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Identification of and Remedial Approaches to Hot Spots

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PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) provides information about the suspected causes and remedial approaches that have been applied to erosion hot spots on several recent beach nourishment projects. These diverse examples form the basis for general identification and steps that can be taken to mitigate for and anticipate the development of hot spots on beach nourishment shore protection and environmental restoration projects.

BACKGROUND: Beach nourishment is an important component in urban flood and storm damage reduction. Impact of coastal storms and nonuniform performance of beach fill-projects can result in expenditure of considerable operations and maintenance and emergency operations resources to restore these projects to their design level in the interval between planned renourishments. Engineering guidance and analysis procedures are needed to anticipate the development of hot spots in the project design phase, identify hot spots after project construction and provide techniques to mitigate for the increased vulnerability to storm erosion and damages that may occur at these hot spot areas, particularly in urban coastal settings with a dense infrastructure of upland development.

DEFINITION OF HOT SPOTS: Hot spots have previously been defined as follows:

a. An area that erodes more rapidly than anticipated during design or more rapidly than adjacent portions of beach (Dean et al. 1999).

b. Regions of higher erosion relative to rest of project and/or regions where design expectations were not met (Bodge et al. 1999).

c. Areas having a high erosion rate as compared to the adjacent beach (Kraus and Galgano 2001).

For this Technical Note a “hot spot” is defined as an area of beach experiencing higher erosion than adjacent beaches. Hot spots are found along beach nourishment projects as well as coasts not altered by engineering activities. In general, hot spots can be identified by shoreline position change (shoreline is displaced landward in hot spot), sediment volume change (loss of sediment volume in hot spot area profile), and/or percent of fill remaining after some time interval post-placement (less fill remaining on active profile in the hot spot area). Hot spots may or may not be recognized on a non-nourished eroding beach, due to the lack of significant dry beach widths. When a sufficient quantity of beach nourishment sand is placed on a beach, the hot spot becomes apparent as the beach readjusts toward the equilibrium profile. The shoreline in the area of the hot spot will usually be further landward than the adjacent shoreline and the volume of sand remaining within the profile will be less than adjacent areas. Information typically available to the coastal engineer to identify and document hot spots include aerial photography, shoreline rate of change data, beach profiles from which beach volume change can be computed, and anecdotal information.

As a corollary to the hot spot, a "cold spot" may form some distance up- or down-coast, where there is more accretion than the adjacent beach. This signal may be present in the seaward movement of the shoreline, or an increase in volume of sand on the profile above adjacent areas, or a gain in sand above the amount placed as fill. The presence of hot and cold spots may indicate three-dimensional (3-D) redistribution of sediment along the coast, where sand is removed from the hot spots and is deposited in the cold spots. This differential erosion and accretion along the coast may result in increased vulnerability to erosion during storms at the areas of hot spots and in some cases may result in problems of too much sand in the areas of cold spots.

Federal beach nourishment project design includes a planned renourishment interval when additional sand is placed on the beach to maintain the design profile and provide the level of protection required. In cases where hot spots are present, the level of protection might be compromised. The hot spot area is presumed to require additional fill or other remedial action to protect the upland property in a shorter time frame than the planned renourishment.

SUSPECTED CAUSES OF HOT SPOTS: In order to understand how to anticipate and mitigate for hot spots, an understanding of the causes and types of erosional hot spots is needed. Dean et al. (1999) first identified 12 types of hot spots and their causes. These are identified in Table 1. Kraus and Galgano (2001) modified these 12 types and added six additional hot spot types as seen in Table 1. Bodge et al. (1999) presented another list of eight basic hot spot types and causes (Table 2). These 26 types of hot spots cover all types of coastal erosion and have various causes.

Table 1
Hot Spot Type Identification I

No.	Type	Cause
1-12 from Dean et al. (1999) modified by Kraus and Galgano (2001)		
1	Dredge selectivity	Variable grain size alongshore placement
2	Pre-existing structure induced slope	i.e., groin, jetty
3	Wave transformation over borrow pit	Wave refraction, focusing
4	Gap in bar	Wave focusing
5	Differential volume of placed fill	Insufficient volume placed to develop equilibrium profile
6	Profile lowering in front of seawall	Wave reflection induced scour
7	Headlands and embayments	Shoreline orientation change
8	Residual fill bathymetry	Uneven fill profile influence on wave refraction
9	Permanent offshore loss	Fill loss through gap in reef or submarine canyon
10	Offshore translation of fill profile	Wave focusing due to irregular translation of fill in offshore direction creating irregular nearshore bathymetric contours
11	Nearshore bathymetry variation	Wave focusing due to irregular nearshore bed
12	Borrow pit located in active profile	Sand moves to fill pit, wave refraction
13-18 from Kraus and Galgano (2001)		
13	Updrift barrier	Blockage of longshore transport
14	Relict inlet offset	Relict (former) ebb and flood shoal bathymetry
15	Transitory longshore sand wave	Excess slug of sand moving alongshore
16	Standing or random sand wave	Seasonal or random sediment supply
17	Isolation of beach from sand source	Change in sediment budget
18	Rip currents on open beach or adjacent to groins/jetties	Move sand seaward

Table 2
Hot Spot Identification II (from Bodge, Gravens, and Srinivas 1999)

No.	Type	Cause
1	Wave focusing	Offshore/nearshore bathymetry; shoreline orientation.
2	Shoreline orientation	Abrupt change in orientation; headlands; Shoreline declination relative to dominant wave angle.
3	Encroachment	Upland development near, at, or seaward of historic natural beach, may require fill further seaward to provide protection.
4	Offshore sinks (canyons, relict borrow areas, rips etc.)	Loss to beach system.
5	Sediment starvation	Block longshore drift (i.e., jetty, groin, seawall, etc.).
6	Design deficiencies or irregularities in prior beach fill	Placement of less than required fill density; irregular fill planform.
7	Taper and end effects	End loss high due to less fill and taper angle.
8	Rhythmic topography, irregular nearshore hardbottoms	Cyclical variation; erosion waves pass through project.

An interaction of coastal processes with coastal morphology leads to the cause of erosion hot spots. The causes listed in the Tables 1 and 2 can be summarized into the following

a. Coastal processes (waves, currents and longshore drift).

b. Geologic controls (underlying geology; hardbottoms including reefs or beachrock; morphology such as headlands or embayments; and bathymetry for example shoals, canyons or channels).

c. Inlet processes (sand bypassing, ebb and flood shoal evolutions, and channel migration).

d. Anthropogenic activity (structures including seawalls, groins/jetties, breakwaters; dredging of channels and borrow areas; upland construction practices; and fill placement).

e. Combinations of *a-d* (wave focusing – refraction over bathymetric feature and/or shoreline orientation – abrupt change due to underlying geology).

f. Enchroachment on the shoreline (development seaward of the historic shoreline or on ephemeral accreted lands).

A series of case studies of hot spots associated with either proposed or constructed beach nourishment projects are examined in an effort to identify the most frequently occurring types of hot spots and to characterize the processes known or suspected to be responsible for their formation.

CASE STUDIES OF PROJECT HOT SPOTS: Twenty-nine participants attended a workshop held in Baltimore, MD, on 19-20 March 2003 from the Atlantic, Gulf of Mexico, Pacific, and Great Lakes Coastal Districts, Divisions, Headquarters, and the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). The purpose of the workshop was to discuss field experiences related to project vulnerabilities resulting from the formation of hot spots and other post-storm erosion conditions on recent beach nourishment projects. Workshop presentations included: (a) how hot spots were identified, (b) what remedial actions were taken, and (c) realized project vulnerabilities. Nine District Offices presented case studies and 20 proposed or recently constructed nourishment projects were discussed. These case studies cover a wide geographic area of the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean and include:

- U.S. Army Engineer District, New York – Coney Island, NY
  – Sea Bright, NJ (3 hot spots)
- U.S. Army Engineer District, Philadelphia – Ocean City, NJ
- U.S. Army Engineer District, Baltimore – Ocean City, MD (5 hot spots)
- U.S. Army Engineer District, Wilmington – 7 projects w/hot spots
- U.S. Army Engineer District, Charleston – Myrtle Beach, SC
  – Folly Beach, SC (3 hot spots)
- U.S. Army Engineer District, Savannah – Tybee Island, GA
- U.S. Army Engineer District, Jacksonville – Dade County, FL (5 hot spots)
- U.S. Army Engineer District, Mobile – Panama City, FL
  – Perdido Key, AL
- U.S. Army Engineer District, Los Angeles – Surfside CA
  – Seal Beach, CA
  – Peninsula Beach, CA

Figure 1 shows the location of the projects on the Atlantic and Gulf of Mexico coasts. The California project locations are shown in a later figure. A short summary of each project follows with (a) an identification of the hot spot problem(s), (b) type of hot spot and probable cause if known, (c) remedial action taken, and (d) vulnerabilities.

Coney Island, NY. Coney Island, the westernmost barrier island on Long Island had its first beach nourishment in 1922-23. The latest U.S. Army Corps of Engineers project placed approximately 1.8 million cu m (2.3 million cu yd) of sand along 5.6 km (3.5 miles) of the beach between June 1994 and January 1995 (Bocamazo and Rahoy 1999). A hot spot developed west of the terminal groin at West 37th Street, at Sea Gate, which is downdrift from the project. Net drift is to the west along this coast. Figure 2 shows the location of the hot spot. Rapid erosion of the Sea Gate fillet was anticipated on the downdrift side of the terminal groin through numerical shoreline change modeling using GENESIS and the hot spot development was identified through profile and air photo analysis. Wave focusing by the East Bank Shoals and interruption of longshore transport by the terminal groin has contributed to the Sea Gate hot spot. Within 2 years of fill placement the hot spot was pronounced (Figure 3). Nearshore wave transformation modeling together with shoreline change modeling provided an indication of rapid sand loss from the Sea Gate fillet. The loss of sand from the Sea Gate beach is most likely from episodic storm events, with no post-storm recovery. Mitigation was performed by trucking approximately 22,938 cu m (30,000 cu yd) of sand from east of the terminal groin and placing it immediately west of the groin. A plan for stabilization through compartmentalization using T-head groin structures is being developed for a long-term solution at the Sea Gate hot spot. A 10-year renourishment schedule is planned with annual fill monitoring.

