jetty. There is no likely sand source in Galveston Bay. Although some sand is carried down the Trinity River, it is deposited in a delta too far from the Galveston entrance to serve as a source (Phillips and Musselman 2003).

Assumption 3. To balance the cell, the remaining material that fills the anchorage area consists of silt and mud from Galveston Bay (approximately 250,000 cu m/year).

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[10] For the first calculation of the sediment budget, a single cell covered the inner and outer bar channels and the anchorage area. When morphological information indicated that littoral material was entering the harbor area through the north jetty, cell 12 was split, forming cells 12a and 12b. The boundaries are approximate, but 12a and 12b are assumed to evenly split the sediment moving out of the harbor to cell 11.

Cell 12b, Inner and Outer Bar Channel

The channel follows the south jetty and provides access to Galveston Harbor and the Houston ship channel. From 1980-1999 dredging averaged 170,000 cu m/year.

Assumption 1. This cell is the source of half of the material that moves out to cell 11 (Entrance Channel), 230,000 cu m/year.

Assumption 2. Littoral input is around 150,000 cu m/year. Based on over 60 samples, the material removed from the channels averages 88 percent sand (see discussion in cell 12a paragraphs). The 21 west-most samples had even higher sand content, almost 93 percent (Figure 17). The unusually high sand content is unexpected, considering that most of Galveston Bay is a muddy environment. The only likely source of this sand is littoral material passing through the south jetty via Big Reef, or possibly brought in via aeolian transport from East Beach.

Assumption 3. To balance the cell, the remaining material that fills the inner and outer bar channels consists of silt and mud from Galveston Bay (approximately 250,000 cu m/year).

Cell 13, East Beach

East Beach, located south of the south jetty, has grown steadily in the 120 years since the jetty was built. Unlike the fillet to the north, here sand has accumulated directly against the jetty. The jetty is porous, as shown by the steady growth of Big Reef, a sand body that projects northward into the navigation channel (Figures 17 and 32). The reef is occasionally mined for sand to be used for beach nourishment. In February 2003, the city of Galveston had fenced off an area of East Beach and was stockpiling sand there for future needs.

Based on translating 2003 profiles by 3.6 m/year, with an active depth of -4m, ΔV = 147,000 cu m/year. Once again, it was not possible to compare the 2003 profiles with the historical profiles because of unresolved datum or positioning errors.

Figure 32. Oblique view of Galveston south jetty and Big Reef, taken 27 July 2003 after Hurricane Claudette. Significant sand moves over jetty into channel, and boat traffic entrains sand towards southwest (photograph courtesy of BEG).

Assumption 1. Sand movement through the jetty into the inner and outer bar channel (with temporary storage in Big Reef) area equals 149,000 cu m/year. This value is based on the dredging of the bar channels multiplied by the average sand percentage of 60 samples (88 percent).

Assumption 2. Onshore sand movement equals 279,000 cu m/year. This is the only way to balance the cell considering fillet growth, loss through the jetty, and minor littoral input from the south.

Determining exactly how much material moves onshore near East Beach needs to be evaluated in greater detail. Seismic studies underway by Texas A&M University have detected sandy facies offshore south of the jetty, so an offshore sand source is feasible[11]. The 1960s movable bed model studies also demonstrated bed movement onshore. With wave direction of S 29°E and S 37°E, bed movement was divided, some material moving north of the south jetty but most onto East Beach. With wave direction of S 37°E and S 66°E, bed movement was exclusively onto East Beach (Plates 59-62 in Simmons and Boland 1969). However, Hall (1976) wrote that the net sediment transport in the lower shoreface was towards the southwest and parallel to Galveston Island. Principal sediment transport agents were near-bottom currents generated by tides, which were superimposed on a semipermanent current flowing toward the southwest. He concluded, "Sandy material placed in the dredged material disposal area has little chance to ever return to the channel and will probably enter the longshore transport system and nourish beaches farther down the Texas coast," (Hall 1976; p. vi). Hall based his conclusions on theoretical considerations of bed shear calculated from monthly vertical current profiles. It is unclear if he considered large-scale morphological factors such as the growth of East Beach over time.

Cell 14, Galveston Seawall

The Galveston Seawall protects the gulf shore of Galveston Island for a total distance of 15,700 m (Figure 33). Part of the wall is now inland because of the growth of East Beach, leaving the western 11,000 m with direct gulf exposure. The city of Galveston has historically been concerned about retaining a beach at the foot of the wall to attract tourists and protect the structure. As a result, a series of groins were built to trap or retain sand, and the city and private interests have placed sand on the beach at various times. Based on 1985 to 2003 records, average annual placement ≈ 34,000 cu m. In 1985, 11,500 cu m were placed in front of the San Luis Hotel; in 1992, 382,000 cu m of material from channel dredging was placed on an offshore berm; and in 1995, 543,000 cu m were placed on the beach from a source offshore of East Beach.

