## 3.0 INLET DREDGING AND DISPOSAL

***Appendix A*** presents a detailed description of dredging and disposal activities at Beaufort Inlet, of which the following presents a summary overview.

### 3.1 Dredging Quantities

Since the commencement of dredging in 1911, through 2004, approximately 72.1 million cubic yards (Mcy) of sediment have been dredged from the Morehead City Harbor Project. Of this, about 54.9 Mcy were for maintenance dredging and 17.3 Mcy were for new work. A summary diagram of dredging & disposal history is shown in ***Figure 3.***

Of the total 72.1 Mcy of dredging, at least 55.8 Mcy were dredged from the outer channel (Range A and Cut-Off), of which at least 45.1 Mcy were for maintenance. The other 16.3 Mcy were dredged from the inner channel, of which 9.8 Mcy were for maintenance.

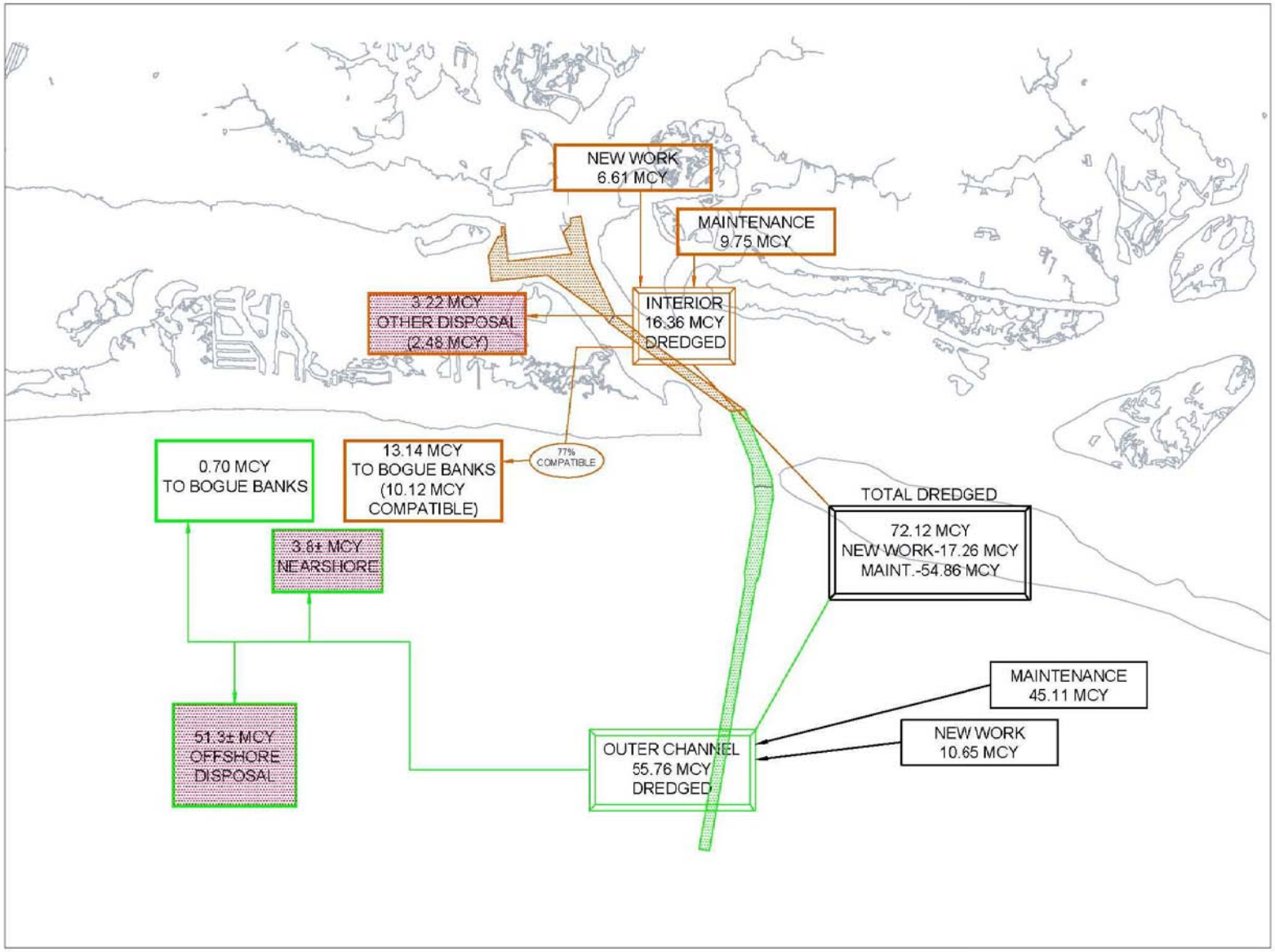



**Figure 3**: Summary of the dredging and disposal history associated with Beaufort Inlet (1911-2004).

Over the 93-year period since navigation improvements began (1911-2004), the average annual maintenance dredging volume has been about 590,000 cy/yr. In detail, though, the average annual maintenance dredging quantities generally increased after each new work improvement (***Figure 4***). For example:

- Prior to 1936, original maintenance dredging totaled less than 91,000 cy/yr.
- After the channel location was maintained in a fixed position in 1936, and the design depth increased from -30 ft to -35 ft in 1961, the total maintenance requirements increased from about 631,000 cy/yr (1936-1961) to 770,000 cy/yr (1962-1978).
- Upon deepening to -40 ft in 1978, maintenance requirements were mostly unchanged, principally because of short term benefits associated with a minor channel re-alignment toward the east.
- After deepening to the existing -45 ft project in 1994, the present rate of maintenance dredging is about 1,170,000 cy/yr (1995-2004).

