CANAVERAL HARBOR, FLORIDA

Integrated Section 203 Navigation Study Report
&
Final Environmental Assessment

Volume 2: Engineering Appendix

October 2012

US Army Corps of Engineers ®

PORT CANAVERAL

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1.0 Engineering Design

1.1 Basis of Design

Two primary USACE publications were consulted in the preparation of the engineering studies and supporting documentation for the Section 203 feasibility study for navigation improvements at Canaveral Harbor.

ER 1110-2-1404 Hydraulic Design of Deep-Draft Navigation Projects

EM 1110-2-1613 Hydraulic Design Guidance for Deep-Draft Navigation Projects

The following publications and references were also consulted with regard to assessing vessel squat, project width considerations, and passing ship and wind effects on moored ships along the channel:

TR-60560OCN NFESC, "Mooring Loads Due to Parallel Passing Ships", 30 September 2005

UFC 4-159-03 DoD, Design: Moorings, 3 October 2005

1. Barass, Dr. C. B., "Squat Formula for Ships in Rivers," The Naval Architect, November 2004, pp. 24 and 25.
2. Barass, Dr. C. B., "Letter to the Editor on Empirical Equation for Determination of Coefficient K for Prediction of Ship Squat," The Naval Architect, September 2005.
3. USACE ERDC/CHL CHETN-IX-14, "Charleston Harbor Ship Motion Data Collection and Squat Analysis," March 2004.

The following publications are referred to herein, but not contained in the attachments to the engineering appendix:

1. McArthur, Christopher J. and Parsons, Mel, "Ocean Current and Wave Measurements at the Canaveral Harbor Ocean Dredged Material Disposal Site, January 2003 through February 2004," USEPA Region 4, EPA-904-R-05-001, January 2005.

1.2 Design Ship Selection

Primary ship types using the commercial Port now and in the future include dry, liquid and break bulk carriers, dry bulk cargo ships, refrigerated cargo ships, passenger (cruise) ships, and product tankers. Ship types including container vessels, LNG, vehicle carriers and RoRo cargo ships are only anticipated to use existing or future berths within Port Canaveral on a very limited basis and of a size that would not be anticipated to drive the design and selection of navigation features. Therefore, these ship types were not considered in design vessel identification and selection.

Port Canaveral is also the base of operations for various government and military missions that occur on the Cape Canaveral Air Force Station (CCAFS) property on the north side of the channel. The Canaveral Port Authority shares Canaveral Harbor with its Mission Partners, the United States Air Force 45th Space Wing (USAF 45 SW) and the Naval Ordnance Test Unit (NOTU) and the Military Sealift Command (MSC), both tenants on the

CCAFS. NOTU currently receives various U.S. and U.K. Navy submarines at the Trident and Poseidon Wharves, within the Trident and Middle Basins. NOTU and MSC also accommodate various military surface ships at the Trident and Poseidon wharves. The USAF 45 SW maintains use of the AF wharf and the Delta Mariner pier located at the north end of Middle Basin. The Delta Mariner pier and mission vessel support the Delta IV rocket launch program at CCAFS. The AF wharf is used for a variety of small scale ship and barge operations. There are no known navigation access issues for the non-commercial vessel traffic using Canaveral Harbor.

1.2.1 Cruise Vessels

A graphical summary of the size and capacity trends in cruise ship builds since 1997 and for those ships under construction or contract through 2012, are presented in Figures 1 and 2. The trend data is based on dimensions and Gross Registered Tonnage (GRT) for 116 ships. The data comes from various sources including Lloyd's Register of Ships, the cruise lines, and cruise industry publications.

Figure 1 shows the distribution of cruise ship GRT with the year that the ship entered or is scheduled to enter service as in the case of new builds under construction or contract. Vessels with a GRT of at least 122,000 gross tons are identified by name or class and represent the largest ships in the market. This group of vessels comprises roughly 17 percent of the ships reviewed for this period.

Figure 2 shows the cruise ship length, beam, and draft dimensions versus gross tonnage. A distinct increase in beam from panamax to post-panamax occurs for GRT greater than 100,000 tons. To date, 24 cruise ships in service or under construction are greater than 305 m (1000 ft) in length. The major lines have each built one or more ship classes with panamax beams and lengths on the order of 290 to 294 m (950 to 965 ft). The Queen Mary 2 with a maximum draft of 10.3m remains the deepest draft cruise ship so far.