Assumption 1. Because of the rigid seawall, the shore is essentially fixed, even though the beach at the base of the wall has changed over the years. Therefore, $\Delta V = 0$.

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[11] Personal communication, 12 November 2003, Dr. Timothy Dellapenna, Assistant Professor, Department of Oceanography, Texas A&M University.

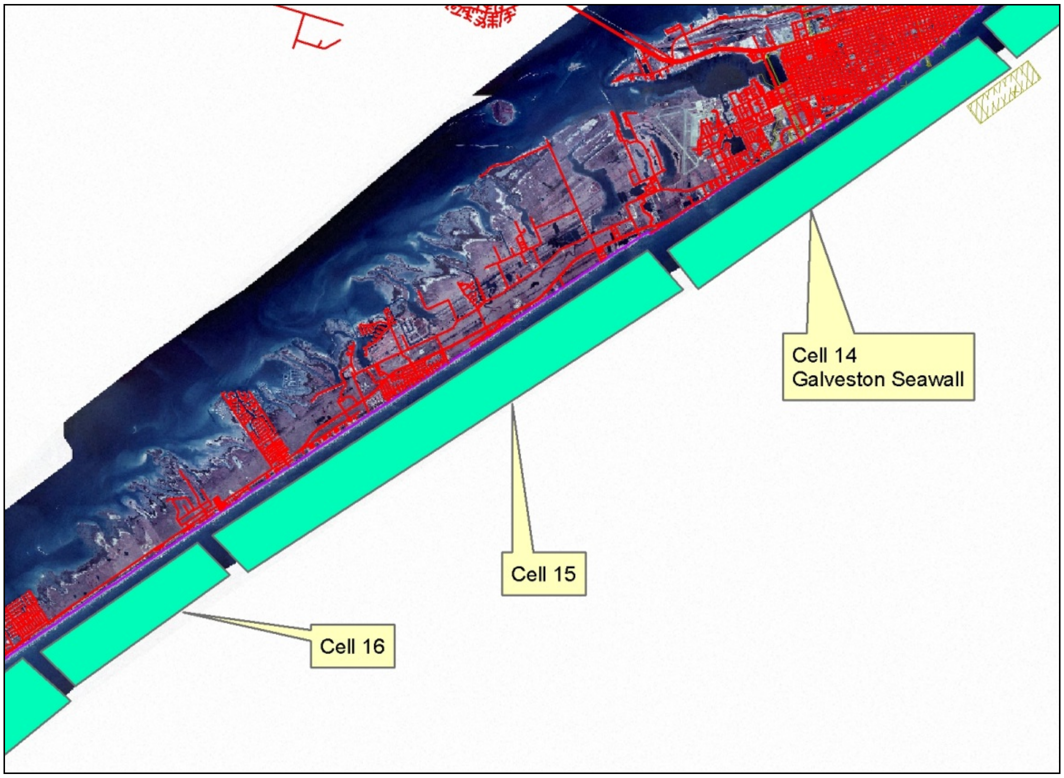

Figure 33. Cells 14, 15, and 16, Galveston Island. Cell 14 includes 11.000-m section of seawall with direct Gulf exposure.

Assumption 2. This cell is a divergence zone. At the west end of the seawall, there is clear morphological evidence that net drift is to the west because the shore has cut back (Figure 34). This erosion zone continues to grow and may need to be repaired using beach fill and some form of structures. Therefore, drift is to the west out of the west end of the cell. As previously described, East Beach continues to grow, indicating some eastward drift out of the east side of cell 14. The simplest assumption is to assign 50 percent of the littoral transport at each end, or 17,000 cu m/year to the east and 17,000 cu m/year to the west.

Figure 34. Eroded beach just beyond west end of Galveston Seawall (19 February 2003). This is border between cells 14 and 15. Sand has been placed on beach to protect dune in front of hotel.

Cell 15

From cell 15 and continuing southwest, net littoral transport is to the west according to King's (in preparation) wave modeling studies. This agrees with most of the published literature for this part of the Texas coast. The beach in cell 15 has retreated, resulting in ΔV = -112,500 cu m/year.

Assumption 1. Beach placement = 10,000 cu m/year. Minor beach nourishments have been reported, but records are incomplete.

Assumption 2. All the material removed from the beach moves west, with $Q_{LST} \approx$ 139,000 cu m/year.

Cell 16

Cell 16 is a stable section of Galveston Island, with ΔV = 0.

Assumption. All the littoral material entering the east side of the cell is transported out the west side.

Cell 17, West Beach

Cell 17 includes an eroding section of Galveston Island, with average retreat of 1.36 m/year (Figure 35). This results in beach change of ΔV = -60,500 cu m/year.

Assumption. With the addition of the beach material to the incoming littoral drift, littoral transport out the west side of the cell increases to 200,000 cu m/year.