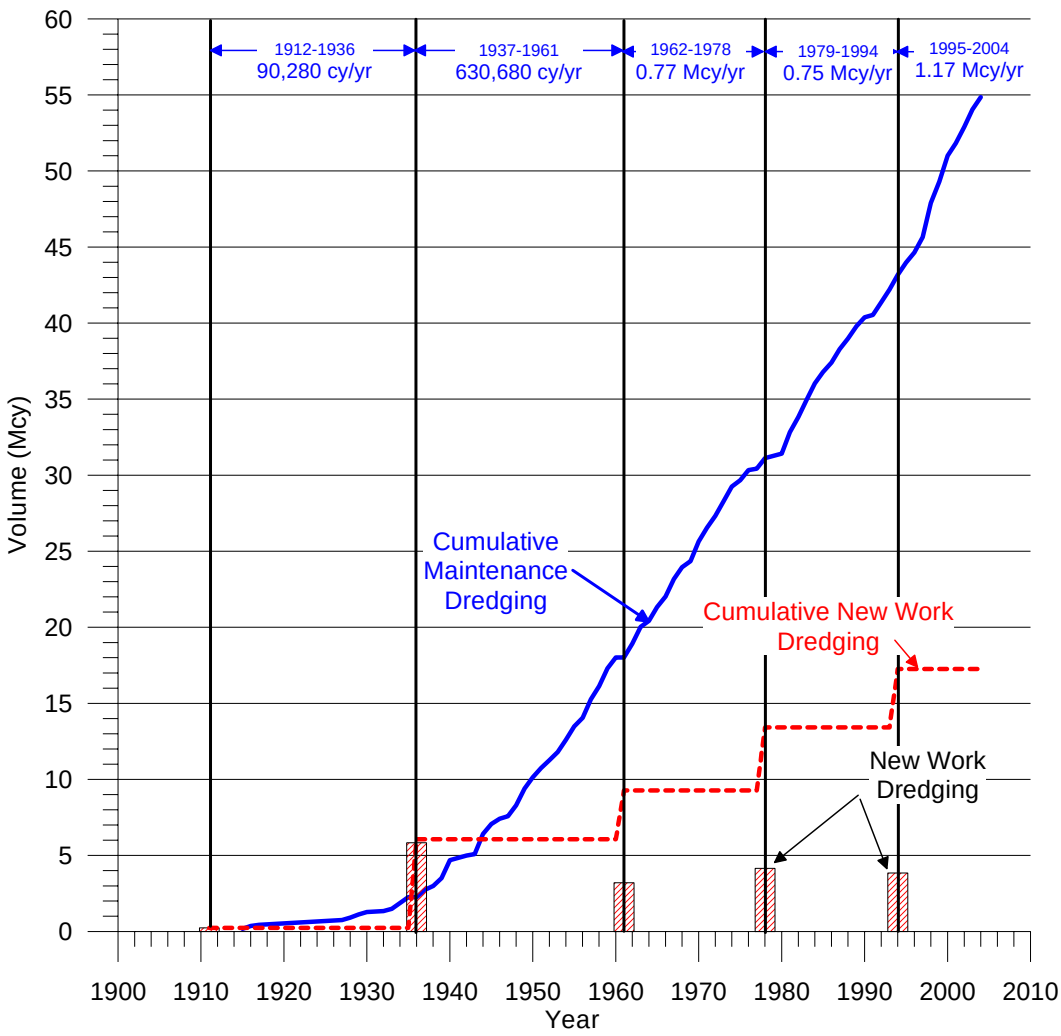



**Figure 4**: Time history of the annual maintenance dredging requirement and dredging volumes associated with new work construction.

The maintenance dredging volumes for the outer channel (Range A and Cut-Off) and for the inner channel (Range B and harbor) are summarized separately in ***Figure 5***, below. The present rate of maintenance dredging (1995-2004) is about 956,100 cy/yr for the outer channel and 213,270 cy/yr for the inner channel.