Sea Bright to Manasquan Inlet, NJ. Construction of the Sea Bright to Manasquan Inlet, NJ, fill project was initiated in June 1994. The project extends 33.8 km (21 miles) from just south of the Gateway National Seashore (Sandy Hook) area in northern New Jersey to Manasquan Inlet. Net drift in this area is to the north. To date, 27 km (17 miles) have been constructed and 37 km (23 miles) are

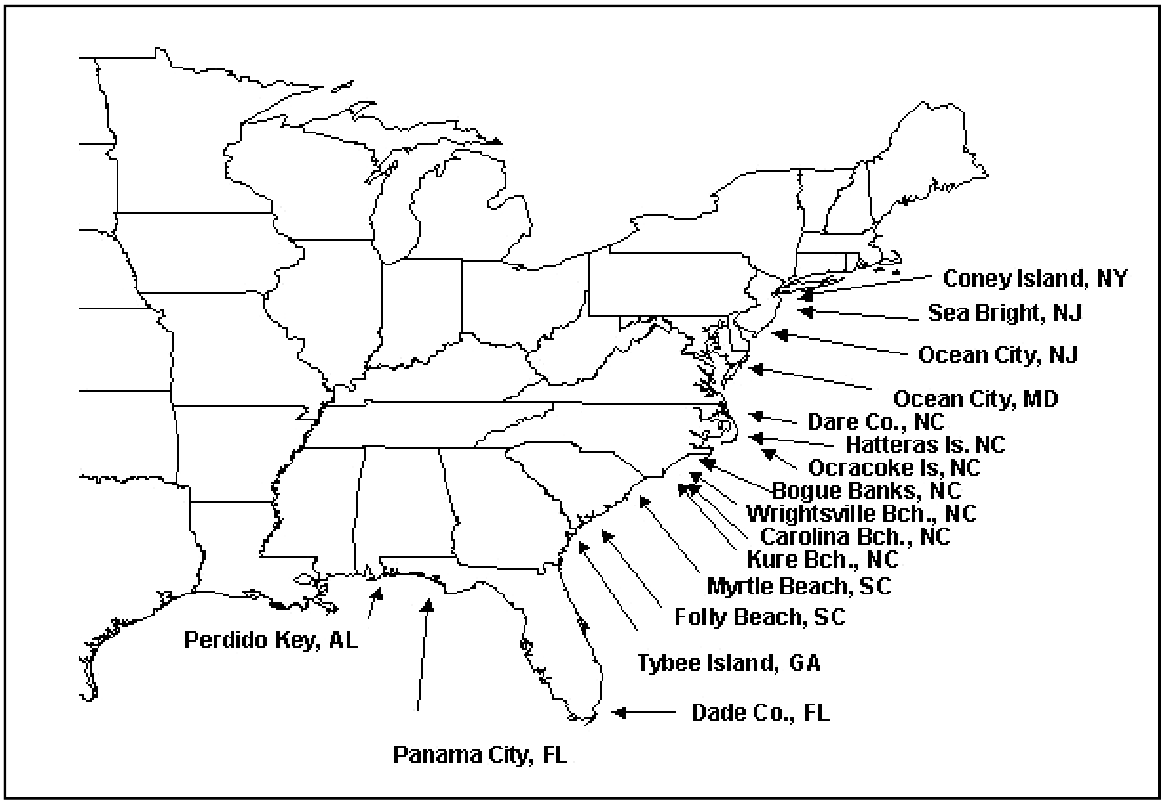

Figure 1. Location of beach-fill project hot spots discussed in paper

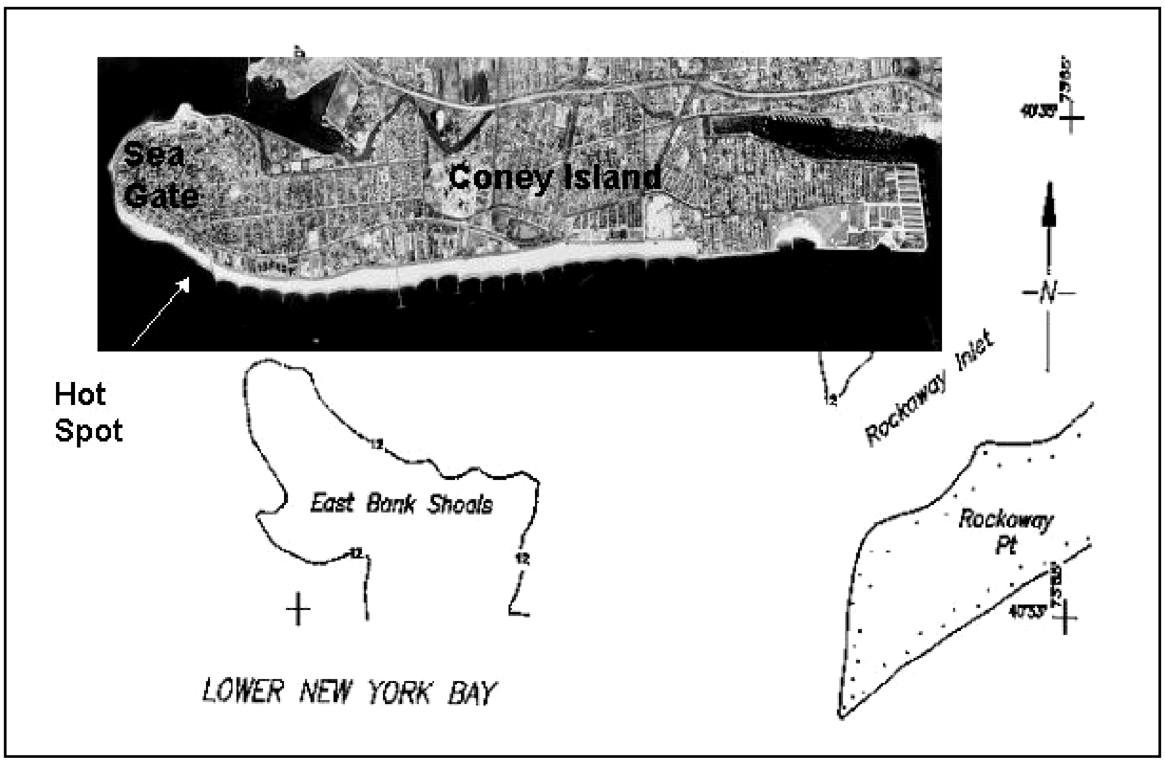

Figure 2. Coney Island, NY hot spot location

Figure 3. Post-fill March 1995 and 2 years later April 1997 at Sea Gate hot spot

being monitored. The project is divided into two sections with Section I extending from Sea Bright to Ocean Township (Loch Arbour) and Section II extending from Asbury Park to Manasquan. Section I has four reaches, one of which has not been constructed yet and Section II has two reaches (Table 3). Figure 4 shows the complex sequence of construction and the location of the project's three hot spots: (a) at Monmouth Beach, (b) at Spring Lake, and (c) the south end of the Sandy Hook spit at Sea Bright.

Table 3
Construction Data for Sea Bright to Manasquan Inlet Beach Nourishment Project

Contract	Contract Award	Beach Fill Complete	Fill Qty cu m	Fill Qty cu yd
Section I: Sea Bright to Ocean Township				
1A (Monmouth)	January 1994	December 1995	3.5 million	4.6 million
1B (Sea Bright)	July 1995	November 1996	2.9 million	3.8 million
2 (Long Branch)	May 1997	December 1998	3.3 million	4.3 million
3 (Deal)	TBD	November 2003 (est)	3.8 million	5.0 million (est)
Section II: Asbury Park to Manasquan				
1 (South Reach)	June 1997	October 1997	3.1 million	4.1 million
2 (North Reach)	June 1999	June 2000	2.4 million	3.1 million
Renourishment	August 2001	November 2002	1.7 million	2.24 million

Hot spot 1 at Monmouth Beach was located at the southern boundary of the first contract reach and covered a 793-m (2,600-ft) section of contract area. The initial fill was placed in November 1994 with 396,827 cu m (519,000 cu yd) placed. To mitigate for the erosion experienced at this hot spot, a second placement occurred in November 1995 with 175,858 cu m (230,000 cu yd) placed. A third placement was needed in May 1998 with 431,234 cu m (564,000 cu yd) of fill placed. Through monitoring and analysis it was determined that the cause was seaward perturbation of the beach due to encroachment of the upland structures onto the beach and the design requirement of a uniform

30-m (100-ft) berm width (Figure 5). This area was also at the southern end of Reach 1A and end losses were suspected as a contributor to loss of fill material. This hot spot was resolved with the addition of fill to the south with placement in the next Reach 2 making the beach planform more uniform along the entire reach and the new fill provided an updrift source of sand for the hot spot (net drift is north along this part of the New Jersey coast). The hot spot area was again renourished in September and October 2002 as planned and will continue to be monitored to assess the behavior of this hot spot.

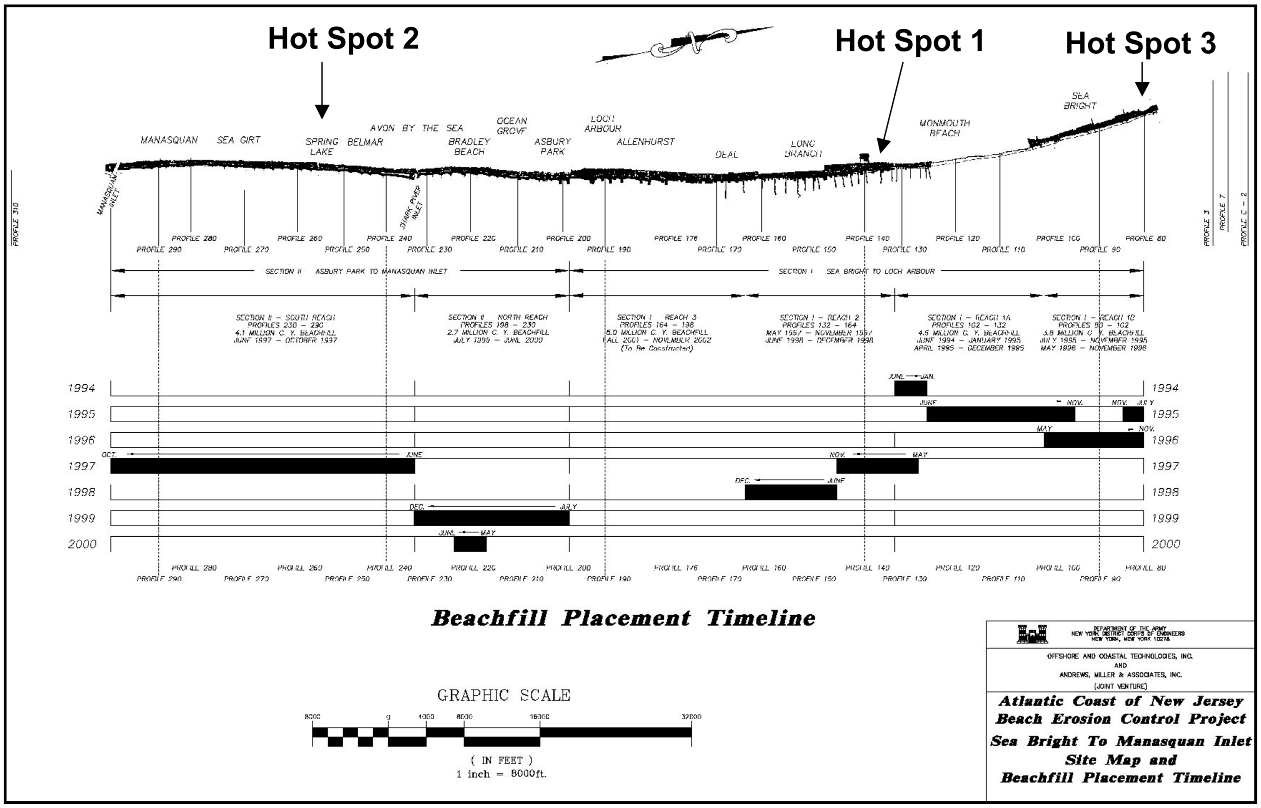

Figure 4. Construction sequence of the Sea Bright New Jersey project (courtesy of Lynn Bocamazo, New York District)

The second hot spot at Spring Lake was located within a groin compartment along a stretch of beach with a groin field. Initial fill was placed between April and October 1997. A visible difference in erosion rates was noticed by the following spring, 610 m (2,000 ft) north of groin 143. To investigate the hot spot, beach profiles and sediment monitoring were increased in this area, and numerical modeling of surf zone hydrodynamics conducted. Construction details were reviewed and a change from one borrow area to another was noted during construction in this area. The wave climate and storm history was also examined for the period after fill placement. The groin length/spacing ratio was examined and groin notching was considered as an alternative to enhance longshore transport and restore the flow of sediments between groin compartments. A determination of causes indicated that the cross-shore adjustment started immediately after fill placement. The average grain size in the erosive hot spot area was smaller than in groin compartments to the south due to the change in borrow areas. Groin 143 should have been notched, because it was trapping too much material.