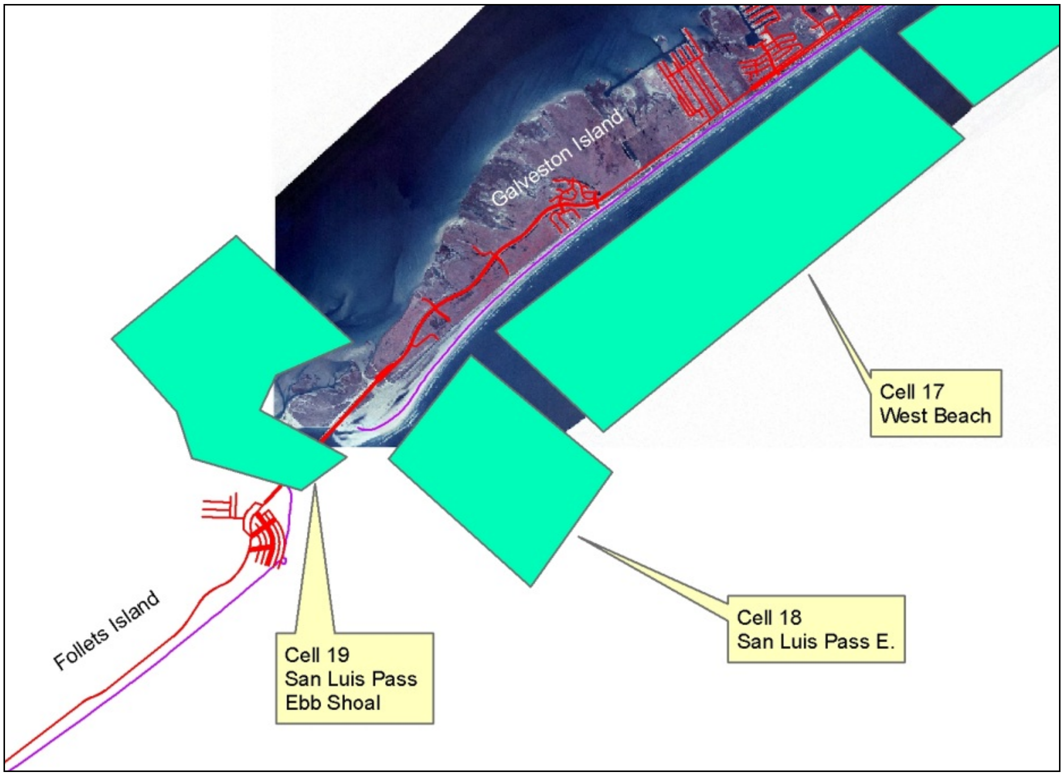

Figure 35. Cells 17, 18, and 19 at west end of Galveston Island.

Cell 18, San Luis Pass East

This cell includes the dynamic east side of the mouth of San Luis Pass. The pass has been in approximately this location since before 1853 (Mason 1981). Because the pass is unstructured, the marginal flood and ebb channels have migrated back and forth over time. The shoreline east of the mouth has advanced in the last 25 years, resulting in ΔV = 123,000 cu m/year.

Assumption. All remaining littoral material not accounted for in beach growth enters San Luis Pass. Therefore, Q_{sink} = 76,000 cu m/year. It is possible that some material bypasses the mouth, but the west side of the pass does not have an obvious attachment bar, as is common at inlets with ebb shoals that bypass littoral material (Figure 36).