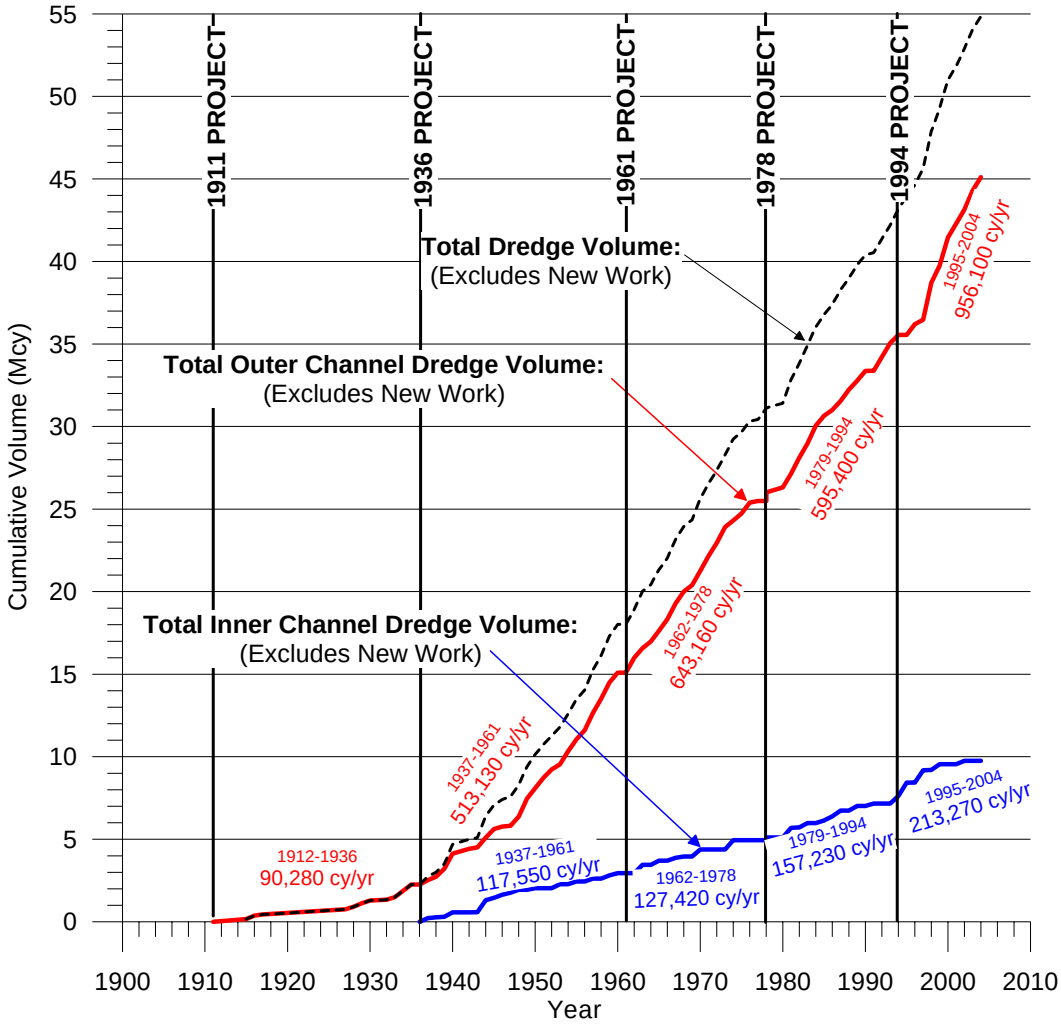



**Figure 5**: Cumulative maintenance dredging volume for Beaufort Inlet. Rates shown are computed from reported maintenance dredge records. No adjustment has been made for littoral fraction and/or compatibility with native beach material. New work construction volumes are not included.

Dredging quantities in this report are from Corps' records and match those published in the Corps' Section 111 study, excepting 1997-98 and as appended for 2001-04. The Corps' dredge records are mostly *pay* volumes and do not necessarily reflect the actual dredging quantities after repeated shoaling, side-slope adjustment and/or 'non-pay' excavation beyond contract limits. Actual dredge volumes are likely larger – particularly

in this instance when the navigation channel is adjacent to islands and bars that shoal directly into the channel and required repeated dredging before acceptance for payment.

In two instances where separate estimates of dredge quantities were available (1997 and 1998, respectively), the Contractor's daily estimates of dredge volume were 39% greater and 31% greater than the Corps' pay volume records. (In the latter case, the Contractor's dredge volume estimate was 92% greater than the dredge volume tabulated in the Corps' Section 111 report, for reasons that are not clear.) Daily dredge reports may over-estimate actual dredging quantities; however, it is equally or more likely that pay volumes *under*-estimate the actual dredging quantities. In sum, estimates of maintenance dredging volumes reported by the Corps and utilized in this report are most probably under-valued. Actual maintenance dredging may have conceivably been on the order of 30% greater than the reported values.

### 3.2 Littoral Fraction of Dredged Material

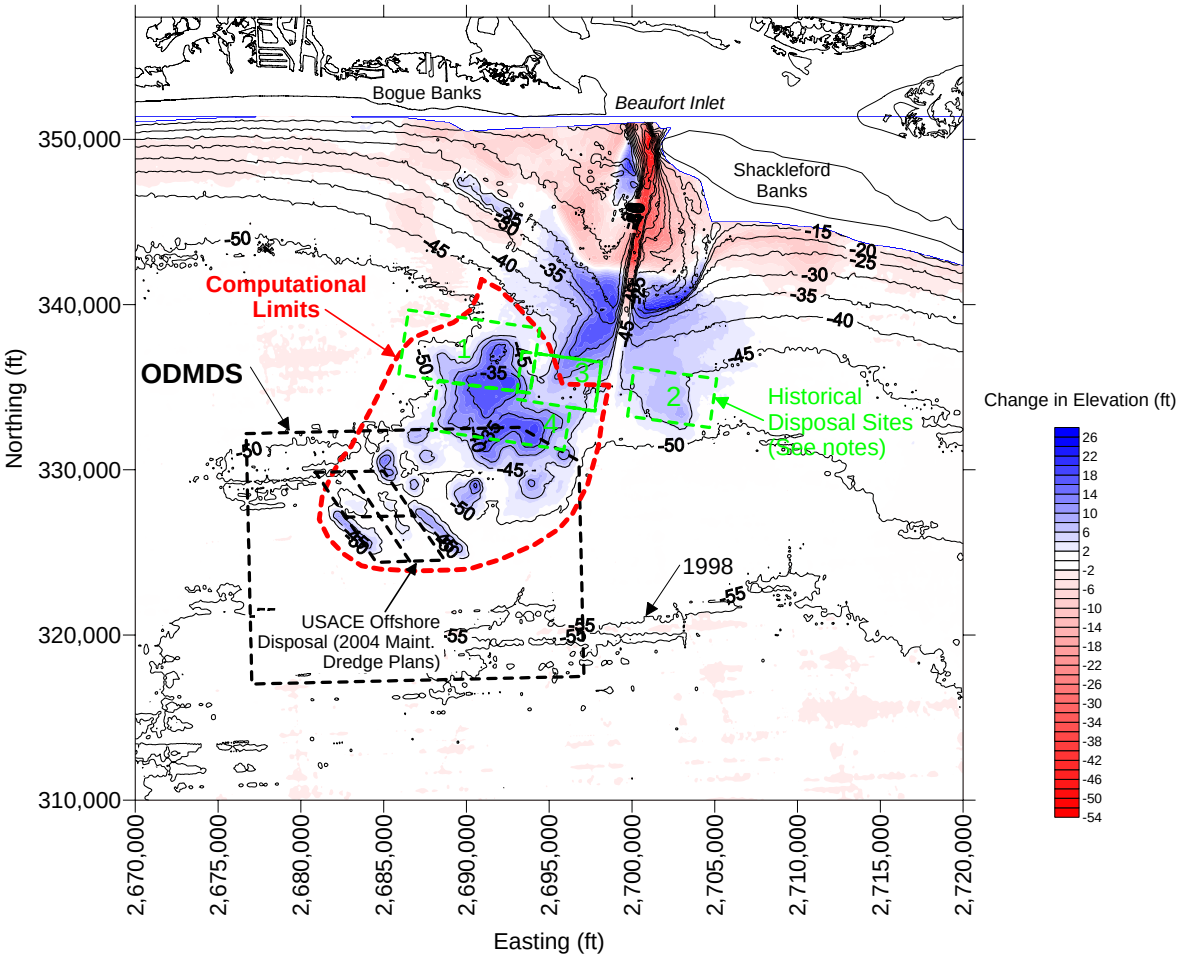
Outer Channel. The Corps' Section 111 report (USACE 2001) initially computes that 91% of the sediment dredged from the outer channel is "littoral" in origin (or, more precisely, beach compatible), and then adjusts the value to 86%. This is based upon a grain-size compatibility analysis using a standard 'James-Krumbein' overfill calculation and a subsequent conservative adjustment by 'Hobson'.

