FEASIBILITY REPORT
AND
ENVIRONMENTAL ASSESSMENT

WILMINGTON HARBOR NAVIGATION IMPROVEMENTS
Appendix B - Engineering

June 2014

US Army Corps of Engineers

Wilmington District

Appendix B

Engineering and Design

Contents

Introduction

The purpose of the study is to determine if navigation channel improvements are needed at Wilmington Harbor. Three areas for improvement have been identified to be addressed in this feasibility study. The three areas are the entrance channel near Bald Head Island, Battery Island Turn, and the Anchorage (Turning) Basin. The Port of Wilmington and channel users have identified each of these areas as having problems. The problems consist of channel alignment and width inadequacies affecting navigation efficiency and ship safety.

Wilmington Harbor Entrance Channel-Baldhead Shoal Channel

Shoaling in Baldhead Shoal Channel

The Wilmington Harbor entrance channel was relocated as part of a 1997 Value Engineering Study. The current alignment has proven susceptible to rapid and persistent shoaling theoretically attributable to a combination of natural forces and impacts from adjacent, private beach renourishment projects, and Federal shoreline disposal projects. Figure 1 displays the pre-2001 and post-2001 channel alignments. The post-2001 alignment bends to the east around station 45+00.

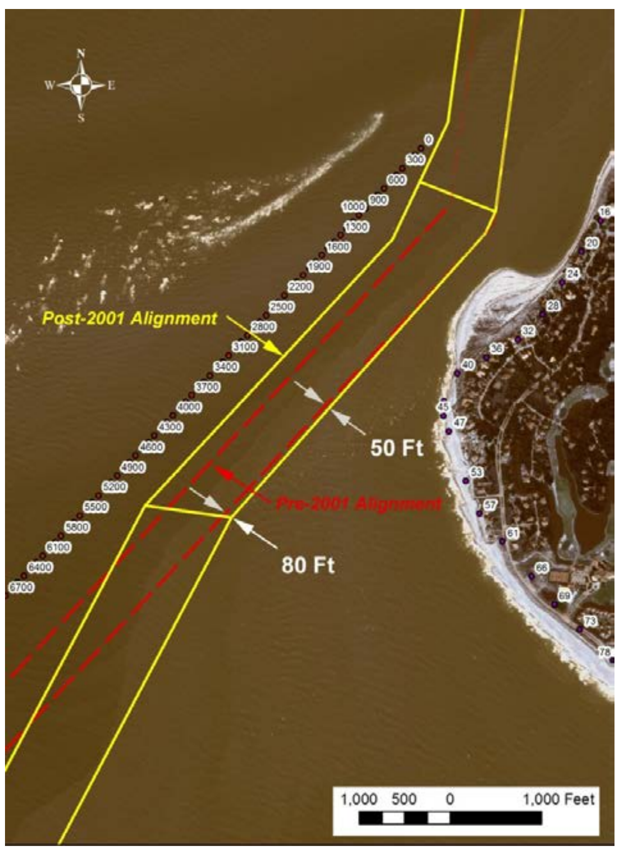

Figure 1. Pre and Post-2001 Wilmington Harbor Entrance Channel Alignments.

The Bald Head Shoal Channel was widened and deepened from 40 ft MLLW to 44 ft MLLW. Figure 2 displays the cross channel templates at station 18+00. The channel condition in February 2013 is shown in Figure 3.

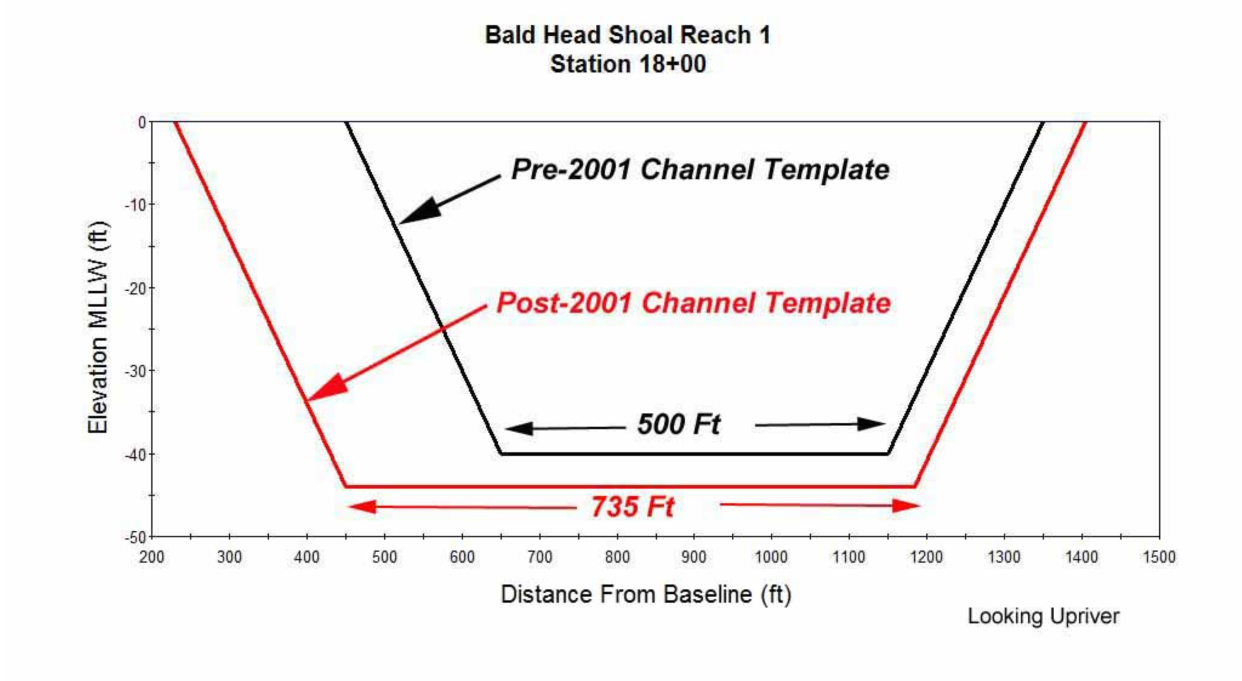

Figure 2. Pre and Post-2001 Bald Head Shoal Channel Templates.

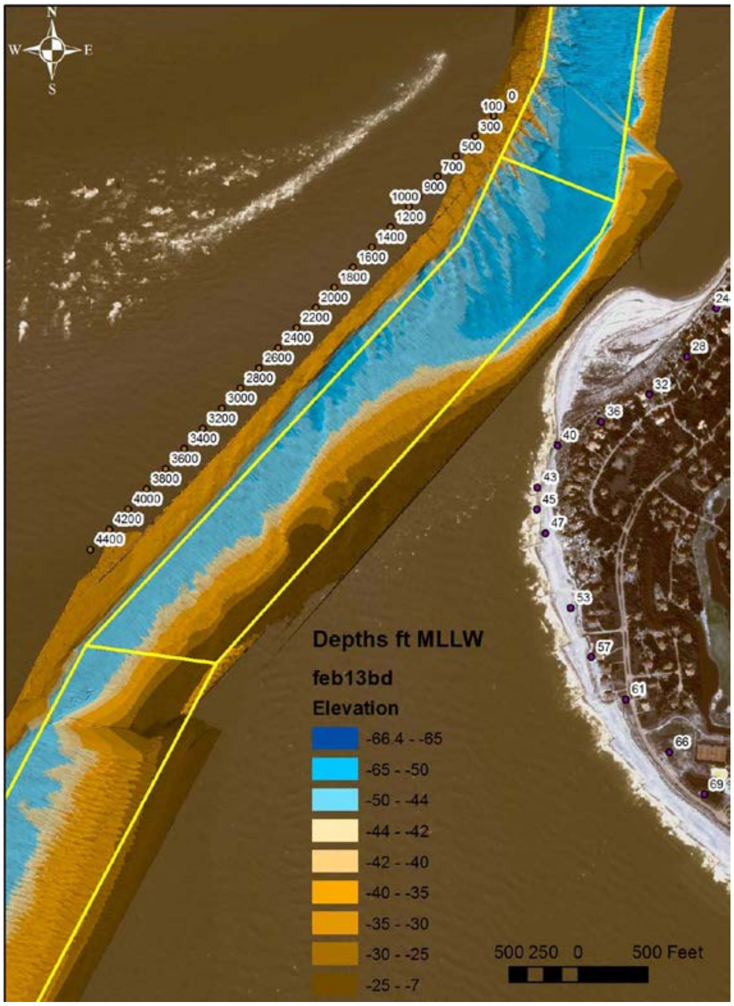

Figure 3. February 2013 Before Dredging Survey.

A comparison of the shoaling volumes pre and post project was made using the volume shoaled in the pre-2001 channel template in order to remove the influence of the larger post-2001 template (See Figure 4). A chart of shoaling volume in the pre-2001 template versus time from 1994 to 2013 is shown in Figure 5 along with beach fill volumes placed on Bald Head Island. The Figure displays the large increase in the shoaled volume within the pre-2001 template after 2001. In order to reduce the influence of time between dredging on the pre and post project shoaling, the monthly shoaling rate is displayed in Figure 6. Similar to the shoaled volume, the monthly shoaling rate had large increases after 2001.

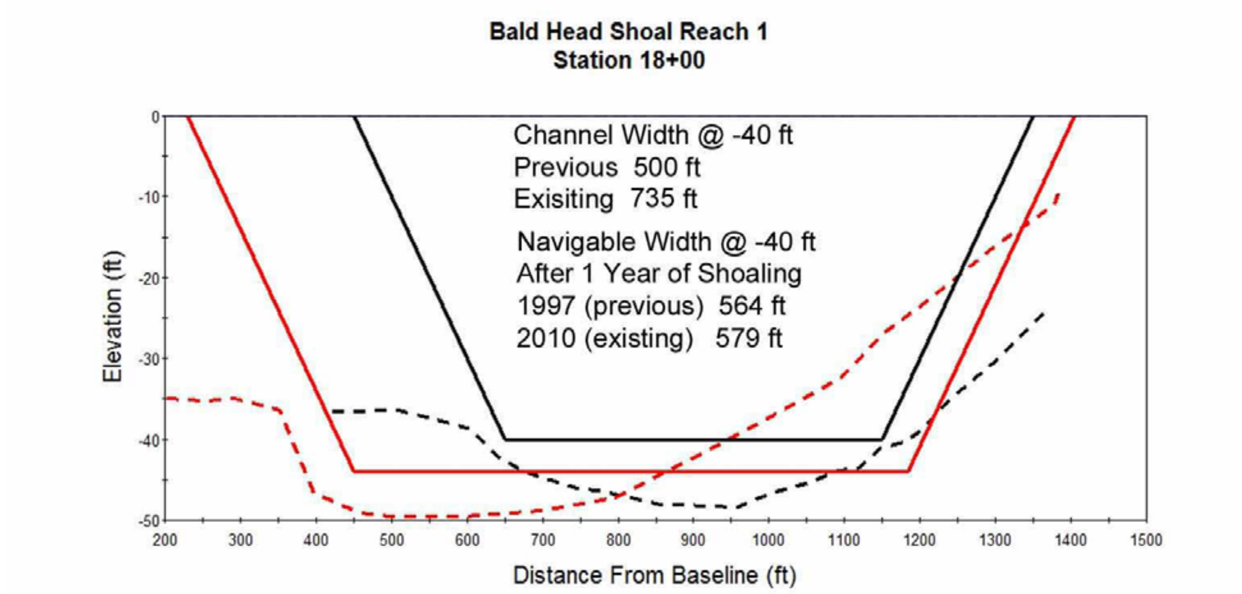

Figure 4. Portion of shoal used for Pre and Post-2001 Comparisons.

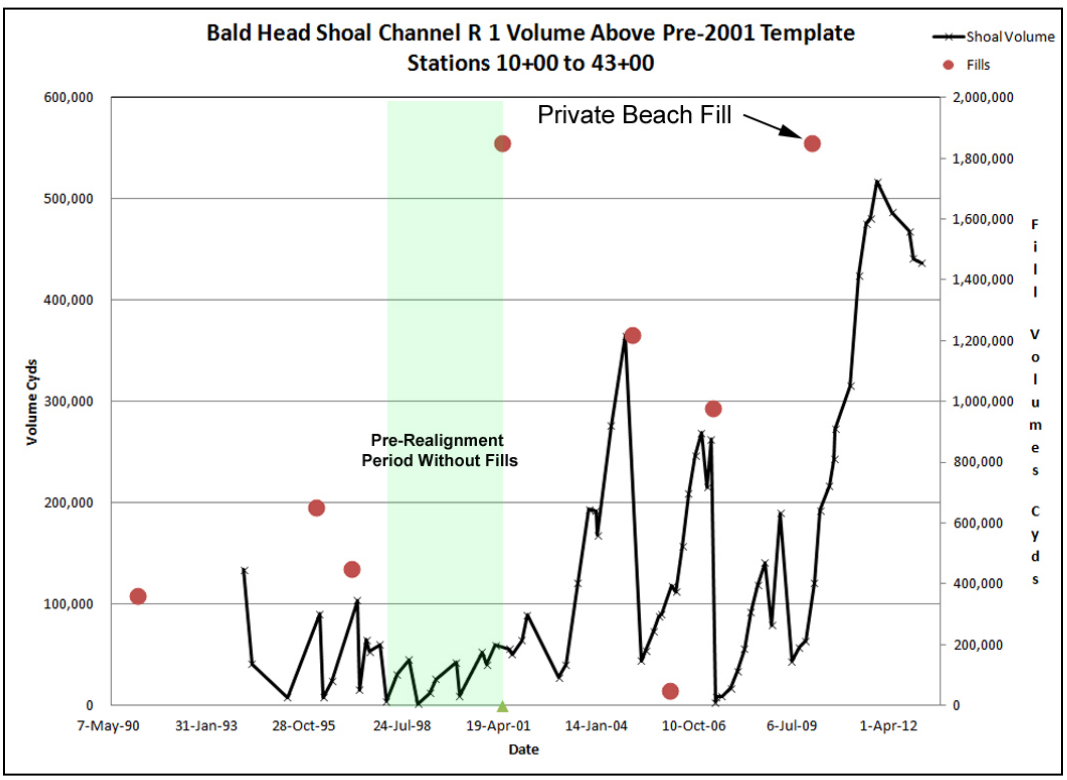

Figure 5. Shoaling Volume in the pre-2001Template versus Time from 1994 to 2013.

