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RELOCATION OF CAPTAIN SAMS INLET — 20 YEARS LATER

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Abstract: Captain Sams Inlet was relocated 20 years ago in March 1983, specifically for erosion control and beach restoration along the downcoast shoreline. Situated between Kiawah and Seabrook Islands near Charleston, South Carolina (USA), the inlet had a history of southerly migration (toward Seabrook) at a rate of ~75 meters (m) per year. Channel migration and sediment trapping by the ebb-tidal delta had caused severe erosion along Seabrook Island. Upward of 3,000 m of downcoast shoreline had been armored with seawalls in the 1970s in response to erosion.

The inlet was relocated by land-based equipment. Earthmovers excavated a basin having similar dimensions as the inlet across Kiawah spit. The basin was left closed to tidal action until a scheduled breach by bulldozers. The new channel was then left to adjust naturally by currents and waves. The abandoned inlet was closed by pushing stockpiled sand across the old channel and building a dike above the normal limit of waves.

By closing the old channel, shoals in the abandoned delta were moved shoreward by waves through the process of shoal bypassing. Four years after relocation, a 2-kilometer-long beach accreted and largely buried a major section of the seawall. Upward of 600 cubic meters per meter (240 cubic yards per foot) accreted and formed a dry beach over 250 m wide.

In 1996, after a renewed cycle of channel migration, the new inlet had returned about 65 percent of the way to its former position. A second relocation was accomplished in April 1996. The relocation of Captain Sams Inlet resulted in the following:

1) Restoration of over 80 percent of the downcoast shoreline.
2) Accretion of ~1.5 million cubic meters along Seabrook Island.
3) Burial of the majority of the seawall.
4) Preservation of a broad conservation zone.
5) Protection of existing salt marsh and expansion of associated estuarine habitats in the sheltered areas created by each relocation.
6) Expansion of recreational beach area and dune habitat.

INTRODUCTION

Captain Sams Inlet, South Carolina (Fig 1) was one of the first inlets in the United States to be relocated specifically for erosion control and restoration of a downdrift beach. Unlike most harbor entrances, channel relocation, in this case, was not made permanent. No jetties were built, nor was maintenance dredging performed after relocation. Instead, the inlet was left to adjust naturally with only minor manipulation of accreting shoals. Inlet migration resumed after relocation and was allowed to continue for a period before the inlet was relocated a second time.

The present paper describes the outcome of two relocations of Captain Sams Inlet, spanning a 20-year period after the first project in 1983. It includes brief summaries of the construction process, morphological changes, environmental impacts, and beach volume changes. For more historical background and detailed analyses of hydraulics, inlet evolution and project planning,

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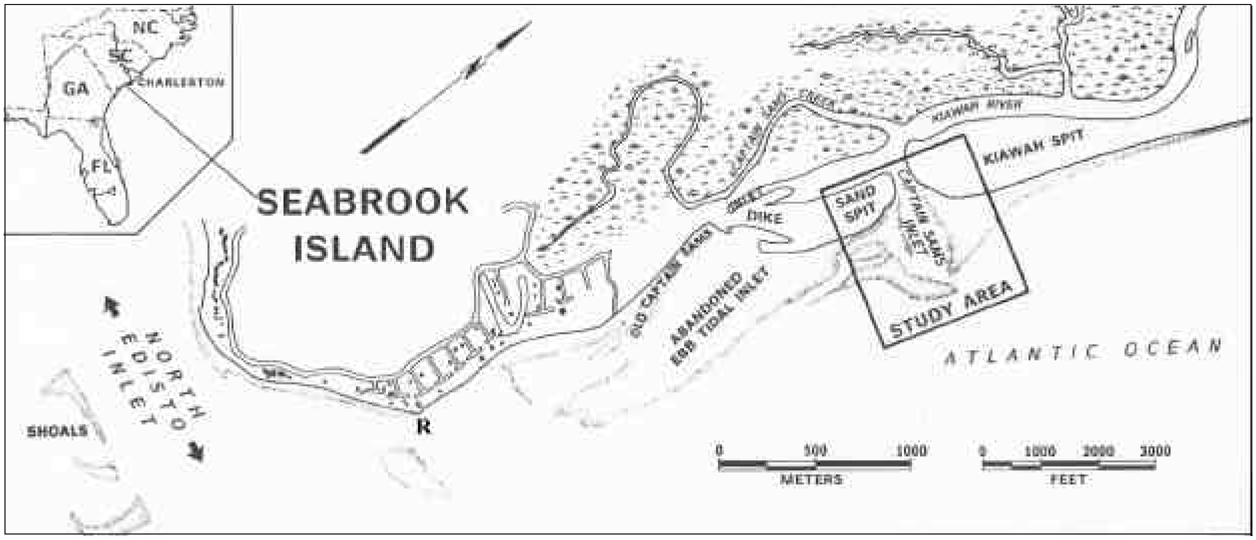


