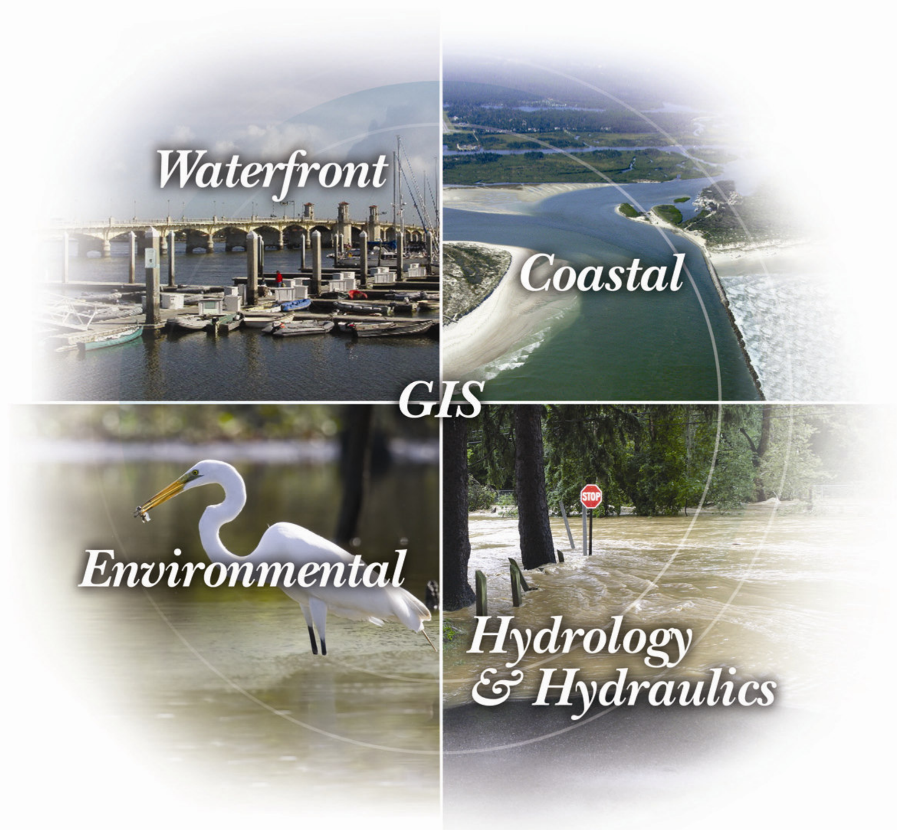
Analysis of Rollover Pass Impacts to Adjacent Beaches and the Littoral System

Galveston County, TX

January 5, 2010



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Prepared for

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1.0 INTRODUCTION

The Closure of Rollover Pass will immediately help reduce the rates of beach erosion along Bolivar Peninsula, reduce the required frequency and costs of Gulf Intracoastal Waterway (GIWW) maintenance dredging, and help improve the effectiveness of future beach restoration projects. The results of numerous studies — documenting the changes to the littoral system and their adverse impacts caused by Rollover Pass — from 1958 to the present support the above statement. This report summarizes the results of several past studies and introduces new data to demonstrate the Pass' adverse impacts and to support the stated project benefits. This report also develops a 1999 – 2008 sediment budget that summarizes beach volume changes and the sediment transport magnitudes and pathways, both natural and artificial, near Rollover Pass for the recent pre-Hurricane Ike period.

2.0 ADVERSE IMPACTS

Rollover Pass' adverse impacts on the coastal system began immediately after construction in 1955 and continue today. The impacts — namely, accelerated beach erosion and increased deposition in the GIWW — arise primarily from the Pass' flood-dominant characteristics that transport and deposit sediments into the Rollover and East Galveston bays and effectively diminish the natural sediment supply to the adjacent beaches. This process starves the beaches of the sand volume required to maintain the natural beach conditions; without this sand, erosion increases. Erosion also results from the trapping of littoral sediments against the Pass' updrift side and through ebb tidal effects. Similar to the above flood tidal process, the Pass' ebb tidal currents disrupt the natural longshore sediment transport by directing sediment offshore where they deposit in an ebb tidal shoal. Though the numerous studies disagree on impact quantities, the studies without exception acknowledge that Rollover Pass traps sediment that would normally reach the adjacent beaches, and consequently causes beach erosion and increases GIWW dredging requirements. The following sections discuss the initial effects of the Pass' construction, the trapping effect of the Pass' flood dominant characteristics, and beach erosion.