Figure 5. Hot spot locations of Sea Bright to Manasquan Inlet Project (courtesy of Lynn Bocamazo, New York District)

Groin 141 was determined to be too short and was not retaining enough material. There was also an anomaly in the bathymetric contours offshore of the eroding area, which lead to higher energy dissipation in the center of the eroding groin cell hot spot area. To remedy the hot spot, several alternatives were proposed, but the State of New Jersey wanted the least effort alternative. This consisted of placing 174,329 cu m (228,000 cu yd) of coarser fill material in the hot spot area north of groin 143 in July 2002 and notching the groin in the fall of 2002 (Figure 5). No conclusions have been reached yet on how well notching and larger grain size material is working to remedy the hot spot.

The third hot spot related to this project was located at the northern end of the town of Sea Bright just at the boundary with the Gateway national recreation area at the base of Sandy Hook. This part of the project was initially filled between July and November 1995 and again between May and November 1996. This area is the north end of the entire project. Monitoring profiles were examined but no additional investigations were carried out. Monitoring data indicated that the fill material is drifting north out of the fill limit into the recreation area (Figure 5). Renourishment material was placed in this area to mitigate for the hot spot in September 2002. No conclusion has been made at this time on the success of this renourishment and monitoring will continue.

Ocean City, NJ. The Great Egg Harbor Inlet and Pecks Beach Shore protection project is located on the northern end of Pecks Beach, a barrier island along the southern New Jersey Atlantic coast. The town of Ocean City occupies the island and the project extends from the Great Egg Harbor Inlet shore at Seaview Road on the north to 36th Street on the south. The State of New Jersey has placed beach fill on the rest of the island's beaches south to 59th Street. Net drift is from north to south. A beach nourishment project was first constructed in 1952 and renourishments have been performed by both Federal and local efforts since that time. The latest Federal project was initiated with Phase I in 1992, with the latest renourishment in 2000. A hot spot developed between 5th and 9th Streets in the center of the downtown urban area (Figure 6). Pecks Beach is a drumstick barrier island (Hayes 1979) and the hot spot area corresponds with the widest part of the island. It is just downdrift of the ebb shoal attachment point. The borrow area is located on the southwest corner of the ebb shoal within about 2,438 m (8,000 ft) of the beach. Typical of drumstick barriers, a local drift reversal is present most likely caused by wave refraction over the ebb shoal and resulting in net longshore drift to the northeast into the inlet from the hot spot area (as well as southwest on the downdrift side of the hot spot). The close proximity of the borrow area to the shore may also have affected the ability of the inlet to naturally bypass material that previously maintained the bulbous morphology at this end of the island.

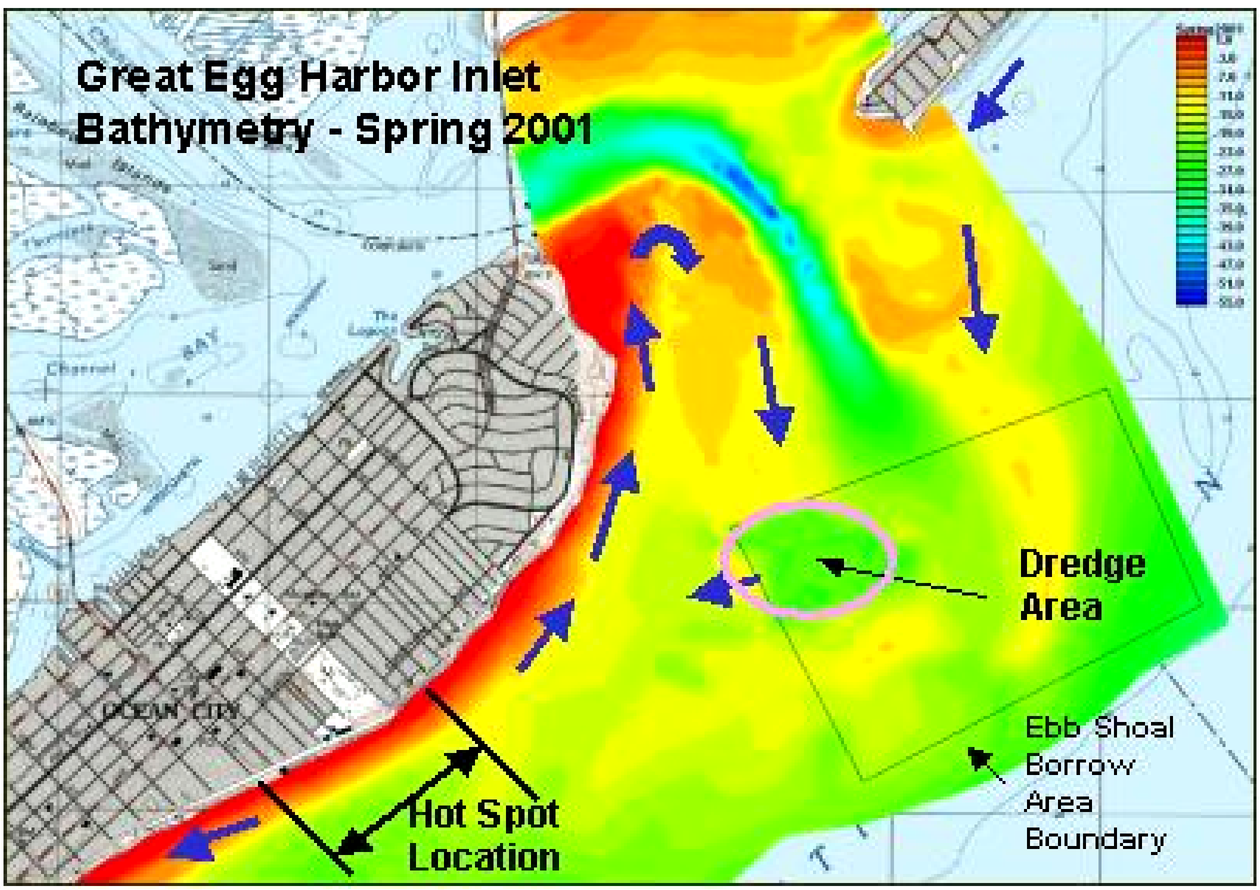

Figure 6. Location of hot spot area, designated borrow area with dredged area on western edge and suspected longshore circulation at Great Egg Harbor Inlet, NJ (courtesy of Monica Chasten and Rob Lowinski, Philadelphia District)

Remedial actions taken include overfilling of the hot spot area in the 1995 and 1997 fills. Scarps formed on the beach as the sand readjusted after fill placement. The design template was redesigned with a lower design berm from 2.67 to 2.21 m (8.75 to 7.25 ft) North American Vertical Datum (NAVD) and a small dune feature was added to the profile for storm protection in the hot spot area only (Figure 7). A new renourishment will take place in the fall of 2003 focusing on the beach area around the hot spot. Other possible remedial actions could be to modify the borrow area dredging location to move it further offshore within the borrow area and to dredge the Ocean City side of the Great Egg Harbor Inlet navigation channel, which is migrating northeast (updrift direction) and narrowing as inlet circulation evolves. No damage to upland structures or boardwalk has occurred since the 1992 nourishment project construction.

Figure 7. View of Ocean City, NJ, hot spot area during initial fill placement (May 1992) and in July 2003 showing constructed dune and berm after 11 years and five renourishments

Ocean City, MD. The Atlantic Coast of Maryland (Ocean City) Shoreline Protection project began in 1988 with the State of Maryland placing an 13.7-km- (8.5-mile-) long recreational beach on the shorefront of the town of Ocean City, MD, located on the Delmarva Peninsula. A Federal project followed in 1990/1991 with the construction of a seawall and dune behind a design fill berm for storm protection. Two rehabilitation fills were required in 1992 and 1994 to bring the project up to design specifications. Three additional backpassing events occurred in 1992, 1993, and 1994 that involved truck hauling sand from the inlet beach to mitigate for hot spot erosion. Two planned renourishments have taken place in 1998 and 2002. Monitoring included operation of wave gauges, which documented more than 66 storms that had wave heights over 2 m (6.6 ft) high for 6 hr, that impacted the project over a 10-year period (1988-1998). An additional 24 storms have impacted the project since the first renourishment (1998-2002).

The project developed five unanticipated hot spots at 15th, 32nd, 52nd, 81st, and 146th Streets (Figure 8). These hot spots were identified by analysis of beach profile data using shoreline position and fill volume change and percent of fill remaining analysis (Stauble and Kraus 1993; Stauble 1994; Stauble and Bass 1999) and wave refraction studies (Smith and Ebersole 1997). The 15th Street hot spot is identified as an orientation change in the shoreline from northwest to a more northward facing shoreline. Extra fill was placed during renourishment and as more sand was placed

Figure 8. Location of the five hot spots along Atlantic coast of Maryland (Ocean City) Shoreline Protection project (Stauble and Bass 1999)

with each renourishment this hot spot area lost less sand volume. The 32nd Street hot spot was caused by a seaward encroachment of the upland property onto the beach requiring fill to be placed seaward of the adjacent beaches to maintain the design requirement of a uniform fill template. As more sand was retained on the profile with each successive fill this hot spot area has also become less of a problem. The hot spots at 52nd and 81st Streets are suspected to be a function of wave focusing at the landward end of two shore-attached shoals. End loss at the northern terminal end of the project at 146th Street is the location of the final hot spot. Overfilling the hot spot areas and back passing sand by truck from the inlet area have been the remedial steps taken. These areas have required 49 percent of the total fill volume placed. Sand eroded from these hot spots has been deposited in a series of "cold spots" where excess sand volume was measured above the fill volume placed and the shoreline is consistently seaward of the adjacent areas (Figure 9). These cold spots suggest a complex 3-D sediment transport mechanism between the hot and cold spots. Even with the high frequency of storms, there has been no upland structure damage since the project inception in 1988. The fill volume requirements have also decreased over time with the renourishment now focused only in the hot spot areas.