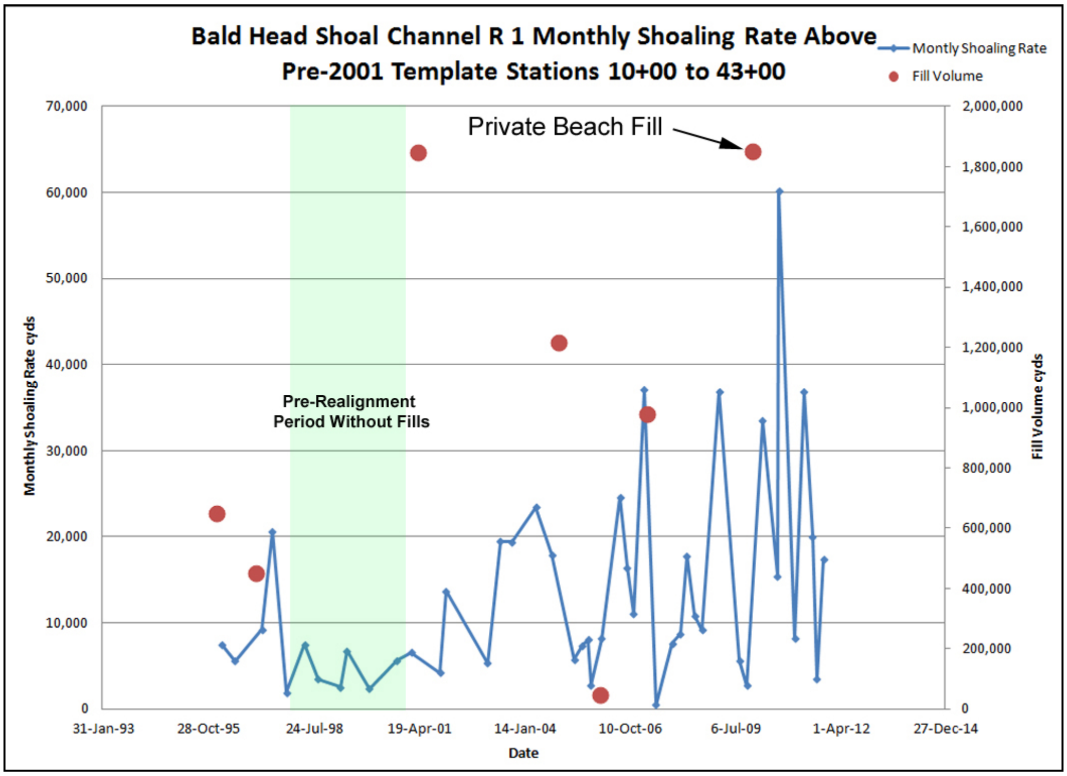

Figure 6. Monthly Shoaling Rates in the pre-2001Template versus Time from 1994 to 2013.

Analyzing the bathymetric surveys in Bald Head Shoal Channel from stations 10+00 to 44+00 produces a pre-2001 average annual shoaling rate of 50,000 cubic yards, Figure 7. The analysis started at station 10+00 because as seen in Figure 3 very little shoaling occurs between stations 0+00 and 10+00 and many of the before and after dredging surveys started at station 10+00. Using the same pre-2001 channel template and stations for consistency, the average annual shoaling rate after 2001 increased to 150,000 cubic yards. If the larger present channel template is used the average annual shoaling rate has increase to 250,000 cubic yards. A large portion of the increase can be attributed to the beach disposal operations which are shown as red dots in Figures 5 and 6. Sand disposed of at the end of the island in the current dominated inlet complex cannot adjust to a more stable profile because the sand is swept away as it migrates down the profile.

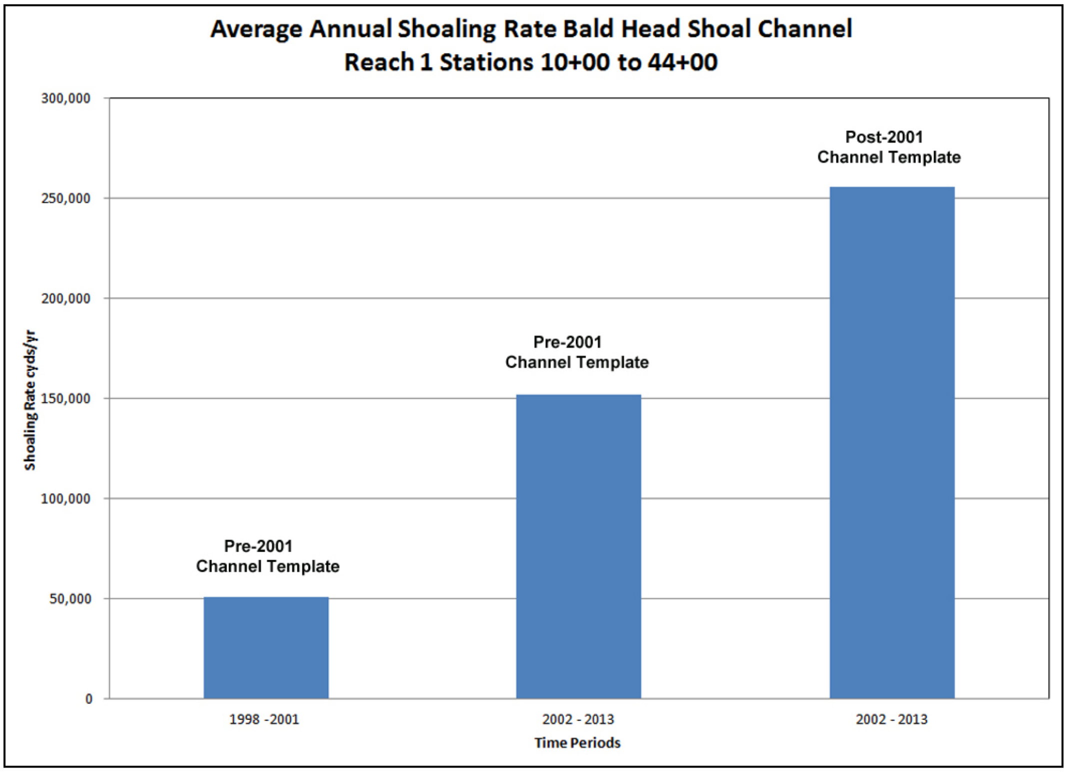

Figure 7. Average Annual Shoaling Volumes in the Bald Head Shoal Channel from Stations 10+00 to 44+00.

Figure 8 displays the volume change per ft of beach during a beach disposal operation and the volume change during the 6 months following the disposal operation. It is readily apparent that the fill at some stations is unstable and is rapidly transported away from where it was placed. The graph should be used to locate stations with erosion or accumulation but not to do a volume balance since the stations used for the calculations do not have equidistant spacing. The beach profiles at station 57 for the pre-disposal, post-construction and 6 month post-construction are shown in Figure 9. During the 6 months after the disposal operation, the beach profile at station 57 lost 150 ft of width. The locations of the stations are shown in Figure 10. In Figure 10 the coloration of the water indicates the location of an ephemeral marginal channel which cuts through the shoal that is located along the navigation channel. The link between the placement location of beach disposal material and increased navigation channel shoaling will be addressed by the Sand Management Plan for the Wilmington Harbor Navigation Project.

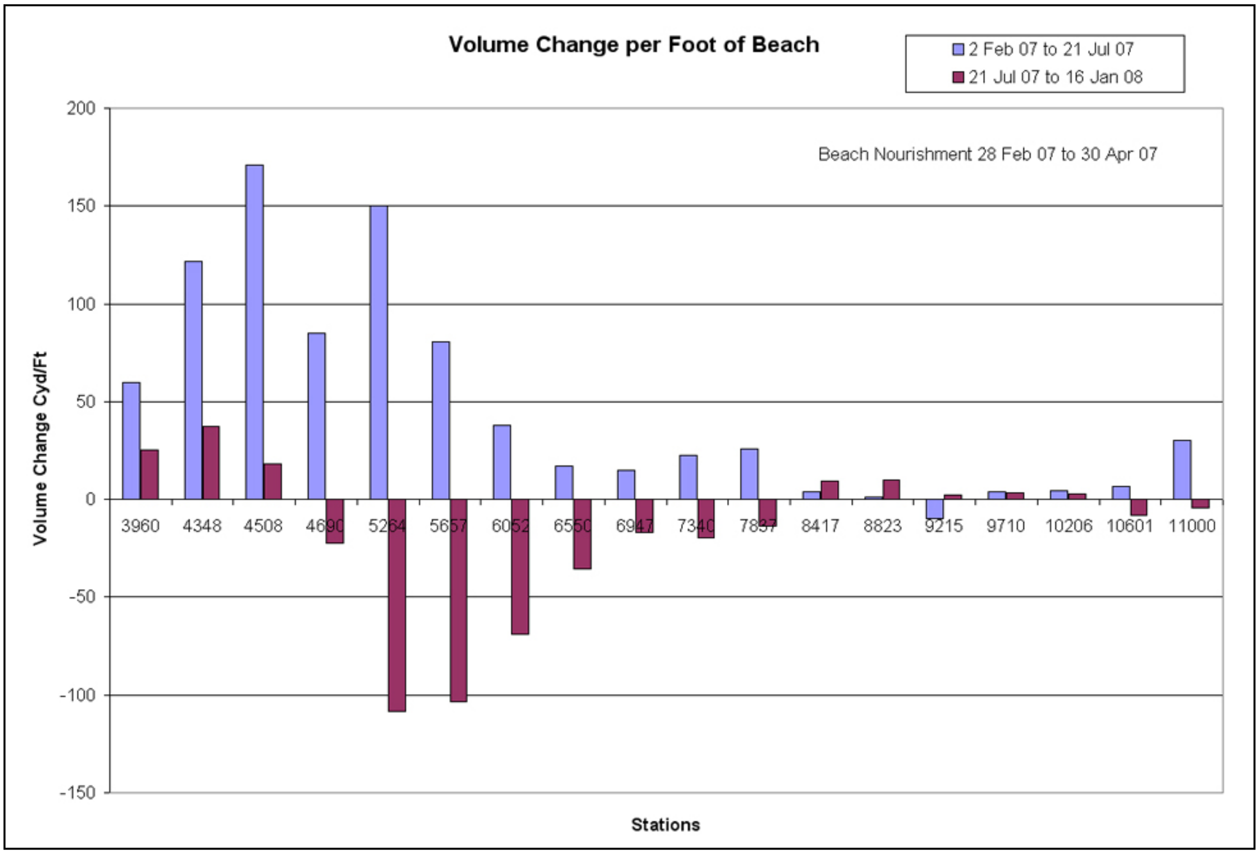

Figure 8. Volume change per ft of Beach due to a Beach Disposal and the Following 6 Months.

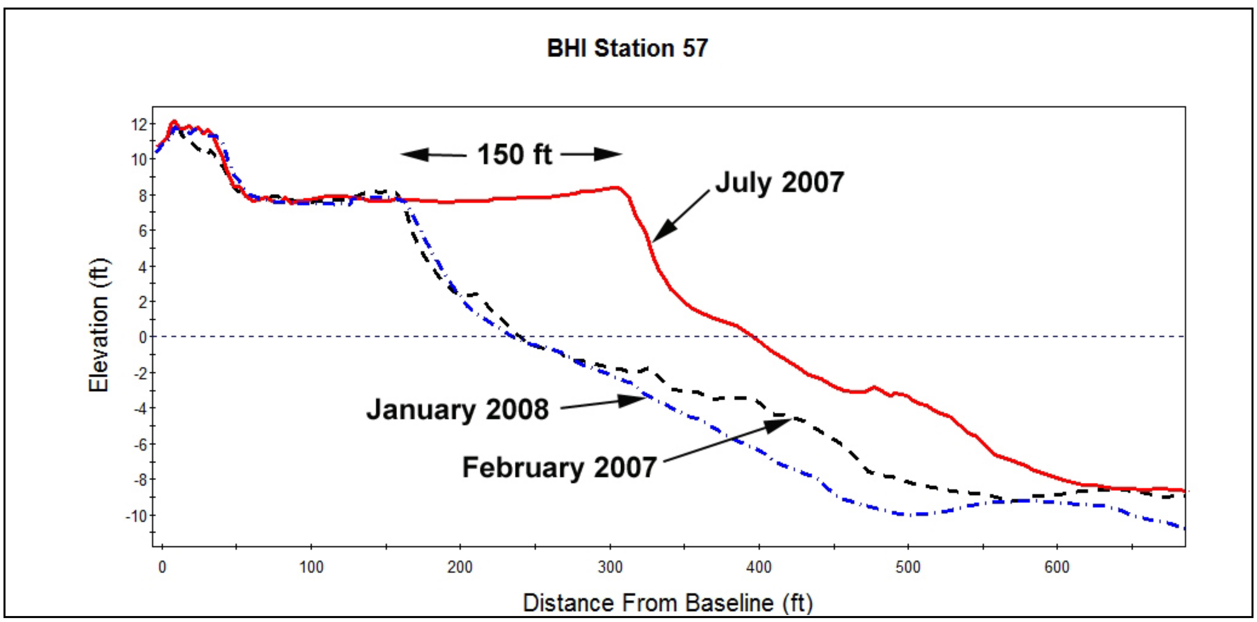

Figure 9. Beach Profiles at Bald Head Island Station 57.