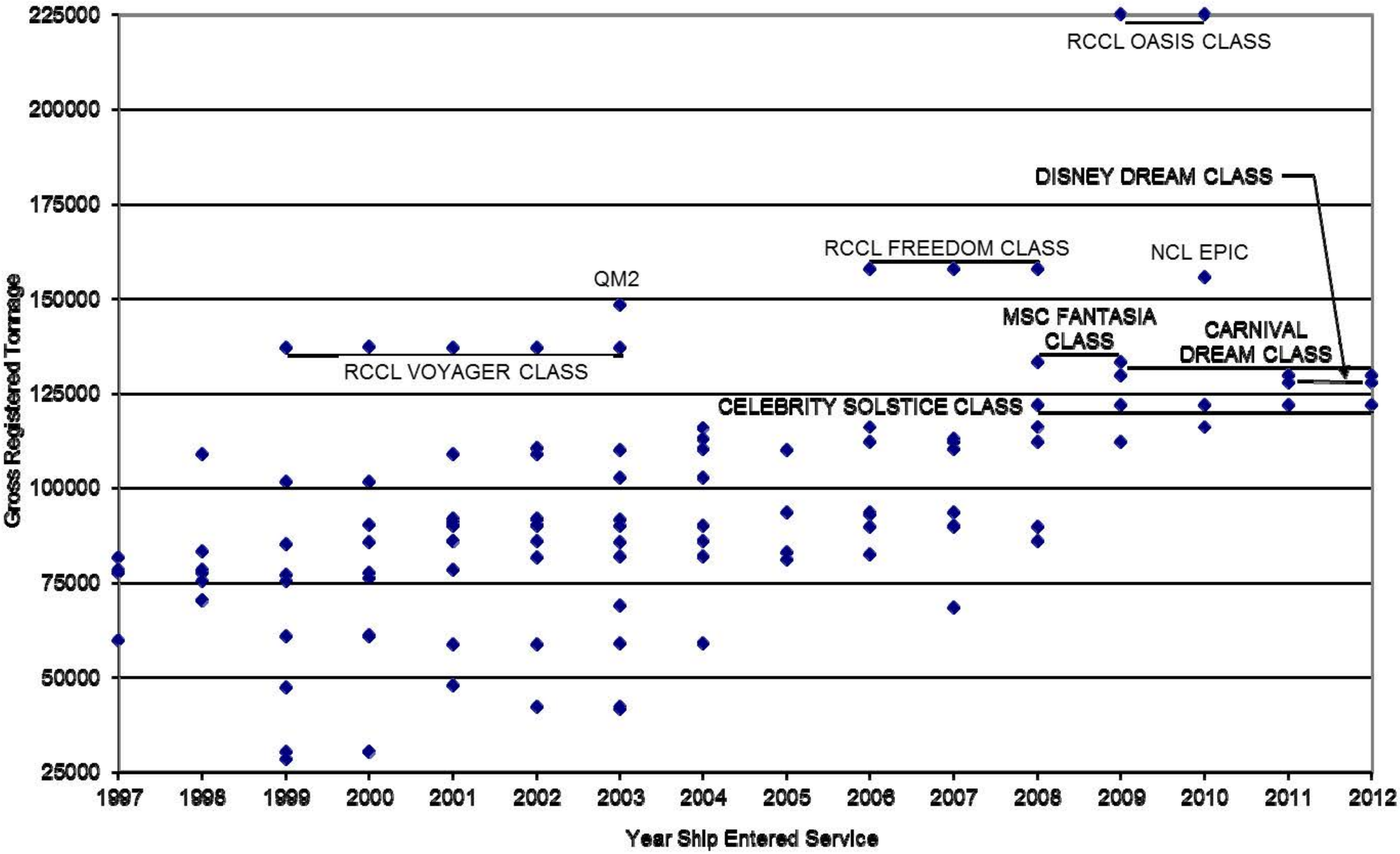

Figure 1. Cruise Ship Gross Tonnage Trends

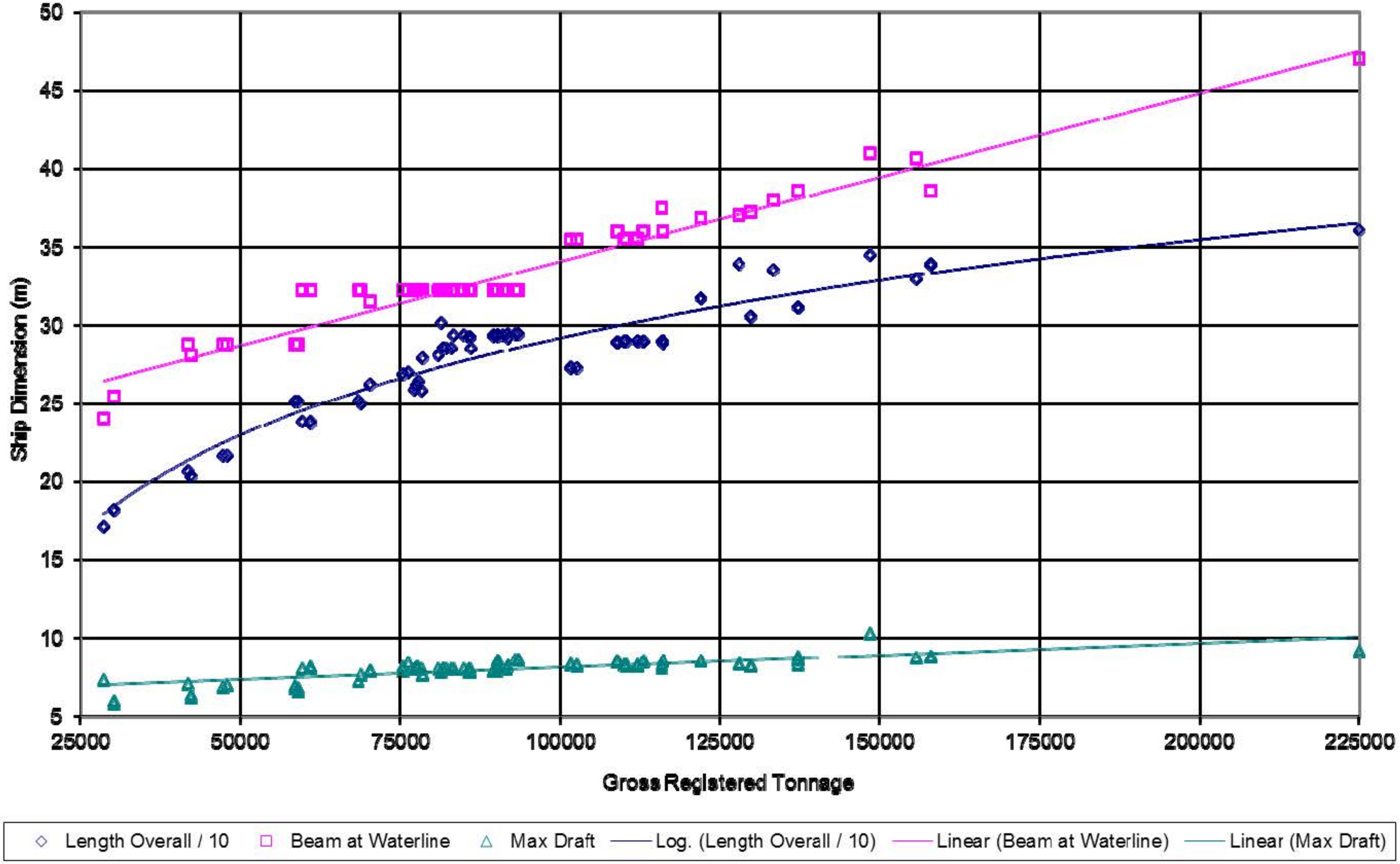

Figure 2. Cruise Ship Dimension Trends

Vessels from Royal Caribbean's Freedom Class, Disney's Dream Class and Carnival's Dream Class, among the largest ships in service, currently operate from Port Canaveral's West Basin on a homeport basis. Royal Caribbean and Carnival have home ported the Freedom of the Seas and the Carnival Dream at Cruise Terminal 10 (CT10) since 2009. Disney began service in late 2010 with the Disney Dream at Port Canaveral's Cruise Terminal 8 (CT8) with the second ship beginning service in 2012. The following list of vessels, in Table 1, describes the present and potential future cruise fleet forecast for Port Canaveral. Tables 1 and 2 summarize key dimensions and propulsion characteristics for the largest current and future vessels with homeport commitments or potential port-of-call and storm refuge considerations at Port Canaveral. Port Everglades has been the home for the initial deployment of Royal Caribbean's Oasis Class (formerly known as Genesis Class) vessels since entering service in 2009 and 2010. Port Canaveral has been identified as a potential port of refuge on an emergency, as needed, space available, basis for these vessels. Recent discussions between the Canaveral Port Authority and Royal Caribbean Cruise Lines indicate no present or future plans to homeport an Oasis Class vessel at Port Canaveral.

Table 1. Present and Future Large Cruise Ships and Classes

CRUISE SHIP OR CLASS	Design Draft (ft)	Length Overall (ft)	Beam at Waterline (ft)	Disp. at Design Draft (m. tons)	Side Wind Sail Area (ft^2)	GRT
Disney Dream/Fantasy Homeport 2011/12	27	1113	121	62,414	132,181	128,000
CCL Dream/ Magic Dream-Homeport 2009-	27	1003	122	62,789	131,191	130,000
RCCL Voyager Class Mariner of the Seas-Homeport 2003-2009	28	1,021	127	62,716	119,523	138,000
NCL Epic Potential Port Call	29	1,081	133	74,800	144,959	150,000
CUNARD Queen Mary 2 Potential Port Call	33	1,131	135	79,827	139,716	150,000
RCCL Freedom Class Freedom of the Seas-Homeport 2009-	28	1,112	127	71,019	140,092	158,000
RCCL Oasis Class Potential Port Call	30	1,187	154	106,000	168,664	225,000

Dimensions rounded up or down to the nearest foot.

Table 2. Large Cruise Ship Propulsion

CRUISE SHIP OR CLASS	Voyager	Freedom	Genesis	Carnival Dream	Disney Dream
Propulsion Type	Diesel Electric	Diesel Electric	Diesel Electric	Diesel Electric	Diesel Electric
Propeller Type	FPP (inward)	FPP (inward)	FPP (inward)	FPP (inward)	FPP (inward)
Pods or Propeller Shafts	2 Azipods 1 Fixipod	2 Azipods 1 Fixipod	3 Azipods	2 shafts	2 shafts
Pod or Shaft Power (each)	19,713 hp (14 MW)	19,713 hp (14 MW)	26,820 hp (20 MW)	29,500 hp (22 MW)	27,900 hp (20.37MW)
Thrusters	4 Bow	4 Bow	4 Bow	3 Bow 2 Stern	3 Bow 2 Stern
Thruster Power (each)	4,023 hp (3 MW)	4,425 hp (3.3 MW)	7,376 hp (5.5 MW)	2,950 hp (2.2 MW)	4,080 hp (3 MW)

FPP=Fixed Pitch Propeller

The above data and figures as well as the long history of good service to the cruise lines, provides a solid indication of future cruise ship trends at Port Canaveral in light of continued programs among the cruise lines for new build vessels. Several West Basin berth improvement projects and berth and navigation access dredging projects discussed in the 203 study have been completed over the years since 2003 to be ready for and to better accommodate a representative segment of the largest cruise vessels every built.

The Canaveral Pilots Association offered additional comments regarding the navigation improvements investigated in the Section 203 Feasibility Study for Port Canaveral in light of the present homeport commitments for Freedom of the Seas and the new Disney ships starting. Their letter is contained in Attachment A. The local pilots consider the present accommodation of the Freedom of the Seas, the Carnival Dream, and the Disney ships, as provisional navigation scenarios until such time as the channel widening, the West Basin entrance widening, and entrance turn expansion outside the jetties are accomplished. Based on the size of many of these vessels and homeport commitments at Port Canaveral, channel modifications have been evaluated for the Freedom Class vessel.

1.2.2 Displacement Cargo Vessels

Ship parameters for some of the largest dry and liquid bulk carriers calling at Port Canaveral are shown in Table 3.

Table 3. Present Displacement Vessel Traffic at Port Canaveral

SHIP	Maximum Draft (ft)	Length Overall (ft)	Beam at Waterline (ft)	Deadweight Tonnage (m. tons)
Gdynia (Dry Bulk-Aggregate)	42.4	738	105.6	65,738
Bernardo Quintana A (Dry Bulk-Limestone)	43.3	753	105.6	67,044
Bregen (Liquid Bulk-Gasoline)	44.7	797	105.6	68,159

Present channel and berth depths limit the ability for these vessels to come in at the full draft-displacement load condition. Presently and subject to harbor pilot discretion, the vessels must arrive at some intermediate load condition and/or wait at the sea buoy until tides are favorable for transiting the channel and unloading at the designated cargo berth. Existing and without-project, future maximum bulk carrier and tanker traffic at Port Canaveral are limited to an operating draft of 36 ft and 39.5 ft without and with the use of tidal advantage, respectively.

Seaport Canaveral, one of the liquid bulk operators, has requested an operational water depth of 42 ft at berth. ASI, a dry bulk operator, has indicated the arrival draft of their current traffic at 39.5 ft, with future vessels of 70,000 to 76,000 Dead Weight Tonnage (DWT) arriving the Port at a draft of 41 to 43 ft, respectively.

In support of defining the design displacement cargo vessel dimensions for Port Canaveral, the Lloyd’s Register of Ships Online (SEA WEB) was consulted. Ship particulars were compiled for bulk and oil products carriers in the range of 60,000 to 70,000 DWT, 70,001 to 80,000 DWT, and 80,001 to 100,000 DWT. A statistical analysis of vessel parameters for these categories is summarized below.

Table 4. Displacement Cargo Vessel Statistics

CATEGORY	Statistic Dimension	Maximum Draft (ft)	Length Overall (ft)	Beam at Waterline (ft)
60,000 to 70,000 DWT BULK CARRIER (464 vessels)	Maximum	45.8	834	125
	Minimum	32.7	679	104
	Average	42.7	742	106
	90^{th} Percentile	43.7	751	106
70,001 to 80,000 DWT BULK CARRIER (925 vessels)	Maximum	48.8	837	121
	Minimum	37.2	713	105
	Average	45.5	742	106
	90^{th} Percentile	46.8	750	106
80,001 to 100,000 DWT BULK CARRIER (213 vessels)	Maximum	49.3	850	141
	Minimum	37.7	689	106
	Average	45.1	761	118
	90^{th} Percentile	47.3	798	141
60,000 to 70,000 DWT OIL PRODUCTS CARRIER (175 vessels)	Maximum	46.2	800	131
	Minimum	36.5	600	105
	Average	42.7	739	108
	90^{th} Percentile	44.7	791	118
70,001 to 80,000 DWT OIL PRODUCTS CARRIER (244 vessels)	Maximum	49.3	810	138
	Minimum	37.6	700	105
	Average	45.0	749	107
	90^{th} Percentile	47.6	750	106
80,001 to 100,000 DWT OIL PRODUCTS CARRIER (293 vessels)	Maximum	52.8	894	158
	Minimum	38	691	106
	Average	45	792	134.5
	90^{th} Percentile	48.8	814	141

The statistical dimensions for 60,000 to 100,000 DWT bulk carriers and oil products tankers in Table 4 led to selection of a design vessel with length of 800 ft and beam of 138 ft. This size vessel tested in the simulator will adequately demonstrate the safety of navigation through Canaveral Harbor to a new tanker berth at NCP 1 in the Middle Basin.

The statistics in Table 4 show that most of the vessels in this DWT range have drafts exceeding the present vessel draft limits for the harbor. At a minimum, the future channel with-project condition should accommodate a vessel having a draft of 39.5 ft without the use of tidal advantage.

In support of the 203 study, full mission bridge simulations were executed on two occasions at the RTM STAR Center, testing the tanker vessel, Jupiter and the Genesis or Freedom Class cruise vessels. Refer to the STAR Center's Port Canaveral 2009 and 2007 modeling and simulation reports (Attachment A), for evaluation of proposed channel improvements for Canaveral Harbor.