FIGURE 1. Shoreline setting for Seabrook Island (SC) and Captain Sams Inlet shortly after the first inlet relocation in March 1983. Shoreline south of point "R" is directly influenced by North Edisto Inlet.

see Hayes (1977), Hayes et al (1980), Sexton and Hayes (1982), Kana et al (1987), Kana and Mason (1988), and Kana (1989).

SETTING

Captain Sams Inlet is an unstable migrating inlet between stable, beach-ridge barrier islands (Kiawah and Seabrook) 30 kilometers (km) south of Charleston, South Carolina. Key inlet parameters are given in Table 1. The relatively large tide range in the area and gentle slopes along the margin produce widely varying high-water and low-water cross-sections.

Average incident waves are 60 centimeters (cm), spilling on a beach slope between 1 on 25 to 1 on 40. Net longshore transport is predominantly to the south at an estimated ~130,000 cubic meters per year (m^3/yr). The estuary drained by Captain Sams Inlet is marsh-filled with several tidal tributaries and negligible river discharge. Tidal prism is of the order 3.5 x 10^6 m^3 (Kana and Mason 1988), and mean throat cross-section (A_c) is approximately 210 square meters (m^2).

Sediments are unconsolidated sand averaging 0.2 to 0.25 millimeters (mm) mean diameter. The intertidal beach is generally hard-packed and driveable by heavy equipment. Equilibrium volume in the ebb-tidal delta has been estimated to be ~0.9 x 10^6 m^3 (Kana and Mason 1988).

TABLE 1. Captain Sams Inlet (Seabrook Island, South Carolina) parameters. Sources: NOAA-NOS, Hayes (1977), Kana and Mason (1988), Kana (1989).

Tidal prism	3.5 x 10^6 m^3		Net longshore transport (southerly)	~130,000 m^3/yr
MSL throat section (A_c)	210 m^2		Historical inlet migration rate (south)	~75 m/yr
Tide range: mean	1.6 m		Ebb-tidal delta volume	–0.9 x 10^6 m^3
Tide range: spring	2.2 m		Ebb-tidal delta area	~785 x 10^3 m^2
MHW throat cross-section	~460 m^2		Mean significant wave height	0.6 m
MLW throat cross-section	~140 m^2		Estimated depth of profile closure	–4.0 m

PLANNING

Relocation of Captain Sams Inlet as a means of erosion control along Seabrook Island was first conceived by Hayes et al (1980). Seabrook is barely 4 km long, strongly influenced by Captain Sams Inlet on its updrift end and by North Edisto Inlet along the downdrift end. The latter inlet is one of the largest on the U.S. coast with a delta volume of the order 120 x 10^6 m^3 (Imperato et al 1988). Its main ebb channel is positionally stable and incised in consolidated, older sediments. Early studies demonstrated that the closer the two inlets are, the more highly irregular Seabrook's shoreline becomes (Fig 2). Shoals associated with both inlets interrupt longshore transport, force marginal channels into the beach, and otherwise complicate maintenance of a stable dune system.

FIGURE 2. Seabrook Island in 1972 with the 1982 shoreline superimposed. Reaches A, B, C, and D are referenced in later graphs. The shoreline becomes increasingly irregular as Captain Sams Inlet (reach D) migrates toward North Edisto Inlet (reach A).

Poor development planning in the 1970s made little allowance for the wide shoreline fluctuations experienced along Seabrook Island. Lots platted in 1970 were lost or threatened by erosion only a few years later. This led many property owners to construct seawalls, the common shore protection method of the day. By 1982, nearly 80 percent of Seabrook's oceanfront was armored, including all of reach A, reach B, and portions of reach C (cf Fig 2). Channels as deep as 7 m [23 feet (ft)] encroached on the seawall along reaches A and B, and only ~1 km of high-tide beach remained on the Seabrook side of Captain Sams Inlet (reach C).