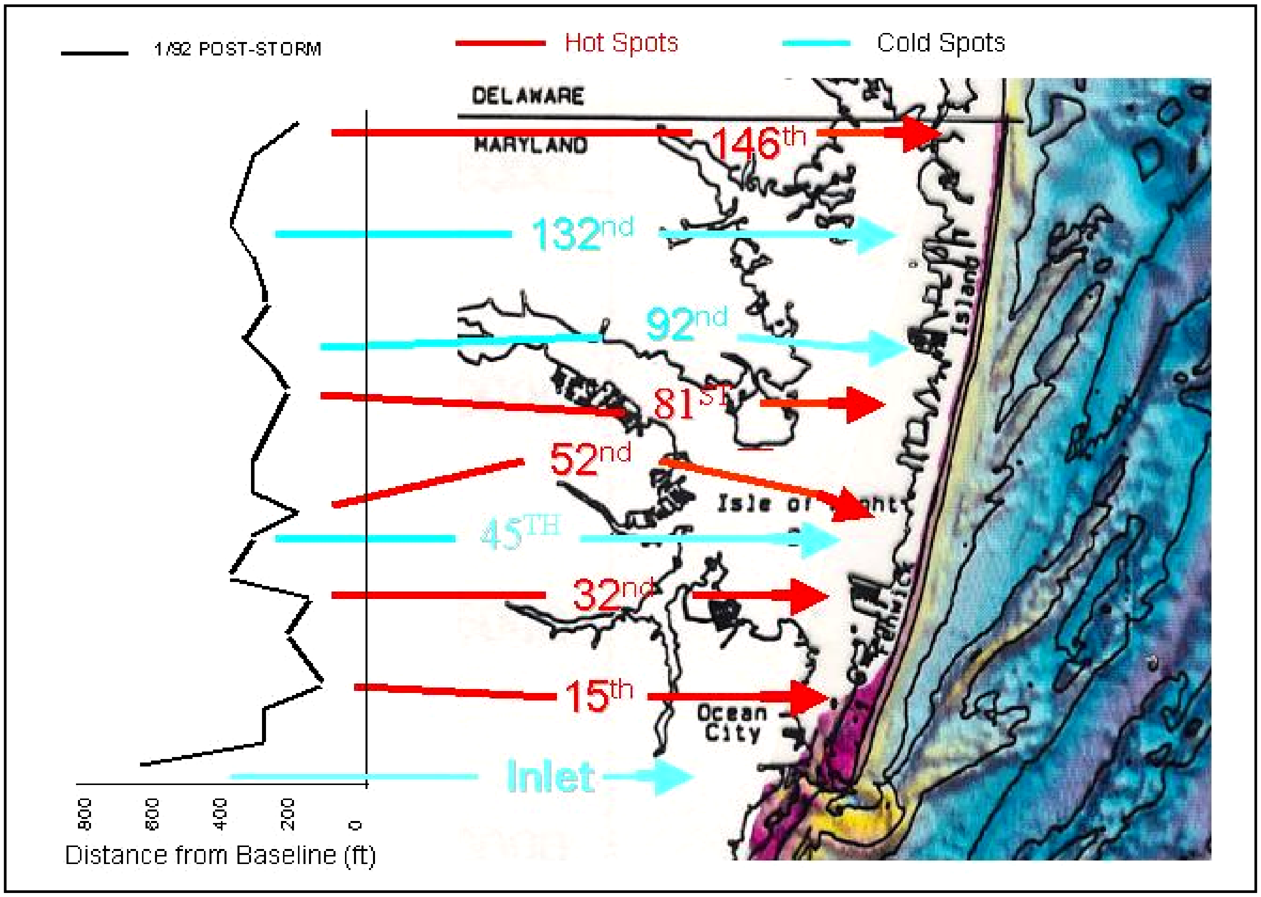

Figure 9. Plot of shoreline change after 1993 storm relative to 1991/1992 fill placement and location of hot (red) and cold (blue) spots relative to nearshore bathymetry of Ocean City, MD (Stauble and Bass 1999)

North Carolina Projects. There are four beach nourishment or inlet navigation dredged material disposal projects that have hot spots along the North Carolina coast, and two proposed project areas that have known existing hot spot locations. The four constructed projects are located in the central and southern part of the coast. Net drift is from north to south and east to west depending on the shoreline orientation along this cuspate shoreline.

The Bogue Banks area, located about 16 km (10 miles) west of Cape Lookout, has a program that places some sand dredged from the navigation channel at Beaufort Inlet and Morehead City Harbor onto the beach about every 4 years at Fort Macon State Park and Atlantic Beach west of the inlet. A beach-fill project for Bogue Banks is presently in the feasibility study phase. Shoreline change studies indicate a hot spot along the Fort Macon and Atlantic Beach shoreline close to the inlet and at Pine Knoll Shores (Figure 10a). It is suspected that erosion in the Fort Macon area is related to the wave refraction over the ebb shoal and a drift reversal into the inlet resulting in local shoreline erosion. Further study is needed to verify if this is a hot spot and its cause. Another area of erosion is indicated some 6,096 m (20,000 ft) to the west in Pine Knoll Shores. Little study has been done, so a cause is undetermined at this time.

Figure 10. Hot spot location at four projects along the North Carolina coast (a) Bogue Banks at Morehead City near Cape Lookout, NC, (b) Wrightsville Beach, (c) Carolina Beach and (d) Kure Beach just north of Cape Fear, NC (courtesy of John McCormick, Wilmington District)

A beach nourishment project exists along the town of Wrightsville Beach, located along the North Carolina coast about 40 km (25 miles) north of Cape Fear. The project began in the mid-1960s and extends about 4.8 km (3 miles) north from Masonboro Inlet to Mason Inlet with a 4-year renourishment cycle. One hot spot is associated with this project and appears to be related to the location of the historic Wrightsville Inlet that is now closed (Figure 10b). There are no modifications to fill placement due to the hot spot. The underlying geology of this former inlet may influence the location of this hot spot.

The Carolina Beach nourishment project and the adjacent Kure Beach nourishment project have existed since 1964. The Carolina Beach project involves a 3-year renourishment cycle. Both projects are located south of Carolina Beach Inlet. A hot spot is located just south of a fishing pier where a seawall has been constructed to protect the upland development (Figure 10c). Remedial efforts include placement of more renourishment sand in the hot spot area. The Kure Beach hot spot is located at the southern end of the project where a natural coquina beachrock outcrop is exposed (Figure 10d). This rock exposure results in longshore drift interruption and possible localized wave focusing to create a hot spot as well as a shoreline orientation change to the south. A rock revetment has been constructed to the south of the project to protect Fort Fisher and this structure's end effects may also influence the hot spot.

The Dare County nourishment project is proposed to fill two sections of eroding coast in the northern part of the state. Within the project area are two persistent hot spots. One hot spot is along the Beach Road in Kitty Hawk, where many houses have been lost. A sand bag revetment/seawall was constructed to protect the road until the fill can be placed. The second area is in Kill Devil Hills (Figure 11a). A poorly understood hot spot is also located in South Nags Head. The two main areas are currently being studied. They have known geologic influences with limited normal coastal sand overlying a silt/clay bed (old river channel). Nearshore shoals, on a 45-deg angle to the coast, also influence the wave focusing on the hot spot areas. Both of these hot spot areas experienced overwash with extensive structural and dune damage as a result of the passage of Hurricane Isabel in September 2003.

Figure 11. Hot spot locations: (a) along Dare County, NC coast (courtesy of William Birkemeier, CHL), and (b) Outer Banks (courtesy of John McCormick, Wilmington District), showing overwash and inlet breach at hot spot locations resulting from Hurricane Isabel (NCDOT)

South of the Dare County beach-fill area there are six other identified natural hot spots along the Outer Banks that require coastal engineering to protect the single access road for the southern Outer Banks. These hot spots extend south of Oregon Inlet to Ocracoke Island (Figure 11b). All six of these hot spots may have a link to underlying geology, which focuses wave activity. These hot spots areas have frequent overwash of the highway and road inundation during storms. At (1) *Northern Pea Island* (National Wildlife Refuge) and (2) *Old Sand Bag Area* (also in the Refuge) sand is placed on the beach just south of the inlet from channel maintenance dredging at Oregon Inlet and the net southward drift carries sand to the hot spot areas. Dunes have been constructed to help prevent overwash. At (3) *Rodanthe S Curve*, the highway has been relocated landward of the main overwash area. This area of the barrier island extends seaward so shoreline orientation plays a part in this hot spot. The updrift coast is oriented northwest-southeast and the downdrift coast is oriented northeast-southwest. At (4) *Buxton/Canadian Hole*, the road has also been relocated landward. This site has had several breaches during large storms with inlet formation. These breaches have been closed mechanically with emergency dredging of sand from the bay to prevent new inlet formation. At (5) *Hatteras Village* on the east/west oriented coast south of Cape Hatteras, the road has been overwashed along a narrow portion of the island. Hurricane Isabel on 18 September 2003 cut a breach in the island in this vicinity. Across Ocracoke Inlet, at (6) *Ocracoke Island*, overwash covers the road during storms. A dune has been built to try to prevent this overwash. All of these hot spots on the Outer Banks are suspected to be from wave focusing over nearshore shoals and were sites of overwash and road inundation during Hurricane Isabel.

Myrtle Beach, SC. Myrtle Beach is located along the northern South Carolina coast and was filled in 1987, 2 years before Hurricane Hugo made landfall in 1989. The project was constructed in three phases that covered Phase I in North Myrtle Beach, Phase II in Myrtle Beach, and Phase III in Surfside/Garden City (Figure 12). The nearshore area has a complex geology as evidenced by sidescan surveys conducted by the U.S. Geological Survey (USGS). The nearshore contains rock outcrops and seaward movement of the fill material was inferred by successive sidescan surveys. Data and interpretation was provided by Paul T. Gayes, Center for Marine and Wetland Studies, Coastal Carolina University. The local and regional geologic framework plays an important role in fill movement and hot spot formation in this project. The fill was placed in a sediment starved system and the fill moved offshore. The loss of sand from the project could not be explained by end losses alone. Localized sand loss to the offshore occurs at low rates so hot spot designation is not entirely accurate. Loss from all areas of fill resulted in poor performance of the fill. Survey evidence shows that the fill sand occupied the nearshore for some 9 months then was eroded and rock was exposed again in the nearshore within 15 months after placement (Figure 13).

Folly Beach, SC. Folly Beach is located south of Charleston, SC. A beach fill was placed in 1992 along the entire length of the barrier island. Three hot spots have developed along the project (Figure 14). The first hot spot is located at the northern end of the project where there is a change in shoreline orientation just south (downdrift) of the ebb shoal attachment point of Lighthouse Inlet. This hot spot area is known locally as the "washout." Nearshore wave transformation and shoreline change modeling indicated a high rate of erosion during the design formulation phase of the project (Ebersole and Neilans 1997). Change in shoreline orientation and possible focusing of wave energy by irregular offshore bathymetry are potential contributors to this hot spot. No design modifications were taken because of an existing rock revetment that supplied storm damage protection to the houses in the area.