1.3 Site Environmental Conditions

1.3.1 Water Levels

Water levels at Canaveral Harbor are mainly the result of semi-diurnal tidal fluctuations in the Atlantic Ocean. Elevations of tidal datum's for Canaveral Harbor are shown in Table 5 based on a tide station located at the Trident Pier in Trident Basin. This tide station, established by the National Oceanic and Atmospheric Administration (NOAA), continuously records water levels and has been in operation since 1994. All datum elevations are in feet and referenced to Mean Lower Low Water (MLLW). The lowest and highest observed water levels have been included to provide an indication of the historical extreme water levels.

Table 5. Water Levels (ft, MLLW) – Trident Pier, Trident Basin

Station 8721604 (Tidal Epoch: 1983-2001)

Highest Observed Water Level (09/26/2004)	7.93
Mean Higher High Water (MHHW)	3.91
Mean High Water (MHW)	3.56
North American Vertical Datum-1988	2.86
Mean Sea Level (MSL)	1.88
Mean Tide Level (MTL)	1.87
Mean Low Water (MLW)	0.17
Mean Lower Low Water (MLLW)	0.00
Lowest Observed Water Level (01/12/2009)	-1.86

1.3.2 Tidal Currents

In support of the Section 203 feasibility study, a current measurement program inside the jetties was accomplished. The Canaveral Locks connecting the Banana River with Canaveral Harbor largely limit tidal current effects within the harbor. Current meter readings taken inside the jetties during August and September of 2005 and calibration of a hydrodynamic model of existing conditions suggest maximum 90%-tile and maximum average current speeds at the west end of the middle reach (Trident Basin entrance) of 0.34 and 0.16 knots, respectively. Current speeds further decrease moving west to the West Basin with predicted maximum 90%-tile and average current speeds of 0.08 and 0.02 knots, respectively. Considering the negligible current speeds measured inside the jetties along with the results of the hydrodynamic modeling, no currents were considered inside the jetties in the STAR Center simulations. Channel cross current or yawing forces associated with currents are absent within the harbor.

In response to discussions at the July 2009 project meeting between the CPA and HQ USACE, a search ensued for available ocean current speed and direction data at a location outside the jetties. The only source of current data found comes from that collected by the US EPA Region 4, in support of the management and monitoring of the Canaveral's offshore dredge spoil disposal site, Canaveral ODMDS. The EPA collected data at a location approximately 0.5 nautical miles west of the Canaveral ODMDS. This location is southwest of the seaward end of the approach channel. See Figure 3 for location. Data was collected in four deployment periods between January 2003 and February 2004. Major findings include:

- Although a tidal component exists, the currents measured here are not dominated by tides.
- Depth-averaged currents predominantly flow in northerly and southerly directions and rarely exceed 0.5 knots. Seasonal differences do not appear to be significant. The first quarter, February through April 2003, recorded the highest depth-averaged currents. The second quarter was absent a strong southerly component and marked the highest percentage of northerly currents. In all quarters, northerly currents occurred twice as frequently as southerly currents and accounted for approximately 50 percent of the measurements. The highest percentage of measurements for each quarter were 0.1 knots or less. For all quarters, 75 percent of the measurements were 0.2 knots or less. For all quarters, northerly currents occurred about twice as frequently as southerly currents. Depth-averaged currents in the vicinity of the Canaveral ODMDS tend to have a net direction of transport to the north northeast, paralleling the coast.
- Near surface currents characterized by the upper 12 feet of the water column are also predominantly northerly and southerly flowing with predominant direction to the north. Surface currents had more frequent easterly currents than westerly. The maximum surface currents exceeded 0.78 knots. Surface currents tend to have a net direction of transport to the northeast.

During execution of the 2007 STAR Center simulations, the participating pilots validated the use of 0.3-knot northerly and southerly setting currents with similar wind directions for the test vessels. Pursuant to the June 2009 simulations, a pre-simulation meeting was held on March 3 at the CPA and attended by CPA consultants and the USACE navigation experts representing the Corps simulation facility in Vicksburg and the Jacksonville District. During this meeting, one of the pilot co-chairman attended and described northerly setting and to a lesser extent, southerly setting, wind-driven currents outside the jetties with estimates of speeds of up to 0.5 knots southerly and 1.0 knots northerly. Therefore, as agreed by all participants at the 2009 simulations, outside the jetties, southerly current speed of 0.5 knots was modeled for both cruise and tanker vessel runs with winds from northerly directions and northerly speeds of 1.0 and 0.75 knots were modeled for cruise and tanker vessel runs, respectively, for winds from southerly directions.

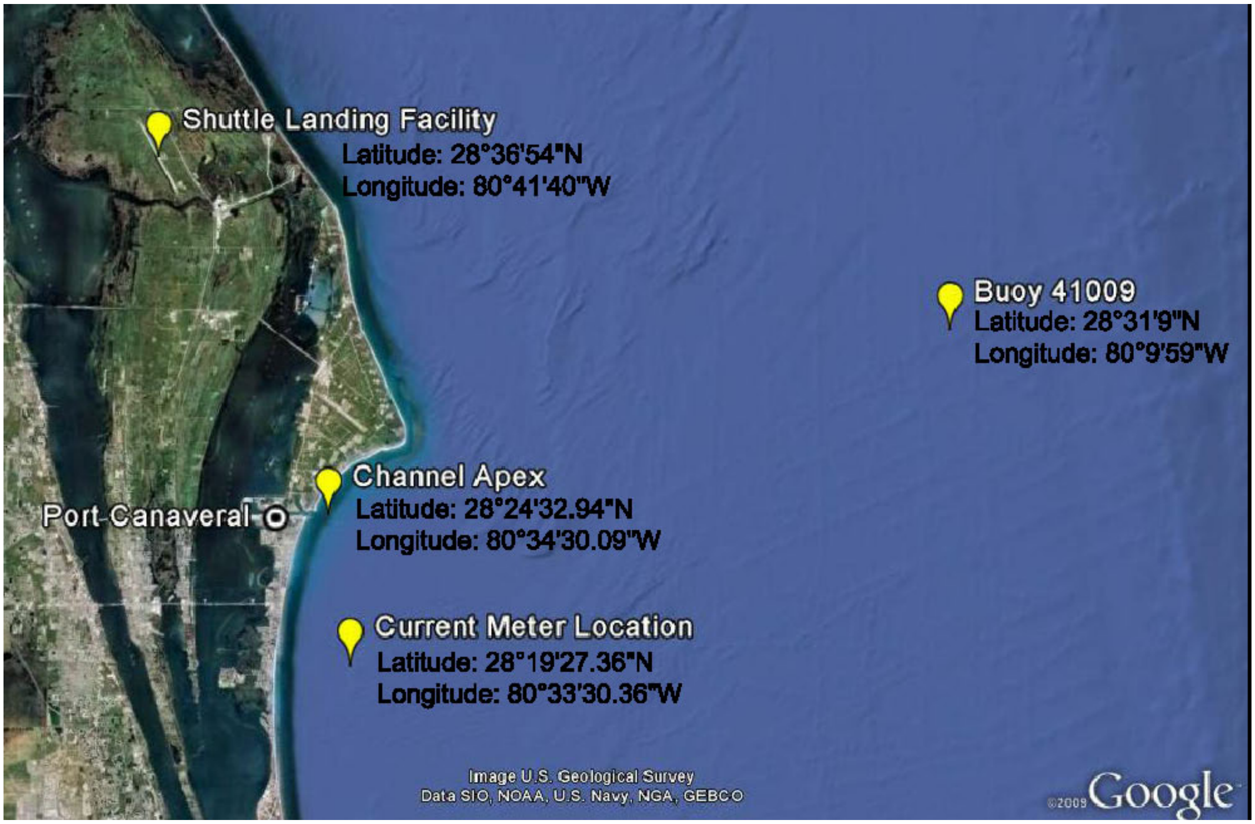

Figure 3. Data Collection Locations

1.3.3 Wind and Wave Climate

The wind and wave climate at Canaveral Harbor influence the transit conditions for vessel traffic at Port Canaveral. The wind particularly influences cruise ship transits owing to the very large vessel sail areas. Several of the larger cruise ships have air drafts exceeding 200 ft. Swell and wind waves from southerly to southeasterly directions affect the navigation of inbound displacement vessel traffic outside of the jetties. Outbound transits are not normally affected by waves beyond the jetties as vessel speed can be increased as needed.

1.3.3.1 Wind Data and Analysis

Analysis of site specific wind data can be used to establish the probability of occurrence of various wind speeds. Historical wind data was available from a number of sources. Two sources were considered in this analysis. Data from NOAA Buoy 41009, located 20 nautical miles east of Cape Canaveral, were available for the period August 1988 through December 2008. These data are collected at a measurement height of 5 meters every half hour. This offshore buoy is owned and maintained by the National Data Buoy Center (NDBC).

In addition, a meteorological station at the NASA space shuttle facility, located approximately 13 miles north of Port Canaveral, has collected hourly wind data from 1979 to the present. Preliminary review of data from the two stations showed that the NASA wind station, located roughly 7 miles inshore, has similar directional characteristics, but consistently recorded lower wind speeds than the offshore buoy. Data from the two stations are considered to be suitable to provide the range of conditions that would bound the actual conditions inside and approaching Port Canaveral.

Figures 4 and 5 present wind roses for data from buoy 41009 for “summer” and “winter” periods with the summer period defined as May 1 through October 31 and the winter period from November 1 through April 30. Inbound and outbound transits of homeport cruise ships typically occur daily from 4:00 am to 8:00 am and from 3:00 pm to 7:00 pm, respectively. As such, each figure contains two wind roses, one representing data collected between 4:00 and 8:00 am and the other for data collected between 3:00 and 7:00 pm. Similar wind roses are included in Figures 6 and 7 based on data from the NASA space shuttle facility.

Tables 6 and 7 present frequency of occurrence tables for the data from NOAA buoy 41009 for the summer and winter periods, respectively. Tables 8 and 9 present the same data in terms of percent frequency of occurrence. Tables 10 through 13 provide similar tables for the NASA space shuttle facility wind data.