The plan for artificially relocating Captain Sams Inlet was modeled after its natural history of relocations. Prior to development in the area, Captain Sams Inlet would periodically breach the updrift spit, then resume its southerly migration (Hayes 1977). The most recent natural breach had occurred in 1948 at the head of the spit. Hayes et al (1980) believed that an artificial breach of the spit would accomplish two primary goals: (1) remove the immediate cause of erosion–inlet migration, and (2) free sand from the abandoned ebb-tidal delta to migrate onshore and nourish the sand-starved beach. A third outcome that proved to be exceedingly important, but was not recognized in early planning studies, was restoration of a straighter beach over which longshore transport could build momentum and shift sand downcoast more efficiently.

1983 – First Inlet Relocation

A plan for the first inlet relocation evolved between 1980 and 1982. By that time, a public access park had been developed at the head of Kiawah spit. Because of concerns over the impact to the park, the new inlet position was a compromise, roughly midway along the spit between Kiawah Island and Seabrook Island. Kana et al (1981) prepared a design that was modeled on the inlet's dimensions, orientation, and position in 1963. This represented a shift approximately 1,500 meters (m) updrift from its 1981 position and ~1,400 m downdrift of the park on Kiawah Island.

Original plans called for excavation of the new channel and closure of the existing channel by dredge. However, controversy and appeals of the construction permit compromised the plan to the point where dredging was not feasible. The amended permit of November 1982 restricted construction to a two-month window in January and February, and restricted sediment discharges to ebb tide-only periods. The latter restriction was directed at protecting the adjacent salt marsh from sedimentation. Permit restrictions made the original plan unworkable. Mr. Robert Cowan (director of maintenance for Seabrook Island Company, the project sponsor), suggested an alternative construction method–doing the entire project by land-based equipment. Cowan's innovations included:

- Excavation of a basin for the new channel in-the-dry. This would allow work to progress during the entire tidal cycle because there would be no sediment discharge below high water until the actual time of the breach.
- Elimination of the sediment slurry associated with dredging operations.
- Better control of channel and closure-dike sections working in-the-dry.

The first relocation was completed on 4 March 1983. The new inlet was breached on a falling tide on 23 February after the basin had been excavated to approximately 60 percent of its design section. Time restrictions on the permit prevented full excavation to design dimensions. A_c of the new channel was only 112 m^2 at the time of the breach. During the next week after the breach, several attempts at closure of the old channel were made on a falling tide. It became clear that excess sand should be stockpiled along the margins of the old channel to accomplish closure. The successful closure sequence involved pushing stockpiles into the 75-m-wide channel on a falling tide such that closure was accomplished before low tide. Then the closure dike had to be reinforced and raised ahead of the rising tide. This was found to be the most critical aspect of construction.

With the exception of some minor sand scraping along the downcoast beach immediately after the 1983 inlet relocation, the area was left to adjust naturally over the next four years in accordance with conditions in the 1982 permit.

Figure 3 illustrates the morphological changes around the inlet between 1983 and 1987. The major impact was onshore migration of the abandoned inlet shoals (ebb-tidal delta) and accretion of new beach ridges nearly 300 m seaward of the former shoreline. One troublesome outcome was formation of a new lagoon seaward of the closure dike. It drained across the newly accreted beach and interrupted downcoast transport of sediment. A favorable outcome, however, was expansion of beach and dune habitat (Table 2). The lagoon was transformed into a 10-hectare salt marsh within a decade of the project, portions of which remain viable and productive 20 years later (Fig 4). The rate of formation of new habitats was exceedingly rapid.

FIGURE 3. Morphological changes at Captain Sams Inlet after inlet relocation in March 1983. Views looking north at low tide. Slough (arrow) drained a new lagoon formed by accreting ridges.

TABLE 2. Habitat changes in the area between old and new Captain Sams Inlet after the March 1983 relocation (based on Baca and Lankford 1987).

Habitat Type	Total Area (hectares)		Net Change (1983-1987)	
	1983	1987	Hectares	Percentage
Original dunes	5.2	1.6	−3.6	−68
Closure dike (dune)	–	0.9	+0.9	+
New dunes (by accretion)	0.8	3.0	+2.2	+375
Washover terraces	1.8	1.0	−0.8	−44
New beach	–	10.3	+10.3	+
Intertidal bars	47.4	36.0	−11.4	−24
Subtidal (lagoon)	11.7	23.2	+11.5	+198
Totals	**66.9**	**76.0**	**+9.1**	**+12**

FIGURE 4. Captain Sams Inlet on 16 January 2003. Original floodway before the 1983 relocation is now a 10-hectare salt marsh (M). (D1) Remnant of 1983 closure dike. (D2) 1996 closure dike. (D3) 1998 outer dike.