In contrast, an alternative method using the less-conservative 'Dean' overfill calculation indicates that 100% of the sediment dredged from the outer channel is beach compatible. Due in part to this observation -- but mostly because (1) the reported maintenance dredging quantities are likely under-estimated, (2) much of the maintenance dredging derives directly from the 'littoral' ebb tidal shoal, and (3) material placed upon the beach from the outer channel and offshore disposal area in 1994 was of high quality -- the present study concludes that 100% of the maintenance dredging from the outer channel is "littoral" in origin. No reduction is applied to maintenance dredge quantities from the outer channel.

Inner Channel. Likewise, the Corps' Section 111 report initially computes that 77% of the sediment dredged from the inner harbor is "littoral" in origin, and then adjusts the value to 69%. The alternative 'Dean' calculation indicates that 100% of the material can be deemed beach compatible. The 100% estimate numerically results from coarse shell fragments that may offset potential losses of fine sands and silt; however, physical examination suggests that the inner-channel dredged sediment is not 100% littoral. The present study concludes that the standard computation of 77% is a reasonable estimate of the littoral nature of the inner-harbor material.

### 3.3 Offshore Disposal

Until 1997, all material dredged from the outer channel was disposed of offshore. Historical disposal sites from nautical charts are indicated in ***Figure 6***. In early years, disposal likely also included ebb shoal areas nearer shore (not shown). Comparison of early (1900) and recent (1998-2004) bathymetric surveys suggests that between 26.6 Mcy and 33.5 Mcy of the outer-channel dredging can be accounted for as offshore disposal beyond the ebb shoal delta, within the computational limits outlined in Figure 6.




| Chart Date | Disposal Notes |
|---|---|
| 1952 and Older | No notes for offshore disposal |
| 1959 | Areas 2 & 3 denoted "Spoil Area" |
| 1968 | Area 1: "Disposal Area", surveyed 1952-1966 |
| | Areas 3&4: Disposal Area (Discontinued), Surveyed 1952-1966<br>Area 2: "Disposal Area (Discontinued) Surveyed 1952-53 & 1955 |
| 1969 | Area 1: "Disposal Area"<br>Areas 3&4: Disposal Area (Discontinued), Surveyed 1952-1969<br>Area 2: "Disposal Area (Discontinued) Surveyed 1952-53 & 1955 |
| 1976 | Area 1: "Disposal Area"<br>Areas 3&4: Disposal Area (Discontinued), Surveyed 1952-1969<br>Area 2: "Disposal Area (Discontinued) Surveyed 1955 |
| 1989 | Area 1: "Discontinued Dump Site (Dredged Material), surveyed 77-86<br>Areas 2, 3, & 4: Not Indicated |

**Figure 6**: Comparison of pre-project and 1998 bathymetric data indicates that up to 33.5 Mcy of dredge disposal can be accounted for within the computational limits shown above. The locations and dates of historical offshore disposal sites (printed on available nautical charts) are indicated.

## 3.4 Nearshore Disposal.

### 3.4.1 Nearshore Disposal Quantities

Since 1997, the Corps has required that all sediment dredged from the outer channel be placed in a nearshore disposal area, subject to allowable sea conditions and Contractor discretion (***Figure 7***). In adverse conditions, the material may be placed in the Offshore Disposal Area ('ODMDS') shown in Figure 6, prior page. Dredging from the outer channel (Range A and Cutoff) is by hopper dredge, allowing for disposal to either the nearshore or offshore areas. In contrast, inner channel/harbor dredging is typically by pipeline dredge and the material is discharged to upland disposal sites (Brandt Island) or to the beach west of the inlet.