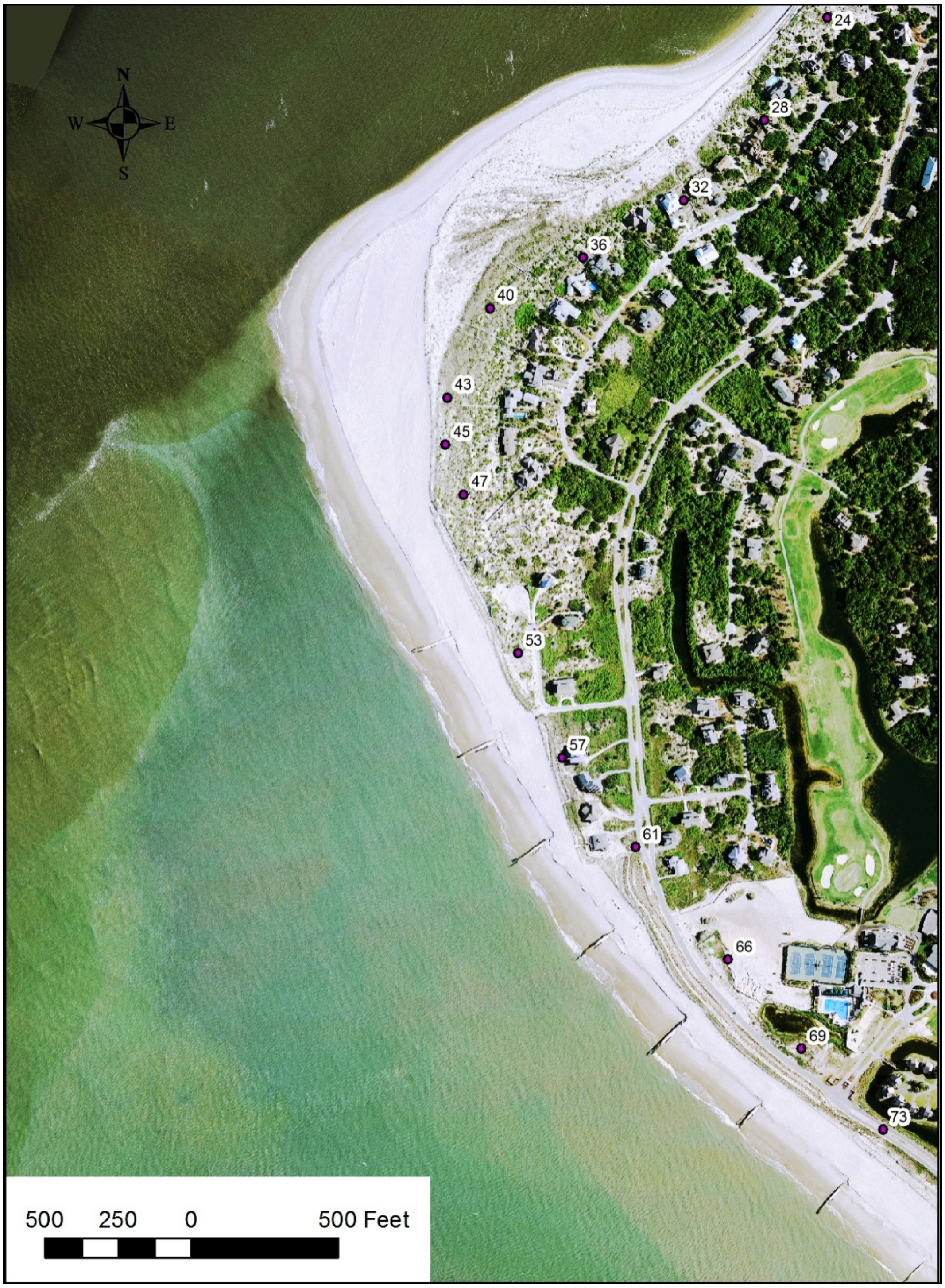

Figure 10 Bald Head Island Station Locations.

Advanced Maintenance

Advanced maintenance was considered as an alternative to mitigate the adverse effects the shoaling has on navigation. However, the way the shoaling occurs does not favor this alternative. Rapid shoaling in the channel first occurs where the littoral sand transport flows into the navigation channel. This initial shoal expands across the channel until the current retards the cross channel growth and the shoal then begins to expand along the side of the channel. The widening of the channel by 235 ft at channel station 18+00 in 2001 can be analyzed as an advance maintenance experiment. The pre-2001 and post-2001 annual channel surveys are shown in Figure 11 along with their respective channel templates. The navigable width at a depth of -40 ft MLLW is essentially the same one year after dredging even though the post -2001 channel template is 235 ft wider. The rapid shoaling into a current controlled channel width precludes advance maintenance as a solution to the channel shoaling problem. A sediment trap on the east side of the channel was not considered due to potential impacts on the adjacent developed shoreline.

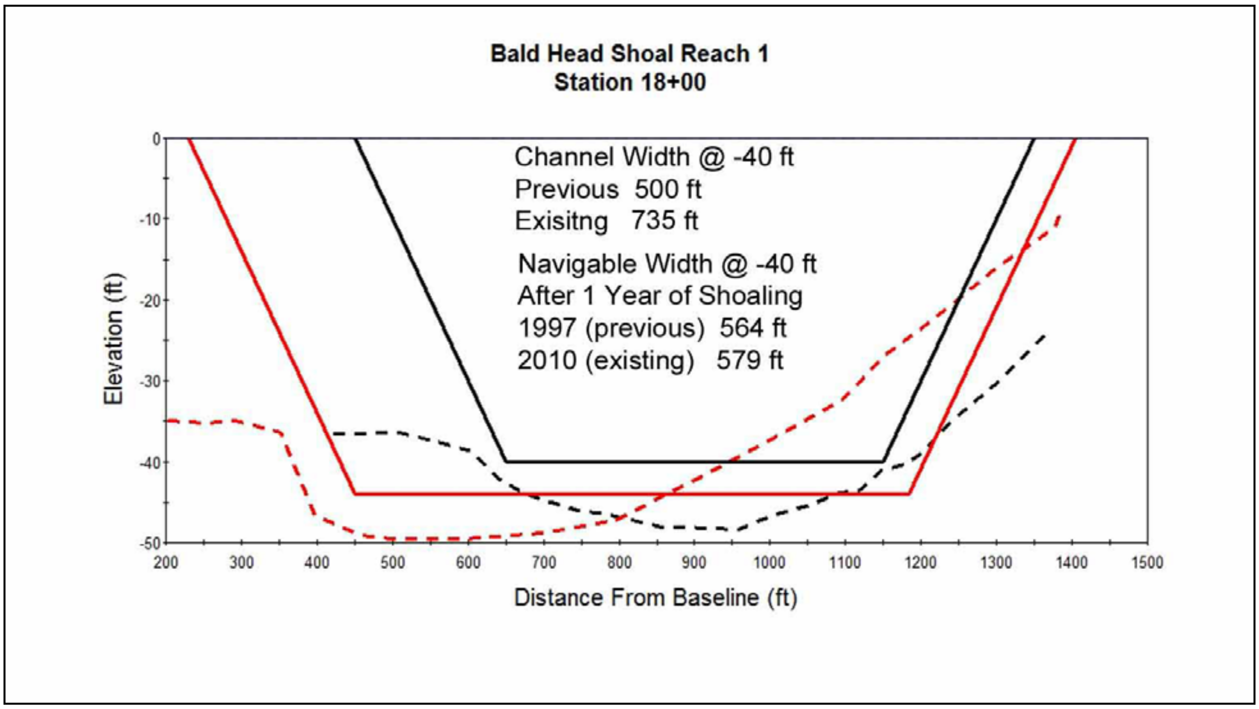

Figure 11 Pre and Post-2001 Shoaling at Channel Station 18+00.

Channel Relocation

Moving the channel was analyzed as a way of obtaining a one-time reduction in the volume dredged. The reduction is a one-time occurrence since moving the channel does not reduce the littoral sediment flow into the channel or the rate at which the channel will shoal. There is an additional benefit from moving the channel further away from Bald Head Island than the pre-2001 alignment. Moving the channel further from Bald Head Island makes moot any claims by the Village of Bald Head Island that the 2001 channel shift has had a negative impact on Bald Head Island. The volume contained in three new alignments for Bald Head Shoal Channel Reach 1 were compared to the volume contained in the existing alignment for the February 2013 before dredging survey. A volume reduction can be obtained by moving the channel to the west away from the shoal that forms on the east side of the channel until the channel starts to cut into the bank on the west side of the channel which offsets reductions obtained from the move away from the shoal on the east side of the channel. The three alignments analyzed are shown in

Figure 12 along with a table of volume reductions. While there is very little difference amongst the volume reductions for all three alignments, alignment 2 has the greatest volume reduction. Figure 13 displays alignment 2 with offsets from the existing channel.

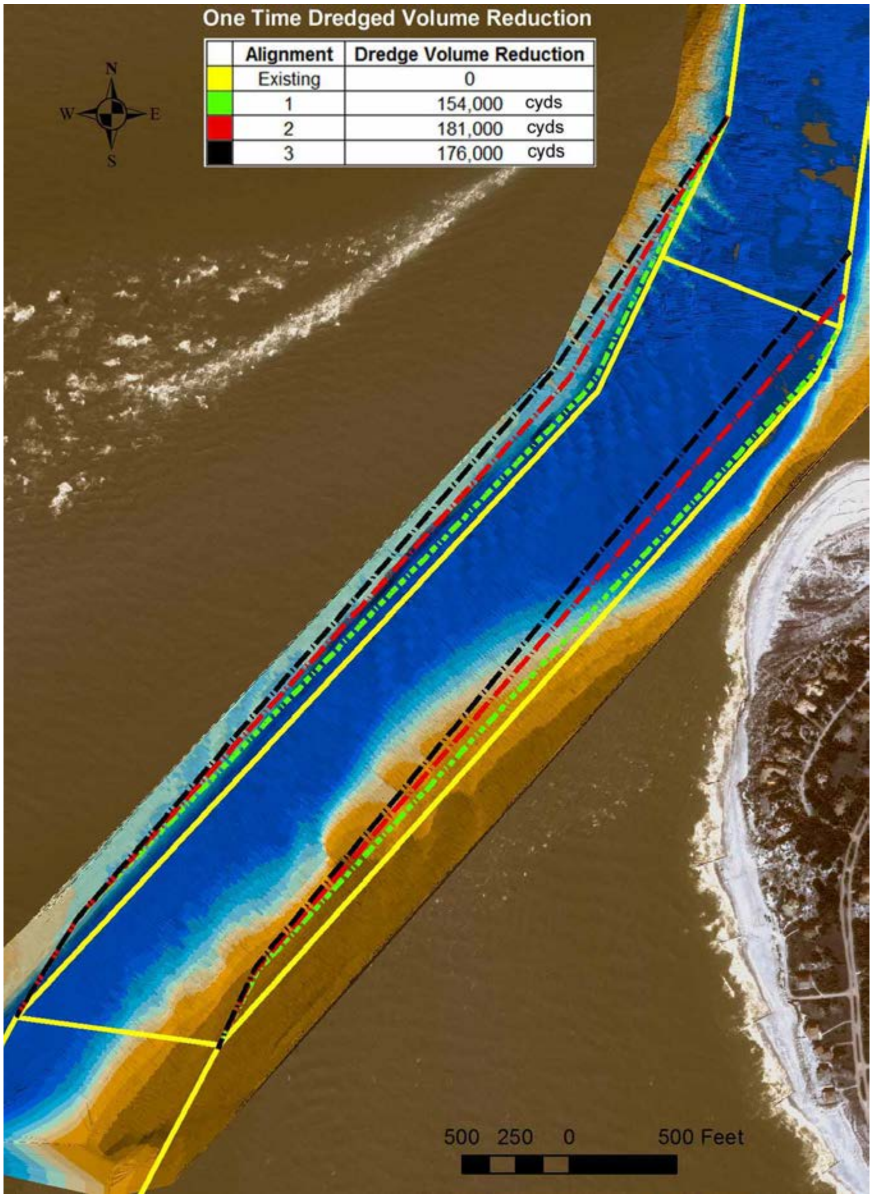

Figure 12. Channel Relocation Alternatives.