North Edisto Inlet – Channel Realignment

While the first inlet relocation was gradually restoring portions of the downcoast beach, longshore transport was insufficient to force a marginal flood channel of North Edisto Inlet away from the seawall along the southern 1.5 km of Seabrook Island. By 1990, the 7-m-deep channel was encroaching on the seawall and threatening to cause catastrophic failure. A plan was developed by CSE (1989) to realign the marginal flood channel by dredge using sand from the adjacent shoal on the updrift side of the North Edisto Inlet ebb-tidal delta. In February 1990, ~500,000 m^3 were excavated from the shoal and placed at the toe of the exposed seawall. This had the effect of displacing the northern marginal flood channel 200 m seaward. Flows through the inlet were unchanged, according to plan.

CSE (1989) used historical data and profile surveys to demonstrate the cycle of beach changes along the downdrift portion of Seabrook's shoreline (Fig 5). The cycle of accretion and erosion was found to be related to the position of Captain Sams Inlet. In general, erosion along Seabrook's southern reaches accelerated as the inlet migrated downcoast. Accretion tended to occur when the inlet was in an updrift position. Using this cycle and experience from other nourishment projects, CSE (1989) developed an empirical model of sand volume changes for the downcoast half of Seabrook Island (Fig 6). The model predicted that two factors would control the profile volume change rate – longshore transport and fill adjustment/ spreading. Longshore transport was assumed to vary from ~10,000 to 40,000 m^3/yr and follow a "20-year" cycle linked to the time it takes Captain Sams Inlet to migrate between its 1963 and 1983 positions at the upcoast end of Seabrook Island. Fill adjustment and spreading to downcoast areas was expected to decline exponentially with an initial loss of about 20-25 percent of the fill in the first year and a loss of about 5 percent in the tenth year. When the two rates are combined, the expected ten-year cycle along Seabrook's downcoast shoreline was erosion for the first five years, then accretion the second half of the decade. Although the model is simplistic, it provided the community with an estimate of anticipated future changes along the beach.

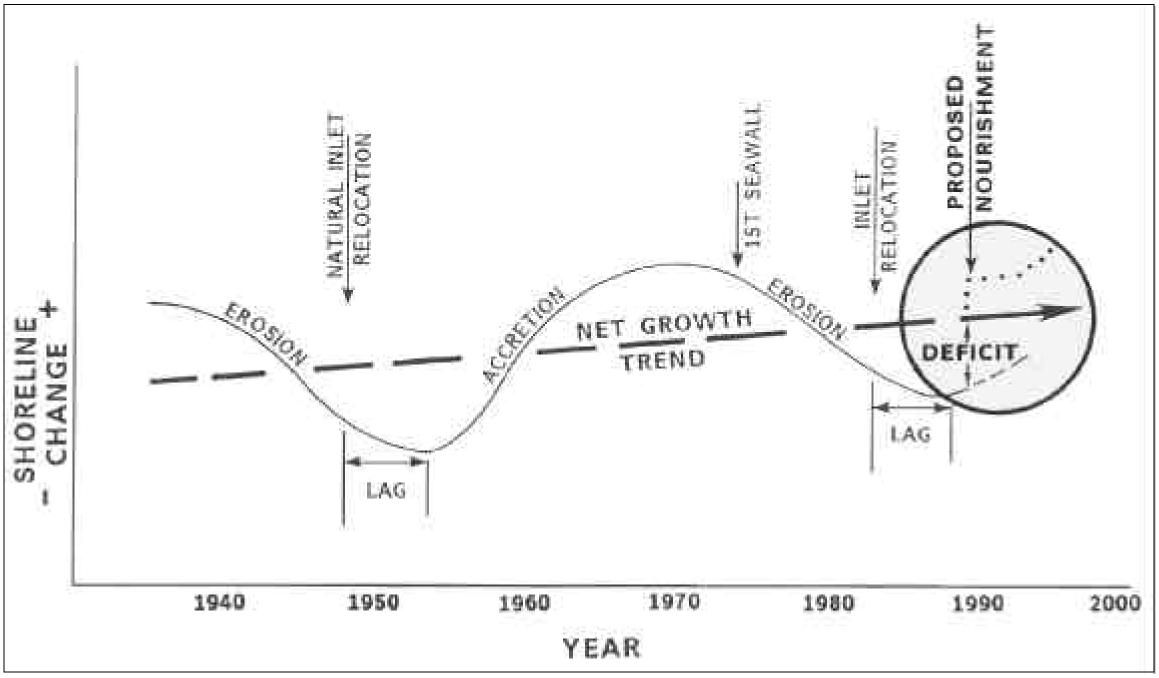
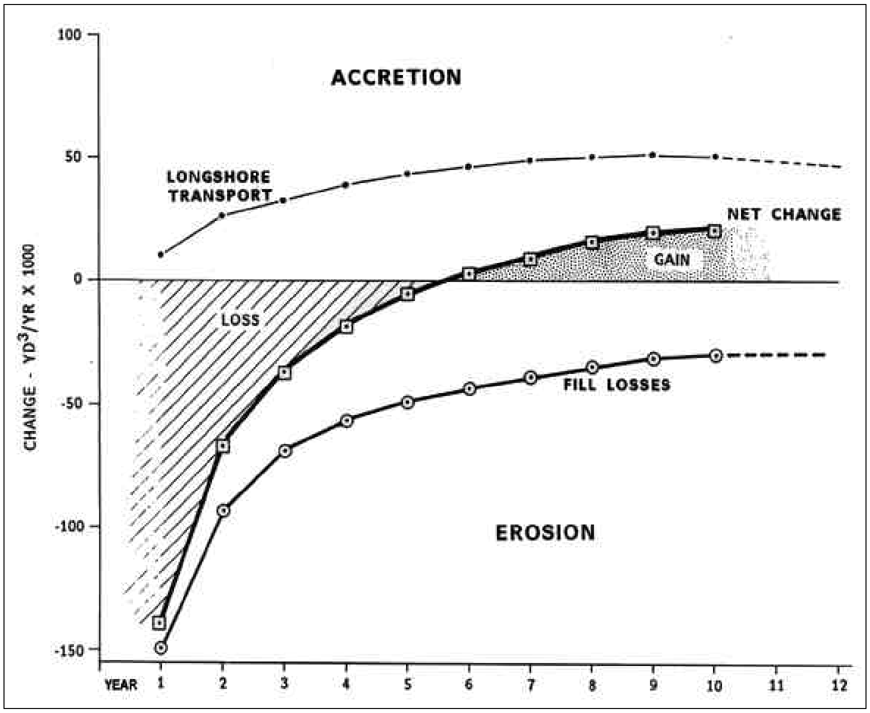