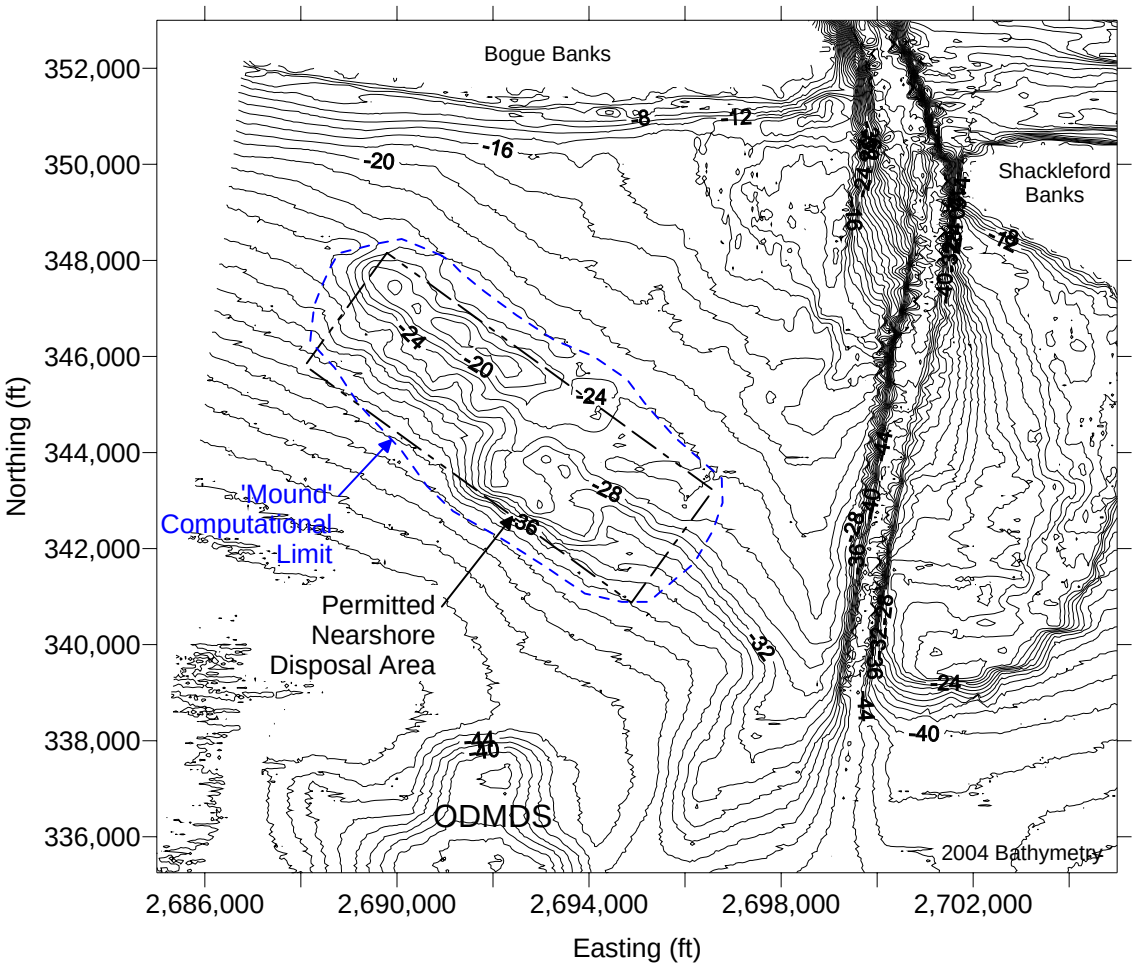



**Figure 7**: Bathymetry used for estimating the present volume of material in the nearshore disposal area. Depth contours represent the 2004 bathymetric survey data, in feet, MLW. The computational limits to estimate the dredge volumes placed within the permitted nearshore disposal area and the apparent 'mound' area are shown.

Available Corps' records do not detail the volumes of dredged material placed to the nearshore disposal area. Comparison of the 1974, 1998, and 2004 bathymetric surveys indicates that there are approximately 3.7 to 3.9 Mcy of dredged material in the nearshore disposal area. Since nearshore disposal commenced in 1997, the total dredge volume from the outer channel (1997-2003) was about 8.1 Mcy. (This excludes 2004, where the dredged material was placed directly to Bogue Banks as Section 933 beach disposal.) It therefore appears that since 1997, between 46% and 48% of the outer-channel dredging has been placed to the nearshore disposal area, and the remainder has been placed offshore (excluding the volume placed to the beach in 2004).

### 3.4.2 Nearshore Disposal - Location and Stability

The Corps' 1992 Design Memorandum and Env. Assessment (USACE 1992) describes use of "annual outer bar maintenance material to construct a nearshore berm on the edges of the ebb tide delta at about the 18- to 20-ft contour." In practice, from Figure 7, the nearshore disposal berm has been constructed in ambient seabed depths between -26 and -40 ft, MLW. The shallowest depths across the disposal mound are -20 to -26 ft.

The Corps' 1992 study found that nearshore disposal in depths of 25 feet (versus 20 to 22 feet) would result in little shoreward movement. Using Corps' methodologies[3] the present study similarly finds that nearshore disposal in 25-ft depth would diffuse but be otherwise stable. Disposal in 20-ft depth would be marginally active, while disposal in 18-ft depth would be likely to migrate toward shore. These results are consistent with the 'depth of closure' for this shoreline, computed as 22.6 ft.[4] Additionally, the survey data show no indication that the nearshore disposal material has moved significantly.

The nearshore disposal area comprises about 8000 ft alongshore, and is located about 3,000 to 10,000 ft west of the channel. Unlike the water depths, these planform dimensions are consistent with the Corps' 1992 study, but are not consistent with the Corps' 1990 feasibility study that recommended disposal 3-5 miles west of the inlet. In its existing location, the nearshore disposal area is located well within the 'transport reversal' zone of the inlet, where net littoral drift is predicted to be directed to the east (toward the inlet), and at elevated magnitudes.

In sum, this study finds that the nearshore disposal activity to-date (1) has likely comprised 3.7 to 3.9 Mcy – equating to less than half (46% to 48%) of the eligible material dredged from the outer channel, and (2) has been placed in water depths that are too deep, and probably too far east, to be of littoral benefit to the adjacent shorelines.

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[3] Hands & Allison, 1991; Coastal Engineering Manual, 2002

[4] Using the method of Hallermeier, 1978. Depth of Closure is the water depth beyond which beach profile variations are predicted to be mostly small or very infrequent.

### 3.5 Beach Disposal of Dredged Material

***Figure 8***, following page, summarizes the placement of dredged material upon the beaches of Bogue Banks, west of Beaufort Inlet. There has been no documented fill placement upon the beaches of Shackleford Banks, east of the inlet.