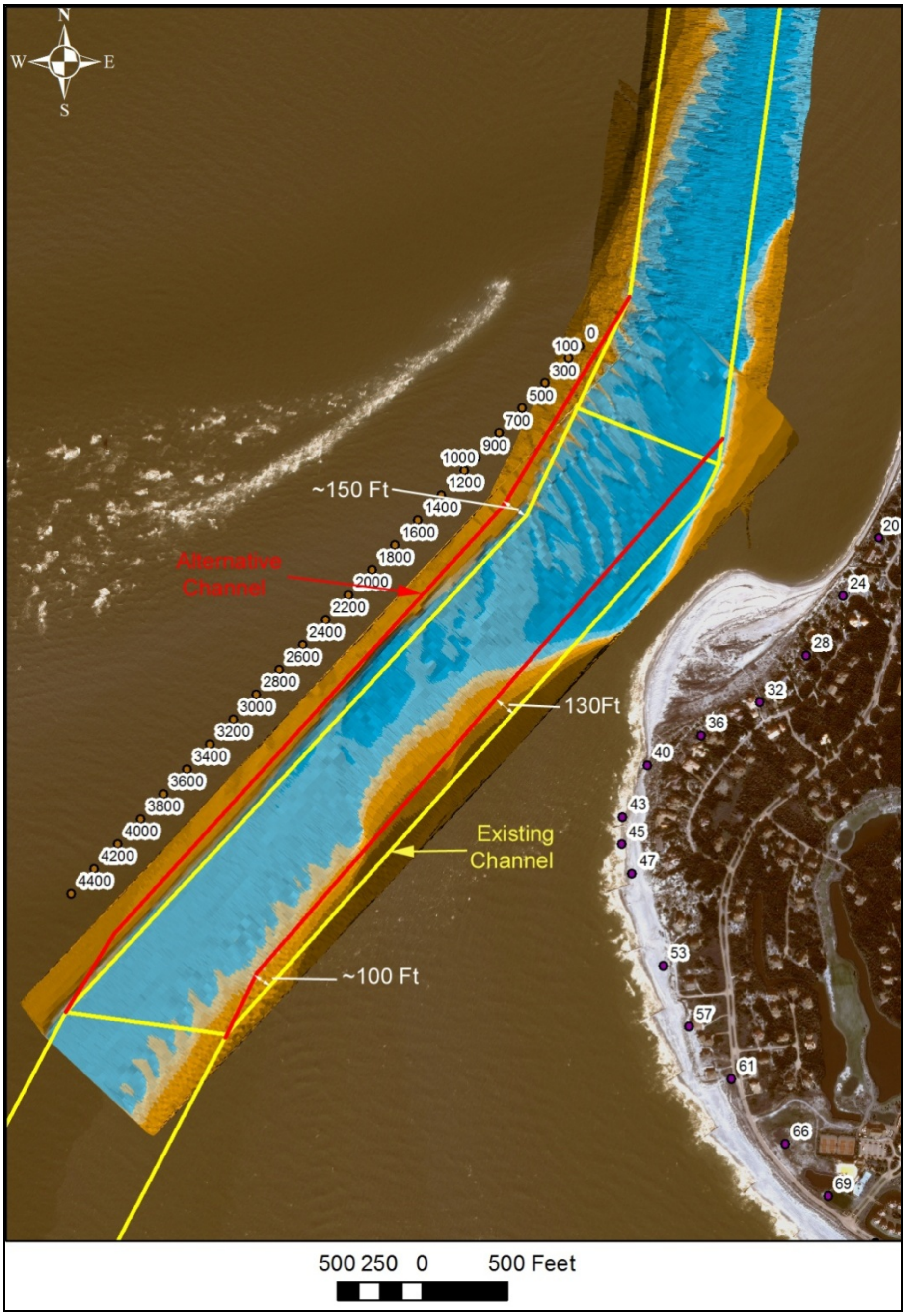

Figure 13. Relocated Channel with Offsets from Existing Alignment.

Battery Island Turn Relocation

Engineer Manual Guidance (EM 1110-2-1613)

Deflect ion Angle between Lower Swash and Southport channels is 96 degrees. The Battery Island channel currently serves as a cut-off channel. The deflection angle between Lower Swash and Battery Island is 65 degrees, and between Battery Island and Southport is 31 degrees.

EM calls for a circle turn with a radius of at least 10 times the ship length for a deflection angle greater than 50 degrees.

EM 1110-2-1613
31 May 06

Table 8-4
Recommended Channel Turn Configurations

Deflection Angle, Deg	Ratio of Turn Radius/ Ship Length	Turn Width Increase Factor (* Ship Beam)	Turn Type
0 - 10	0	0	Angle
10 - 25	3 - 5	2.0 - 1.0	Cutoff
25 - 35	5 - 7	1.0 - 0.7	Apex
35 - 50	7 - 10	0.7 - 0.5	Curved
>50	>10	0.5	Circle

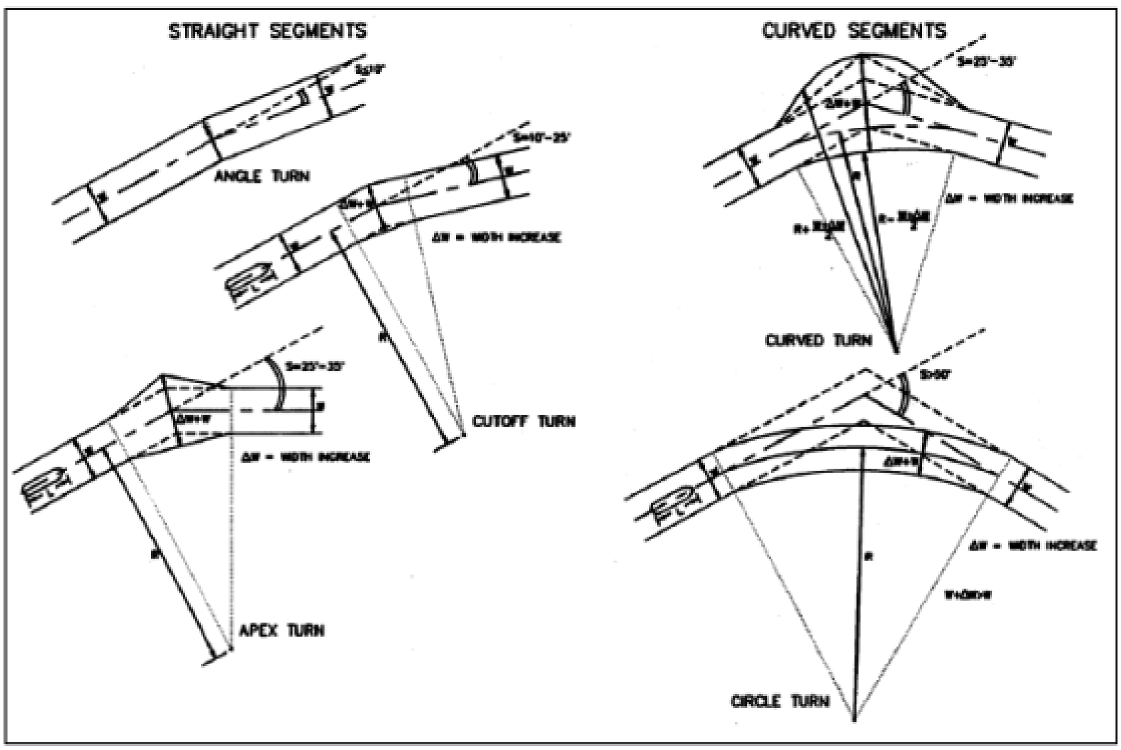

Figure 8-4. Channel turn configurations

Figure 14. Table and Figure from EM 1110-2-1613

However, using the 10 fold multiplier would require a radius greater than 9,650 feet. Such a curve would cut through Battery Island and essentially bypass Lower Swash, Battery Island and Southport channels (Figure 15). Adherence to this guideline is not reasonable in this situation. Ships have been using the general alignment around Battery Island for many years with some slight adjustment to channel cut-off limits. The current ratio of turn radius/ship length is about 3, suggesting minimum deflection angle of about 25 degrees as shown in Figure 14 (Table 8-4). Actual deflection angle is 65 degrees. Per the EM guidance, the channel width in the turn should be increased by a minimum of 2 times the ship beam or a width increase of 210 feet. This gives a minimum total channel width of 710 feet (500' + 210') in the turn.

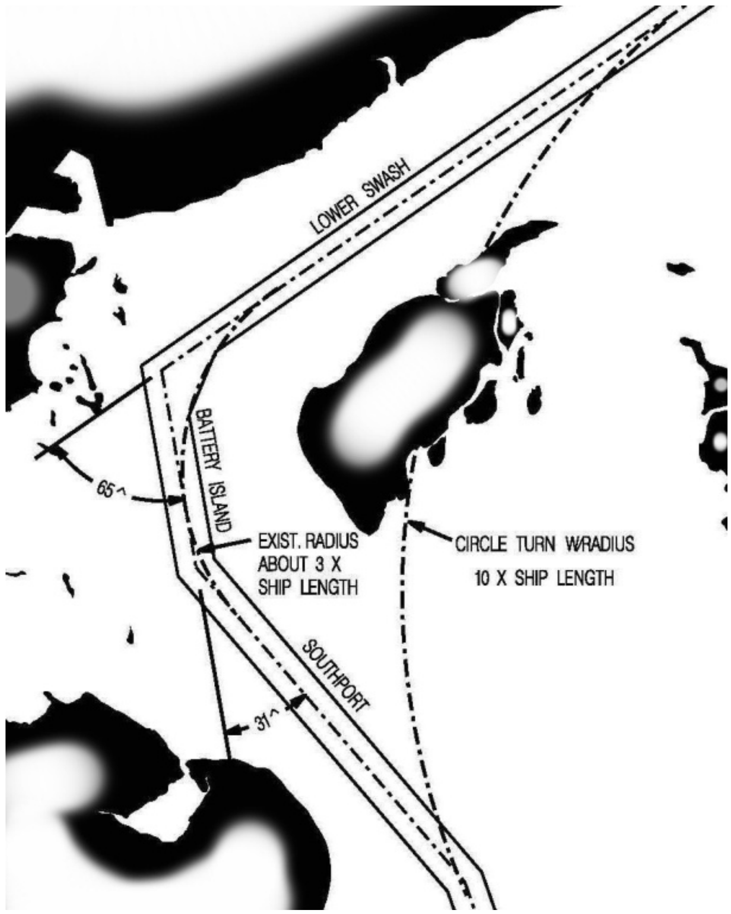

Figure 15. Existing Channel deflection angles

Ship Simulation Background

The realignment of the bar channel in the late 1990's was studied and accomplished as part of the Wilmington Harbor '96 Act harbor deepening effort. The study involved some ship simulations of the bar channel and partially up the harbor thru Battery Island channel into Lower Swash. The design vessel was similar and only slightly shorter (950' vs. 965'). At least 40 simulations were conducted for the 950' ship using both ebb and flood tides. Note that these simulations were not testing any changes to the Battery Island turns, but rather the realignment of the bar channels. Data plots of these simulations have been used for improvement considerations in the Battery Island turns. The simulations data plots indicate the need to soften the turns in this region.

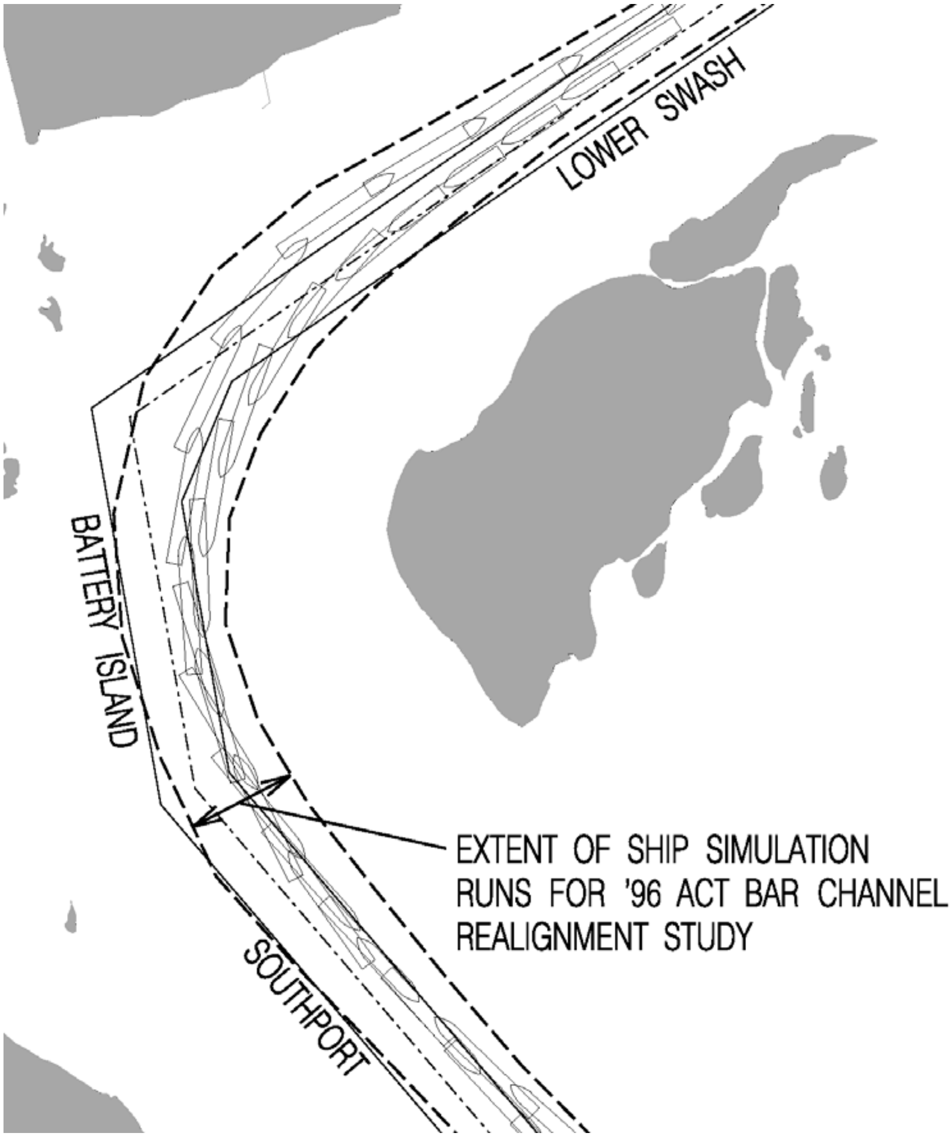

Figure 16. Illustration of ship simulations and extent of ship paths.