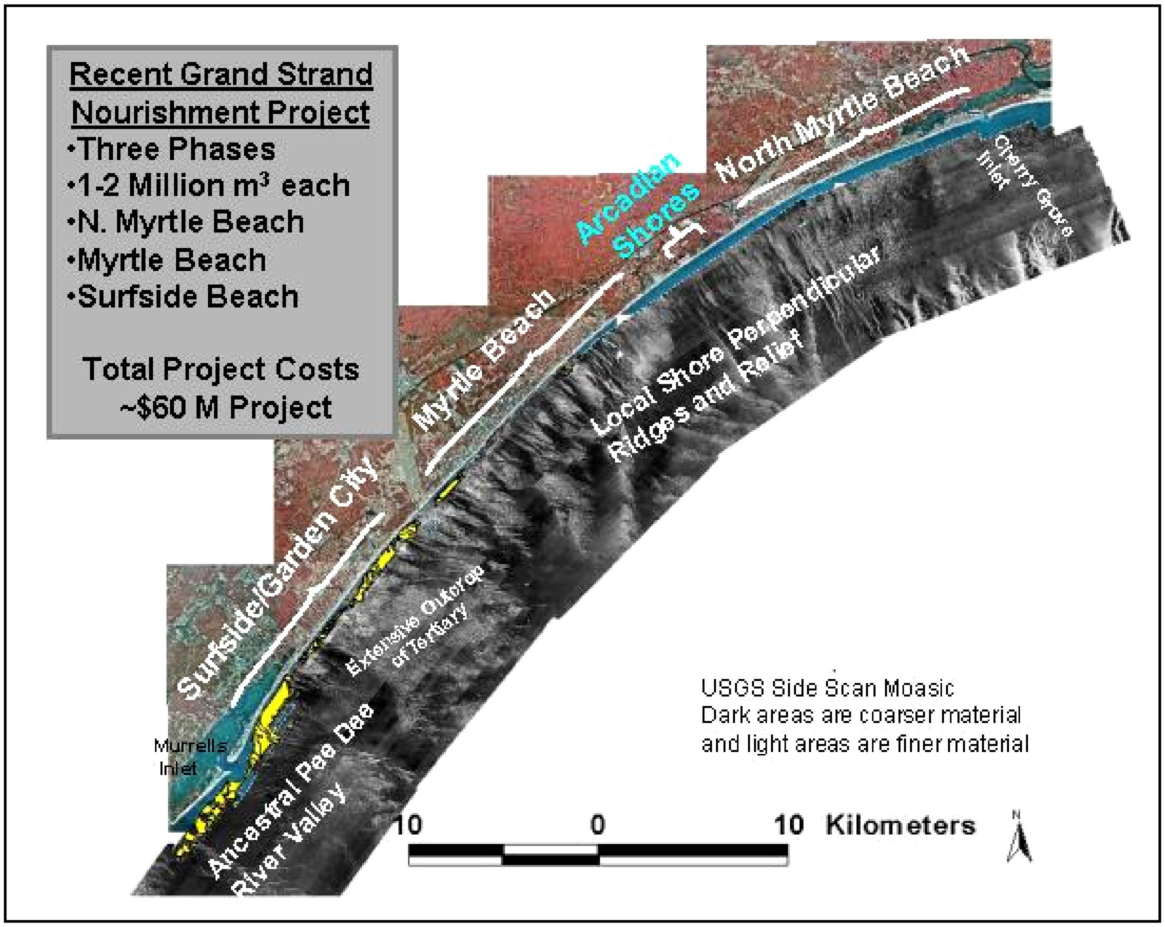

Figure 12. Variation in nearshore geology along the three phases of the Myrtle Beach, SC project (courtesy of Paul Gayes, Coastal Carolina University)

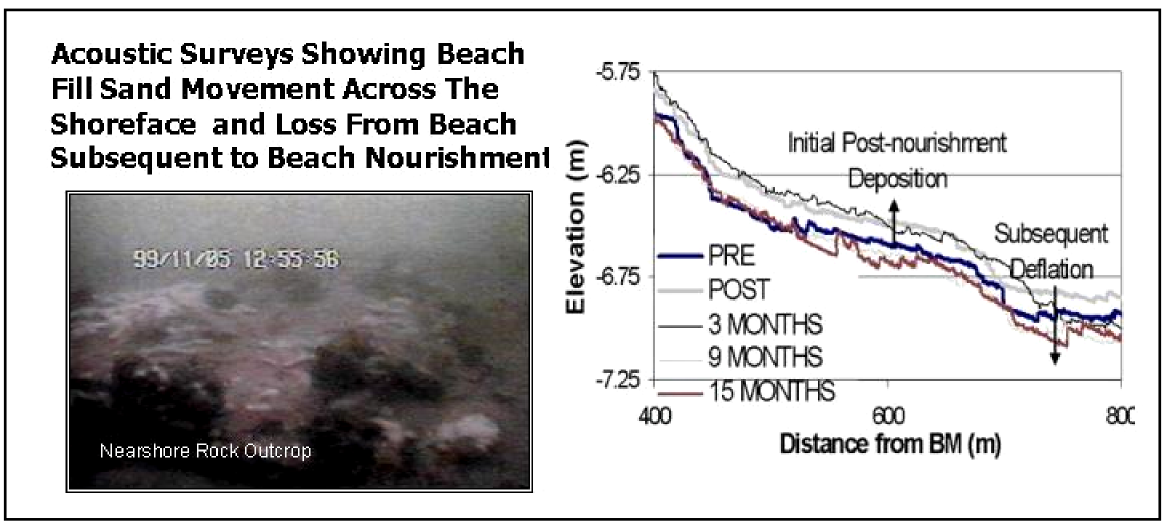

Figure 13. Nearshore rock outcrop and deflation of fill profile at Myrtle Beach, SC (courtesy of Paul Gayes, Coastal Carolina University)

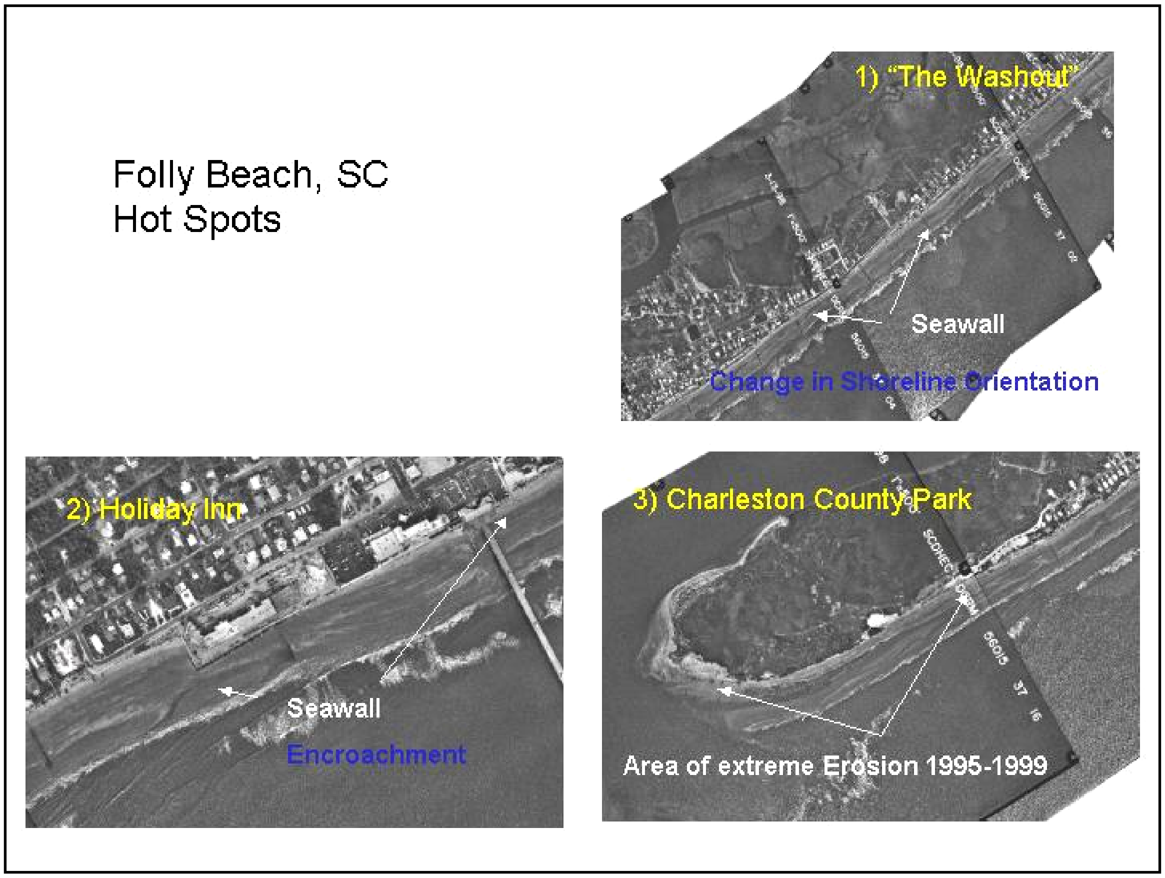

Figure 14. Location of three hot spots at Folly Beach, SC, fill project (courtesy of Paul Gayes, Coastal Carolina University)

A second hot spot was located around the Holiday Inn in the center of the island. The hotel seawall encroached seaward of the adjacent shoreline and the design berm width wrapped seaward around the two-block-long seawall. As the fill readjusted to the coastal processes, fill material in front of the seawall was removed. The cause of this "perceived" hot spot was infrastructure encroachment on the active beach.

A third hot spot was associated with the area of fill located just north of Stono Inlet at the south end of the island. This downdrift terminal end of the project lost fill sand due to both inlet processes and end effects. Sand from the beach is suspected to be transported into the inlet flood and ebb shoal area and then downcoast by the net southerly transport.

The behavior of the fill was measured by change in beach contours and their movement relative to the pre-fill conditions. An examination of sidescan survey data indicated complex nearshore geology (Figure 15). Data and interpretation on this project was also provided by Paul T. Gayes, Center for Marine and Wetland Studies, Coastal Carolina University. Over time, the bathymetric contours moved offshore indicating seaward transport of sand over the project area. A longshore transport drift reversal is indicated at the north end of the island toward Lighthouse Inlet. Consequently, the "washout" area acts as a source of sand to both the north and south beaches and also to the offshore.