The tables present results for morning and evening periods separately with each 4 hour period treated as a single event. For example, entries in the speed columns (max, min, and avg) represent maximum, minimum, and average speeds for a given 4 hour period. Because the ships will be affected more by winds to their beams, abeam-component (Abeam-comp) columns were included to account for the reduced affect that winds will have if it approaches from an angle other than directly abeam. The abeam-component is the vector component of the wind velocity in the north- or south- direction when the ship is in the east-west oriented portion of the channel. A pilot taking wind readings will take direction into account when assessing the potential effects on his/her ship. Using the abeam-component is felt to be a reasonable approach to quantifying the reduced affect that would be estimated by a knowledgeable pilot for winds at angles other than 90 degrees to port or starboard. These columns are similar to those for the speed, but frequency of occurrence is tallied for the magnitude of the north-components of the speeds rather than the full magnitude of the speed. For example, a 30 knot wind blowing from directly abeam of the ship would affect the ship more than a 30 knot wind blowing from its stern or than a quartering wind. A 30 knot wind blowing from a bearing of 45 degrees (from the northeast) would have an abeam component of approximately 21 knots. The abeam component columns reduce winds in this manner in order to better estimate the potential for impact on the ship movements.

The last three columns, under the heading “window”, look at the “best” 1-, 2-, or 3-hour weather window that would allow the ship to transit into or out of the port within the given 4-hour period. Speeds used to define the windows are also based on the magnitude of the north-component (abeam-component) of the wind speed. Each window is evaluated by looking at a window of the given duration that “slides” within the 4-hour event period. The speed associated with a window is the maximum speed that is contained within the window (i.e. all other measurements within the window are less than or equal to the associated wind speed) at a given location within the 4-hour event period. The “best” window is the window at the location within the 4-hour period that results in the lowest maximum wind speed.

All data used to generate Tables 6 through 13 were first corrected to an observation height of 50 meters, corresponding with the approximate elevation of anemometers used on cruise ships. The conversion from wind speed at 10 meters to wind speed at a different height is a function the vertical wind speed profile, which in turn is a function of wind speed and air-sea temperature difference. Based on plots presented in the Coastal Engineering Manual (CEM)[1], a conversion

[1] Coastal Engineering Manual, Chapter 2 Meteorology and Wave Climate. USACE EM 1110-2-1100 (Part II) (Change 2) 30 April 2005.

factor of 1.2 was conservatively estimated for calculating wind speed at 50 meters based on a 10 meter wind speed.

The wind roses show distinct differences in seasonal as well as daily wind characteristics. Comparison of the morning and afternoon roses for the summer season shows morning winds predominantly from the south and southwest and afternoon winds largely from the east to southeast. Winter season roses show greater wind speeds and show afternoon winds with a greater north/south orientation compared with the summer wind data. The latest navigation simulations at the STAR Center considered maximum winds from the north and south directions. Wind speeds were varied from 30 to 35 knots for most full harbor transits and 35 to 40 knots for ocean turn widener evaluation transits by the cruise ships.

Table 14 presents cumulative frequency of exceedance for the buoy data based on the data in Tables 8 and 9. Similarly, Table 15 was generated for the NASA Space Shuttle Facility data based on Tables 12 and 13. Exceedance probabilities are presented for wind speeds between 15 and 40 knots for maximum and average abeam-component wind speeds and for the best 1-hour, 2-hour, and 3-hour weather windows within the periods during which cruise ships will be entering or leaving port. As indicated above, the weather windows are defined by the maximum wind speed abeam-component over the span of the window. The "best" weather window is the window with the lowest maximum wind speed over the given 4 hour period.