FIGURE 5. Cycle of shoreline change along the downcoast half of Seabrook Island based on historical shoreline analysis (CSE 1989). Net trend is accretion at century time scales. Accretion periods lag inlet relocations by about five years. A 1990 project (proposed nourishment) involved direct placement of sand from North Edisto Inlet, in an attempt to accelerate recovery of the beach.



Fill Erosion Rate ($\cancel{V}_t$) $\quad V_t = \cancel{V}_o t^{-a}$ (1)

where V_o = 150,000 yd^3/yr initial rate (20-25% losses) – Year 1
t = years
a = 0.7

Net Longshore Transport (Q_{in}) $\quad Q_{in} = Q_o + bt - c(t^2)$ (2)

where Q_o = 10,000 yd^3/yr (initial rate)
Q_{10} = 50,000 yd^3/yr (peak rate – Year 10)
b = 9,000 yd^3/yr (constant)
c = 500 yd^3/yr^2 (constant)

Constants based on historical trends for setting.

FIGURE 6. Predicted volumetric losses and gains along the southern half of Seabrook Island after realignment of the northern marginal flood channel of North Edisto Inlet. The model predicted a reversal from erosion to net accretion by Year 6. [From CSE 1989]
Note: 1 cy/yr = 0.765 m^3/yr

1996 – Second Inlet Relocation

Based on the outcome of the first inlet relocation, CSE (1995) recommended a second relocation of Captain Sams Inlet in 1996, 13 years after the first. The new inlet had migrated ~65 percent of the distance to its 1982 position by then. Recognizing that the proximity of the new inlet to North Edisto Inlet would generate increasingly irregular shoreline changes and eliminate an incipient marsh that had formed in the old floodway, the community authorized another recut.

Construction methodology was the same as the first relocation with the work performed by land-based equipment. The major difference with the 1996 project was subsequent reshaping of accreting ridges one to two years after inlet relocation. CSE (1995) recommended linkage of accreted bars and construction of an outer barrier spit about 150 m seaward of the closure dike. The barrier's alignment was based on the adjacent strand lines of Kiawah Island and Seabrook Island (see Fig 4). The outer dike would serve two purposes: (1) accelerate straightening of the new beach and resumption of longshore transport to the south and (2) shift drainage of an incipient lagoon (abandoned floodway) toward the new inlet and away from the oceanfront.