2.1 Initial Effects

The Texas Game and Fish Commission (now the Texas Parks and Wildlife Department) constructed Rollover Pass through a natural wash-over area, periodically breached during high tides and hurricanes, to improve local fishing conditions. The original Rollover Pass channel design included an 80-foot (ft) bottom width, an 8-ft depth, and sloping earthen sides throughout except for a steel sheet pile bulkhead along the southwest side. Unanticipated tidal currents through the Pass caused extensive erosion as construction neared completion; the Gulf entrance widened to about 500 ft and the channel bottom scoured to a depth of 30 ft under the Highway 87 bridge. Immediate protection measures included additional pilings to protect the bridge abutments, groins along the northeast side of the Pass to stop erosion, and a protective cover of shell, broken concrete, stone and other rubble along all exposed banks (Prather and Sorensen, 1972). Subsequent erosion during unusually high tides in spring and summer of 1955 caused additional problems. The shoreline, extending approximately one mile southwest of the Pass, receded landward and undermined some structures houses, which were subsequently moved. Along the northeast side of the inlet; the Highway 87 bridge showed indications of possible scour damage. In November 1955, in an effort to stop erosion, a steel sheet pile wall, or sill, was constructed across the Pass 40 ft south of the bridge to close the Pass temporarily. Shortly thereafter, alternative piles of the sill were driven 2 ft below mean sea level to reopen a portion of the Pass. The Pass remained partially open until inlet stabilization measures were enacted in 1958 – 1959 based on U.S. Army Corps of Engineers (USACE, 1958) recommendations. Today, although the Pass remains open and various structural improvements have stabilized the inlet, chronic erosion problems still persist.

The beach and channel erosion that occurred immediately after construction of Rollover Pass demonstrate the Pass' significant sediment transport capability and its disruptive effect on the natural littoral system. The USACE, in 1958, authored the first of many reports aimed at correcting or managing the Pass' adverse impacts. The following sections cite relevant published data regarding the Pass' effects on the adjacent beaches and waterways.

2.2 Sediment Transport into Rollover Pass

Sediment transport directed into Rollover Pass represents the crux of the Pass' adverse impacts. Field measurements and analytical conclusions reported in several past studies (e.g., Bales and Holley [1985], Mason [1981], and Prather and Sorensen [1972]) document the flood-dominant characteristics of the Pass. The strong flood tidal currents intercept the natural longshore sediment transport and carry the sediment predominantly through the inlet into Rollover Bay and then into the deeper waters of the GIWW where the majority of sediment is deposited. This process directly increases adjacent beach erosion and the frequency and hence increases costs to the USACE to dredge the GIWW navigation channel in this area. Several studies have calculated the sediment transport rate into Rollover Pass. Although the estimates vary widely, the studies without exception agree that Rollover Pass adversely affects adjacent beach areas significantly by funneling sediments through the Pass into the adjacent Rollover Bay and GIWW areas.

Table 1 contains previously published estimates of sediment transport rates into Rollover Pass. The estimates, based on various calculation methods, range from 3,800 cy/yr to 290,000 cy/yr. Bales and Holley (1989) conducted a thorough analysis using three different methods. Bales and Holley acknowledged the limitations of all three calculation methods, and they considered the results based on longshore transport rates to be the least reliable due to the uncertainties in such rates and the results based on dredging records — "substantiated by limited direct measurements and by conditions in East Bay and Rollover Bay" — to be the most reliable. The dredging data presented in Bales and Holley document a dramatic increase in dredging requirements coinciding with the construction of Rollover Pass as shown in Figures 1 and 2. Notably, the Figure 2 data, which indicate a 290,000 cy/yr dredged-volume increase after Pass construction, include dredging volumes between GIWW stations 1900+00 and 2450+00. A more conservative estimate that includes only the portion of the GIWW within the confines of Rollover Bay indicates an 80,000 cy/yr increase in Rollover Pass dredging requirements (Bales and Holley, 1989).

Table 1 Estimates of the Sediment Transport Rate into Rollover Pass

Source	Estimated Sediment Transport Rate (cy/yr)	Basis of Estimation
USACE (1958)	18,000	Beach erosion rates
Bales and Holley (1989)	3,800 – 29,000	Percentage (i.e., 5 – 25%) of the longshore sediment transport rate
Bales and Holley (1989)	9,000 – 26,000	Beach erosion rates
Bales and Holley (1989)	240,000 – 290,000	GIWW dredging records
Bales and Holley (1989)	80,000	GIWW dredging records
Parchure (2000)	15,400	GIWW dredging records
Pacific International Engineering (2002)	>150,000	November 2000 – June 2001 bathymetric survey comparisons