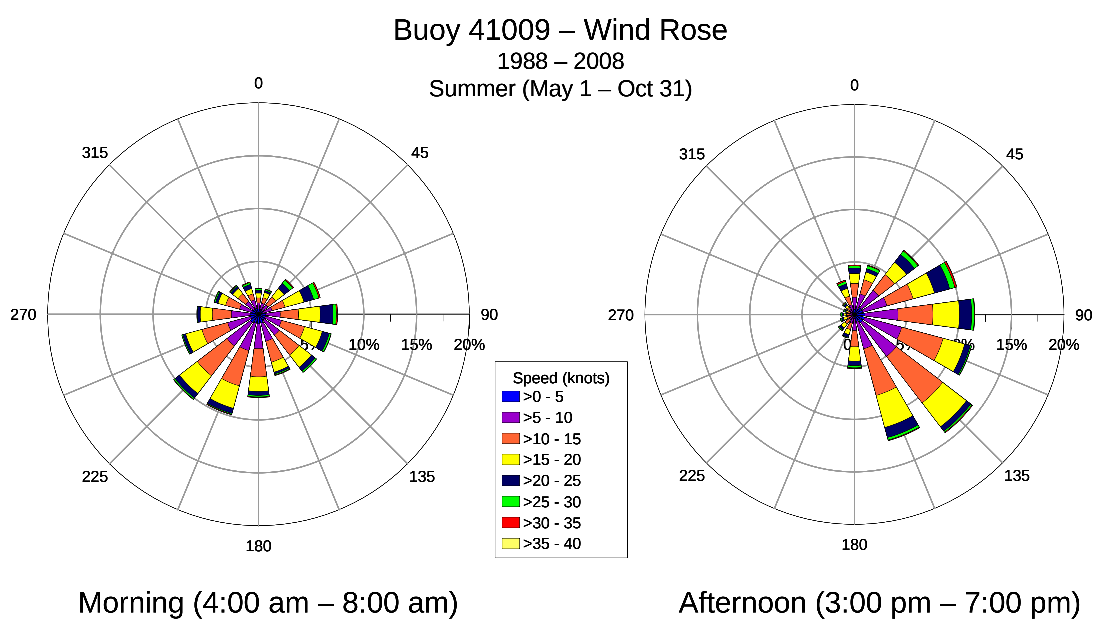

Figure 4. Wind Roses for Station 41009 Data -- Summer Season

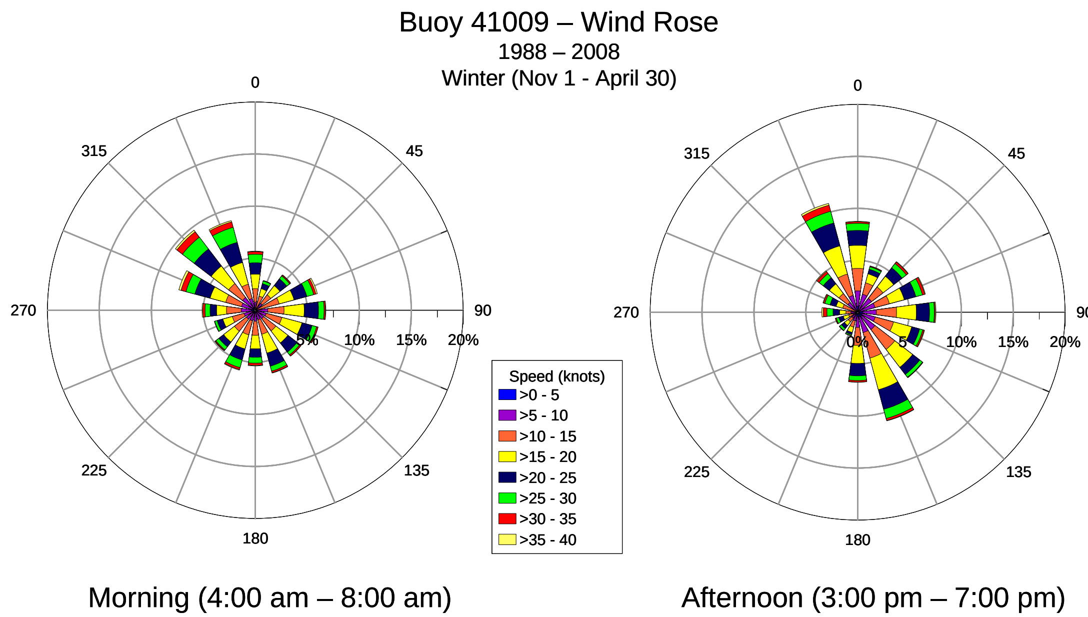

Figure 5. Wind Roses for Station 41009 Data -- Winter Season

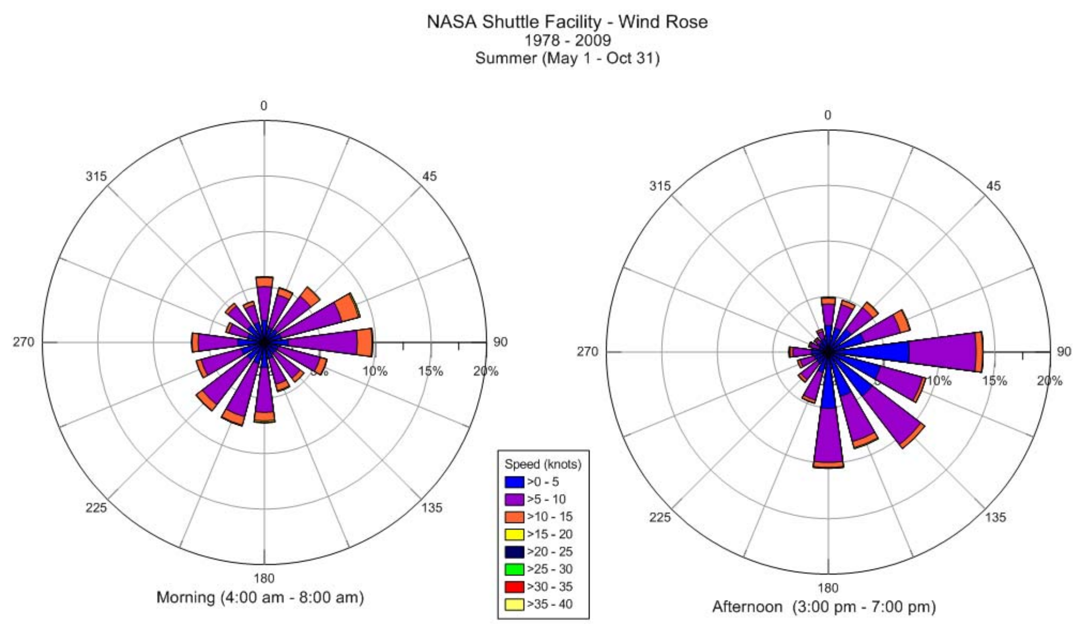

Figure 6. Wind Roses for NASA Shuttle Facility -- Summer Season

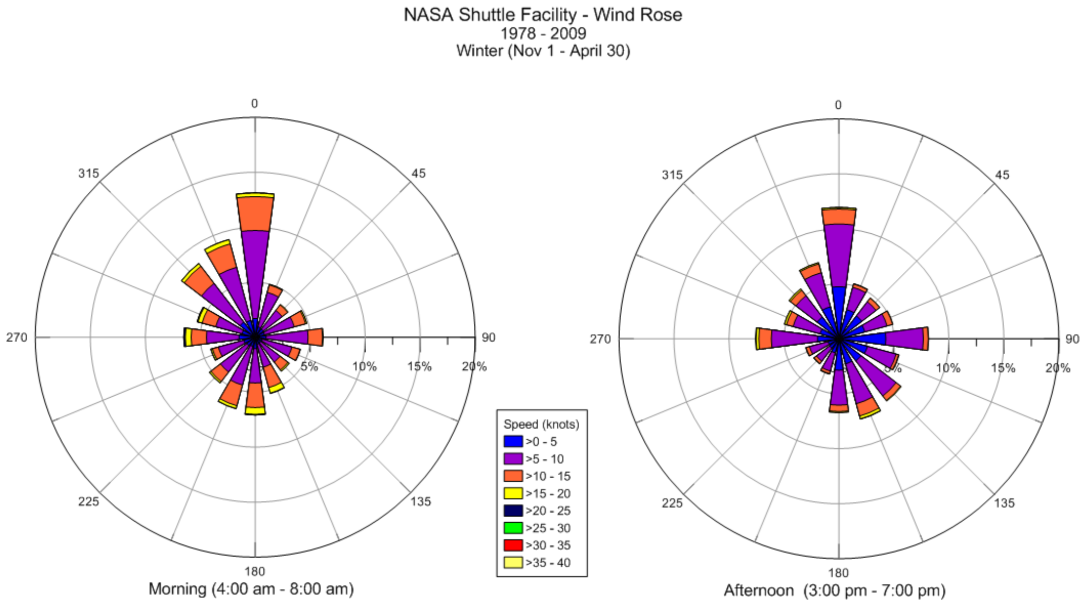

Figure 7. Wind Roses for NASA Shuttle Facility -- Winter Season

Table 6. Wind speed Frequency of Occurrence – Summer – Station 41009

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		2	2	2	1	0	1	1	1	1
55	60	2	0	0	1	0	0	0	1	1
50	55	5	1	2	2	1	1	1	0	1
45	50	12	2	5	5	1	0	0	2	4
40	45	27	3	10	7	1	5	5	6	6
35	40	60	17	32	22	3	7	9	15	12
30	35	161	46	76	49	10	23	20	26	36
25	30	382	108	195	111	27	35	36	66	100
20	25	748	286	489	324	54	124	115	178	242
15	20	970	588	845	687	187	366	319	441	565
10	15	783	862	974	1004	401	741	676	811	942
5	10	335	856	705	1009	775	1170	1034	1137	1091
0	5	47	761	199	312	2072	1061	1318	850	533
Afternoon period (3:00 pm – 7:00 pm)										
> 60		3	0	2	1	0	0	0	0	1
55	60	6	1	1	0	0	0	0	1	0
50	55	5	0	3	3	0	1	1	3	3
45	50	12	4	2	3	0	1	2	1	1
40	45	48	1	9	17	1	4	2	5	14
35	40	113	15	34	35	3	12	12	14	25
30	35	241	41	70	87	13	23	27	48	63
25	30	455	119	217	174	30	68	53	94	137
20	25	752	233	479	410	78	163	159	240	326
15	20	959	521	903	711	182	410	370	506	628
10	15	735	819	1104	920	438	784	692	819	915
5	10	188	993	627	892	767	1123	1006	1052	942
0	5	7	777	73	271	2012	935	1200	741	469

Table 7. Wind speed frequency of occurrence – Winter – Station 41009

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		1	0	0	0	0	0	0	0	0
55	60	4	0	1	2	0	0	0	1	2
50	55	13	0	3	0	0	0	2	1	0
45	50	49	2	13	13	0	1	1	4	8
40	45	106	30	51	32	1	9	8	20	29
35	40	239	72	138	93	10	38	38	53	65
30	35	489	182	307	211	49	103	95	137	192
25	30	633	377	530	347	131	227	213	269	302
20	25	724	542	669	514	252	372	334	407	475
15	20	689	702	770	722	389	544	524	596	660
10	15	383	709	613	707	540	689	651	699	722
5	10	118	516	306	639	667	825	757	775	684
0	5	10	326	57	178	1419	650	835	496	319
Afternoon period (3:00 pm – 7:00 pm)										
> 60		2	1	1	0	0	0	0	0	0
55	60	4	0	0	1	0	0	0	0	1
50	55	14	0	3	1	0	0	0	1	0
45	50	23	5	16	6	0	2	2	2	5
40	45	96	16	36	23	1	8	7	15	21
35	40	203	58	88	85	20	29	31	43	59
30	35	402	119	240	179	30	78	68	121	155
25	30	598	305	437	360	127	210	202	254	297
20	25	754	475	676	538	231	387	357	435	497
15	20	689	658	739	674	395	550	521	564	629
10	15	495	680	681	745	536	704	632	735	760
5	10	178	611	464	619	661	828	751	741	693
0	5	9	539	86	236	1466	671	896	556	350

Table 8. Wind speed percent frequency of occurrence – Summer – Station 41009

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%
40	45	0.8%	0.1%	0.3%	0.2%	0.0%	0.1%	0.1%	0.2%	0.2%
35	40	1.7%	0.5%	0.9%	0.6%	0.1%	0.2%	0.3%	0.4%	0.3%
30	35	4.6%	1.3%	2.2%	1.4%	0.3%	0.7%	0.6%	0.7%	1.0%
25	30	10.8%	3.1%	5.5%	3.1%	0.8%	1.0%	1.0%	1.9%	2.8%
20	25	21.2%	8.1%	13.8%	9.2%	1.5%	3.5%	3.3%	5.0%	6.8%
15	20	27.4%	16.6%	23.9%	19.4%	5.3%	10.4%	9.0%	12.5%	16.0%
10	15	22.2%	24.4%	27.6%	28.4%	11.3%	21.0%	19.1%	22.9%	26.7%
5	10	9.5%	24.2%	19.9%	28.6%	21.9%	33.1%	29.3%	32.2%	30.9%
0	5	1.3%	21.5%	5.6%	8.8%	58.6%	30.0%	37.3%	24.1%	15.1%
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%
45	50	0.3%	0.1%	0.1%	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%
40	45	1.4%	0.0%	0.3%	0.5%	0.0%	0.1%	0.1%	0.1%	0.4%
35	40	3.2%	0.4%	1.0%	1.0%	0.1%	0.3%	0.3%	0.4%	0.7%
30	35	6.8%	1.2%	2.0%	2.5%	0.4%	0.7%	0.8%	1.4%	1.8%
25	30	12.9%	3.4%	6.2%	4.9%	0.9%	1.9%	1.5%	2.7%	3.9%
20	25	21.3%	6.6%	13.6%	11.6%	2.2%	4.6%	4.5%	6.8%	9.3%
15	20	27.2%	14.8%	25.6%	20.2%	5.2%	11.6%	10.5%	14.4%	17.8%
10	15	20.9%	23.2%	31.3%	26.1%	12.4%	22.2%	19.6%	23.2%	26.0%
5	10	5.3%	28.2%	17.8%	25.3%	21.8%	31.9%	28.5%	29.9%	26.7%
0	5	0.2%	22.0%	2.1%	7.7%	57.1%	26.5%	34.1%	21.0%	13.3%

Table 9 Wind speed percent frequency of occurrence – Winter – Station 41009

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
50	55	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
45	50	1.4%	0.1%	0.4%	0.4%	0.0%	0.0%	0.0%	0.1%	0.2%
40	45	3.1%	0.9%	1.5%	0.9%	0.0%	0.3%	0.2%	0.6%	0.8%
35	40	6.9%	2.1%	4.0%	2.7%	0.3%	1.1%	1.1%	1.5%	1.9%
30	35	14.1%	5.3%	8.9%	6.1%	1.4%	3.0%	2.7%	4.0%	5.6%
25	30	18.3%	10.9%	15.3%	10.0%	3.8%	6.6%	6.2%	7.8%	8.7%
20	25	20.9%	15.7%	19.3%	14.9%	7.3%	10.8%	9.7%	11.8%	13.7%
15	20	19.9%	20.3%	22.3%	20.9%	11.2%	15.7%	15.2%	17.2%	19.1%
10	15	11.1%	20.5%	17.7%	20.4%	15.6%	19.9%	18.8%	20.2%	20.9%
5	10	3.4%	14.9%	8.8%	18.5%	19.3%	23.9%	21.9%	22.4%	19.8%
0	5	0.3%	9.4%	1.6%	5.1%	41.0%	18.8%	24.1%	14.3%	9.2%
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.7%	0.1%	0.5%	0.2%	0.0%	0.1%	0.1%	0.1%	0.1%
40	45	2.8%	0.5%	1.0%	0.7%	0.0%	0.2%	0.2%	0.4%	0.6%
35	40	5.9%	1.7%	2.5%	2.5%	0.6%	0.8%	0.9%	1.2%	1.7%
30	35	11.6%	3.4%	6.9%	5.2%	0.9%	2.2%	2.0%	3.5%	4.5%
25	30	17.2%	8.8%	12.6%	10.4%	3.7%	6.1%	5.8%	7.3%	8.6%
20	25	21.7%	13.7%	19.5%	15.5%	6.7%	11.2%	10.3%	12.5%	14.3%
15	20	19.9%	19.0%	21.3%	19.4%	11.4%	15.9%	15.0%	16.3%	18.1%
10	15	14.3%	19.6%	19.6%	21.5%	15.5%	20.3%	18.2%	21.2%	21.9%
5	10	5.1%	17.6%	13.4%	17.9%	19.1%	23.9%	21.7%	21.4%	20.0%
0	5	0.3%	15.5%	2.5%	6.8%	42.3%	19.4%	25.8%	16.0%	10.1%