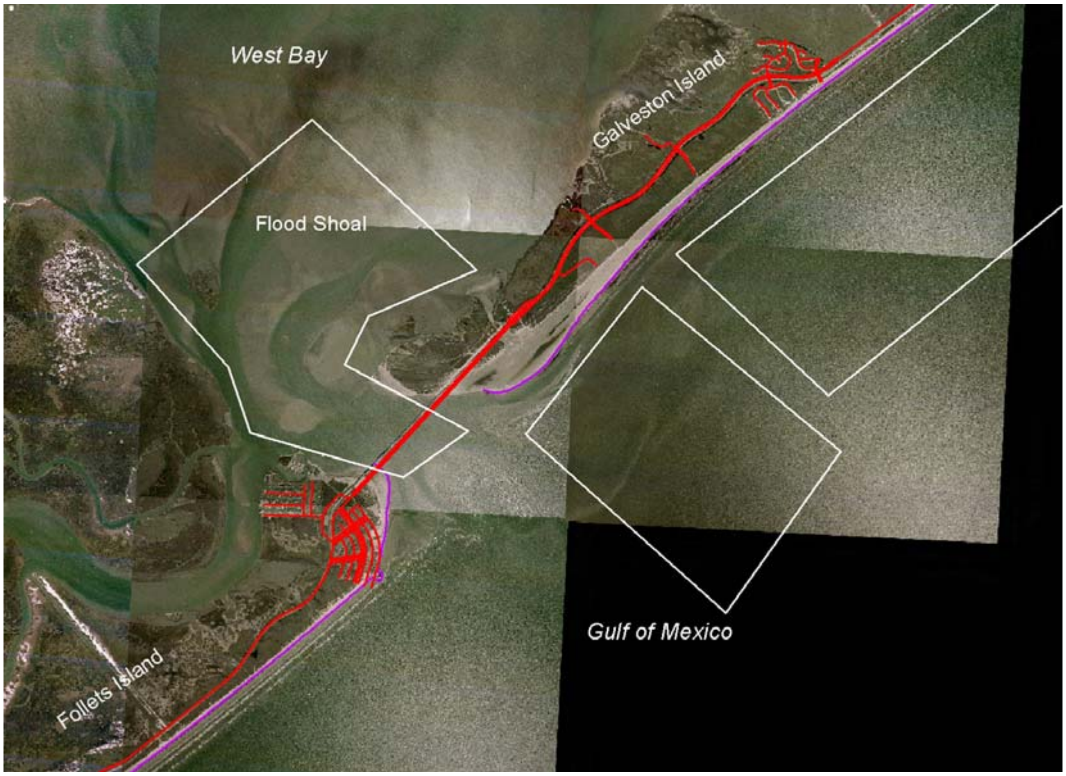

Figure 36. Morphologic features of San Luis Pass. Cells 17, 18, and 19 are outlined (1999 mosaic courtesy of Texas BEG).

Cell 19, San Luis Flood Shoal

Most researchers believe San Luis Pass is a sediment sink. The ebb shoal may contain 3.1 million cu m of sand, but growth or loss rates are unavailable[12]. The flood shoals also appear to be significant reservoirs of sand and have increased in volume steadily. Bathymetry coverage is insufficient to determine the quantities of sand involved, but BEG is conducting surveys to quantify the volumes.

Assumption. The flood shoal is a sink for all littoral material entering the pass. Sediment input is at least 76,000 cu m/year. The numbers cannot be refined until complete bathymetry surveys are available.

[12] Volume based on ongoing sediment studies being conducted by BEG (Personal communication, 12 November 2003, Dr. James Gibeaut, research associate, Bureau of Economic Geology, University of Texas).

6 Recommendations to Refine Sediment Budget

The North Texas sediment budget had the advantage of excellent data, some of which was commissioned specifically for the feasibility study. Some of these data, such as the shoreline change statistics and the cross-shore profiles, were critical to computing volumes of sediment in the shoreface. However, no sediment budget is ever complete, and there is never enough data to answer all the questions. To refine the North Texas budget, the following areas, in particular, would benefit from better characterization:

a. Sediment transport through Sabine Pass.

- More sediment surface grab samples to characterize material being carried down the channel.
- Estimates of bed-load transport (possibly obtained using side-scan sonar to measure bed forms or sediment traps).

b. Better characterization of sediment type between High Island and Sabine Pass. What are the percent sand, silt, and clay?

- Bulk samples need to be collected on a regular spacing or pattern.
- Borings or cone penetrometer to measure the thickness of the sand veneer.

c. Onshore movement of sand at both sides of the Galveston jetties.

- Seismic surveys to measure sand veneer.
- Tracer studies to determine sediment pathways.

d. Better estimate of beach volume changes at both sides of the Galveston jetties.

- Re-examine monumentation and coordinate systems to try to resolve datum problems with 1960s and 1970s cross-shore profiles.
- If the datums can be determined, commission new profile surveys to match monument position and azimuth of 1960s and 1970s profiles and compare volume changes.

e. Function of San Luis Pass as a sediment sink.

- Locate historical bathymetry surveys of flood and ebb shoal.
- Conduct a complete bathymetry survey of flood and ebb shoals and compare with the historical surveys to calculate volume changes.

f. Maintain a database of beach fill and placement statistics to improve calculation of volume changes on beaches.

g. How do the beaches respond to storms and flooding?

- Continue cross-shore profiles to match the 2002 surveys. To reduce cost, every second or fourth survey line may be adequate (1- or 2-km spacing).
- Establish tangible survey monuments to improve repeatability in future surveys.

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Appendix A: Dredging Summary

Table A1. Galveston and Bolivar roads dredging summary.