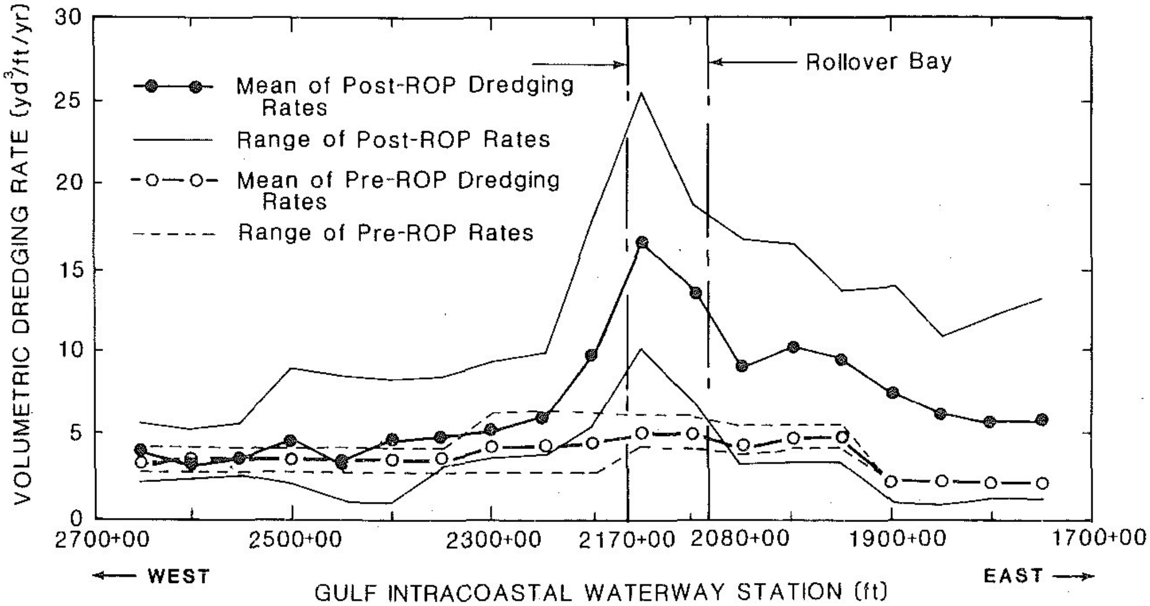

Figure 1 Observed Mean and Extreme Intracoastal Waterway Dredging Rates, Station 1700+00 to Station 2700+00, 1943–1980 (Source: Bales and Holley, 1989)

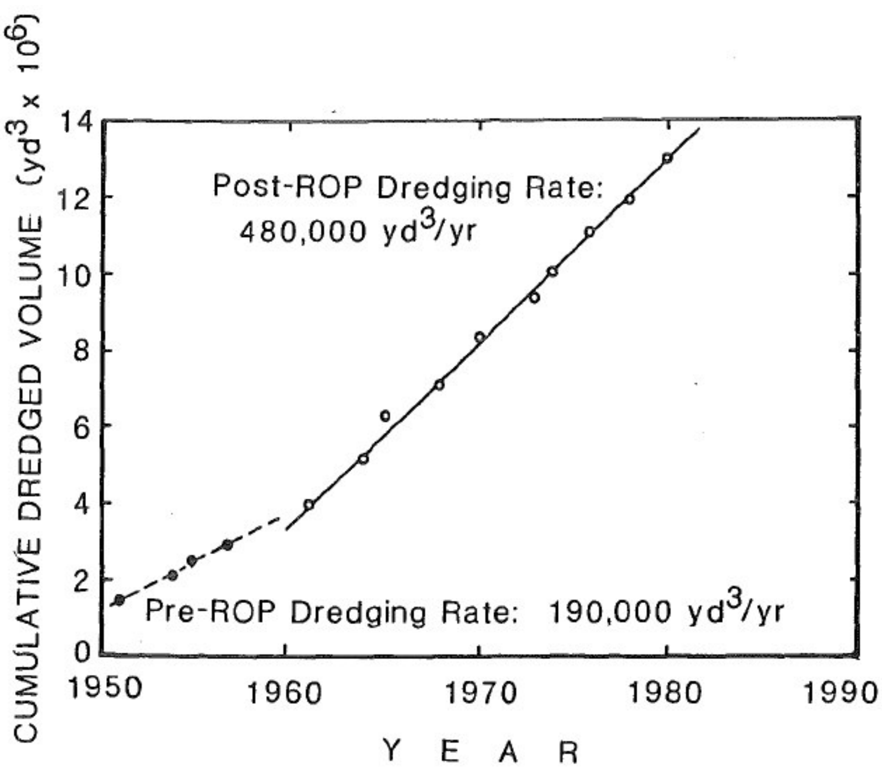

Figure 2 Cumulative Volume Dredged from Gulf Intracoastal Waterway, Station 1900+00 to Station 2450+00 (Source: Bales and Holley, 1989)

2.3 Beach Erosion

The beaches in the Rollover Pass vicinity would naturally experience background erosion absent the effects of Rollover Pass. However, as discussed above, Rollover Pass causes accelerated beach erosion by reducing the natural sediment supply to adjacent beaches. Numerous studies have documented such effects in terms of shoreline and beach volume change rates.

USACE (1958), as cited in Lockwood et al. (1974), calculated an average shoreline recession rate of 5 ft/yr from 1850 – 1956 (i.e., the data period selected by the study authors to represent pre-construction conditions). Subsequently, the USACE (as cited in Lockwood et al, 1974) documented an increased shoreline recession rate of 8.5 ft/yr from 1956 – 1974 within the first mile (5,280 feet) southwest of the Pass compared to a recession rate of 3 – 4 ft/yr over the next 10 miles (mi). In separate studies, Morton (1975) and the USACE, as cited in Mason (1981), found that shoreline recession rates varied between 15 – 25 ft/yr and between 7 – 14 ft/yr, respectively. Through analysis of beach profile changes, Mason (1981) estimated that Rollover Pass causes an additional 26,080 cy/yr of beach volume loss (i.e., erosion) over a 14,000-ft-long shoreline segment southwest of the Pass. Through analysis of aerial photographs of the beach within 6,900 ft of each side of the Pass, Bales and Holley (1989) estimated the Pass causes and additional 9,000 cy/yr of erosion within their study area southwest of the Pass. The above estimates clearly indicate that Rollover Pass has increased the shoreline recession and beach volume loss rates of the nearby beaches. Figure 3 illustrates the effect of adjacent erosion, indicated by the landward retreat of the beach contours (6.0 ft, 2.5-ft, and -2-ft contours shown) southwest of the Pass relative to the contours northeast of the Pass.