Table 10. Wind speed frequency of occurrence – Summer – NASA Shuttle Facility

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0	0	0	0	0	0	0	0	0
55	60	0	0	0	0	0	0	0	0	0
50	55	0	0	0	0	0	0	0	0	0
45	50	0	0	0	0	0	0	0	0	0
40	45	0	0	0	0	0	0	0	0	0
35	40	1	0	0	0	0	0	0	0	0
30	35	8	0	0	3	0	0	0	0	3
25	30	53	1	5	21	0	0	0	8	14
20	25	271	12	61	122	2	11	13	47	78
15	20	1266	165	557	671	38	187	193	392	552
10	15	2103	947	1731	1476	352	962	784	1078	1316
5	10	1631	2511	2472	2279	1456	2124	1930	2160	2244
0	5	239	1936	746	1000	3724	2288	2652	1887	1365
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0	0	0	0	0	0	0	0	0
55	60	0	0	0	0	0	0	0	0	0
50	55	0	0	0	0	0	0	0	0	0
45	50	0	0	0	0	0	0	0	0	0
40	45	0	0	0	0	0	0	0	0	0
35	40	0	0	0	0	0	0	0	0	0
30	35	5	0	0	1	0	0	0	0	1
25	30	19	0	2	6	0	0	0	1	5
20	25	92	6	24	34	0	4	4	12	21
15	20	535	65	189	237	23	55	61	116	173
10	15	1248	364	804	710	134	352	268	414	551
5	10	2949	1943	2437	2266	812	1455	1308	1714	2042
0	5	754	3224	2146	2348	4633	3736	3961	3345	2809

Table 11. Wind speed frequency of occurrence – Winter – NASA Shuttle Facility

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0	0	0	0	0	0	0	0	0
55	60	0	0	0	0	0	0	0	0	0
50	55	0	0	0	0	0	0	0	0	0
45	50	0	0	0	0	0	0	0	0	0
40	45	1	0	0	0	0	0	0	0	0
35	40	1	0	0	0	0	0	0	0	0
30	35	4	1	1	1	0	0	0	1	1
25	30	11	0	2	7	0	1	0	1	4
20	25	74	2	9	29	1	4	3	12	17
15	20	563	32	132	187	7	34	42	84	137
10	15	1991	396	1043	802	94	285	259	435	641
5	10	2704	2341	3186	2952	776	1777	1572	2214	2583
0	5	422	2999	1398	1793	4893	3670	3895	3024	2388
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0	0	0	0	0	0	0	0	0
55	60	0	0	0	0	0	0	0	0	0
50	55	1	0	0	0	0	0	0	0	0
45	50	0	0	0	0	0	0	0	0	0
40	45	0	0	0	0	0	0	0	0	0
35	40	2	0	0	1	0	0	0	0	0
30	35	4	0	1	1	0	0	0	0	1
25	30	13	1	0	1	0	0	0	0	0
20	25	65	1	13	27	0	3	2	9	16
15	20	341	22	58	141	6	17	14	54	93
10	15	1255	168	525	578	44	168	128	274	408
5	10	3365	1668	2737	2470	521	1317	1073	1648	2124
0	5	729	3915	2441	2556	5204	4270	4558	3790	3133

Table 12. Wind speed percent frequency of occurrence – Summer – NASA Shuttle Facility

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	45	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
35	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	35	0.1%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
25	30	1.0%	0.0%	0.1%	0.4%	0.0%	0.0%	0.0%	0.1%	0.3%
20	25	4.9%	0.2%	1.1%	2.2%	0.0%	0.2%	0.2%	0.8%	1.4%
15	20	22.7%	3.0%	10.0%	12.0%	0.7%	3.4%	3.5%	7.0%	9.9%
10	15	37.7%	17.0%	31.1%	26.5%	6.3%	17.3%	14.1%	19.3%	23.6%
5	10	29.3%	45.1%	44.4%	40.9%	26.1%	38.1%	34.6%	38.8%	40.3%
0	5	4.3%	34.7%	13.4%	17.9%	66.8%	41.1%	47.6%	33.9%	24.5%
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	45	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
35	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	35	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	30	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%
20	25	0.1%	0.4%	0.6%	0.0%	0.1%	0.1%	0.2%	0.4%	0.1%
15	20	1.2%	3.4%	4.2%	0.4%	1.0%	1.1%	2.1%	3.1%	1.2%
10	15	6.5%	14.4%	12.7%	2.4%	6.3%	4.8%	7.4%	9.8%	6.5%
5	10	34.7%	43.5%	40.4%	14.5%	26.0%	23.3%	30.6%	36.5%	34.7%
0	5	57.6%	38.3%	41.9%	82.7%	66.7%	70.7%	59.7%	50.1%	57.6%

Table 13. Wind speed percent frequency of occurrence – Winter – NASA Shuttle Facility

Speed Range (knots)		Speed frequency			Abeam-comp frequency			"best window"		
from	to	max	min	avg	max	min	avg	1-hr	2-hr	3-hr
Morning period (4:00 am – 8:00 am)										
> 60		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	45	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
35	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	35	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	30	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
20	25	1.3%	0.0%	0.2%	0.5%	0.0%	0.1%	0.1%	0.2%	0.3%
15	20	9.8%	0.6%	2.3%	3.2%	0.1%	0.6%	0.7%	1.5%	2.4%
10	15	34.5%	6.9%	18.1%	13.9%	1.6%	4.9%	4.5%	7.5%	11.1%
5	10	46.9%	40.6%	55.2%	51.2%	13.4%	30.8%	27.2%	38.4%	44.8%
0	5	7.3%	52.0%	24.2%	31.1%	84.8%	63.6%	67.5%	52.4%	41.4%
Afternoon period (3:00 pm – 7:00 pm)										
> 60		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
55	60	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50	55	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
45	50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	45	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
35	40	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	35	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
25	30	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20	25	1.1%	0.0%	0.2%	0.5%	0.0%	0.1%	0.0%	0.2%	0.3%
15	20	5.9%	0.4%	1.0%	2.4%	0.1%	0.3%	0.2%	0.9%	1.6%
10	15	21.7%	2.9%	9.1%	10.0%	0.8%	2.9%	2.2%	4.7%	7.1%
5	10	58.3%	28.9%	47.4%	42.8%	9.0%	22.8%	18.6%	28.5%	36.8%
0	5	12.6%	67.8%	42.3%	44.3%	90.1%	73.9%	78.9%	65.6%	54.3%

Table 14. Wind speed cumulative frequency of exceedance – Station 41009

Speed (knots)	Frequency of Exceedance (%)			
	Summer[1]		Winter[2]	
	AM[3]	PM[4]	AM[3]	PM[4]
Maximum abeam-component				
15	34.1	40.9	56.0	53.9
20	14.7	20.7	35.1	34.5
25	5.5	9.1	20.2	19
30	2.4	4.2	10.2	8.6
35	1.0	1.7	4.1	3.4
40	0.4	0.7	1.4	0.9
Average abeam-component				
15	15.9	19.2	37.5	36.5
20	5.5	7.6	21.8	20.6
25	2.0	3.0	11	9.4
30	1.0	1.1	4.4	3.3
35	0.3	0.4	1.4	1.1
40	0.1	0.1	0.3	0.3
Best 1-hour weather window				
15	14.3	17.8	35.2	34.3
20	5.3	7.3	20.0	19.3
25	2.0	2.8	10.3	9.0
30	1.0	1.3	4.1	3.2
35	0.4	0.5	1.4	1.2
40	0.1	0.2	0.3	0.3
Best 2-hour weather window				
15	20.8	25.9	43.0	41.3
20	8.3	11.5	25.8	25.0
25	3.3	4.7	14.0	12.5
30	1.4	2.0	6.2	5.2
35	0.7	0.6	2.2	1.7
40	0.3	0.2	0.7	0.5
Best 3-hour weather window				
15	27.2	34.0	50.1	47.9
20	11.2	16.2	31.0	29.8
25	4.4	6.9	17.3	15.5
30	1.6	3.0	8.6	6.9
35	0.6	1.2	3.0	2.4
40	0.3	0.5	1.1	0.7

[1] Summer period defined as May 1 through October 31
[2] Winter period defined as November 1 through April 31
[3] AM period is between 4:00 and 8:00 am
[4] PM period is between 3:00 and 7:00 pm

Table 15. Wind speed cumulative frequency of exceedance – NASA Shuttle Facility

Speed (knots)	Frequency of Exceedance (%)			
	Summer[1]		Winter[2]	
	AM[3]	PM[4]	AM[3]	PM[4]
Maximum abeam-component				
15	3.9%	3.0%	14.7%	5.0%
20	0.6%	0.5%	2.6%	0.7%
25	0.1%	0.1%	0.4%	0.1%
30	0.0%	0.0%	0.1%	0.0%
35	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%
Average abeam-component				
15	0.7%	0.3%	3.6%	1.1%
20	0.1%	0.1%	0.2%	0.1%
25	0.0%	0.0%	0.0%	0.0%
30	0.0%	0.0%	0.0%	0.0%
35	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%
Best 1-hour weather window				
15	0.8%	0.3%	3.8%	1.2%
20	0.1%	0.0%	0.2%	0.1%
25	0.0%	0.0%	0.0%	0.0%
30	0.0%	0.0%	0.0%	0.0%
35	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%
Best 2-hour weather window				
15	1.7%	1.1%	8.1%	2.3%
20	0.2%	0.2%	1.0%	0.2%
25	0.0%	0.0%	0.1%	0.0%
30	0.0%	0.0%	0.0%	0.0%
35	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%
Best 3-hour weather window				
15	2.8%	1.9%	11.6%	3.6%
20	0.4%	0.3%	1.7%	0.5%
25	0.1%	0.0%	0.3%	0.1%
30	0.0%	0.0%	0.1%	0.0%
35	0.0%	0.0%	0.0%	0.0%
40	0.0%	0.0%	0.0%	0.0%

[1] Summer period defined as May 1 through October 31
[2] Winter period defined as November 1 through April 31
[3] AM period is between 4:00 and 8:00 am
[4] PM period is between 3:00 and 7:00 pm

Based on these two datasets, it appears that generally the likelihood for delays increases in the winter with average abeam-component winds speeds over the periods the ships will enter or leave port exceeding 15 knots between about 2 to 37% of the time compared with 0.5 to 17% of the time for the summer season. The lower numbers in these ranges are daily averages based on the NASA space shuttle facility data where the upper limits are daily averages based on the buoy data. Similarly maximum abeam-component wind speeds exceed 15 knots between about 10 to 55% of the time during the winter compared to between about 3.5 to 37.5% of the time in the summer.