By the time of the second inlet relocation, Seabrook's northern reach had accumulated over one million cubic meters and grown seaward by over 300 m. Large portions of the seawall had become buried by new sand and set back hundreds of meters from the shoreline. With the extra shaping of "North Beach" in 1998 and 1999, the Seabrook community gained the longest and widest contiguous dry beach it had had since development began in the early 1970s. Figure 7 shows the area between 1997 and 2003 compared with 1983. A key difference between the first and second inlet relocation projects was extra reshaping of accreted bars after the 1996 recut. This speeded up straightening of the downdrift beach and accelerated longshore transport past point D.

Surveyed Changes

Detailed surveys have been conducted each year along Seabrook's beach for purposes of tracking changes, scheduling inlet relocations, and identifying critical conditions along the seawall. Five reaches are considered here (see Fig 2 for general locations):

Reach A – Downcoast ~1,500-m area along the marginal flood channel and main ebb channel of North Edisto Inlet.
Reach B – Next upcoast reach approximately 750 m long.
Reach C – Downcoast side of abandoned (old) Captain Sams Inlet.
Reach D – Upcoast side of old Captain Sams Inlet.
Reach E – Downcoast side of new Captain Sams Inlet (contiguous with and updrift of reach D, but not shown on Figure 2).

FIGURE 7. Oblique aerial photographs at low tide, looking updrift from Seabrook Island to Captain Sams Inlet and Kiawah Island. Point A marks the excavated inlet. Point B is the terminus of the original inlet. The area from Point C to Point D is armored. The reach downdrift of Point D (out of the photographs) is the margin of North Edisto Inlet, an adjacent littoral compartment.

Figures 8 and 9 show the 20-year trend in average (unit width) volume change by reach since the first inlet relocation in March 1983. Figure 8 gives unit-width volumes measured to low-tide wading depth (−1.5 m NGVD, the survey limit of earliest surveys) along reaches B, C, and D, and to the centerline of the northern channel (of North Edisto Inlet) along reach A. Figure 9 extrapolates the unit volume changes for reaches A-D. (E is omitted because it is in the immediate floodway of new Captain Sams Inlet.) Some highlights are as follows:

1) Combined, the projects have added at least 1.5 million cubic meters to Seabrook. (The total is conservative because computations do not include the entire profile volume to closure depth.)
2) The average unit-width profile gain since 1983 has been ~240 cy/ft (600 m^3/m), a volume about twice that of a typical large nourishment project.

As shown in Figure 8, profile volume changes by reach lag inlet relocations with distance. Reaches C and D (in the lee of old Captain Sams Inlet) gained sand before reach B. The volume change curves tend to flatten when a given reach achieves equilibrium. At that point in time, the reach has straightened and is bypassing sand more efficiently to the next downcoast compartment. Reach D exhibits the greatest rise and fall with present volumes matching those of 1982. While this may appear problematic, it is actually a favorable result because reach D (in the lee of old Captain Sams Inlet) was the only area with surplus volume before the first inlet relocation. To place the reach in context, its present shoreline remains over 500 m seaward of its 1972 shoreline (cf, Fig 2).