Recent studies by the USACE (2006) and Galveston County (2008) document beach changes without specifying the level of erosion caused by the Pass versus that caused by background conditions. The USACE (2006) calculated erosion rates of 42,500 cy/yr over an area extending 6,300 meters (m) (20,670 ft) southwest of the Pass and 36,000 cy/yr over an area extending 4,300 m (14,108 ft) northeast of the Pass. Galveston County (2008) analyzed 1999 – 2008 beach profile data to monitor beach changes associated with geotextile tube shore protection projects. The data, covering a 7-mile stretch of shoreline centered at the Pass, indicates the shoreline southwest of Rollover Pass receded 22.6 ft (2.5 ft/yr) on average and the northeast shoreline receded 4.5 ft (0.5 ft/yr). Though the above shoreline and volume changes do not specifically quantify the erosion caused by the Pass, the data clearly shows the southwestern (i.e. downdrift) beach suffers significantly more erosion than the northeastern beach.

Additionally, this erosion occurs despite the significant infusion of sand from beach and dune nourishment projects further discussed below.

Notably, the Bales and Holley and USACE (2006) volume change estimates originate from shoreline changes. Bales and Holley applied a sediment-volume conversion factor, developed by USACE (1984), of 0.7 cy per square foot of beach eroded to convert shoreline change to volume change. USACE calculated volumes changes by translating beach profiles (surveyed in 2002) by appropriate shoreline change distances (based on analysis of 1974, 1982, 1995 aerials and 2000 LIDAR topography by the University of Texas Bureau of Economic Geology). The USACE (2006) results correspond to conversion factors of 0.784 cy per square foot of beach eroded southwest of the Pass and 0.659 cy per square foot of beach eroded northeast of the Pass. The current study applied the conversion factors derived from USACE to the shoreline changes presented in Galveston County (2008) to calculate 1999 – 2008 beach volume changes extending 3.5 miles southwest and northeast of the Pass. The results indicate approximately 36,167 cy/yr of sand erode from the beach southwest of the Pass and 6,053 cy/yr erode northeast of the Pass within the monitoring area.

Figure 3 2008 Beach Contours near Rollover Pass (adapted from Galveston County, 2008)

3.0 1999 – 2008 SEDIMENT BUDGET

A sediment budget delineates sediment transport magnitudes and pathways and tallies sediment gains and losses within a specified domain. A 1999 – 2008 sediment budget for Rollover Pass provides an update to historic analyses cited above and helps evaluate the recent effects of the Pass. The sediment budget divides the Rollover Pass vicinity into three cells. These cells, illustrated in Figure 4, represent the beach extending 3.5 mi northeast of the Pass (cell 1), the beach extending 3.5 mi southwest of the Pass (cell 2), and the GIWW and Rollover Bay channel (cell 3). The following sections discuss the sediment budget input data — including beach volume changes, sediment transport rates, and beach nourishment and dredging data — and the sediment budget results.

3.1 Beach Volume Changes

As discussed above, Taylor Engineering calculated beach volume changes within cells 1 and 2. The volume estimates, based on shoreline change data reported in Galveston County (2008) and sediment volume conversion factors derived from USACE (2006) data, indicate erosion of 6,053 cy/yr in cell 1 and 36,167 cy/yr in cell 2. Notably, the conversion factors correspond to beach volume changes extending to -4 m (-13 ft) NAVD 88, the depth of closure as determined by the USACE (2006). Thus, the above erosion volumes theoretically represent volume changes to the same depth. Also of note, preferable volume changes based on direct comparison of beach profile surveys extending to the depth of closure are unavailable; however, the above estimates appear reasonable based on historic estimates similar in magnitude.

3.2 Longshore Sediment Transport Rates

Estimated in numerous studies, the longshore sediment transport rate near Rollover Pass is a critical component of the sediment budget. Bales and Holley (1989) reported previous estimates including 96,000 cy/yr (USACE, 1984), 75,000 cy/yr (Prather and Sorensen, 1972), 58,000 cy/yr (Mason 1981), and 54,000 cy/yr (Hall, 1976). All estimates represent a net southwesterly transport direction. The estimates of Mason and Hall include only wave-induced transport, whereas those of USACE and Prather and Sorensen include both wave and wind-current induced transport. Considering a separate USACE (1984) wind-induced transport estimate of 57,000 cy/yr, Bales and Holley (1989) present a possible 75,000 cy/yr – 115,000 cy/yr range of total longshore transport. In their study, the authors assume that addition of the independent wave- and wind-induced transport rates (i.e., addition of the 57,000 cy/yr wind-induced transport rate to the wave-induced rates estimated by Mason [1981] and Hall [1976]) reasonably represent the total rate. Recently, King (2007) applied numerical modeling techniques to simulate longshore sediment transport along Bolivar Peninsula. The sediment budget, which specifies the rate at the northeast boundary of cell 1, applies a transport rate of 91,600 cy/yr obtained from King.