Input from Ship Pilots

Since early 2010, ship pilots have proposed a cutoff in Battery Island/Lower Swash turn based on the existing design vessel (950' x 106'). In January of 2010, the Cape Fear Pilots met with SAW Navigation personnel to discuss the Battery Island turns. The group performed some tabletop exercises using the pilot's local knowledge, hydrographic survey plots of the channels and scaled hardboard cutouts to represent the ship. The result of these exercises was a recommendation for an additional expansion of the inside channel prism at the BI/LS junction (per conversation with RH Varnam, 3/2013).

The proposed cutoff expansion at BI/LS (recommend outcome of Jan 2010 meeting) shifts the existing cutoff about 250' to the inside of that turn. Widening this cutoff allows more favorable alignment as the ship sweeps thru the turns around Battery Island. No action was taken on this proposal.

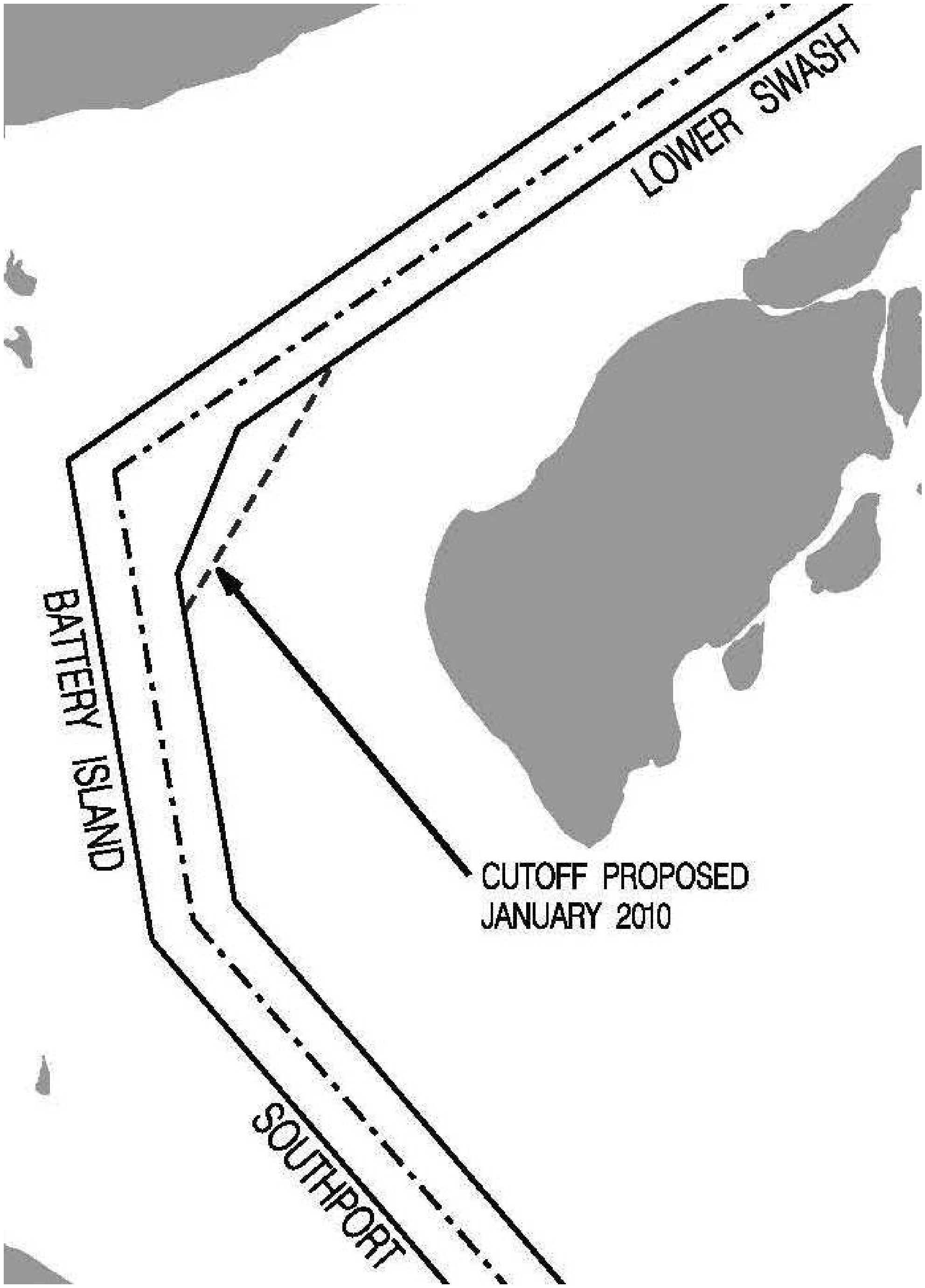

Figure 17. Initial cutoff proposed in January 2010.

In a more recent meeting with the Cape Fear Pilots (April 12, 2013), the pilots explained how the turn continues to be restrictive and difficult to maneuver due to the narrow width, tight radius and hydrodynamic effects of the channel bank. The pilots continued to support a cutoff between Battery Island and Lower Swash channels as well as a wider Battery Island channel. Their input was incorporated into the proposed improvements outlined below.

Turn Alignment Proposal

The following channel improvements are based on a combination of EM guidance, previous ship simulations and input from ship pilots.

The EM guidance suggests a channel width requirement of at least 720 feet due to the large deflection angles and small radius.

Ship simulations, done in the 1990's indicate that the passage around Battery Island (Lower Swash thru Southport channels) required an average channel width of about 750' along 8,000' of channel(Figure 16). Currently, Lower Swash channel is 400' wide, Battery Island channel is 500' wide and Southport channel is 500' wide. An existing cutoff at Lower Swash/Battery Island widens the channel to about 700' wide along the apex of the turn.

The following improvements are proposed. (1) Battery Island channel is widened to 750'; (2)A 750' wide by about 1,300' long cutoff provided between Battery Island and Lower Swash channels; (3) Additional tapers are provided where Southport and Lower Swash channels join the widened Battery Island channel. These geometric changes, shown in Figure 18, increase the available turning radius from about 2,850' to about 3,900'; a 37% increase.

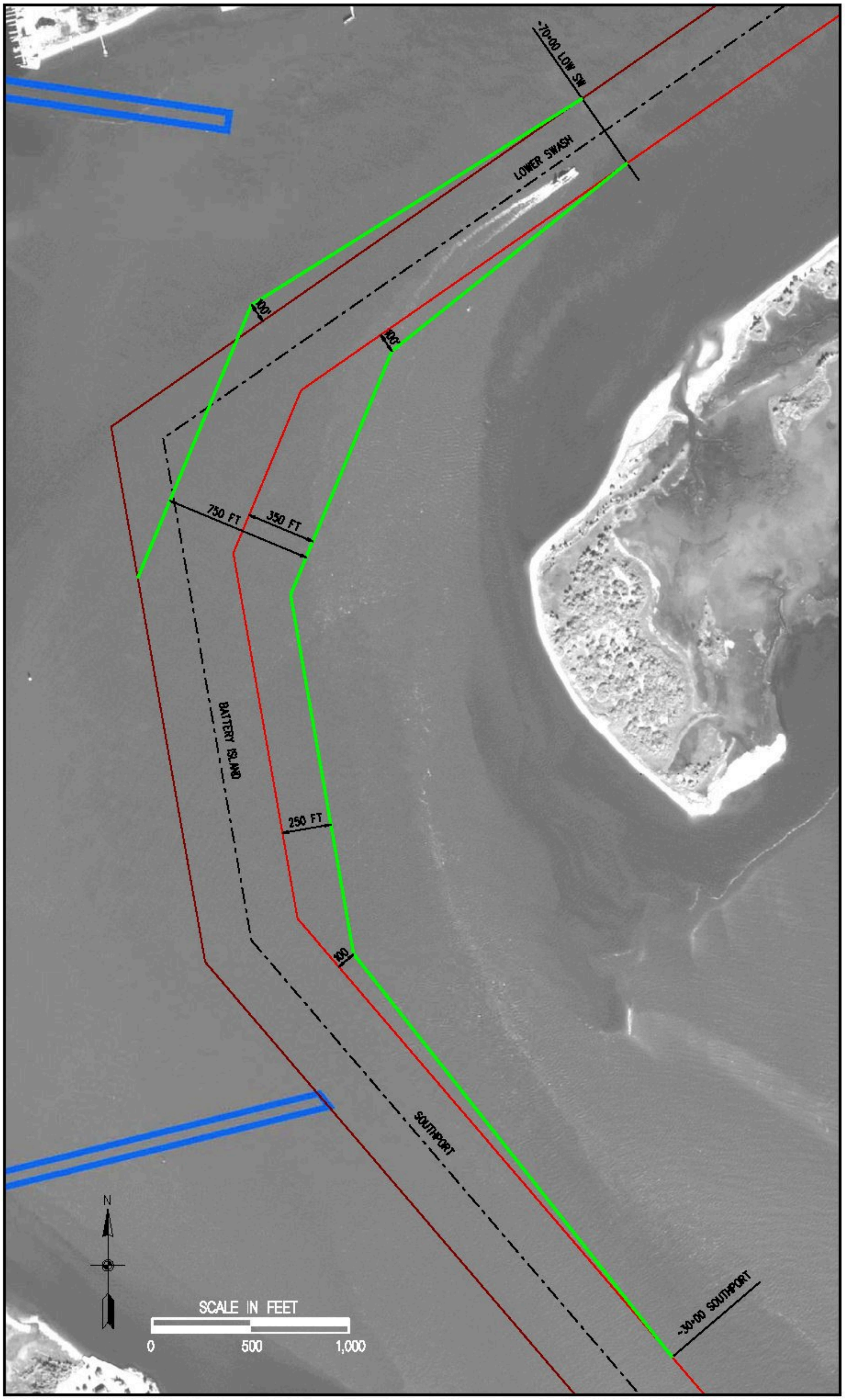

Figure 18. Proposed improvements to the turn around Battery Island.

Estimated Channel Shoaling

The shoaling that currently occurs in the area of this turn is localized and typically restricted to the east side of Battery Island Channel with occasional dredging requirements near the junction of Southport Channel on the east side. The material is sandy, likely originating from Battery Island and is shaped by the currents into linear features reaching into the channel prism.

Historically, dredging has been required in Battery Island channel on average about every 2 years. The northern part of Southport channel has required dredging about every 4+ years. Existing average annual volumes for Battery Island channel (including northern portion of Southport Channel) is about 12,000 cubic yards per year.

With the proposed alignment, the shoaling rate within the turn is expected to be similar to current rates because the forces that form the impeding shoals would continue to be somewhat similar. Projected shoaling rates for the turns thru the Battery Island channel (includes northern part of Southport channel and southern part of Lower Swash channel) are estimated at 12,000 cubic yards per year. The basis for the estimate is dredging pay quantities over the four dredging events that have taken place from 2004 to 2012.

Although long term channel shoaling is projected to be similar (as stated above), there will likely be a stabilization period soon after realignment construction when higher shoaling rates may occur. During the previous channel deepening project in this reach, initial deepening construction was followed up after 3 years with a “clean sweep” of all the channel prisms. Excessive stabilization shoaling was not noted at the time. A conservative approach for cost estimating would be to assume about 25% increase in shoaling volume per year for the two years following construction.

Ship Induced waves in the area of the Battery Island channel improvements proposed in WHIP

A basic desktop analysis was conducted to investigate potential changes in ship induced waves in the area of the proposed Battery Island turn widening improvements.

General factors which affect the wave system are:

- Ship dimensions and hull design to include length, width and slenderness/bluntness
- Ship draught – affects displacement of water within the channel
- Ship speed through the water – major wave generating factor - ship speed is not forecast to change
- Depth and width of river/channel – only width is proposed to be changed
- Distance from the sailing line – widener allows ship to sail closer to shoreline

Note that a project purpose for the widened channels at Battery Island is to allow the existing ship fleet to pass thru the Battery Island turns without waiting for a high tide. Factors 1 through 3 above do not change with or without the widener project. The river pilots have informed the District that the proposed improvements will not increase the ship's speed, factor 3, through the turn. Only factors 4 and 5 will change slightly since a widening is proposed (no deepening is proposed) and the widener can allow the ship to sail about 350 feet closer to Battery Island or about 100 feet closer to the waterfront at the town of Southport.

The existing ship fleet includes both large vessels such as the 950' by 106' container ship used for harbor geometric design (design vessel) and many smaller vessels such as tankers and bulk haulers (500' to 700' long by 106' width). The existing ship fleet is forecast to call with or without the improvements to Battery Island turn. The shorter tankers and bulk haulers generate larger waves than the larger design vessel.

The existing ship fleet forecast includes likely transits from a Generation 1 Post-Panamax vessel which has the dimensions of 953' length and 131' width. This size of vessel was analyzed as well. The shorter tankers and bulk haulers generate larger waves than the Gen 1 Post-Panamax ship.

Ship speed through the water has a major affect on the maximum wave height generated. Using information requested from the US Coast Guard, ship position data was analyzed for a 2 year period to determine average speed in the area of Battery Island. The data was filtered to include only ships with maximum draughts of more than 30 feet that passed thru the Battery Island channel area. The average speed of the nearly 2,000 data points is 10.7 knots. A speed of 11 knots was used for wave height calculations.