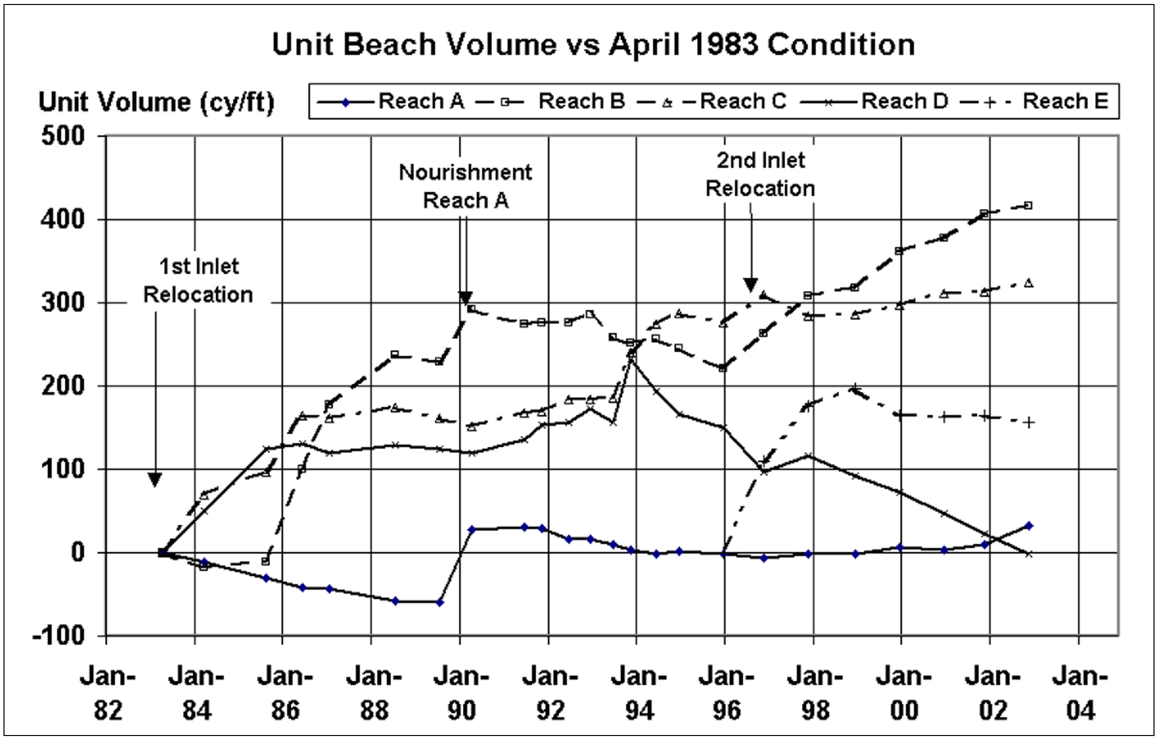


FIGURE 8. Average unit-volume profile changes by reach since inlet relocation (March 1983). Note: 1 cy/ft ≅ 2.5 m^3/m.

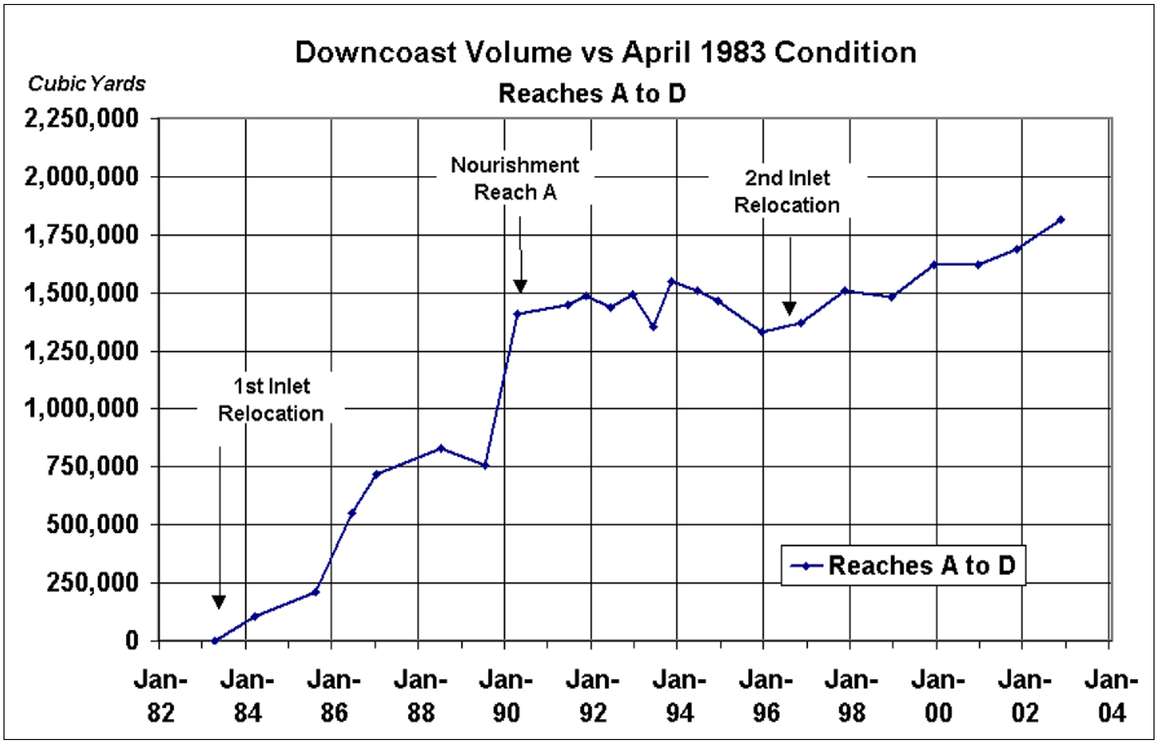


FIGURE 9. Net volume change along Seabrook Island since inlet relocation (March 1983). Note: 1 cy ≅ 0.76 m^3.