3.3 Sediment Transport into Rollover Pass

As cited above, previous research led to a wide range of sediment transport estimates varying by an order of magnitude from 3,800 cy/yr to 290,000 cy/yr. This study selected a midrange of 80,000 cy/yr – 150,000 cy/yr based on data reported in Bales and Holley (1989) and PIE (2002). Notably, without any published data specifying the proportion of sand entering the inlet from the updrift and downdrift sides, this sediment budget assumes that 60% originates from the updrift beach. Notably, the 60% value corresponds to the southwesterly-directed proportion of gross sediment transport derived from King (2007). Numerical model results presented in King (2007) indicate gross sediment transport of roughly 650,000 cy/yr and net southwesterly sediment transport of roughly 133,500 cy/yr at the Pass. This data suggests the southwesterly-directed component of gross transport equals 391,750 cy/yr (or 60% of the gross transport) and the northeasterly-directed component equals 258,250 (or 40% of the gross transport).

3.4 Beach and Dune Nourishment and Dredging History

The sediment budget includes an average annual artificial placement of 64,675 cy/yr and 155,901 cy/yr of material onto the beaches northeast (cell 1) and southwest (cell 2) of Rollover Pass and removal of 185,668 cy/yr from the GIWW and Rollover Bay channel (cell 3) from 1999 – 2008. Taylor Engineering derived these quantities from annual beach and dune nourishment data (i.e., volumes, placement locations, and sand sources) from Galveston County (2008) and Texas General Land Office (personal communications) as presented in Table 2. Notably, cell 3 of the sediment budget corresponds to the reach associated with the dredging events documented in Table 2. Also, this analysis excludes a 2008 project that placed 134,700 cy southwest of the Pass; this nourishment event occurred after the 2008 survey used by Galveston County (2008) to determine shoreline changes.

3.5 Sediment Budget Results

Figures 5 and 6 illustrate alternative sediment budgets with differences that stem from different sediment transport rates entering the Pass. Alternative 1 (Figure 5) includes 80,000 cy/yr entering the Pass, and Alternative 2 (Figure 6) includes 150,000 cy/yr entering the Pass. Both alternatives specify the longshore transport rate (91,600 cy/yr) entering the domain of cell 1 at the northeast boundary, the artificial transport (i.e. dredging and beach nourishment) magnitudes, and the proportions of transport entering the Pass from updrift (60%) and downdrift (40%). All other transport rates — including transport into the GIWW from interior waters and longshore transport rates at the Pass (i.e. from cell to cell) and at the southwest domain boundary of cell 2— represent a balance of volumes such that the transport volume exiting a cell equals the sum of volumes entering the cell and volume changes within the cell. Both alternatives assume the net change within cell 3 equals zero (i.e., dredging rates equal deposition rates); thus, the sediment transport entering from interior bay waters equals the difference between the dredging rate and the sediment transport entering the Pass from offshore. Both alternatives assume zero offshore transport through the beach cell boundaries.

Comparison of Alternatives 1 and 2 provide insight into sediment transport as follows:

- Alternative 1 and Alternative 2 indicate that approximately 114,300 cy/yr and 72,300 cy/yr travel from the northeast beach cell (cell 1) to the southwest beach cell (cell 2) cell. The greater transport into the Pass (Alternative 2), which diminishes sediment supply downdrift, accounts for the volume difference.

- Alternative 1 and Alternative 2 indicate that approximately 274,400 cy/yr and 204,400 cy/yr exit downdrift of the southwest beach cell (cell 2). Both estimates appear higher than previously estimated rates; the assumption of zero offshore transport and a possible underestimation of the transport into Rollover Bay could account for the higher than expected rates.

- Alternative 1 and Alternative 2 indicate 105,700 cy/yr and 35,700 cy/yr deposit into cell 3 via siltation from interior waters. The Alternative 1 estimate represents about 57% of the dredged volume. The Alternative 2 estimate represents about 19% of the dredged volume. Historic dredging records discussed above show evidence of increased deposition after construction of Rollover Pass, and several studies hypothesize that sediment transported from the beach rather than the bay region comprise the majority of deposited sediments. As such, the above results suggest that the 80,000 cy/yr transport of Alternative 1 underestimates the actual transport rate into the Pass.