A conservative assumption is that ships could sail 1) up to 100' closer to the Southport waterfront and 2) up to 350' closer to the Battery Island shore due to the widening. It is estimated that shorter distance would increase the maximum wave heights by about 16% on Battery Island and only 2% along the Southport waterfront. However, a more likely scenario is that the ships will continue to sail as close to the revised channel centerline as possible, resulting in 1) effectively no closer distance to Southport waterfront and 2) up to about 320' closer to Battery Island. The likely scenario results in 1) no change to ship waves at Southport waterfront since revised channel centerline is no closer to shore, and 2) maximum wave heights on the southern shore of Battery Island of about 14% higher due to 320' shift of centerline toward the island shore. For these calculations, a 500' tanker ship, a 950' container ship and a 953' Gen 1 Post-Panamax ship were considered at speed of 11 knots with the greatest increase in wave height calculated to be just less than 1.5 inches. This small of an increase is deemed negligible.

Deep-draft vessels sailing in confined channels with relatively shallow banks create long period surge waves (related to the vessel drawdown or squat) and these waves are more pronounced than the short period waves at the bow and stern. Squat (or drawdown) for a 950' by 106' design vessel in a confined channel will reduce if the channel is widened. Calculations show a range of

15% to 40% reduction in the ship squat for 106' wide vessels after widening the channel. For the wider, Gen 1 Post-Panamax ship (953' x 131'), the squat is reduced about 5% to 25%. Only reductions in ship squat are expected with the widened channel. The reduction in ship squat with a widened channel would point to a reduced surge wave generated by the vessels as compared to the existing channel.

In conclusion, the ship-induced waves along the Southport shoreline are not expected to be significantly changed from the existing condition by implementing the proposed channel wideners. The southern shore of Battery Island could experience somewhat higher ship waves since the channel is moved closer (increase of about 14%), however for existing vessel speeds, a 14% wave height increase is less than 1.5 inches and is considered negligible. The river pilots have informed the District that the proposed improvements will not increase the ship's speed.

Although larger vessels are expected to call to Wilmington's port (Gen 1 Post Panamax) with or without the project, these are not expected to generate larger waves in the area of the Battery Island turn improvements.

Additional extensive wave modeling could be performed to provide a more thorough analysis of ship induced wave predictions and resulting potential shoreline impact on Battery Island. The modeling effort would require detailed data gathering and model runs and would need significant funding.

Anchorage (Turning) Basin Improvements

The existing anchorage basin design includes a 1,200 foot wide by 1,000 foot long section of the -42 foot plus 2 feet of allowable overdepth channel for use as the ship turning basin. While the design currently accommodates vessels up to 965 foot in length, width of the turning basin does not allow for significant margin of error. To comply with the current design standards in EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects (USACE 2006), the channel turning basin has been modified to a design width of 1,450 feet. This is equivalent to 1.5* the length of the 965 foot design vessel. The length of the new basin will remain at 1,000 feet which is currently sufficient to accommodate vessel current drift. The depth of the turning basin will remain as authorized at 42 feet plus 2 feet of overdepth below mean low water. To account for changes in anticipated shoaling resulting from the reconfiguration of the anchorage basin a shoaling analysis was completed for the existing configuration and then used to project shoaling rates to the improved basin.

Historic Data

The data used for the evaluation of the shoaling rates at the Wilmington Harbor Anchorage Basin were historic channel surveys taken by the USACE ranging in date from January 2008 through July 2012. These surveys included both partial channel surveys and full channel width surveys. In addition, some of the surveys were condition surveys obtained at various points during the dredging cycles while others were obtained before dredging or just after dredging. The length of the surveys varied from partial coverage up to the entire length of the Anchorage Basin.

Assumptions

The following assumptions were made for the calculation of Anchorage Basin shoal rates:

The analysis is based on a comparison of surveys to the authorized pay dredging template only. A straight comparison between surveys was not conducted.

All comparisons were made within the lateral bounding limits of the channel polygon. Any dredging that may have occurred outside the authorized pay channel lateral limits was not considered.

Shoaling rates were limited to between the years 2008 and 2012 due to funding and time limitations.

Methods

Historic surveys obtained from the Wilmington District Navigation Section were individually processed using ARCGIS and the Beach Morphology Analysis Package (BMAP) software to ensure adequate cross-channel coverage as well as to remove invalid survey observations. Cross sections of the surveys were developed for every 100 foot section of the Anchorage Basin as seen in Figure 19. These 100 foot sections were based on a project baseline developed for this analysis which has station 0+00 at the southern end of the Anchorage Basin and station 83+00 at the northern end.

For the time period analyzed there were five distinct dredging periods. The total number of surveys used in the analysis after verifying adequate coverage and quality varied along the channel within these dredging periods from as few as three surveys to as many as eight.

Existing Basin Volumetric Change Rates

Volumes were calculated for every 100 foot section of the Anchorage Basin by comparing the individual surveys to the authorized pay dredging template for the reach. These calculated volumes were then used to develop volumetric change rates for each 100 foot section of the Anchorage Basin. This was accomplished by computing a least squares regression through the measured template volumes at each station location for each survey. The least squares regression was computed separately for each dredge cycle time period defined to start with an “after dredge” survey and concluding with the “before dredge” survey taken just prior to the next dredging cycle. For the Anchorage Basin there were five distinct dredging cycles between 2008 and 2012 for which the least square regression was computed. These regression rates were then averaged to produce a representative volumetric change rate for every 100 foot interval within the Anchorage Basin (Figure 19). Shown in Figure 19 is how the rates gradually increase from the north (station 83+00) to south to approximately station 42+00 where a dramatic increase in shoaling rates is seen. This location is just south of where the dredging depth has historically changed from -40 foot mlw to -44 foot mlw. Rates remain relatively high and consistent from station 42+00 through station 26+00, averaging 39,500 cy/year in this section of the channel. South of station 26+00 rates rapidly decrease to nearly zero at the southern end of the Anchorage Basin. A cross sectional view of station 42+00 is shown in Figure 20 displaying the rapid shoaling in this area of the channel over only a two month period. This figure shows the authorized pay template cross section in green with example surveys from one dredging cycle overlaid. The picture is oriented “looking toward the south” and shows that shoaling in this area is relatively uniform across the entire channel width. Figure 21 shows a similar plot at station 80+00. This figure, which covers the same time period, shows there is little change in the survey measurements and the area is relatively stable with little shoaling.

The calculated volumetric change rates for each 100 foot station of the existing Anchorage Basin alignment were annualized and are shown in Table 1. The summation of the values in this table shows the annual shoaling volume for the Anchorage Basin to be approximately 1,251,804 cubic yards per year. To verify the projected annual shoaling rate for the Anchorage Basin is reasonable, a comparison was made to the historic contract dredging quantities. The total volume dredged from the Anchorage Basin between 2004 and 2011(8 events) was 9,253,556 which correspond to an annual dredging volume of 1,156,694 cubic yards per year, within 10% of the calculated annual shoaling rate. Calculated annual rates are typically higher than historic dredging records due in part to the fact that dredging records are bases on a comparison of before dredge and after dredge survey volumes. They do not account for the amount of material removed from the dredging area that shoals while a dredge is operating. The longer the duration between the before and after dredge surveys, the larger the difference. A second reason for the discrepancy is that due to funding limitations a section of a channel may not be fully dredged during each cycle. These quantities that accumulate within the channel limits would therefore not be captured in the before-after dredge survey comparisons. For these reasons it is important to calculate the annual shoaling volume using a least squares regression method that can be projected to an annual rate and better represent the amount of material being removed from the channel to allow for proper planning within the authorized disposal areas.

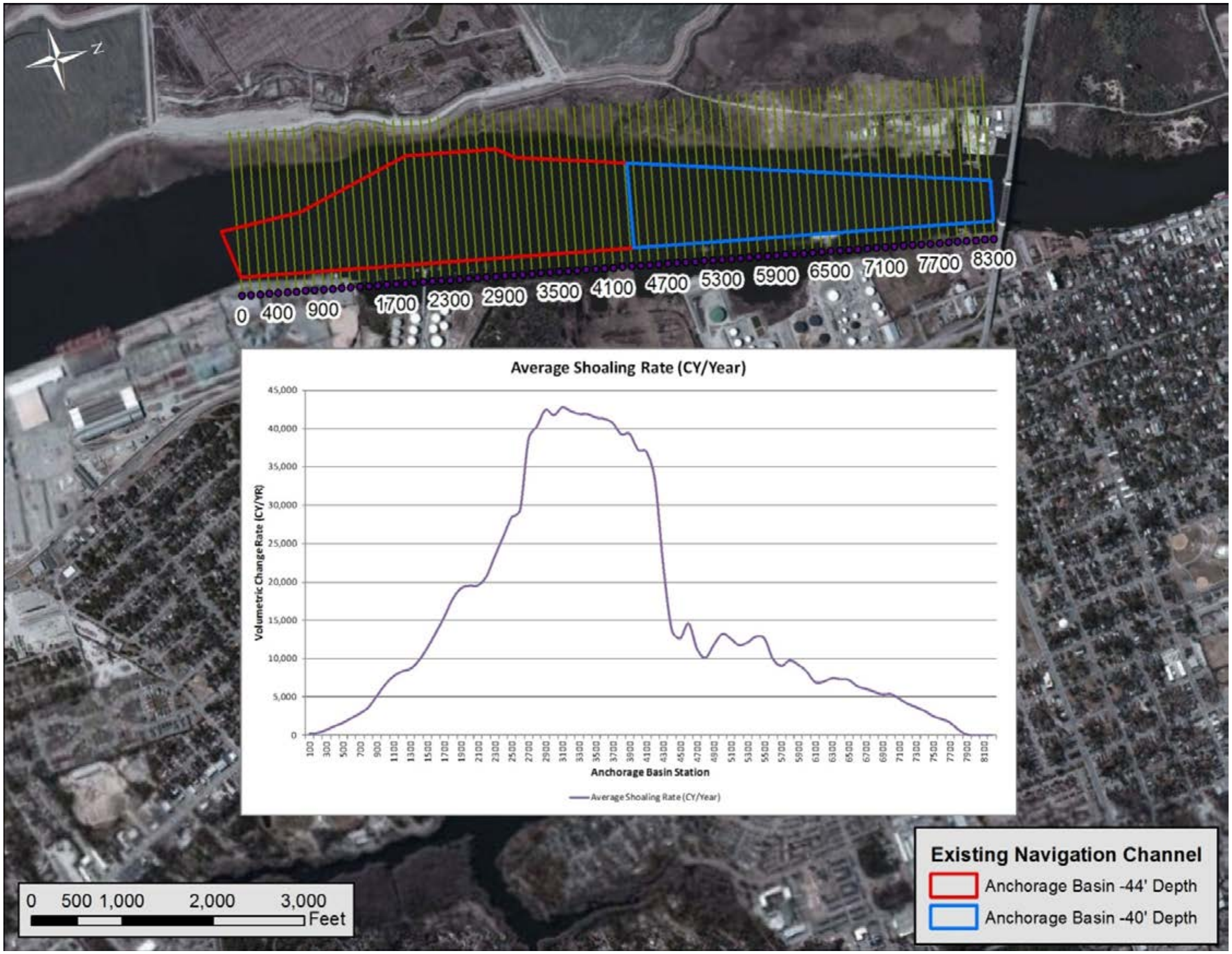

Figure 19. Range A Historic Volumetric Change Rate.

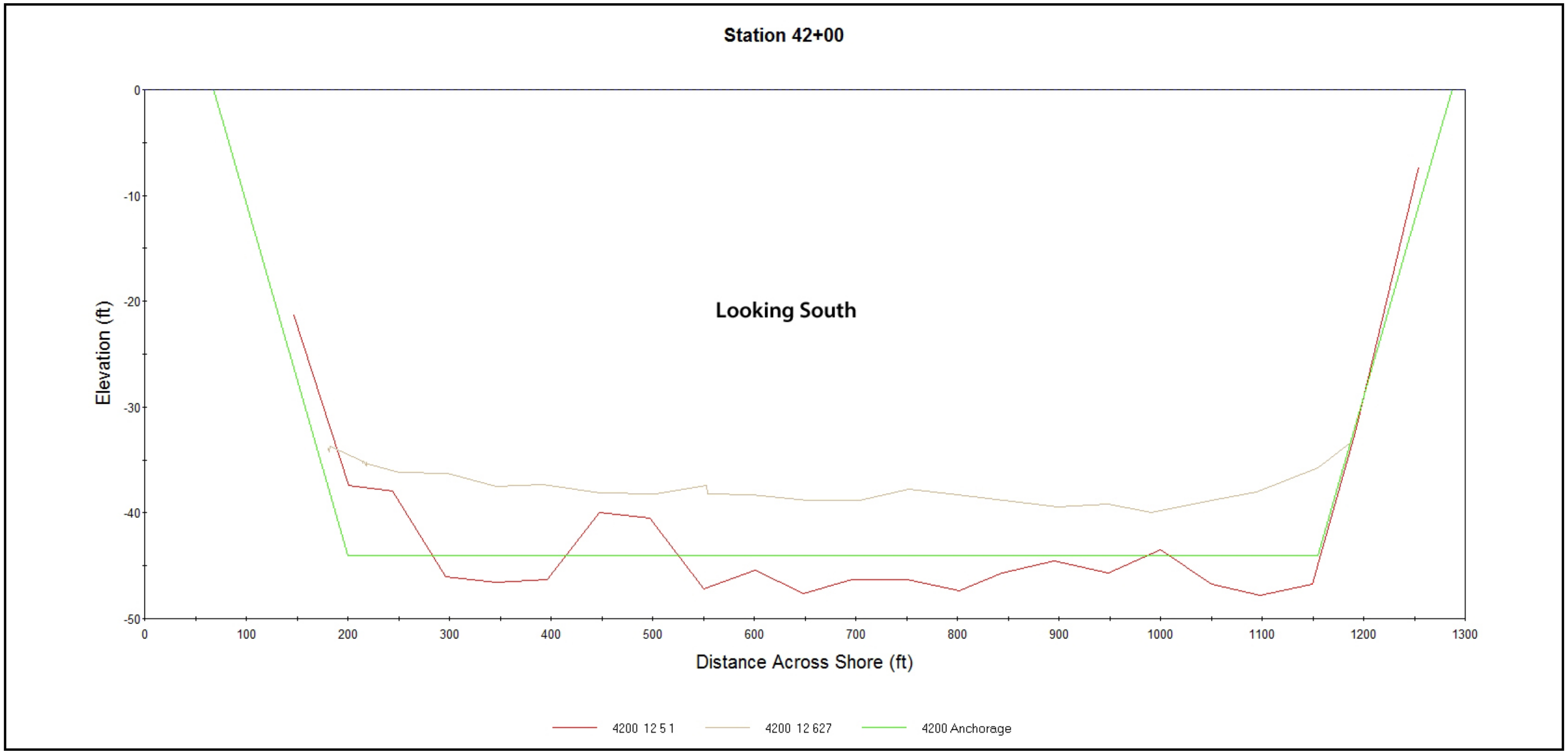

Figure 20. Station 42+00 Cross Section Sample Surveys.