Channel	EndDate	DSStation	USStation	PresActYard	Notes
Bolivar					
Bolivar Roads Channel	09-Jul-00	13+900	(-)6+000	4,337,712	Channel deepening
Galveston Entrance					
Galv. Entrance Channel	31-Mar-97	56+000	36+000	1,457,011	
Galv. Entrance Channel	25-Aug-93	56+000	36+000	1,751,450	
Galv. Entrance Channel*	05-Dec-90	56+000	35+000	1,563,252	
Galv. Entrance Channel	04-Oct-88	56+000	30+675	692,977	Estimate: 2/3 of 1,038,946 cu yd
Galv. Entrance Channel	31-Jul-86	56+000	30+675	1,656,469	
Galv. Entrance Channel	25-Jul-84	56+000	30+675	2,909,507	
Galv. Entrance Channel	05-Aug-80				
Total 1980 - 1997				10,030,666	
Years 1980 - 1997	16.7			16.7	
Annual dredging cu yd				602,384	
Annual dredging cu m				460,583	
Galveston Anchorage					
Galv. Anchorage Area	31-Mar-97	17+400	12+000	603,695	
Galv. Anchorage Area	25-Aug-93	15+400	11+969	296,160	
Galv. Anchorage Area*	05-Dec-90	19+400	11+969	1,073,134	
Galv. Anchorage Area	04-Oct-88				
Total 1988 - 1997				1,972,989	
Years 1988 - 1997	8.5			8.5	
Annual dredging cu yd				232,463	
Annual dredging cu m				177,740	
					(Continued)

Table A1 (Concluded)

Channel	EndDate	DSStation	USStation	PresActYard	Notes
Inner and Outer Bar					
Galv. Outer and Inner Bar Chan.	31-Mar-97	25+000	4+649.75	464,826	
Galv. Inner Bar Channel	30-Jul-95	21+912.37	4+649.75	691,683	
Galv. Outer and Inner Bar Chan.	25-Aug-93	25+000	4+649.79	845,012	
Galv. Outer and Inner Bar Chan.*	05-Dec-90	29+400	0+200	792,838	
Galv. Outer and Inner Bar Chan.	04-Oct-88	30+675	4+649	345,969	Estimate: 1/3 of 1,038,946 cu yd
Galv. Outer and Inner Bar Chan.	31-Jul-86	30+675	4+649	556,099	
Galv. Outer and Inner Bar Chan.	25-Jul-84	30+675	4+649	1,577,900	
Galv. Outer and Inner Bar Chan.	05-Aug-80				
Total 1980 - 1997				5,274,327	
Years 1980 – 1997	16.7			16.7	
Annual dredging cu yd				316,746	
Annual dredging cu m				169,730	

Notes:
EndDate = end of contract. Contract may have extended over many months.
DSStation = Downstream station.
USStation = Upstream station.
PresActYard = Actual yardage removed.
Dredging database reformatted and provided by Tim Baumer, CESWG-IM, (409) 766-3874.

Table A2. Sabine Waterway dredging summary

Channel	EndDate	DSStation	USStation	PresActYard	PresEstYard
Sabine Bank (Offshore)					
Sabine Bank Channel	13-Aug-02	86+000	0+000	2,877,918	
Sabine Bank Channel	2000	80+000	50+000		2,185,000
Sabine Bank Channel	25-Sep-97	90+000	0+000	4,742,465	
Total 1997-2002[1]				5,062,918	
Years 1997-2002	4.9			4.9	
Annual cu yd				1,037,146	
Annual cu m				793,002	
Entrance Channel (Jetties)					
Sabine Entrance Jetty Chan.	07-Oct-98	-214+88.3	-46+00		1,370,000
Sabine Entrance Jetty Chan.	15-Sep-87	?	?	1,000,000	
Sabine Entrance Jetty Chan.	09-Sep-77	-214+88	-55+00	3,000,000	
Sabine Entrance Jetty Chan.	20-Nov-74	-214+88.3	0+00	2,520,638	
Sabine Entrance Jetty Chan.	30-Jun-71	?	?	277,000	
Sabine Entrance Jetty Chan.	25-Feb-71	?	?	953,500	
Total 1971 - 1998[1]				7,890,638	
Years 1971 - 1998	27.3			27.3	
Annual cu yd				289,334	
Annual cu m				221,225	
Outer Bar Channel (Seaward of Jetties)					
Sabine Outer Bar Channel	Oct-01	50+000	0+000	4,065,517	
Sabine Outer Bar Channel	07-Oct-98	18+000	0+000		2,050,000
Sabine Outer Bar Channel	06-May-96	40+000	0+000	3,723,835	
Sabine Outer Bar Channel	12-Sep-94	70+000	0+000	3,248,407	
Sabine Outer Bar Channel	07-Nov-92	18+000	0+000	2,363,990	
Sabine Outer Bar Channel	20-Jul-91	25+000	0+000	5,251,477	
Sabine Outer Bar Channel	16-Oct-88	18+000	2+000	3,002,319	
Sabine Outer Bar & Jetty Chan.[2]	15-Sep-87	20+000	-130+00	3,572,109	
Sabine Outer Bar Channel	16-Jul-86	12+000	2+000	2,905,719	
Total 1986-2001[1]				27,277,654	
Years 1986-2001	15.2			15.2	
Annual dredging cu yd				1,793,226	
Annual cu m				1,371,101	

[1] Note: Total does not include first dredge volume listed. Totals are combined volume from that date to the latest date listed.
[2] Note: 1,000,000 cu yd assumed to be from jetty channel.