Inner Harbor Dredging. Beach placement of dredged material from the Morehead City Harbor project was first constructed in 1978, with 'new work' dredging from inner harbor improvements. To-date, from 1978 through 2004, approximately 13,143,000 cy of dredged material from the inner-channel/harbor have been placed along the eastern 6 miles of Bogue Banks. Of this 13.1 Mcy:

- All of this placement has been along Atlantic Beach and/or Fort Macon State Park, east of Pine Knoll Shores.
- About 4.5 Mcy (about one-third of the total) has been placed on the shoreline within 2.4 miles west of the inlet, within the zone of 'reversal transport', where the net littoral drift is predicted to be toward the inlet (to the east). Of this amount, about 2.9 Mcy were placed along Fort Macon State Park, and 2.6 Mcy were placed along eastern Atlantic Beach.
- The remaining 7.7 Mcy were placed along central and western Atlantic Beach, between 2.4 and 6 miles west of the inlet, where the net littoral drift is predicted to be mostly westerly-directed.

All of the 13.1 Mcy placed to Atlantic Beach/Ft. Macon State Park was dredged from the inlet interior (Range B and inner harbor). It was either placed directly to the beach or offloaded from the Brandt Island upland disposal area. The Brandt Island site has been offloaded to the beach in 1986, 1994, and 2004-05.

Outer Channel Dredging. Direct beach placement from outer-channel dredging was not undertaken prior to 2003/04. In 2004, approximately 0.7 Mcy of maintenance-dredged material from the outer channel was placed along Indian Beach/Salter Path and western Pine Knoll Shores, using hopper-dredge pumpout. The beach placement was a Section 933 project (WRDA 1986), cost-shared between the Corps and Carteret County.

Additionally in 2004, approximately 0.16 Mcy were dredged from the inlet's offshore disposal area (ODMDS) and placed along portions of Emerald Isle. This beach fill was part of FEMA funded storm-erosion reparations, and was constructed by hopper-dredge pumpout. Both hopper-dredge pump-out operations on to the beach -- from the Section 933 maintenance-dredging of the outer channel and from the ODMDS disposal area – were reported to result in high-quality beach fill material.

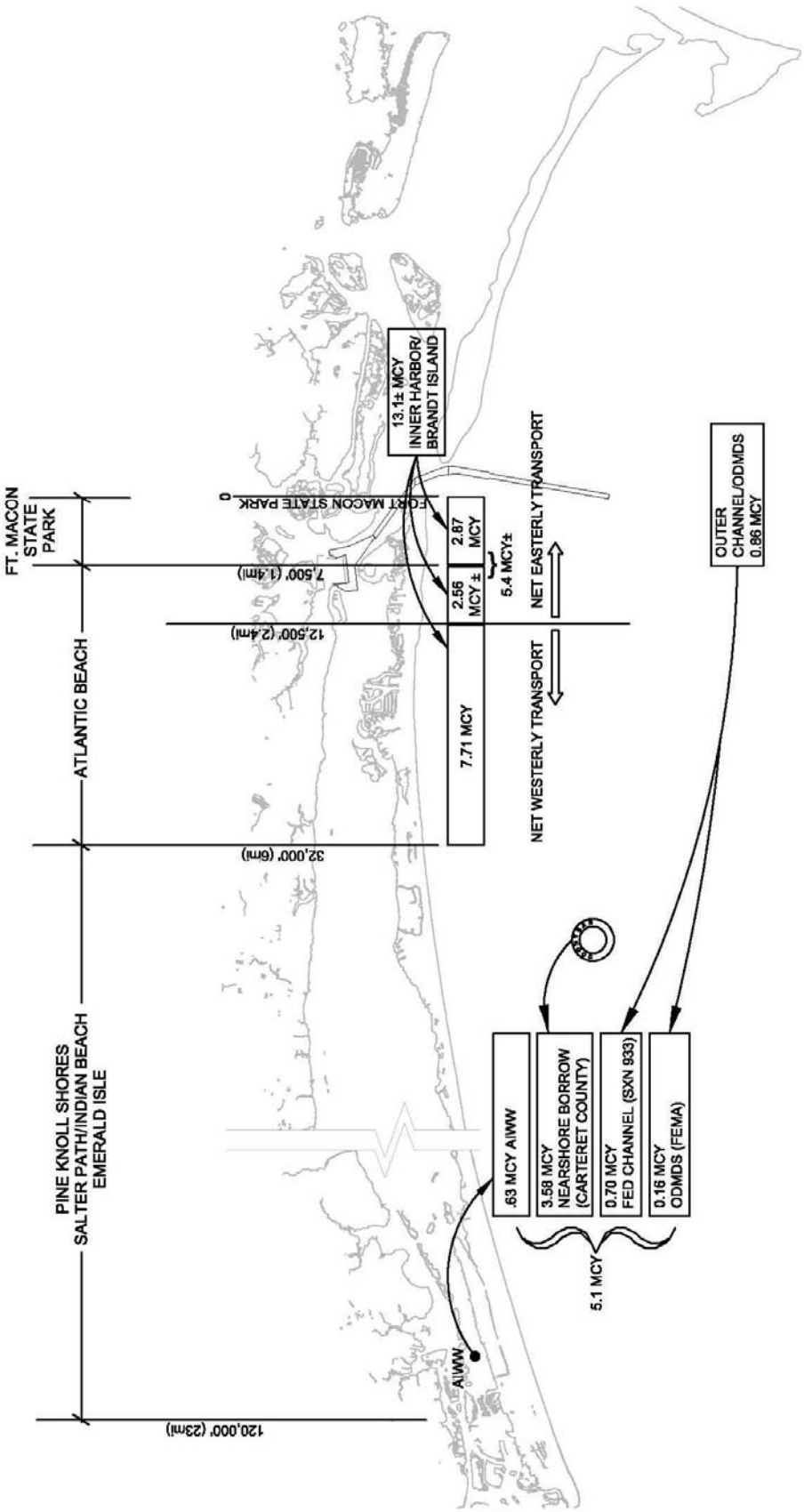


**Figure 8:** Summary of beach fill placement along Bogue Banks.

Other Non-Inlet Beach Fill Projects. Beyond beach fill placement from the federal navigation project, an additional 3.58 Mcy of non-federal beach nourishment has been placed by Carteret County along Pine Knoll Shores, Salter Path/Indian Beach, and Emerald Isle (2002-03). This sand was dredged from seabed borrow areas offshore of Bogue Banks of varying quality. An additional 0.63 Mcy were placed from maintenance dredging of the Atlantic Intracoastal Waterway (1984-1990).