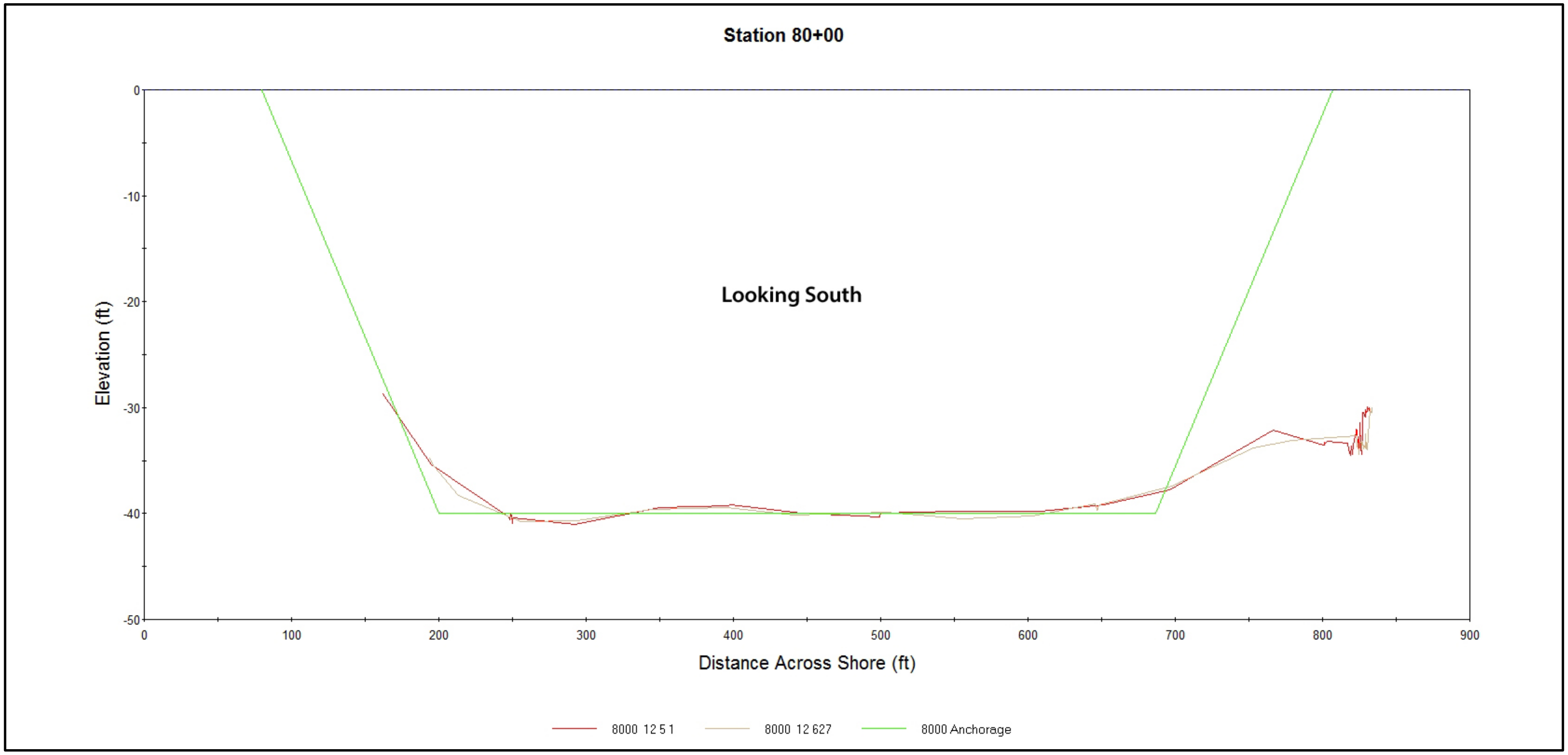

Figure 20. Station 80+00 Cross Section Sample Surveys.

Table 1 Representative Annual Shoaling Rates (Existing Channel)

Station	Representative Change Rate (CY/YEAR)	Station	Representative Change Rate (CY/YEAR)
100	261	4200	33,316
200	369	4300	22,064
300	740	4400	13,772
400	1,246	4500	12,638
500	1,691	4600	14,596
600	2,304	4700	11,306
700	2,909	4800	10,148
800	3,697	4900	11,833
900	5,175	5000	13,249
1000	6,674	5100	12,626
1100	7,750	5200	11,767
1200	8,361	5300	12,136
1300	8,709	5400	12,879
1400	9,809	5500	12,660
1500	11,462	5600	10,003
1600	13,412	5700	9,092
1700	15,470	5800	9,790
1800	17,807	5900	9,256
1900	19,193	6000	8,356
2000	19,516	6100	6,973
2100	19,569	6200	7,006
2200	20,748	6300	7,466
2300	23,372	6400	7,359
2400	25,913	6500	7,247
2500	28,445	6600	6,454
2600	29,385	6700	6,099
2700	38,638	6800	5,733
2800	40,294	6900	5,349
2900	42,421	7000	5,419
3000	41,728	7100	4,807
3100	42,747	7200	4,144
3200	42,258	7300	3,706
3300	41,899	7400	3,217
3400	41,866	7500	2,558
3500	41,429	7600	2,171
3600	41,250	7700	1,717
3700	40,686	7800	797
3800	39,262	7900	149
3900	39,316	8000	-
4000	37,210	8100	-
4100	36,955	8200	-
Total Volume (CY/Year)			1,251,804

Alternative Basin Volumetric Change Rates.

The proposed modifications to the turning basin are shown in Figure 22. Proposed alternative 1 is shown in Figure 22 shaded in blue. This alternative shifts the turning basin north to allow for increases in the design width of the turning basin as described above while minimizing upland impacts. Additionally, this alternative allows for the abandoned sections of the existing turning basin (resulting from the northern shift) to shoal in and reduce dredging maintenance requirements. Adjustments to the existing shoaling rates from Table 1 were made to accommodate the increased width and depth of the turning basin, as well as the reduced width in the abandoned portions of the old turning basin. The increases in depth are a result of the northern shift of the turning basin into an area that has historically been dredged only to -40 feet mllw, although the area is authorized to a depth of -44 feet mllw. The increases to the shoaling rates within the widened portions of the anchorage basin were made based on the most recent conditon survey for the area from June 2012. The increases were based on the assumption that the thickness of the material along the western side of the channel to be widened would be similar to the thickness along the western side of the newly widened anchorage basin. Using this assumption and the calculated width increase at each station, a volumetric increase was calculated and incorporated into the Alternative 1 shoaling rates shown in Table 2. For the areas of the existing anchorage basin that will be allowed to shoal, a decrease in volume was calculated using the same June 2012 survey. The volume used to reduce the shoaling rate in these areas was calculated between this survey and the channel template based on the measured reduction in width and are also included in Table 2. Figure 23 is a comparison of the existing shoaling rates to the Alternative 1 shoaling rates for the entire anchorage basin. The total projected annual shoaling rate for Alternative 1 increased to approximately 1,469,807 cubic yards per year. This is an increase over existing conditions of approximately 218,003 cubic yards per year.

Alternative 2 is an identical change to the alignment and width of the anchorage basin as described in Alternative 1, with the exception that the portions of the existing anchorage basin abandoned in Alternative 1 will be retained. These portions of the existing turning basin were retained in this alternative as a result of comments received from the pilots for the Port of Wilmington. The shoaling rates for this alternative were calculated in the manner described previously and are shown in Table 3. The total projected annual shoaling rate for the Alternative 2 configuration of the anchorage basin is approximately 1,539,748 cubic yards per year, an increase of approximately 287,944 cubic yards per year over the existing configuration. A comparison of the existing shoaling rates to the adjusted rates for Alternative 2 is displayed in Figure 24.

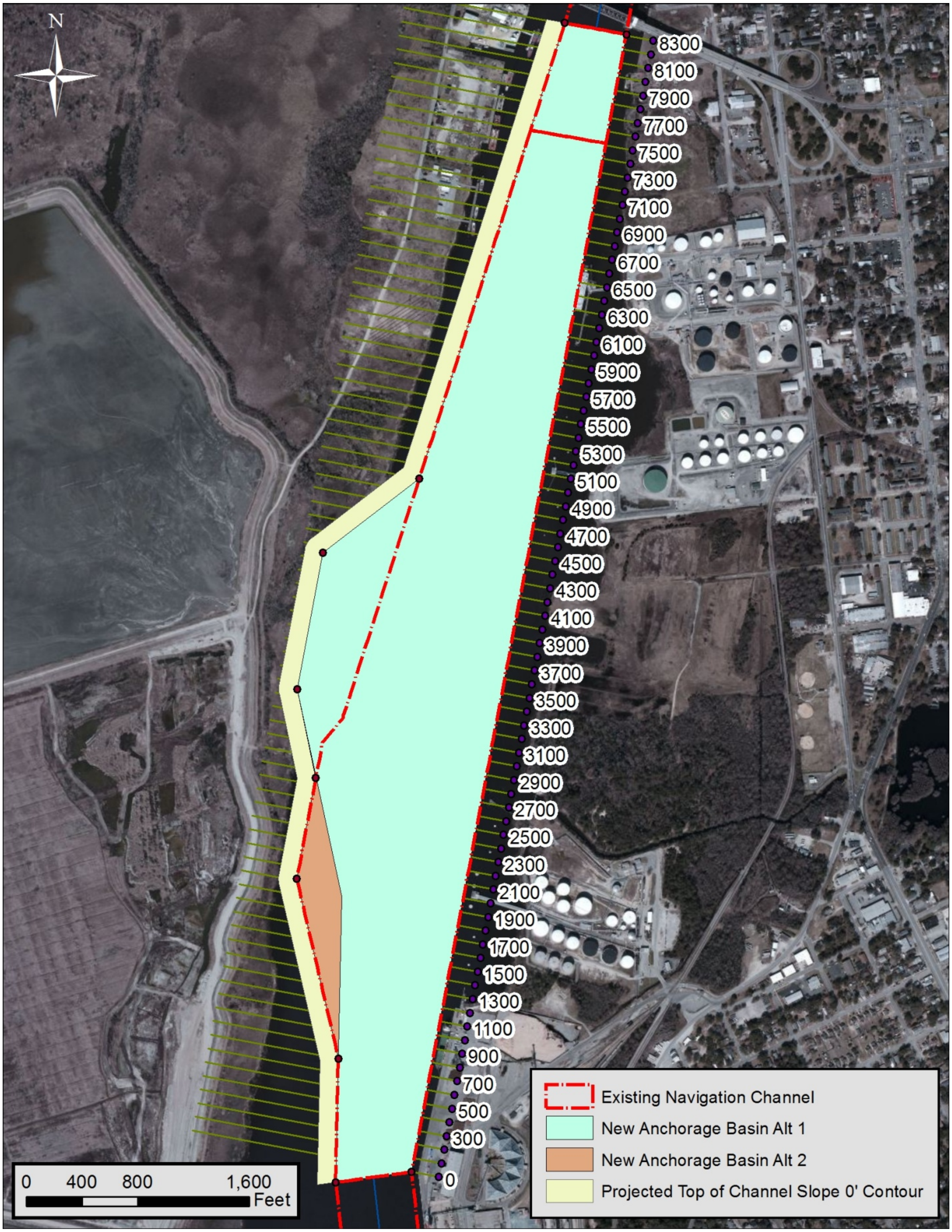

Figure 22. Proposed Anchorage Basin Alignments

Table 2. Representative Annual Shoaling Rates (Alternative 1)

Alternative 1 Shoaling Rate			
	(CY/YEAR)		(CY/YEAR)
Station		Station	
100	261	4200	53,462
200	369	4300	37,469
300	740	4400	36,122
400	1,246	4500	34,235
500	1,691	4600	28,020
600	2,304	4700	24,547
700	2,909	4800	23,209
800	3,682	4900	11,833
900	4,946	5000	13,249
1000	5,968	5100	12,626
1100	6,229	5200	11,767
1200	6,242	5300	12,136
1300	6,823	5400	12,879
1400	8,004	5500	12,660
1500	8,719	5600	10,003
1600	9,411	5700	9,092
1700	10,029	5800	9,790
1800	10,779	5900	9,256
1900	10,251	6000	8,356
2000	11,429	6100	6,973
2100	12,324	6200	7,006
2200	14,681	6300	7,466
2300	18,259	6400	7,359
2400	22,099	6500	7,247
2500	26,112	6600	6,454
2600	28,538	6700	6,099
2700	39,446	6800	5,733
2800	42,724	6900	5,349
2900	47,187	7000	5,419
3000	49,547	7100	4,807
3100	53,028	7200	4,144
3200	54,838	7300	3,706
3300	58,092	7400	3,217
3400	53,595	7500	2,558
3500	55,035	7600	2,171
3600	61,496	7700	1,717
3700	51,908	7800	797
3800	52,452	7900	149
3900	52,871	8000	-
4000	53,219	8100	-
4100	51,242	8200	-
Total Volume (CY/Year)			1,469,807