Table 2 1999 – 2008 Sediment Budget Nourishment Data and Dredging Volumes

Year	Nourishment Type	Volume (cy)	Sand Source
Northeast Shoreline Nourishments (Cell 1)			
2000	Beach	300,000	Rollover Bay[3] (dredge placement)
2000	Dune	22,000[2]	Upland source (truck haul)
2001	Dune	17,800	Upland source (truck haul)
2003	Beach	104,000	GIWW (dredge placement)
2004	Beach	74,274	GIWW (dredge placement)
2005	Dune	64,000	Upland source (truck haul)
Total	-	582,074	-
1999 – 2008 annual average	-	64,675	-
Southwest Shoreline Nourishments (Cell 2)			
1999	Beach	175,000	GIWW (dredge placement)
2000	Beach	138,400	GIWW (dredge placement)
2000	Dune	22,000[2]	Upland source (truck haul)
2001	Beach	126,000	GIWW (dredge placement)
2001	Dune	6,600	Upland source (truck haul)
2002	Beach	119,000	GIWW (dredge placement)
2004	Beach	102,523	Upland source (truck haul)
2004	Dune	8,247	Upland source (truck haul)
2005	Beach	361,000	GIWW (dredge placement)
2005	Dune	71,000	Upland source (truck haul)
2006	Beach	87,737	GIWW (dredge placement)
2007	Beach	185,600	GIWW (dredge placement)
Total	-	1,403,107	-
1999 – 2008 annual average[1]	-	155,901	-
Dredging Volumes (Cell 3)			
1999 – 2008 Total[1]	-	1,371,011	GIWW
	-	300,000	Rollover Bay channel[3]
	-	1,671,011	Cell 3 total
1999 – 2008 annual average[1]	-	152,335	GIWW
		33,333	Rollover Bay channel[3]
		185,668	Cell 3 total

[1]The data excludes a 2008 nourishment of the southwest shoreline that placed 134,700 cy of GIWW dredged material; this event occurred after the 2008 survey that defines the sediment budget period.
[2]Event included placement of 44,000 cy southwest and northeast of the Pass, but the placement distribution is unknown to the study authors. Thus, the data presented above assumes equal distribution to both sides of the Pass.
[3]The 2000 dredging event removed sediment from the permitted borrow area located along the Rollover Bay channel.