(Continued)

Table A2 (Concluded)

Channel	EndDate	DSStation	USStation	PresActYard	PresEstYard
Sabine Pass Channel (Inshore of Jetties)					
Sabine Pass Channel	12-Feb-02	118+00	296+24.3	1,795,611	
Sabine Pass Channel	31-Jul-99	105+00	296+24	2,102,577	
Sabine Pass Channel	27-Apr-97	105+00	296+24.3	1,034,000	
Sabine Pass Channel	12-Jan-93	165+00	263+92.4 4	703,237	
Sabine Pass Channel	18-Feb-91	227+11	296+24	3,011,203	
Sabine Pass Channel	14-Jul-88	100+00	296+24.3	1,508,923	
Sabine Pass Channel	17-Dec-84	227+11	296+24.3	907,127	
Total 1984-2002[1]				10,155,551	
Years 1984-2002	17.2			17.2	
Annual dredging 1984-2002				591,975	
Annual cu m				452,624	

Notes:
EndDate = end of contract. Contract may have extended over many months.
DSStation = Downstream station.
USStation = Upstream station.
PresActYard = Actual yardage removed.
PresEstYard = Estimated yardage to be removed in a contract.
Dredging database reformatted and provided by Mr. Tim Baumer, CESWG-IM, (409-766-3874).

Appendix B: Sediment Budget

Table B1 is the sediment budget for the North Texas shore between Sabine and San Luis Passes. The location of the cells can be seen in figures in the main report, and Table B2 lists the east and west boundaries (in UTM coordinates) of the cells that parallel the beaches.

Table B1. Sediment budget.

Cell	Variable	Value	Notes, Source
Sabine 3 bar channel	$Q_{source1}$	0	Possible mud input from channel
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	Possible mud loss offshore
	$Q_{source3}$	1371	From deposition basin to west
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	1371	Placed in basin to west, 6% sand
	DeltaV	0	
	Residual	0	
Sabine 2 jetty chan.	$Q_{source1}$	209.6	Mud and minor sand input from Sabine River
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	Offshore loss of fine material (may be much more)
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	11.4	Probably mostly mud
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	221	Disposal unknown, offshore? East?
	DeltaV	0	
	Residual	0.0	

Notes:
See text and figures for location of budget cells. Last update: 26 November 2003.
Blue = Inlet or pass cell. Yellow = coastal cells.
References are listed in the reference list of the main text.

Nomenclature:
Units: 1,000 cu m/year.
Source 1 = bluffs, river influx, wind.
Sink 1 = wind-blown loss.
Source or sink 2 = offshore.
Source or sink 3 = other (inlet, channel, trap).
LST1 = right (east) side of cell.
LST2 = left (west) side of cell.