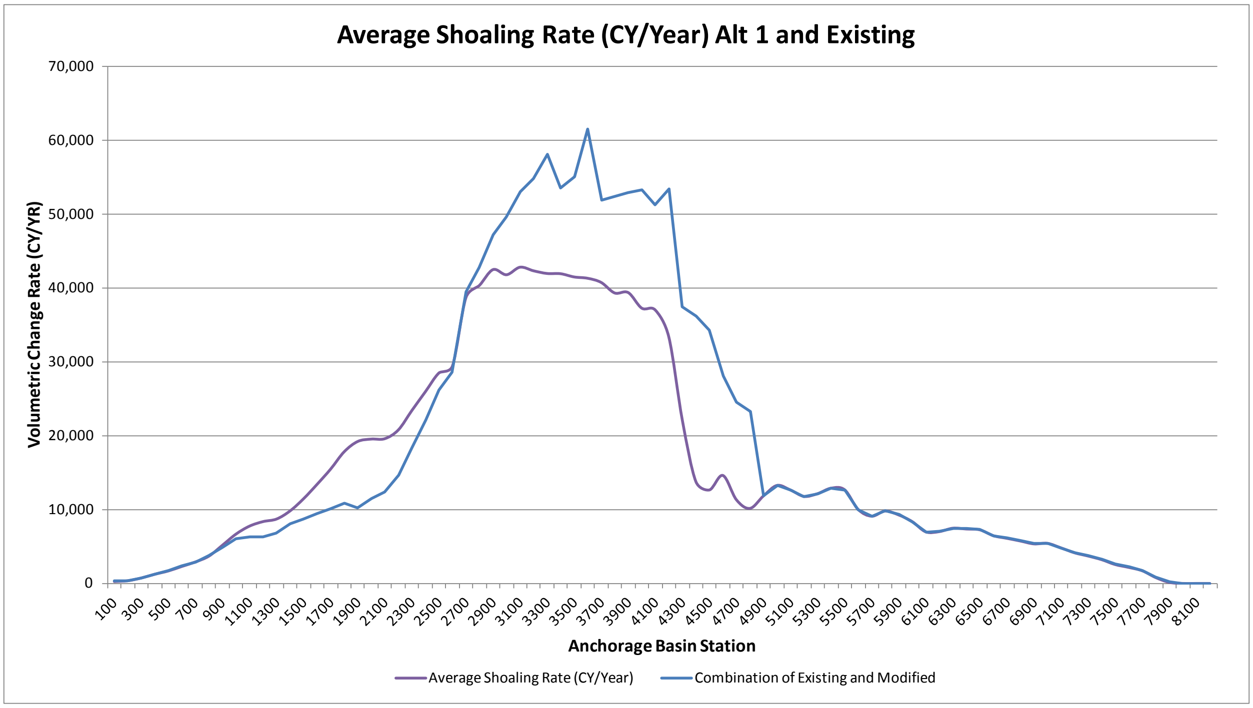

Figure 23. Alternative 1 Shoaling Rate Comparison

Table 3. Representative Annual Shoaling Rates (Alternative 2)

Alternative 2 Shoaling Rate			
	(CY/YEAR)		(CY/YEAR)
Station		Station	
100	261	4200	53,462
200	369	4300	37,469
300	740	4400	36,122
400	1,246	4500	34,235
500	1,691	4600	28,020
600	2,304	4700	24,547
700	2,909	4800	23,209
800	3,697	4900	11,833
900	5,175	5000	13,249
1000	6,674	5100	12,626
1100	7,750	5200	11,767
1200	8,361	5300	12,136
1300	8,709	5400	12,879
1400	9,809	5500	12,660
1500	11,462	5600	10,003
1600	13,412	5700	9,092
1700	15,470	5800	9,790
1800	17,807	5900	9,256
1900	19,193	6000	8,356
2000	19,516	6100	6,973
2100	19,569	6200	7,006
2200	20,748	6300	7,466
2300	23,372	6400	7,359
2400	25,913	6500	7,247
2500	28,445	6600	6,454
2600	29,385	6700	6,099
2700	39,446	6800	5,733
2800	42,724	6900	5,349
2900	47,187	7000	5,419
3000	49,547	7100	4,807
3100	53,028	7200	4,144
3200	54,838	7300	3,706
3300	58,092	7400	3,217
3400	53,595	7500	2,558
3500	55,035	7600	2,171
3600	61,496	7700	1,717
3700	51,908	7800	797
3800	52,452	7900	149
3900	52,871	8000	-
4000	53,219	8100	-
4100	51,242	8200	-
Total Volume (CY/Year)			1,539,748

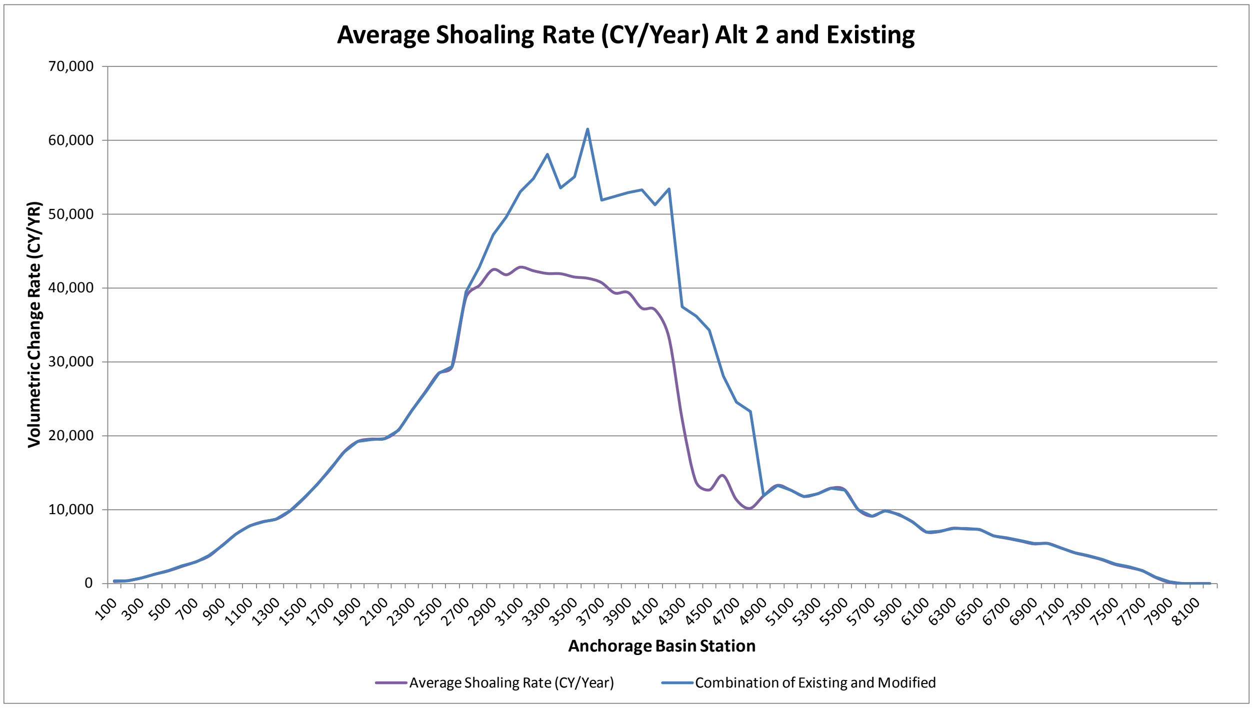

Figure 24. Alternative 2 Shoaling Rate Comparison

Dredging Volume Computations

Dredging quantities were computed for the entrance channel realignment near Bald Head Island, Battery Island Channel turn improvement and the Anchorage (Turning) Basin improvement. Data gathered included bathymetry, LiDAR data and subsurface data.

The bathymetry data for Battery Island Channel and the Anchorage Basin came from recent Corps of Engineers channel surveys. The channel surveys provided adequate coverage for the Battery Island Channel turn improvements. LiDAR data obtained from the North Carolina Floodplain Mapping Program was used to provide topographic coverage of the shoreline area impacted by the proposed Anchorage (Turning) Basin improvements. The LiDAR data was converted from NAVD88 vertical datum to MLLW and combined with the bathymetry data to provide full coverage of the turning basin improvements area. The conversion was based on the benchmark Wilmington, NC (Station ID 8658120). 2.41' was added to the elevations to convert from NAVD88 to MLLW.

The subsurface data is based on vibracore borings and washprobes. The subsurface data was used to determine an estimated top of rock surface. See Geotech appendix for additional subsurface data information.

InRoads surfaces were created from the bathymetry, LiDAR and subsurface data. InRoads surfaces were also created for the channel deepening and widening templates. The templates included 5H:1V side slopes for the Battery Island Channel turn improvements and 3H:1V side slopes for the Anchorage (Turning) Basin widener.

The entrance channel realignment proposed channel depth is -44' plus 2' of allowable overdepth and side slopes are 5H:1V. The proposed channel depth for the Battery Island Channel turn improvement is -42' plus 1' of required depth plus 2' of allowable overdepth (-45') for station 70+00 of Lower Swash Channel to the Battery Island intersection (part 1)and -44' plus 1' of required depth plus 2' of allowable overdepth (-47') for Battery Island intersection to station 30+00 of Southport Channel (part 2). The proposed channel depth for the Anchorage (Turning) Basin improvements is -42' plus 1' of required depth plus 2' of allowable overdepth (-45'). The 1 foot required overdepth is required due to the presence of rock for safety clearance purposes. Two foot allowable overdepth is provided because of the inability to dredge to a uniform depth.

Total dredging and rock quantities for the Battery Island Channel turn improvement and the Anchorage (Turning) Basin improvement were computed using the Bentley InRoads triangle volume method. The volumes for the entrance channel realignment near Bald Head Island were calculated from before dredging navigation surveys using an average end method at 100 foot increments. Rock is not expected to be encountered within the dredging template for the entrance channel realignment. Quantities are provided in Attachment 1.

Anticipated Methods of Dredging and Disposal

As has been historically performed, it is expected that the channel improvements will be accomplished by either a cutterhead suction dredge or clamshell dredge, but a hopper dredge might also be considered for some of the work. The Baldhead Shoal Entrance Channel improvements will likely be accomplished by a large ocean certified cutterhead suction dredge, but could also be dredged by hopper dredge. The dredged material is expected to be suitable for beach disposal and will either be pumped to the Bald Head Island beach or to the Oak Island beach. The Battery Island Channel turn improvements could be accomplished by any of the dredge types mentioned above. Some rock is expected to be encountered in the Battery Island Channel turn and may require special removal equipment if it cannot be dredged. Dredged material from the Battery Island Channel turn improvements will be transported to and disposed of in the Wilmington Ocean Dredged Material Disposal Site (ODMDS). If some of this dredged material is determined to be beach quality, it may be placed on the Bald Head Island beach or to the Oak Island beach or in a zone within the ODMDS set aside for sandy material. The Anchorage (Turning) Basin improvement will most likely be accomplished by a large cutterhead suction dredge and/or a clamshell dredge. Rock is expected to be encountered, so the dredge performing the work must be able to remove rock. If the dredge is not capable of dredging the insitu rock, drilling and blasting will be required prior to dredging. Disposal of dredged material from the Anchorage (Turning) Basin improvement will be either in the upland Eagle Island Disposal Area or in the ODMDS.

Literature Referenced

Ship-Induced Waves and Sediment Transport in Gota River, Sweden, Althage, 2010

An empirical model for ship-generated waves, Kriebel and Seelig, 2005

EM 1110-2-1100 Part 2 (USACE Coastal Engineering Manual)

Attachment 1

Battery Island Channel Turn Improvements

Part 1

Station 70+00 Lower Swash Channel to Battery Island Channel Intersection

Dredging Depth: -42' plus 1' required overdepth plus 2' of allowable overdepth

Depth (FT)	Overburden (CY)	Rock (CY)	Total (CY)	Dredging
-42	66,195	5	66,200	
-43	82,200	200	82,400	
-44	100,300	900	101,200	
-45	120,000	2,400	122,400	

Part 2

Battery Island Channel Intersection to Station 30+00 Southport Channel

Dredging Depth: -44' plus 1' required overdepth plus 2' of allowable overdepth

Depth (FT)	Overburden (CY)	Rock (CY)	Total (CY)	Dredging
-44	263,870	30	263,900	
-45	299,100	300	299,400	
-46	336,300	700	337,000	
-47	374,800	1,500	376,300	

Anchorage (Turning) Basin Improvements

Dredging Depth: -42' plus 1' required overdepth plus 2' of allowable overdepth

Depth (FT)	Overburden (CY)	Rock (CY)	Total Volume (CY)
-42	1,099,500	123,900	1,223,400

-43	1,118,200	145,000	1,263,200
-44	1,135,800	167,500	1,303,300
-45	1,151,200	192,500	1,343,700

Note: Total dredging quantities include sediment and rock.

Entrance Channel Realignment near Bald Head Island

Dredging Depth: -44' plus 2' of allowable overdepth

Depth (FT)	Volume (CY)
-46	181,000