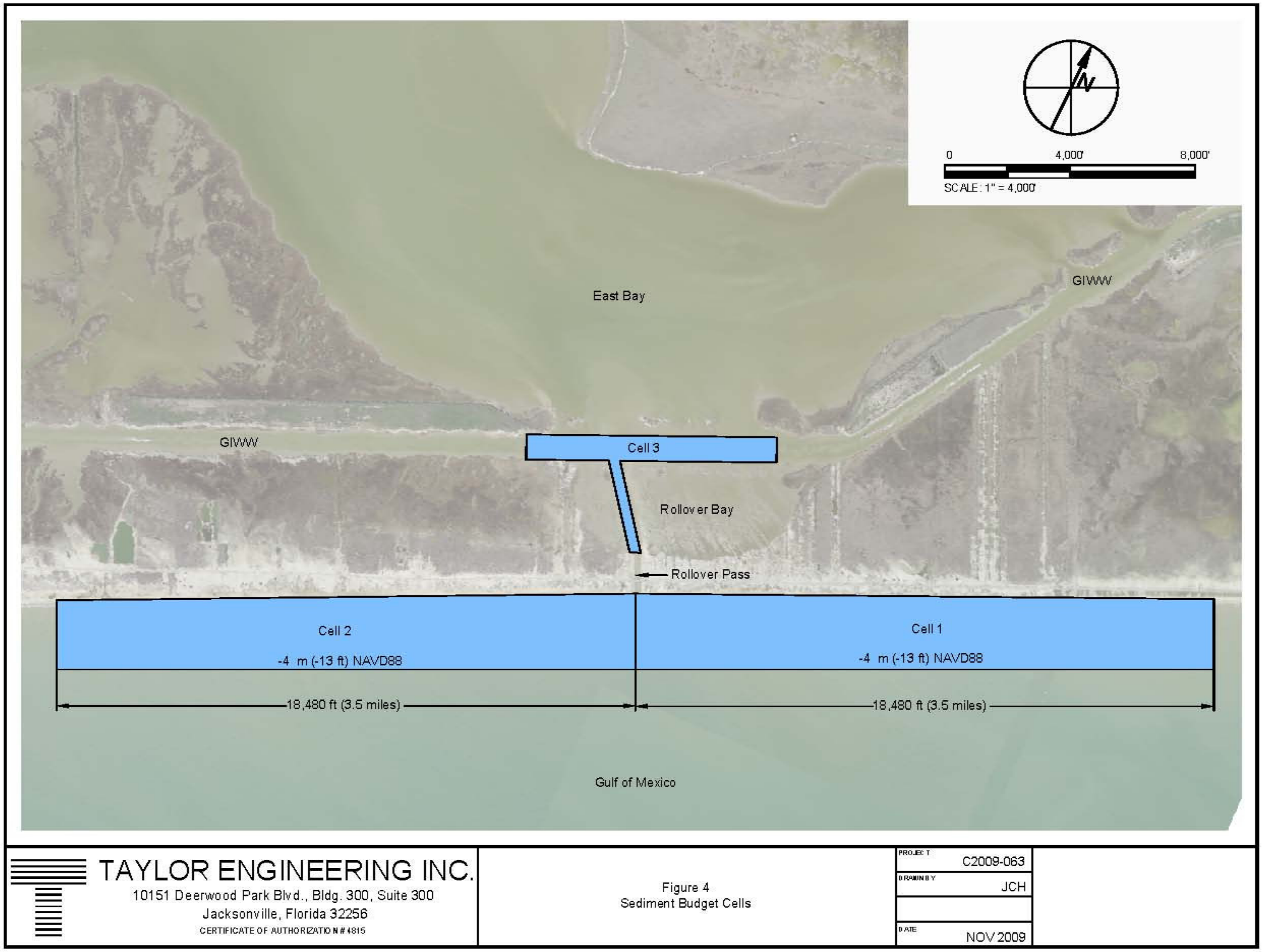

Figure 4 Sediment Budget Cells

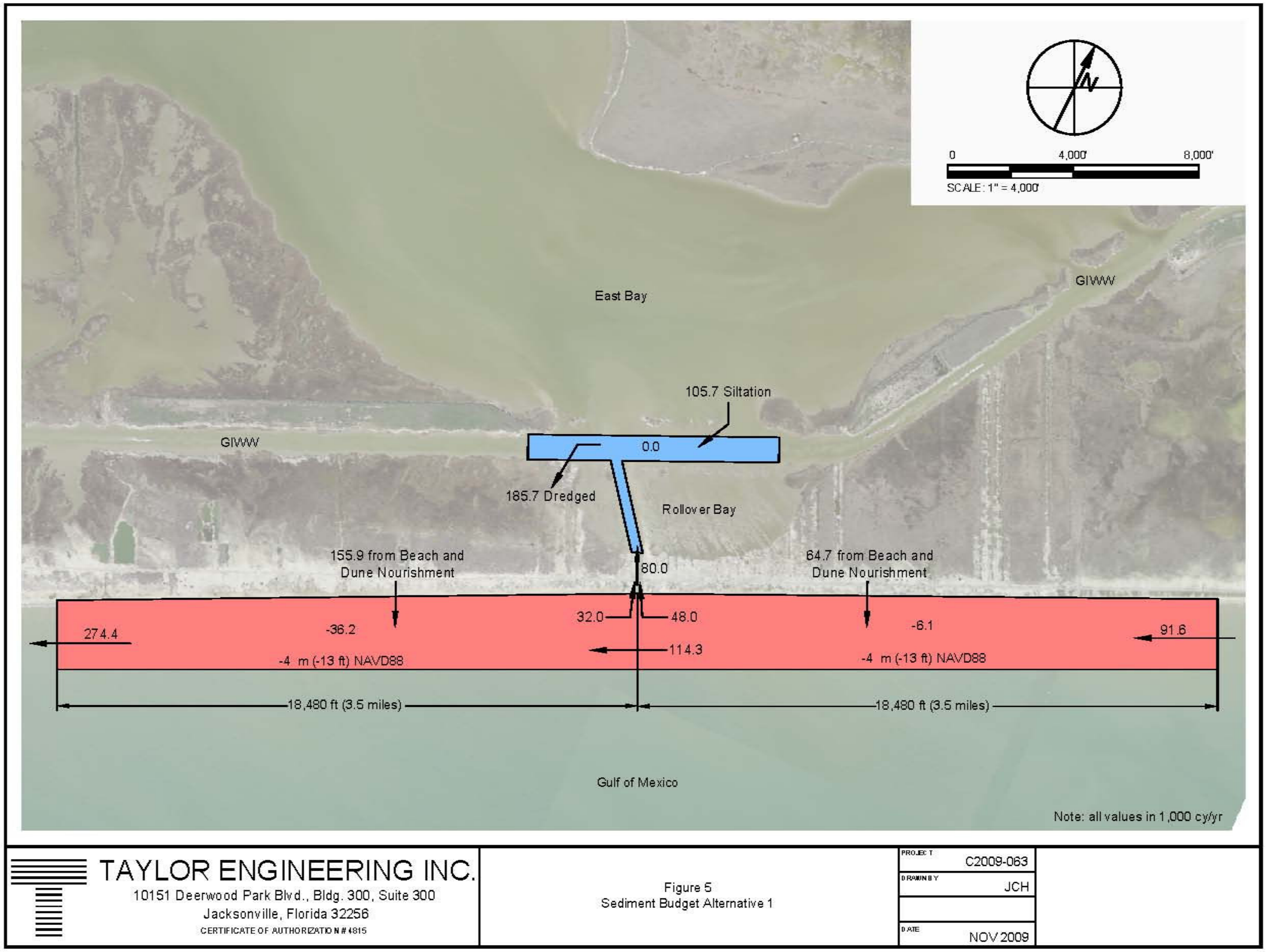

Figure 5 Sediment Budget Alternative 1

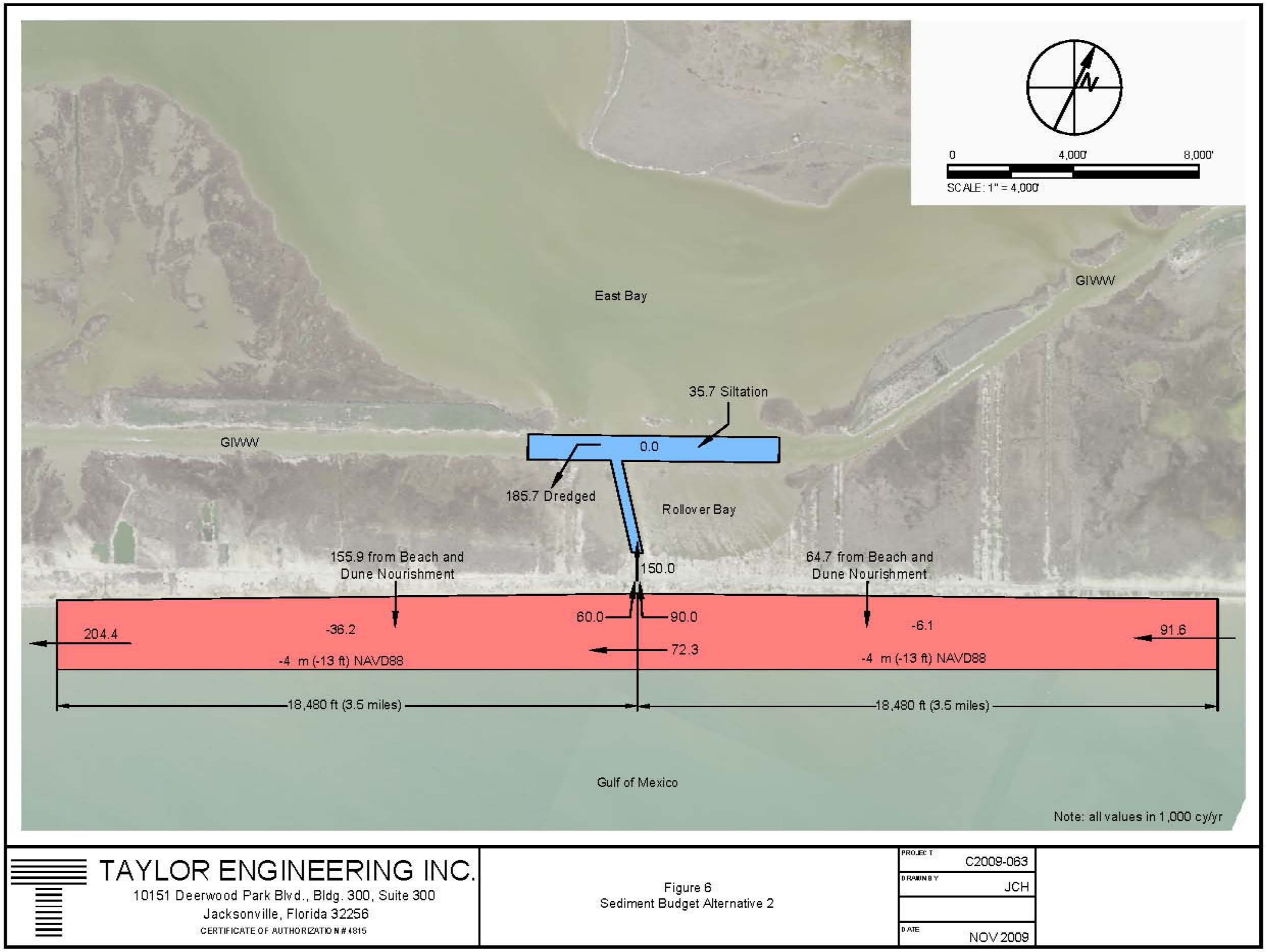

Figure 6 Sediment Budget Alternative 2

In summary, the sand transport rate into Rollover Pass remains debatable, but the sediment budget results suggest rates of 150,000 cy/yr or more are likely. Closing Rollover Pass would eliminate this sediment transport pathway and return the littoral system to a more natural state. In effect, the longshore transport will feed the beaches as naturally intended and alleviate the accelerated erosion rates caused by the Pass. Eliminating the sediment pathway into the Pass will also reduce deposition in the GIWW and Rollover Bay and help decrease the high dredging frequency currently required to maintain the GIWW. Additionally, future beach restoration projects, subject only to background erosion rates rather than the accelerated rates from the Pass, should perform more effectively.

4.0 CONCLUSION

This report cited numerous studies from 1958 to the present that indicate Rollover Pass causes erosion of the adjacent beaches and increases the frequency and, hence, costs to dredge the GIWW. Such adverse impacts arise primarily from the Pass' flood dominant characteristics that transport material from the natural littoral zone into the Pass interior. This report also developed an alternative 1999 – 2008 sediment budget that summarizes the beach volume changes and the sediment transport magnitudes and pathways, both natural and artificial, near Rollover Pass for the recent pre-Hurricane Ike period. The sediment budget alternatives suggest that a sediment transport rate of 150,000 cy/yr or more into Rollover Pass appears possible likely. Collectively, the results of this study justify closure of Rollover Pass to help reduce erosion of the adjacent beaches, reduce the required frequency and costs of GIWW maintenance dredging, and help improve the effectiveness of future beach restoration projects.

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