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Sabine 1 pass chan.	$Q_{source1}$	662.6	20% sand average (may be more, but how to measure?)
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	209.6	Mud and sand passing out to sea (to jetty channel)
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	453	CDF placement, removed from system
	DeltaV	0	
	Residual	0	
Cell 1 Sabine fillet	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	11.4	To Sabine jetty channel (mud and minor sand?)
	$Q_{source\text{-}LST2}$	19.2	From cell 2
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	0	
	DeltaV	7.8	Mud fillet? Used -6 ft (-2 m) m active depth (Dr. Billy Edge 11/14/03)
	Residual	0.0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 2 Texas Pt. NWR	$Q_{source1}$	0	
	Q_{sink1}	116.2	Assume 35% overwash losses (Dr. Billy Edge 11/14/03)
	$Q_{source2}$	0	
	Q_{sink2}	132.8	Assume 40% material (mud) lost offshore
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	19.2	5% to cell 1 (east transport) - assume mud
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	63.8	Approx. 20% to cell 3. West transport predicted by Pacific International Engineers wave study. Assume sand/shell
	Placement	0	
	Removal	0	
	Delta*V*	-332	Beach erosion, assume 90+% mud. Some sand and shell may be moving east to jetty channel, some west to cell 3. Used -2 m active depth (Dr. Billy Edge 11/14/03)
	Residual	0.0	
Cell 3 Sea Rim Park	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	63.81	From cell 2
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	26.2	From cell 4
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	0	
	Delta*V*	90	Beach growth. Sand according to Osborne and Edge (dunes on shore). Active depth -2 m (Dr. Edge 11/14/03)
	Residual	0.01	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 4 McFadden NWR	$Q_{source1}$	0	
(mud coast east)	Q_{sink1}	104.8	Overwash losses (Dr. Billy Edge 11/14/03)
(sandy west)	$Q_{source2}$	0	
	Q_{sink2}	104.8	Assume 40% material (mud) lost offshore
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	26.2	10% to cell 3 (east transport) - assume sand
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	26.2	10% to cell 5 (west transport) - assume sand
	Placement	0	
	Removal	0	
	DeltaV	-262	Beach erosion. Used -3 m active depth (Dr. Billy Edge, 11/14/03).
	Residual	0	
Cell 5 w. of High Is.	$Q_{source1}$	0	
(sandy environment)	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	26.2	From cell 4
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	26.2	To cell 6
	Placement	0	
	Removal	0	
	Delta$V$	0	Stable shore
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 6 Rollover E	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	5.9	Sand into Rollover Pass (50% each side)
	$Q_{source\text{-}LST1}$	26.2	From cell 5
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	74.3	To cell 8
	Placement	26.5	2003 fill of 104,000 cu yd divded by 3 years
	Removal	0	
	Delta$V$	-27.5	Based on translating 2002 profiles -1.18 m
	Residual	0	
Cell 7 Rollover	$Q_{source1}$	35.8	Normal siltation from bay sources
Sections 2166 to 2136 of Intracoastal	Q_{sink1}	0	
Intracoastal	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	11.8	"Excess siltation" above regional average in the "high siltation zone" of Parchure et al. 2000
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	47.6	Variable placement (some to beaches)
	Delta$V$	0	
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 8 Rollover W	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	5.9	Sand into Rollover Pass (50% each side)
	$Q_{source\text{-}LST1}$	74.3	From cell 6
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	186.4	To cell 9
	Placement	85.5	1997-2002 placements (Shiner Moseley)
	Removal	0	
	Delta$V$	-32.5	Based on translating 2002 profiles -0.8 m, -4 m active depth
	Residual	0.00	
Cell 9	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	186.4	From cell 8
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	172.4	To cell 10
	Placement	0	Minor placements at geotubes?
	Removal	0	
	Delta$V$	14	Based on translating 2002 profiles 0.22 m, -4 m active depth
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 10 Galv. N. Fillet	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	227	From offshore - ONLY WAY TO BALANCE
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	172.4	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	156	Sand into Bolivar Roads (anchorage area) past jetty
	Placement	0	
	Removal	0	
	Delta*V*	243	Based on translating 2002 profiles 3.26 m. (Note: profile comparison 1970's and 2002 yielded 420: too much, unrealistic)
	Residual	0.0	
Cell 11	$Q_{source1}$	0	
Galv. Entrance Chan.	Q_{sink1}	0	
	$Q_{source2}$	0	Assume no offshore source
	Q_{sink2}	0	
	$Q_{source3}$	460.6	From Galveston Bay, Bolivar Roads
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$		
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	460.6	1980-97 dredging (excl. 2000 deepening)
	Delta*V*	0	
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 12a	$Q_{source1}$	251.6	Fine grain from Galveston Bay
Anchorage Area	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	230.3	To cell 11 Entrance Channel
	$Q_{source3}$	156.4	Sand from cell 10 via N jetty (based on mean sand content of 88% for samples in inner and outer bar channels, using 1953-1997 samples).
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	177.7	1988-97 dredging
	Delta*V*	0	
	Residual	0	
Cell 12b	$Q_{source1}$	250.7	Fine grain from Galveston Bay
Inner & outer bar	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	230.3	To cell 11 Entrance Channel
	$Q_{source3}$	149.3	Sand from cell 13 via S jetty and aeolian (based on mean sand content of 88% for samples in inner and outer bar channels, using 1953-1997 samples)
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	169.7	1980-97 dredging
	Delta*V*	0	
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 13 East Beach	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	261.2	From offshore - ONLY WAY TO BALANCE. Without any other source, this is the only way to account for fillet growth.
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	131.2	Sand to cell 12b via S jetty and aeolian
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	17	From cell 14
	$Q_{sink\text{-}LST2}$	0	Assume all moves to east
	Placement	0	
	Removal	0	
	Delta$V$	147	Based on translating 2002 profiles 3.59 m. (Note: Profile comparison 1970s and 2002 yielded 37: much too low.)
	Residual	0.0	
Cell 14 Galv. Sea Wall	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	17	Assume 50% to east
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	17	Assume 50% to west
	Placement	34	1985-2003 placements
	Removal	0	
	Delta$V$	0	Armored shore, fixed in place
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 15 Galv. State Park	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	17	From cell 14
	$Q_{sink\text{-}LST1}$	0	Assume no east movement
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	139.4	
	Placement	10	Minor placements (estimated vol.). Need specific placement details.
	Removal	0	
	Delta$V$	-112.4	2002 profiles translated -1.17 m
	Residual	0	
Cell 16	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	139.4	From cell 15
	$Q_{sink\text{-}LST1}$	0	Assume no east movement
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	139.4	To cell 17
	Placement	0	
	Removal	0	
	Delta$V$	0	Stable shore
	Residual	0	

Table B1. (Continued)