The best weather windows are a measure of the best conditions over a given period and are meant as a measure of the ability of ships to enter or leave the port during a given 4-hour period. Ships arriving at the port during the morning or evening period, but outside of the given “best” weather window may encounter greater wind speeds and potential for delays may be under-represented by the percentages given for the 1- and 2-hour weather windows in Tables 14 and 15.

1.3.3.2 Wave Climate and Design Vessel Motions

The entrance from Port Canaveral sees some protection from wind waves from deep water from the north through east directions due to the Cape Canaveral land mass to the north and the Southeast Shoal approximately 8 to 10 nautical miles east of the harbor.

Wave climate for the entrance channel was forecast for wind speeds ranging from 15 to 20 knots for tanker and bulk carrier traffic and 25 to 30 knots for cruise traffic. The wave conditions at the entrance to the harbor are duration-limited, so the wave growth in terms of height will be limited by the length of time the wind blows. Table 16 summarizes the wave parameter predictions for the Canaveral Harbor entrance. Parameters estimated include spectral wave height (Hmo), peak spectral period (Tp), and wave length (L) for durations of 1, 2, and 3 hours and for wind speeds of 15, 20, 25, and 30 knots based on linear wave theory for an average water depth of 45 ft.

Table 16. Wave Predictions – Entrance to Canaveral Harbor

	Duration-Limited Wind Speed (knots)											
Duration	15			20			25			30		
of Wind (hrs)	Hmo (ft)	Tp (sec)	L (ft)	Hmo (ft)	Tp (sec)	L (ft)	Hmo (ft)	Tp (sec)	L (ft)	Hmo (ft)	Tp (sec)	L (ft)
3	1.8	3.0	46	2.8	3.7	70	4.1	4.3	94	5.5	5.0	125
2	1.4	2.5	32	2.1	3.1	49	3.0	3.7	70	4.1	4.2	90
1	0.8	1.9	19	1.3	2.3	27	1.9	2.8	40	2.5	3.2	52

1.4 Canaveral Harbor Existing Project Features

The existing Federal project was authorized by the Rivers and Harbors Acts of 2 March 1945 and 23 October 1962, as well as Sections 101, 114, and 117 of the Water Resources Development Act of 1992. The following table summarizes the Federal authorized dimensions of the existing Port Canaveral project features. In addition, a paid overdepth allowance of 2 ft below the project depths shown is authorized.

Table 17. Port Canaveral Existing Project Features

Project Feature	Cut and Centerline Station Start / End (ft)	Existing Federal Dimensions Depth X Width X Length (ft)
Outer Reach	Cut 1A, 0+00 to 110+00 Cut 1B 0+00 to 55+00 Cut 1, 0+00 to 125+00	44 X 400 X 29,000 (USN) 41 X 400 X 29,000 (CW)
44-ft Turn Widener		44 X Irregular Shape (USN)
41-ft Turn Widener		41 X Irregular Shape (CW)
Middle Reach	Cut 2, 125+00 to 181+70	44 X 400 X 5,670 (USN) 41 X 400 X 5,670 (CW)
Trident Access Channel	T.A.C., 5+00 to 32+33.60	44 X Width Varies X 2,733.6 (USN)
Trident Turning Basin	T.T.B., 0+00 to 15+00	41 X 1,200 X 1,500 (USN)
Inner Reach	Cut2, 181+70 to 207+00 Cut 3, 207+00 to 215+00	40 X 400 X 3,330
Middle Turning Basin	M.T.B., 215+00 to 241+70	39 X 2,670 X Irregular Shape w/ 1200-ft DIA
West Access Channel (East of Sta 260+00)	W.A.C., 241+60 to 260+00 Cut A, 0+00 to 18+40	39 X 400 X 1,840
West Access Channel, (West of Sta 260+00)	W.A.C., 260+00 to 277+30 Cut A, 18+40 to 36+70	31 X 400 X 1,730 CPA to 35’
West Turning Basin		31 X Irregular Shape w/ 1400-ft DIA, CPA to 35’
Canaveral Barge Canal	Cut 1 to Canaveral Lock, 141+60 to 227+70	12 X 125 X 8,610
Pilot’s Draft Limits/Restrictions		36 ft w/o tidal advantage, 39.5 ft w/ maximum tidal advantage and good conditions

USN – US Navy Project
CW – Civil Works Project

Attachment C presents drawings depicting Canaveral Harbor existing conditions and authorized channel depths.

1.5 Navigation Simulation Studies

Two separate simulation studies have been executed in 2007 and 2009 in direct support of this navigation improvements feasibility study. Both studies took place at the RTM STAR Center, Dania Beach, Florida. The 2007 simulations considered the test vessels, tanker Jupiter and Genesis Class cruise ship. In the 2009 simulations, a test matrix, coordinated with representatives from the USACE navigation community (Vicksburg, MS and Jacksonville District), was developed for additional tests of the tanker Jupiter and the presently home ported Freedom Class vessel. Both studies were conducted in the STAR Center's 360-degree field-of-view, ship handling simulator with the participation of CPA's consultants and the Canaveral Pilots in both cases and the USACE navigation representatives in the 2009 simulations.

Alternative Plans A and B, also referred to as Plans 2 and 1 in the Main Report, respectively, were investigated in the 2009 simulations. Only alternative Plan A was evaluated in the 2007 simulations. Table 18 summarizes the width geometry for each major navigation feature identified for improvement.

Table 18. Simulations Plan Width Geometry

Project Width Navigation Feature	Plan A (Main Report Plan 2)	Plan B (Main Report Plan 1)
Ocean Turn Widener	22.24 acres	11.14 acres
North Side Channel Widener (Inner Reach to North Jetty)	100 ft for 500-ft Channel	50 ft for 450-ft Channel
Channel Widener	87.5 ft, South Side	87.5 ft, South Side
(West Access Channel, Both Cuts)	12.5 ft, North Side	12.5 ft, North Side
West Basin Turn Area	1725-ft Diameter	1675-ft Diameter

Figures 8 through 10 detail the differences between Plan A and Plan B in the areas mentioned in Table 18.

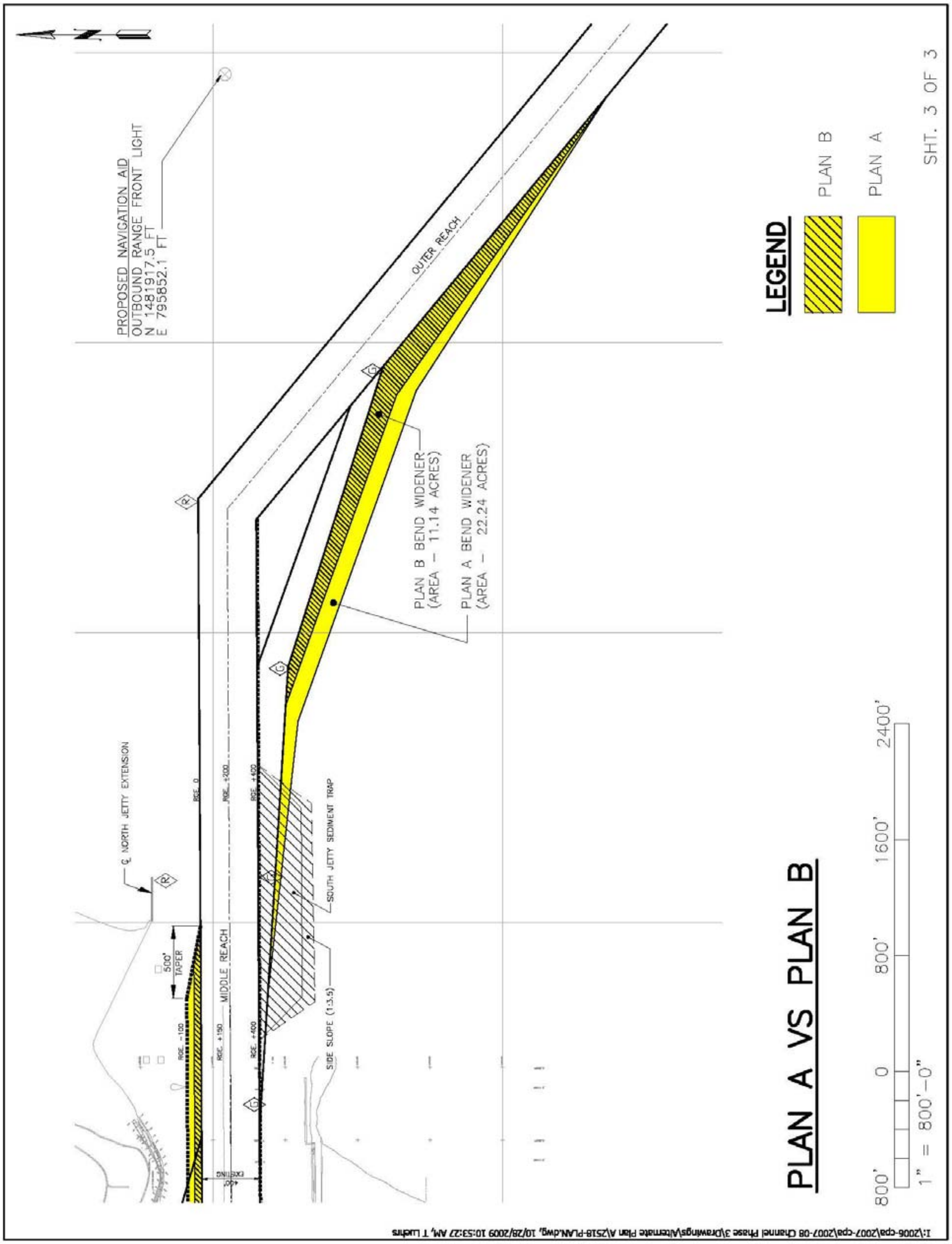

Figure 8. Plan A and Plan B comparison (1 of 3).