Beach Fill Suitability. The beach fill material placed to Bogue Banks from dredging of the inlet's Outer Channel and ODMDS, in 2004, appears to have been fully beach compatible (see ***Appx. A-1***). On the contrary, fill placed to eastern Bogue Banks from the Brandt Island disposal area and the Inner Harbor has typically included non-compatible material comprised of clay, high fractions of silt and large shell (***Figure 9***).

**Figure 9**: Beach fill placed from Brandt Island to Atlantic Beach in 2004. *Upper left and upper right*: fill construction in November 2004. *Lower left and lower right:* clayballs in surf zone, and clay/shell and compact fine sand remaining in fill berm at 8-months post construction (July 2005). Photos – S. Howard.

Limited sampling of the fill material placed to Atlantic Beach from Brandt Island in November 2004 -- compared to the 'native' beach sand – indicated that the material was about 71% beach-compatible[5]. About eight months after placement, fill material that had been washed by the waves exhibited less fine sands and whole shell; but expansive deposits of large clayballs persisted throughout the surf zone. This indicates that the incompatible fill material does not simply 'wash away' in rapid fashion. These samples were from among the poorest-quality fill area, between the Sportsman and Oceanana Piers.

[5] Computed overfill ratio = 1.4, based upon traditional James-Krumbein method. Dean method yields 1.0.

After concerns regarding the incompatible beach fill in 2004, the Corps partitioned the Brandt Island disposal area in order to initiate works that might segregate poor-quality dredged material from potentially beach-compatible material.

For the present study, per Section 3.2 (page 10) above, beach fill material placed from the Inner Harbor/Brandt Island is considered to be 77% beach-compatible on average.[6] In this way, the net *effective* volume of beach fill placed from the Inner Harbor/Brandt Island is estimated as about 77% of the total reported volume; or, 0.77 x 13.1 Mcy = 10.1 Mcy. (The Corps' Section 111 report assumes a smaller allowance of 69% compatibility.)

The sand quality of the AIWW and County beach fill projects is specific to those projects' sand sources, and is not considered herein.

Summary. From 1978 through 2004, a total of about 13.8 Mcy of dredged material has been placed from the Morehead City Harbor navigation project onto the Bogue Banks beaches. Of this amount, about 13.1 Mcy was from the inner channel and placed along Atlantic Beach and Fort Macon State Park; and 0.7 Mcy was dredged and placed from the outer channel to western Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle.

Adjusting for beach compatibility of the material placed along Atlantic Beach and Fort Macon (77%), the total effective volume of beach fill placement from the federal navigation project is approximately 0.77 x 13.1 + 0.7 = 10.8 Mcy. About 38% of the beach disposal volume was placed within 2.4 miles west of the inlet[7] – within the zone of easterly-directed transport toward the inlet – and was thus of limited direct benefit to the remainder of Bogue Banks. In sum, after adjusting for beach compatibility, the net effective volume of beach fill placement from the federal navigation project totals about 10.8 Mcy, of which

- about 5.95 Mcy of fill was placed within the net *westerly*-directed transport zone of Bogue Banks between about 2.4 and 5.5 miles west of the inlet,
- about 0.7 Mcy placed to central Bogue Banks by Section 933 beach disposal, and
- about 4.15 Mcy was placed within the net *easterly*-directed 'reversal' transport zone of eastern Atlantic Beach and Fort Macon State Park, within about 2.4 miles west of the inlet.

[6] For sediment budget computation purposes later in this report, half of the material placed within 12,500 feet of the inlet (within the easterly-directed transport reversal zone) is credited at 100% volume because it is assumed that 100% was directly transported back to the inlet and re-dredged as maintenance.

[7] 5.4 Mcy in total, or 4.15 Mcy after adjustment for beach compatibility

### 3.6 Channel Shoaling Patterns

***Figure 10*** (following page) depicts the typical shoaling patterns of the channel based upon Corps' conditions surveys from 2000 through 2004. Highlighted areas indicate those areas along the channel that are chronically shallower than -45 ft MLW, the project's nominal authorized design depth.

Based upon the current, average annual maintenance dredging requirement of the outer channel (Range A + Cutoff) of about 956,100 cy/yr, the prevailing shoaling patterns appear to be on the order of the following:

- About 583,000 cy/yr along the landward 10,000 feet of Range A, plus another 115,000 cy/yr along the Cutoff channel (inlet throat) – for a total of about 698,000 cy/yr along the outer channel most proximate to the adjacent shorelines and inner ebb tidal shoal.
- About 258,000 cy/yr from the seaward half of the outer channel along the outer ebb shoal platform.

The Corps' Section 111 report (USACE 2001) reported that approximately 65 to 70% of the total shoal material is deposited along the western edge of the channel.

The patterns shown in Figure 10 clearly imply the littoral origins of the shoaling sediments. Shoaling pressure is evident from

(1) the terminus of Shackleford Banks (marker '16'),

(2) the spit(s) at Fort Macon at the east end of Bogue Banks (marker '19'),

(3) the ebb tidal bar extending eastward from Bogue Banks (markers '11-15'), and

(4) to a less evident extent, the ebb tidal platform along the remainder of the channel (markers '9-10' and '12').

The first of these three shoaling areas, in particular, suggest a strong, direct deposition of sand from the adjacent barrier islands to the navigation channel along depth contours of about -18 ft and shallower.