Cell	Variable	Value	Notes, Source
Cell 17 West Beach	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	139.4	From cell 16
	$Q_{sink\text{-}LST1}$	0	Assume no east movement
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	199.7	To cell 18
	Placement	0	
	Removal	0	
	Delta$V$	-60.3	Based on 2002 profiles translated -1.36 m
	Residual	0.0	
Cell 18 San Luis E.	$Q_{source1}$	0	
	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	0	
	Q_{sink3}	76.2	Into San Luis Pass flood shoals
	$Q_{source\text{-}LST1}$	199.7	From cell 17
	$Q_{sink\text{-}LST1}$	0	Assume no east movement
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	All material moves into inlet?
	Placement	0	
	Removal	0	
	Delta$V$	123.5	2002 profiles translated 7.6 m
	Residual	0	

Table B1. (Concluded)

Cell	Variable	Value	Notes, Source
Cell 19 San Luis Pass	$Q_{source1}$	0	
Ebb Shoal	Q_{sink1}	0	
	$Q_{source2}$	0	
	Q_{sink2}	0	
	$Q_{source3}$	76.2	From cell 18
	Q_{sink3}	0	
	$Q_{source\text{-}LST1}$	0	
	$Q_{sink\text{-}LST1}$	0	
	$Q_{source\text{-}LST2}$	0	
	$Q_{sink\text{-}LST2}$	0	
	Placement	0	
	Removal	0	
	Delta$V$	0	
	Residual	76.2	INCOMPLETE, NEED FLOOD SHOAL GROWTH DATA

Table B2. Boundaries of coastal sediment budget cells.

Cell	West Boundary Easting	West Boundary Northing	East Boundary Easting	East Boundary Northing	Transect West	Transect East	LR-M-YR	LR-F-YR
1. Sabine Fillet	417,890	3,283,450	418,960	3,282,490	879	895	4.12	13.5
2. Texas Point	405,940	3,284,030	417,890	3,283,450	639	878	-7.94	-26.0
3. Sea Rim	394,945	3,281,960	405,940	3,284,030	414	638	2.11	6.9
4. McFaddin NWR	364,690	3,269,280	394,945	3,281,960	-242	413	-1.80	-5.9
5.	358,550	3,266,700	364,690	3,269,280	-375	-243	0.00	0.0
6. Rollover E	354,660	3,265,070	358,550	3,266,700	-485	-376	-1.18	-3.9
8. Rollover W	348,870	3,262,560	354,660	3,265,070	-596	-462	-0.80	-2.6
9.	339,650	3,257,970	348,870	3,262,560	-792	-597	0.22	0.7
10. Galveston N	331,610	3,249,260	339,650	3,257,970	-1005	-793	3.26	18.0
13. East Beach	327,380	3,242,360	332,350	3,245,980	345	463	3.58	11.8
14. Seawall	318,390	3,236,220	327,380	3,242,360	127	344	0.00	0.0
15. Galv. State Park	305,690	3,228,000	318,390	3,236,220	-176	126	-1.17	-3.8
16.	300,790	3,224,690	305,690	3,228,000	-294	-177	0.00	0.0
17. West Beach	295,570	3,220,590	300,790	3,224,690	-427	-295	-1.36	-4.5
18. San Luis East	293,800	3,219,350	295,570	3,220,590	-462	-428	7.60	25.0

Notes:
Coordinates mark the east and west side of each cell, with position at the 2000 shoreline. Coordinate system: UTM Zone 15, NAD83, metric.

Nomenclature:
Transect = BEG transect number.
LR-M-YR = Linear change per year (meters). Positive means shoreline advance.
LR-FT-YR = Linear change per year (feet).

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14. ABSTRACT

The North Texas sediment budget was developed to support the U.S. Army Corps of Engineers, Galveston District's Sabine Pass to Galveston Bay, Texas, Shoreline Feasibility Study. Data sources included dredging data from the 1970s to the present, beach fill quantities, sediment grain size statistics, aerial photographs, shoreline data, and information from the literature and historical sources.

For this study area, 23 sediment cells have been defined based on prominent morphologic or man-made features. In general, longshore sediment movement is from east to west, although reversals occur east of Sabine Pass, south of Rollover Pass, and south of Galveston entrance. Sabine Pass is heavily dredged, but material from the jetties and further landward is disposed on land. Therefore, the pass is primarily a source of fine-grain material, which disperses over the shoreface. At Galveston entrance, about 25 percent of the sediment in the channel is fine-grained material from Galveston Bay, with the remainder supplied from littoral sources from north and south of the jetties. The quantity of sand entering Galveston harbor via the south jetty or by aeolian transport is about 300,000 cu m/year. To balance the budget at Galveston entrance, significant onshore transport is must occur on both sides. A sediment node occurs off the Galveston seawall, with material moving to the NE towards East Beach and to the SW along the island, eventually to San Luis Pass.

15. SUBJECT TERMS
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