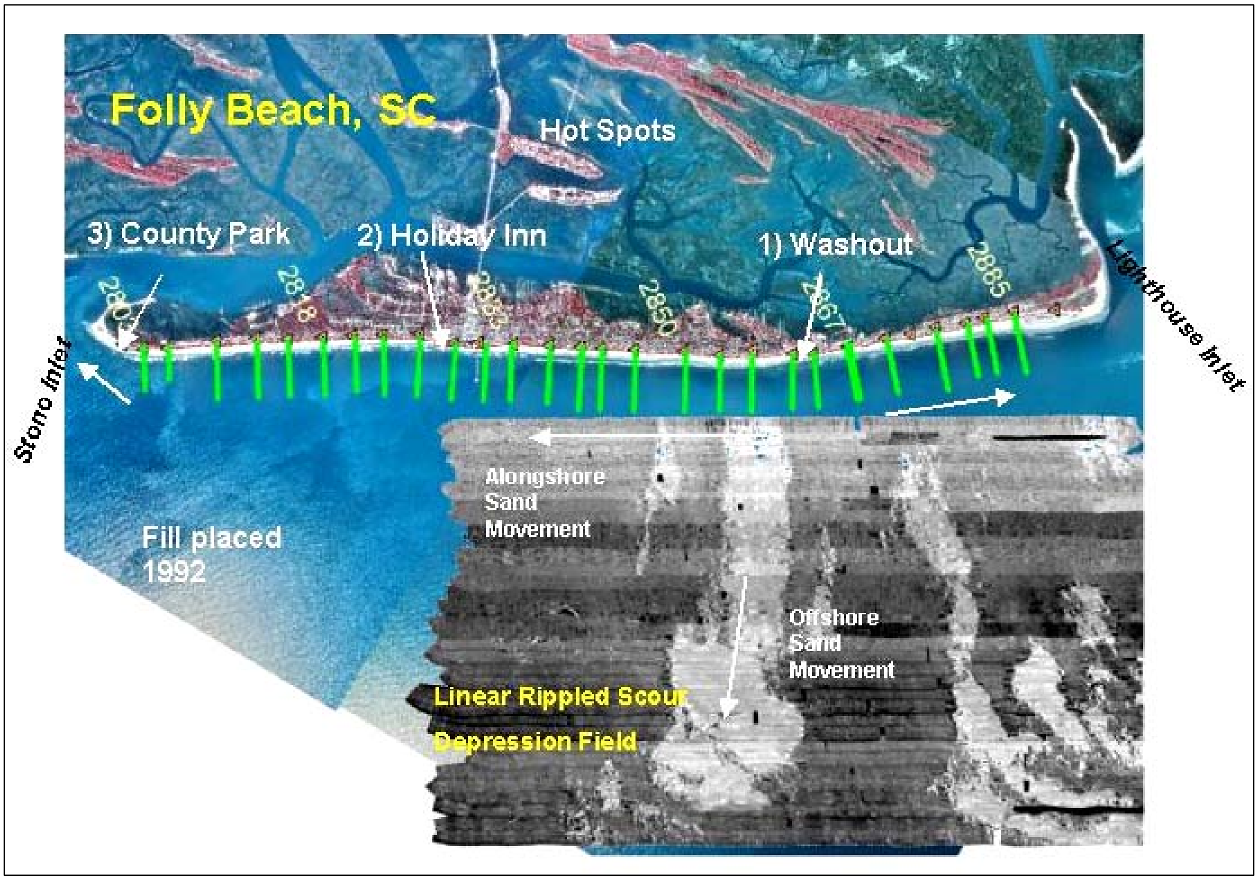

Figure 15. Nearshore geology of Folly Beach, SC, in relation to the three hot spots (courtesy of Paul Gayes, Coastal Carolina University)

Tybee Island, GA. Tybee Island is located on the upper Georgia coast and has a long history of beach fill, seawall and groin construction in response to shore front erosion. The latest Tybee Island Shore Protection project consists of several project features including: construction of a north end terminal groin, a south end terminal groin, an oceanfront beach fill, additional sand placed at the island's south tip beach with t-head groin rehab, and a Back River groin field and beach fill to mitigate for erosion on the back side of the island's southern tip. These components were completed by July 2000.

One hot spot has formed on the ocean beach in the middle of the island (Figure 16). The suspected cause of this hot spot is a change in shoreline orientation, which is also a nodal point for sediment transport north into the Savannah River entrance and south to Tybee Creek (Back River) inlet. The hot spot has become a sediment source for transport in both directions away from the placement area. Methods taken to addressing the hot spot include the construction of groins at the hot spot area to interfere with the longshore transport, lengthening and sand tightening of the north end groin to trap sand from loss into the Savannah River entrance, increasing the beach's berm width and increasing the frequency of renourishment to provide a sand supply to this nodal point.

Figure 16. Hot spot location and nodal point at Tybee Island, GA, fill project (courtesy of Carol Abercrombie, Savannah District)

Dade County, FL. The Dade County Shore Protection Project has undergone several construction phases and covers almost the entire county. Sand has been placed on the beach at various times from Sunny Isles in the north to Key Biscayne in the south. The beach nourishment project has developed five hot spots (Figure 17). The first hot spot is located at Sunny Isles and results from end losses at the northern project limit taper. A second hot spot is located downdrift (south) of Bakers Haulover Inlet at Bal Harbor. This hot spot results from downdrift inlet effects from the two navigation jetties. The third hot spot is located in the vicinity of 63rd Street in Miami Beach and is suspected to result from wave energy focusing over nearshore hardbottom reefs. The fourth hot spot is located at 32nd Street, Miami Beach and is the result of an orientation change in the shoreline. The fifth hot spot is located at the southern terminus of the project at Government Cut and is suspected to be the result of sand leakage through the porous north jetty.

Mitigation of the Dade County hot spots involves a variety of approaches (Figure 18). The Sunny Isles end effect hot spot was mitigated by construction of two submerged rubble-mound breakwaters in 2001. These breakwaters were designed to lower the wave energy as it approached the beach and reduce end losses to the north. The breakwaters have performed well and are holding the fill material in place. No mitigative action has been taken at the south jetty of Bakers Haulover Inlet at this time. The hot spot at 63rd Street will become part of the National Shoreline Erosion Control Development and Demonstration Program (Section 227) project to construct and test innovative shore protection

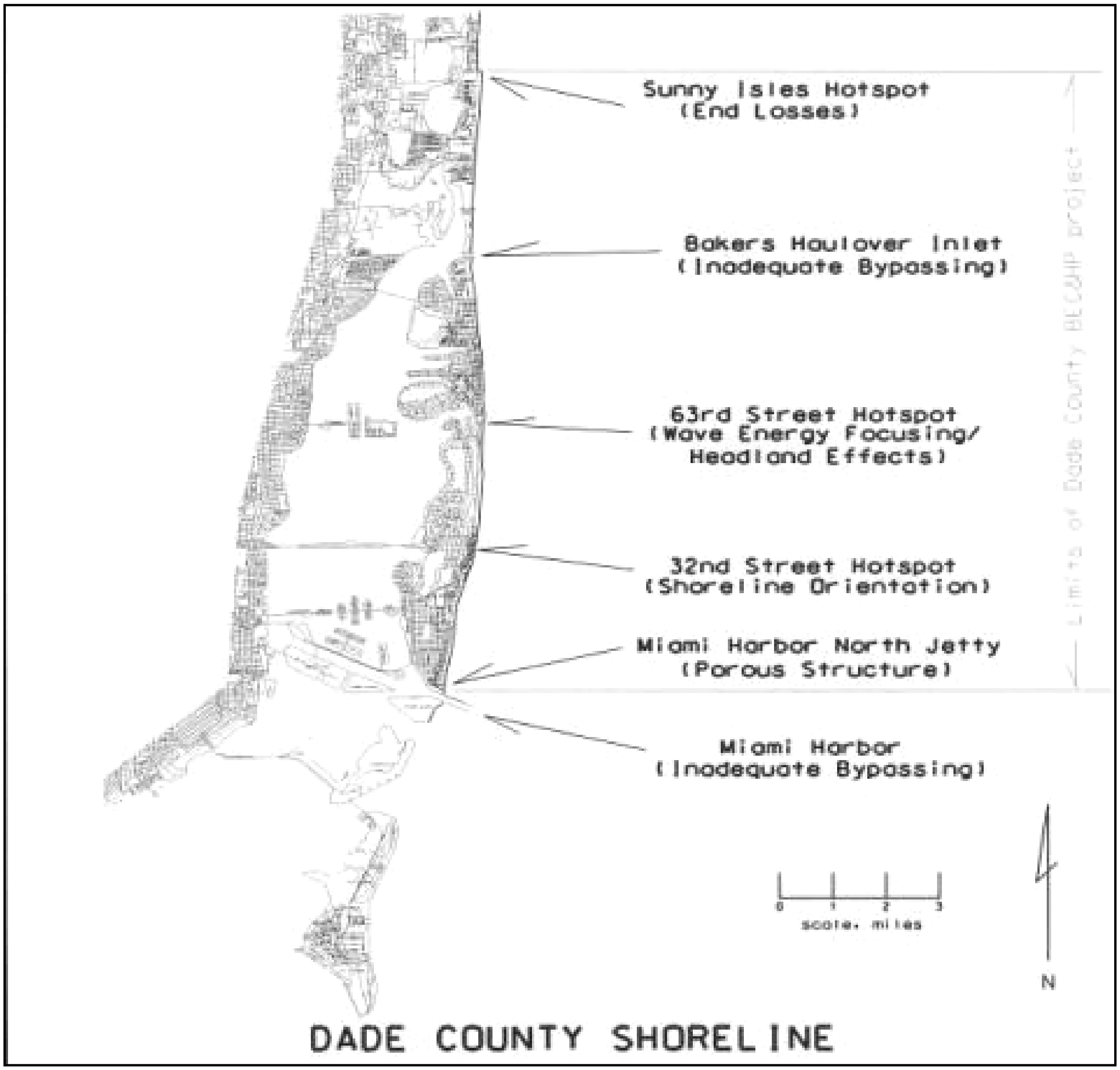

Figure 17. Hot spot locations along the Dade County, FL, fill project (courtesy of Tom Martin, Jacksonville District)

devices. A submerged nearshore reef ball breakwater will be constructed at this site in the near future to lower the wave energy and soften focusing of waves by the irregular bottom caused by natural coral reefs prevalent in the nearshore at this site. At the 32nd Street site, three emergent nearshore coral rock rubble-mound breakwaters were constructed in 2002, at the hot spot location where the shoreline orientation changes from north/south to more northeast/southwest. Tombolos (a sand tongue attachment between the breakwater and beach) were constructed by trucking fill sand from further down the beach, back updrift and placing it behind each of the breakwaters. At the present time the breakwater/tombolo configuration has stabilized the hot spot associated with the local shoreline orientation change. The natural coral reef in this area enhances wave focusing resulting in

Figure 18. Photographs of the five hot spots along Dade County, FL, fill with remedial measures taken or planned

the shoreline orientation change. At Government Cut entrance, the north jetty has been sand tightened, which has eliminated the loss of fill material into Government Cut, and has stabilized the beach width at this southern terminus of the project.