From Figure 10, it is also clear that the eastward shift in channel alignment (c. 1978) was successful in reducing shoaling from the west at markers '15-17'. However, at marker '16', the channel alignment is now up against Shackleford Banks (or vice-versa), and the foundation-toe of the Shackleford island must be dredged in order to keep the channel limits clear. Vessels navigate to the west to clear the Shackleford shoal, but then must clear the Bogue shoal at Fort Macon. Unless it is desired to retain the national seashore of Shackleford Banks as a sand source for dredging and disposal, it seems clear that the navigation channel's east bank limits at Shackleford – at the junction of the Cutoff and Range A – should be abandoned and/or shifted westward.

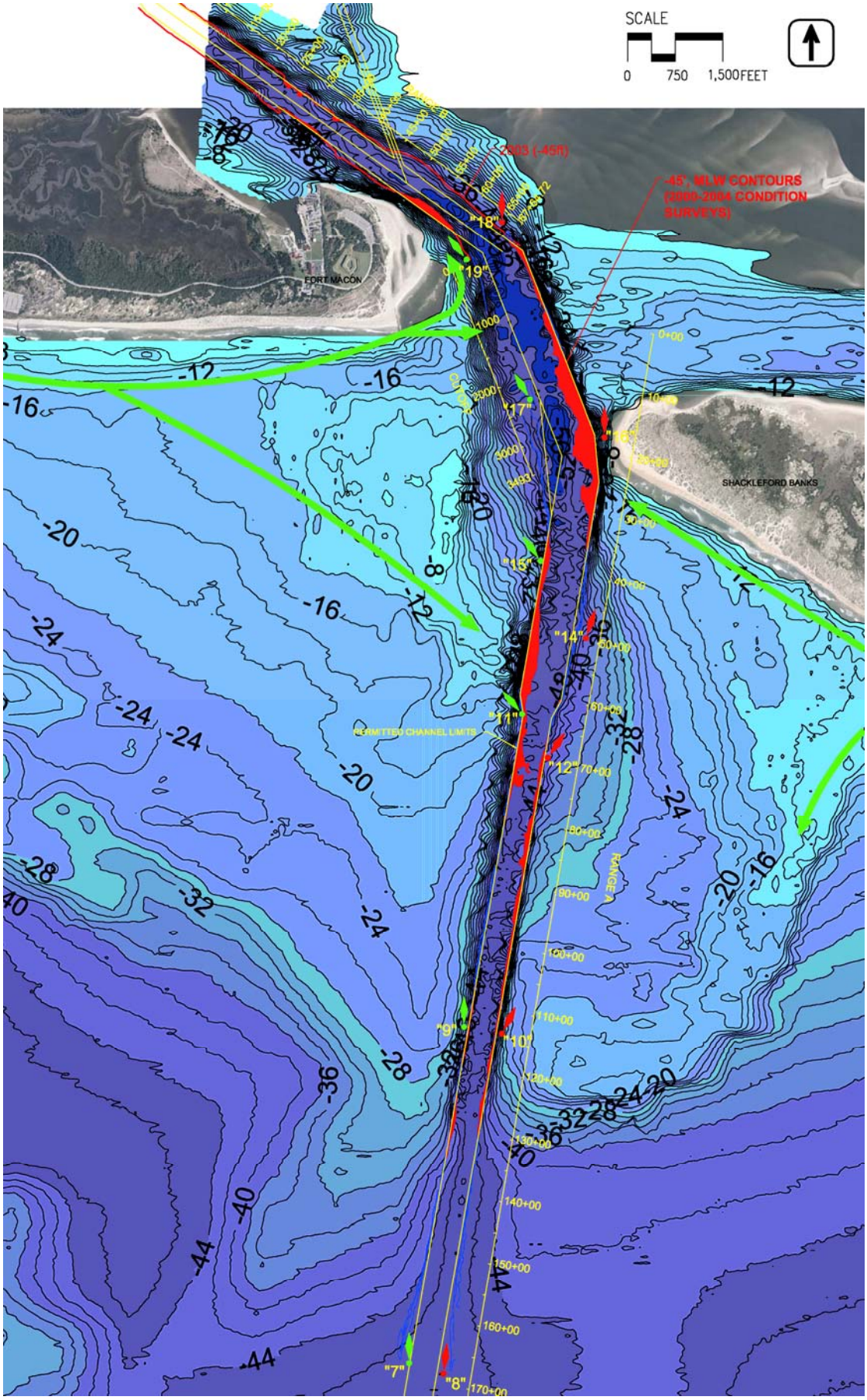


**Figure 10**: Location of -45 ft, MLW contour depicting the historical envelope of shoals within the Morehead City Harbor channel. Derived from USACE annual condition surveys (2000-2004). Bathymetric contours represent conditions in July 2004 (ft, MLW). Date of aerial photographs is September 2004. Vectors represent apparent sediment transport pathways.

### 3.7 Dredge (Maintenance) Depths

Since 1994, the current authorization for the navigation project along the ocean bar channel, Range A, calls for a depth of -45 ft MLW plus 2-ft wave allowance (= -47 ft MLW), plus 2-ft of allowable advance maintenance. This depth is referred to as "47+2". The remainder of the outer channel is at depth "45+2".

The Corps' contracts for FY1999 and plans for maintenance dated October 2000 show a dredging depth requirement for Range A of "47+2". Condition surveys for these and earlier years confirm that the channel depths are generally at or deeper than 47 ft.

But over the last few years, the Corps' plans have decreased the dredge-depth requirement. For example, plans dated November 2001 and June/September 2004 require dredging of only "45+1" and "45+2", respectively, for Range A. Indeed, condition surveys for the last few years confirm that the channel depths along Range A are generally *shallower* than 47 ft. The Bar Pilots likewise confirm that the Corps had dredged the channel to over 47 feet in the past, but that the controlling depth is now shallower than 47 feet. This requires that some vessels must await high tides for reliable entry across the bar.

Along Range A, 2-ft of over-dredge requirement (i.e., dredging to -49' ft relative to the outer channel's typical existing depth of -47' or less) would result in an additional dredge volume of up to about 400,000 cy.