The impact of the 1990 northern channel realignment is seen in the sudden rise in volume in that year for reach A. The downcoast end of Seabrook has changed the least of all reaches in the past two decades. However, the effects of the second inlet relocation can be seen in Figure 8 with the jump in volumes after 1996.

Figure 10 compares the volume changes in reach A with CSE's (1989) predictions of fill erosion (cf Fig 6) after the 1990 realignment of the North Edisto Inlet marginal channel. The results show agreement in the rate and absolute volume lost over the first five years after the project. The timing of recovery is also correctly predicted around 1995-1996. However, since 1996 (second inlet relocation), longshore transport has accelerated beyond the predicted peak rate of ~40,000 m^3/yr into reach A. This is an indication that there is finally (after 20 years) sufficient sand moving along Seabrook's beach to overwhelm the northern marginal flood channel of North Edisto Inlet, force it away from the shoreline, and restore the last segment of dry beach.

It is estimated that the total expenditures for seawalls (including repairs) along Seabrook Island (1974-1998) has been US$6 million. The cost of two inlet relocations by land-based equipment, one channel realignment by dredge, and 20 years of engineering, permitting, and surveying has cost the community approximately US$3 million.

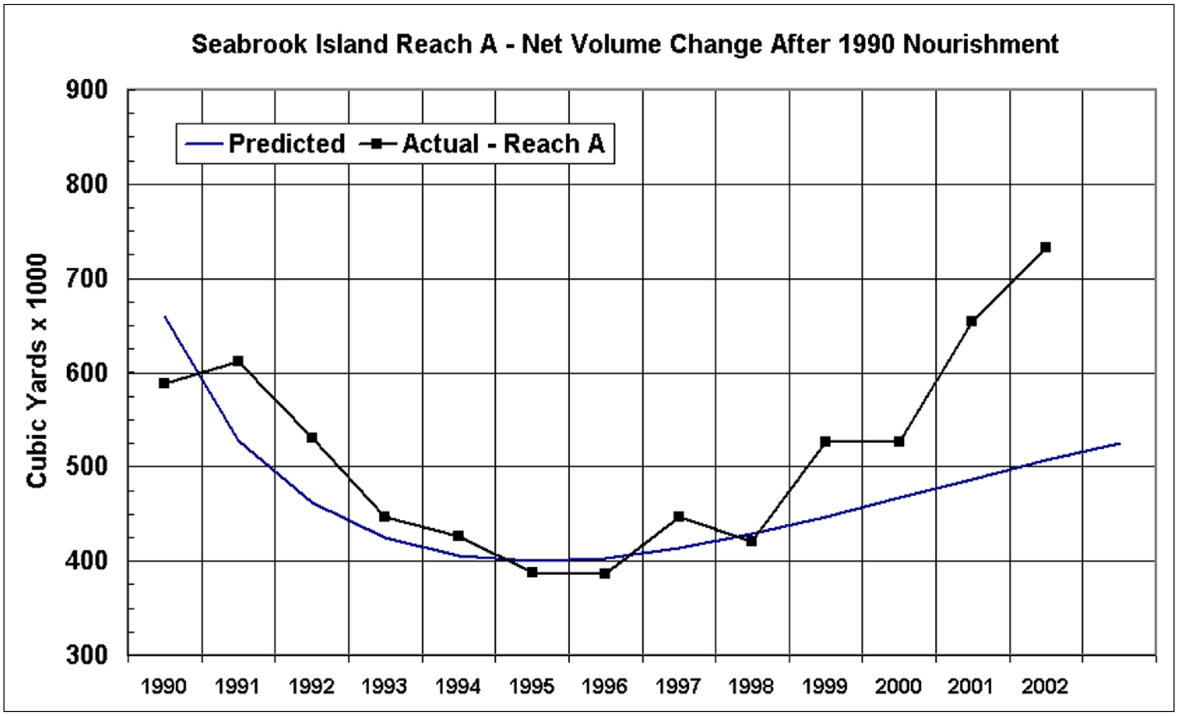


FIGURE 10. Projected versus actual volume changes along reach A following the 1990 realignment of the northern channel of North Edisto Inlet and 1996 (second) relocation of Captain Sams Inlet (cf Fig 6).

Acknowledgments

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KEY WORDS:

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