Panama City, FL. The Panama City beach fill was completed in 1999. Panama City is located on the Gulf Coast of the Florida panhandle (Figure 19). The fill covered 28 km (17.5 miles) from Phillips Inlet on the west to Panama City Harbor Entrance (St. Andrews Inlet) on the east. Monitoring of shoreline change and volume of fill remaining was achieved through a series of beach profiles located at the Florida Department of Environmental Protection (DEP) monuments R-1 to R-91. Five hot spots were found at the west end of the project at R-4 and at R-10 to R-12 in Hollywood Beach, R-19 to R-25 in Sunnyside Beach, around R-60 to R-65 in Panama City, and at the east end between R-84 to R-91 near St. Andrews Inlet (from Coastal Planning and Engineering 2002).

No definitive cause was given for these hot spots, but the borrow areas were close to the beach in several areas along this project and may have resulted in fill placed on the beach moving back to the borrow trough areas. A general correlation exists between the locations of the borrow areas and the hot spots. Wave refraction over these borrow holes, as well as other irregular bathymetry, may have caused wave focusing at the hot spots, but no studies have confirmed this as yet. Both terminal ends also measured losses.

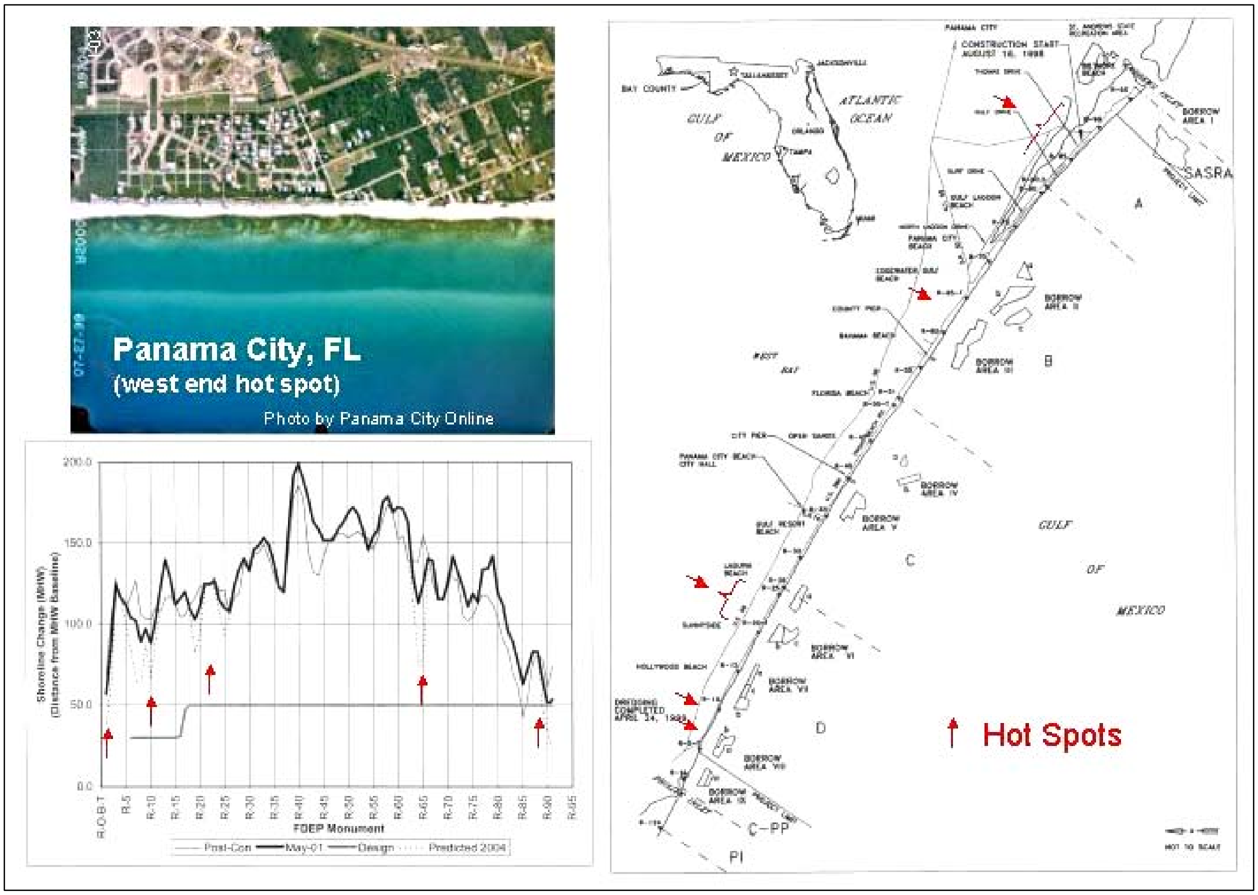

Figure 19. Aerial photograph (from Bay County, FL) location map and shoreline change analysis (courtesy of Linda Lillycrop, Mobile District) of the five hot spots along Panama City, FL, fill project

Perdido Key, AL. The hot spot is located on the east (updrift) side of Perdido Pass along this Gulf of Mexico beach area just west of the Florida/Alabama border (Figure 20). The hot spot is a naturally occurring erosion area and no fill has yet been placed here. Perdido Pass migrated 1.3 km (0.8 miles) to the west over the past 100 years (prior to being stabilized with navigation jetties in 1968-69) and the hot spot is just to the east of the old inlet location. Possible wave focusing occurs from irregular nearshore bathymetry. Remedial action may include placement of fill material in the hot spot area.

Southern California Projects. Three hot spots have formed along the southern California coast south of Los Angeles/Long Beach Harbor. The southernmost hot spot is at the northwest end of the Surfside/Sunset Beach nourishment project. This area is in the vicinity of the south (downdrift) arrowhead jetty of the entrance into Anaheim Harbor and the Naval Weapons Station (Figure 21). Wave reflection off the arrowhead jetty produces a highly oblique reflective wave train that scours nourishment sand placed on the beach adjacent to the jetty. The second hot spot is on the eastern end of Seal Beach on the northern (updrift) side of the north arrowhead jetty. The third hot spot is located on Peninsula Beach, located northwest of the northwest jetty at the three jetty entrances into the Long Beach Marina and the San Gabriel River mouth. Localized drift reversals flow to the northwest

Figure 20. Location of hot spot at Perdido Key, FL (courtesy of Linda Lillycrop, Mobile District), and insert of SHOALS bathymetry showing associated shore-attached shoal

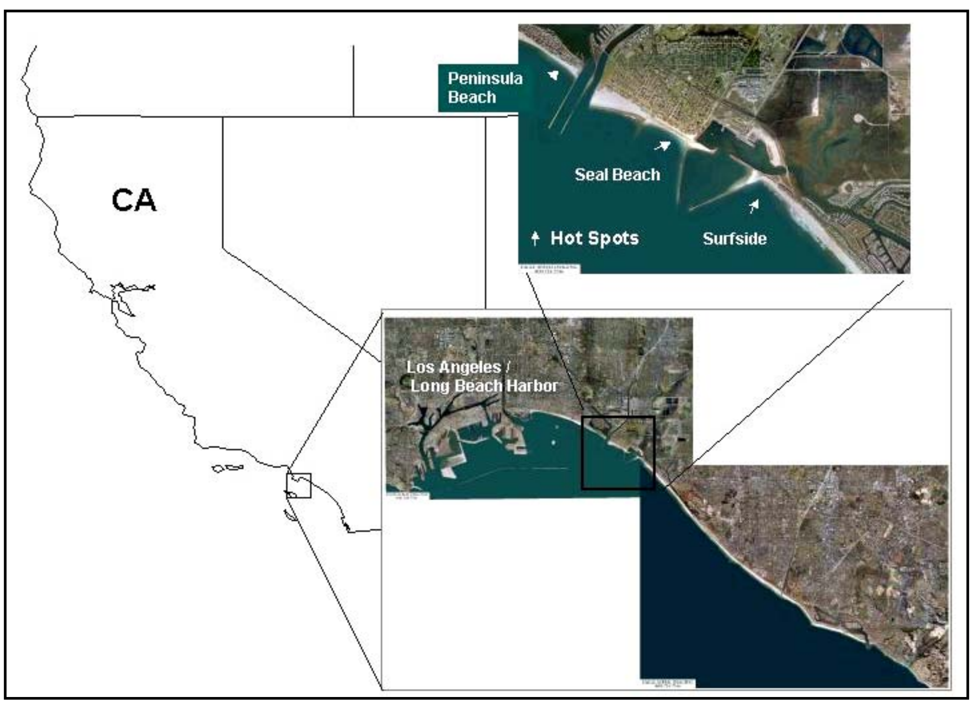

Figure 21. Location of three hot spots at Surfside, Seal Beach, and Peninsula Beach along southern California coast (courtesy of Chuck Mesa, Los Angeles District)

against the net southeast drift direction in both Anaheim and Alamitos Bays. The local net sand transport reversals are associated with the long jetties at the harbor entrances as well as the breakwaters of the Los Angeles/Long Beach Harbor.

Mitigation for the hot spots include periodic beach nourishment using a nearshore borrow area for Surfside (Figure 22). The first fill was placed using an upland source in 1964. The project has been filled 11 times since then on a roughly 6-year renourishment cycle, with the last one in May 2002. The dredging of the channel into the Naval Weapons Station was used as a source of fill on two occasions, but most of the fill has been from nearshore borrow areas. The hot spot at Seal Beach was nourished with an upland fill source that was moved by rail to the coast and truck hauled onto the beach by local interests. Local interests filled the Peninsula Beach hot spot with sand back-passed by truck from the wide beach to the west back to the beach adjacent to the jetty.

Figure 22. Photographs of mitigation for the three hot spots along southern California coast showing pipeline fill renourishment from offshore borrow area at surfside, upland fill placement at Seal Beach and truck haul backpassing at Peninsula Beach (courtesy of Chuck Mesa, Los Angeles District)

ANTICIPATING HOT SPOTS IN PROJECT DESIGN: As illustrated by the preceding case studies, hot spots tend to be present in many, if not most beach nourishment projects. These hot spots can, in some cases, introduce unanticipated project costs related to mitigation activities. In other cases, subdesign conditions exist over much of the renourishment cycle, which may represent increased vulnerability to damage. As such, prudent beach nourishment project design would include a focused examination of the potential for hot spot development. Identifying the potential for hot spot occurrence in the feasibility or design phase of project development will enable design modifications to address the hot spot area, provide a more accurate estimate of project costs and performance, and educate project shareholders and sponsors about the potential for nonuniform project performance. Realistic expectations about possible hot spot occurrence will help to eliminate the perception of poor project performance or inadequate project design.

Often the presence of an erosional hot spot is evident prior to project construction. However, in some cases the existence of a hot spot may not be apparent due to the eroded state of the preproject beach. That is, the preproject dry beach width may be sufficiently narrow or, in fact, nonexistent, which can mask the signal of the erosional hot spot. Data and analysis tools are typically available to aid the examination of the potential for hot spot development. These include historic records of shoreline position and shoreline rates of change, detail nearshore hydrographic survey data, and numerical models for nearshore wave transformation (STWAVE) and shoreline evolution (GENESIS). Based on the case study summary information listed in Table 4, it is seen that wave focusing by nearshore bathymetric irregularities or coastal structures is the most frequently identified cause for hot spot development. Underlying geology is the next most frequently identified cause for hot spot development (which may also influence wave focusing) followed by inlet effects, structure-induced impacts, end effects, and development encroachment on the active beach. Investigation of underlying geology using cores, subbottom seismic and sidescan survey mosaics, and review of the coastal geologic literature will improve the discovery of geologic controls on hot spot occurrence.

Table 4
Project Hot Spot Summary Data

Project	#	Type	Cause	Remedial Action
Coney Island, NY	1	Updrift barrier/wave focusing	Terminal groin/nearshore shoal induced wave focusing	Sand bypass/additional groins proposed
Sea Bright –Manasquan, NJ	1	Monmouth Beach - encroachment/temp. terminal end	Seaward displacement of fill material/end losses	Additional fill added - resolved w/ next reach filled
	2	Spring Lake - updrift barrier/nearshore bathymetry	Groin too long/ nearshore contour change/finer borrow material	Notch groin/add coarser fill
	3	Sea Bright - terminal end	End losses	Renourishment
Ocean City, NJ	1	Wave focusing/drift reversal	Borrow pit/ebb shoal	Renourishment/modify borrow area dredge location away from beach
Ocean City, MD	1	15th St. - shoreline orientation	Change in shoreline orientation	Renourishment
	2	32nd St. - encroachment	Upland property is seaward	Renourishment/ backpassing
	3	52nd St. - nearshore bathymetry variation	Shore-attached shoal wave focusing	Renourishment overfill/ backpassing
	4	81st St. - nearshore bathymetry variation	Shore-attached shoal wave focusing	Renourishment overfill/ backpassing
	5	146th St. - terminal end	End losses	Change taper
Bogue Banks, NC (Navigation channel dredge disposal)	1	Inlet - wave focusing/drift reversal	Wave focusing over ebb shoal	Periodic navigation channel disposal placement

(Continued)

Note: ? = possible cause, exact cause unknown.

Table 4 (Concluded)

Project	#	Type	Cause	Remedial Action
Wrightsville Beach, NC	1	Historic inlet location	Underlying geology?	No special treatment
Carolina Beach, NC	1		Pier effects? Inlet effects?	Additional sand/seawall
Kure Beach, NC	1	Rock outcrop/groin effect	Geologic control	Additional sand
Dare County, NC	1	Kitty Hawk – wave focusing?	Geologic control?	Proposed fill project Sand bag revetment
	2	Kill Devel Hills – wave focusing?	Geologic control?	Proposed fill project Local truck fills
Outer Banks, NC	1	Pea Island North - overwash	Wave focusing over ebb shoal?	Placement of inlet channel material
	2	Pea Island - overwash	Wave focusing? Underlying geology?	Placement of inlet channel material
	3	Rodanthe - Overwash Shoreline Orientation	Wave focusing? Underlying geology?	Realign road landward
	4	Buxton Breach - Frequent breach	Wave focusing? Underlying geology?	Emergency fills
	5	Hatteras Island -overwash	Wave focusing? Underlying geology?	Rebuild road
	6	Ocracoke Island -overwash	Wave focusing? Underlying geology?	Dune repair
Myrtle Beach, SC	1	Offshore sink	Wave focusing? Underlying geology?	Fill placement
Folly Beach, SC	1	Washout - shoreline orientation Drift reversal	Inlet ebb shoal wave focusing/shoreline changes orientation	Rock revetment seawall behind fill protects upland
	2	Holiday Inn - encroachment	Sea wall extends seaward/offshore sand movement	Fill eroded back to seawall – no additional action
	3	Stono Inlet - terminal end	Inlet effects	Shoreline erodes into inlet shoal system
Tybee Island, GA	1	Shoreline orientation/ nodal point in LST	Wave focusing/ nearshore bathymetry	Overfilling, groins, increase renourishment frequency
Dade County, FL	1	Surfside - nearshore bathymetry/ encroachment	Wave focusing	Two nearshore submerged breakwaters
	2	Bal Harbor- Inlet Jetty	Block Inlet bypass	Fill placement
	3	63rd St. - nearshore hardbottom	Wave focusing	Section 227 breakwater type structure
	4	32nd St. - nearshore hardbottom/shoreline orientation	Wave focusing	Three breakwaters and backpassing to form tombolos
	5	Government Cut - terminal end	Porous inlet jetty	Sand tighten jetty
Panama City, FL	1	R-5	End effects?	
	2	R-10 to R-12 Hollywood Beach	Wave focusing over borrow area?	
	3	R-19 to R-25 Sunnyside Beach	Wave focusing over borrow area?	
	4	R-60 to R-65 Panama City	Wave focusing over borrow area?	
	5	R-84 to R-91 St Andrews Inlet	End losses/Inlet effects?	
Perdido Key, AL	1	Updrift of pass	Relict Inlet/wave focusing?	Fill placement?
Surfside, CA	1	Jetty end effect	Wave focusing?	Fill placement
Seal Beach, CA	1	East Beach – updrift of jetty	Wave focusing?	Upland fill placement
Peninsula Beach, CA	1	Updrift of jetty	Wave focusing?	Backpassing truck haul

A change in shoreline orientation was also identified as a hot spot cause, where there is a nodal point with longshore sand transport away from the hot spot in one or both directions. Underlying geology, inlet morphology, and/or nearshore shoals control local shoreline orientation changes in many cases.

CONCLUSIONS: Based on the case studies presented herein and discussions at the workshop the following analyses are recommended as components of a feasibility or design phase detailed examination for the potential for hot spot development:

a. Examination of historic photographs, shoreline position, and rate change data.

b. Comparison of historic and existing shoreline orientation and morphology.

c. Comparison of line of upland development with existing and historic shoreline position (to identify development which encroaches on the active beach).

d. Detailed nearshore wave transformation and an examination of breaking wave energy and direction along the project shoreline (both for preproject conditions and also for postproject conditions after dredging of nearshore borrow areas if applicable). Estimates of potential longshore transport rates and gradients in rates can indicate potential locations of hot spots. This may require detailed pre- and postproject hydrographic survey data.

e. Shoreline change modeling.

Further research is needed to develop, document, and provide field training on specific methodologies and procedures for assessing project vulnerability to flood and storm damages associated with coastal storm impacts and nonuniform project performance due to hot spots. Based on this review of recent and proposed beach nourishment project hot spots, the following paragraphs review the frequently identified causes of erosion hot spots and some approaches to minimizing their impact.

Nonuniform wave characteristics (height and direction) along the project shoreline was a common factor on most of the projects, with the hot spot being located where wave focusing resulted in a mechanism for higher erosion rates. Numerical simulation of nearshore wave transformation can provide important information regarding the potential for hot spot development. Shoreline change (one-line) modeling with nearshore wave information can be helpful in identifying longshore transport gradients and net longshore transport reversals, which indicate the potential for hot spot development. Shoreline change modeling is especially important in projects where the dry beach is narrow or nonexistent, because in these cases, the highly eroded state of the beach may mask any signal of hot spot erosion patterns in the historical shoreline position data set. Hot spots caused by wave focusing have been addressed in a variety of ways including structural reduction in wave energy, compartmentalization of the hot spot area shoreline with coastal structures, relocation of project borrow areas, and placement of additional nourishment to "feed" the hot spot erosion while maintaining the design shoreline width.

Underlying geology is often associated with wave focusing in that the underlying geology (be it shoal features, reefs, or rock outcrops) produces bathymetric relief that results in wave focusing. However, other geologic controls such as silt, clay or peat substrates may be more or less erodable than the adjacent coastal sands. Other geologic controls, including inlet morphology and migration, natural headlands and large-scale barrier island transgression, can be important factors associated with erosional hot spots. In the wave focusing related cases, it may be possible to remove the geologic feature that produces the wave focusing. Hot spots that result from geologic controls can be more difficult to resolve, in that there is often little that can be done to change those geologic controls. In these cases, alternative approaches including limiting future development, buy-out of existing infrastructure, and alternative land use should be considered.

Structure-induced erosional hot spots come about primarily due to interruption of the net longshore transport along the beach by the structure or wave reflection from the structure. These hot spots have also been treated in a number of ways. Sand bypassing around navigation channel structures can be an effective way of eliminating the interruption longshore transport that creates some hot spots. Notching of groins in the swash zone has proven effective in restoring longshore transport in New Jersey. Periodically renourishing the beach at Surfside/Sunset Beach is the approach taken to deal with wave reflection from the Anaheim jetties.

Hot spots at locations where development encroached on the active beach were also identified in a number of the case studies. These often result because the design required a uniform berm width along the project. Consequently, at the location of the encroaching structure there is a seaward bulge in the design shoreline, which behaves as an extremely short nourishment project embedded within the larger project. Based on experience and theory, the longevity of a beach nourishment project goes with the square of the project length. In the absence of any other measures, it will be difficult if not impossible to maintain the desired beach width. As such, when there are encroaching structures within a given project reach, it will be difficult to maintain a uniform design berm width throughout the project. Alternatively, a reduced level of protection at the encroaching structure should be acknowledged or storm protection for the encroaching structure should be provided by other means (structural or otherwise). If a structural approach is taken, it is important to minimize direct interaction between the shore protection structure and the surf zone to minimize what little sand is in the system from being scoured out and transported offshore and downdrift of the beach.

On some projects, the nonuniform size distribution of sand along the project also enhanced the erosion potential in areas where finer borrow material was placed. Identification and use of multiple borrow areas with similar sediment characteristics are recommended. If unanticipated changes in sediment characteristics are found in designated borrow areas during construction, it is advisable to investigate the possibility of using other borrow areas in order to limit the use of fine grain size fill material. An unexpected change in borrow area sediment characteristics indicates insufficient borrow sampling.

Hot spots at the ends of projects were identified in several of the case studies. The erosion and fill losses at the nourishment project's terminal ends should be anticipated in all projects. These areas probably should not be considered hot spots at all. That is, the design analysis should specifically examine and quantify project end losses and expected beach widths in the vicinity of the terminal ends of the project. The project shareholders and sponsors should be made aware of these expectations in the design phase prior to project construction. Considerations should be given to add a terminal structure at the end of a fill if high end losses are anticipated. If a project is to be terminated adjacent to a terminal groin or inlet jetty, consideration should be given to sand tightening the structure to prevent loss of fill material through the structure and unwanted deposition in adjacent navigation channels. Sand tightening can be achieved through reconstruction of the structure, use of grout, sheet piles, or the placement of sand filled geo-tubes.

Recognition of the potential for hot spot development and numerical modeling of the project's evolution in the feasibility and design phase of project development can identify the possible problem areas associated with certain types of hot spots (but probably not all). Detection of potential hot spots through more comprehensive pre- and postproject monitoring and mitigation in the design phase or prior to the first renourishment can result in more sand retained on the project. This can result in fewer unanticipated problems regarding sand loss and improve the project's performance.

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