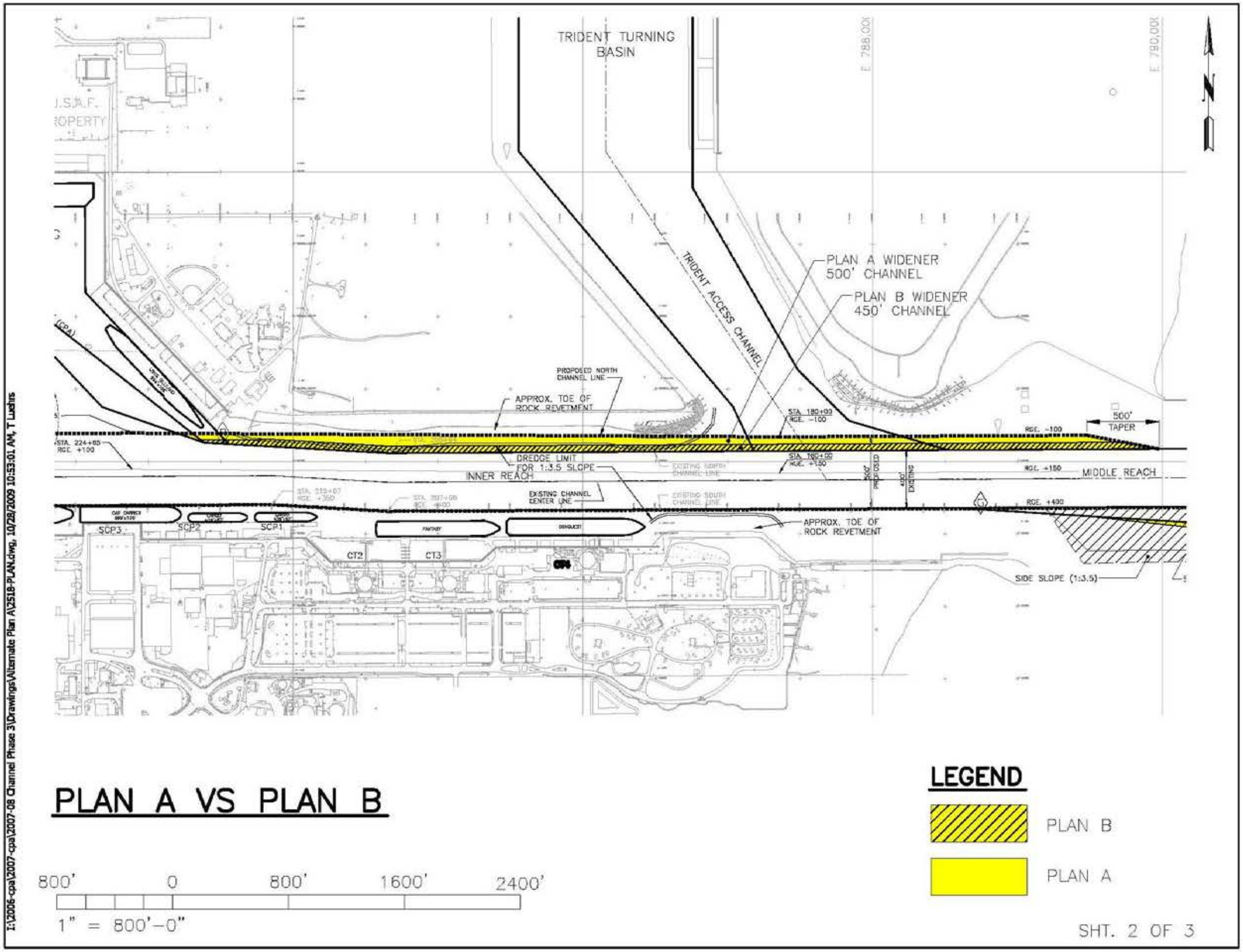

Figure 9. Plan A and Plan B comparison (2 of 3)

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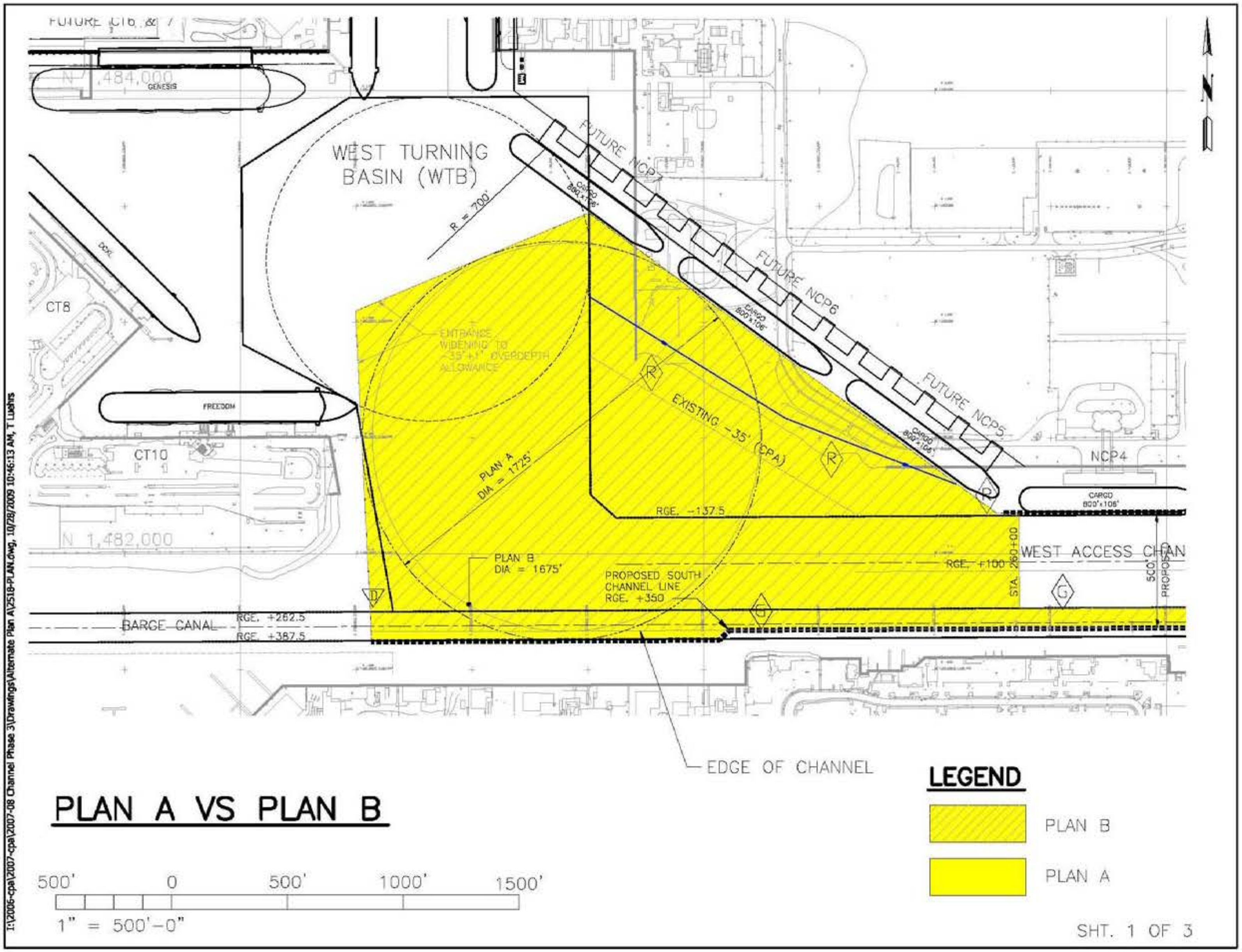

Figure 10. Plan A and Plan B comparison (3 of 3)

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The STAR Center utilized three hydrodynamic vessel response models in the simulations: two very large passenger cruise ships, the Genesis and Freedom Class vessels, and the Jupiter, a medium-sized (AFRAMAX) tanker. The Genesis and Freedom models were evaluated for one load condition in all runs. The Jupiter was modeled in a partially loaded condition for inbound runs and a ballasted condition for outbound runs. Table 19 contains the particulars for the ships.

Different model wind and current conditions were used in the 2007 and 2009 simulations. The 2007 simulations evaluated all exercises for wind speeds from 15 to 25 knots with current outside the jetties at 0.3 knots setting northerly or southerly, sometimes opposing the wind, other times in the same direction as the wind. In the 2009 simulations and with USACE navigation team input, higher wind speeds of 30 to 40 knots were used for the cruise ship exercises and 25 to 30 knots for the tanker exercises with northerly setting currents of 0.75 and 1.0 knots and southerly setting currents of 0.5 knots. The 2009 simulations also considered wind and current applied in the same direction. In both simulation studies, three tugs were secured to the tanker and available for use by the pilots as needed. Two 3,000-hp conventional tugs were made fast on the port and starboard bow and one 4,000-hp tractor tug assist was available at the stern. Attachment A contains the complete STAR Center Simulation Reports and each matrix of runs. Subsequent paragraphs of this Engineering Appendix discuss the simulations findings with regard to the project features investigated.

Table 19. STAR Center Ship Response Model Characteristics

SHIP MODEL	Freedom Class (Cruise)	Genesis Class (Cruise)	Jupiter (Tanker)
Length Overall	1111.6 ft (338.9m)	1185.7 ft (361.5m)	800.3 ft (244.0m)
Beam at the waterline	126.6 ft (38.6m)	154.2 ft (47.0m)	137.8 ft (42.0m)
Displacement (m. tons)	72,330	103,252	97,200 Partially Laden 54,260 Ballasted
Modeled Draft, forward and aft	Fwd 27.9 ft (8.5m) Aft 27.9 ft (8.5m)	Fwd 30.2 ft (9.2m) Aft 30.2 ft (9.2m)	Partially Laden (Inbound) Fwd 39.4 ft (12.0m) Aft 39.4 ft (12.0m) Ballasted (Outbound) Fwd 18.7 ft (5.7m) Aft 27.2 ft (8.3m)
Propulsion Type	Diesel Electric	Diesel Electric	Diesel
Propeller Type	Fixed Pitch (inward)	Fixed Pitch (inward)	Fixed Pitch CW
Number of Propulsion Pods or Propeller Shafts	2 Azipods (Port/Stbd) 1 Fixipod (Centerline)	3 Azipods	1 Shaft
Shaft Horsepower (each shaft or pod)	18,774 hp	26,820 hp	19,713 hp
Number of Thrusters	4 (Bow)	4 (Bow)	None
Thruster Horsepower	4,425 hp	7,376 hp	--

1.6 Project Width Alternatives

The very large cruise ship length and beam dimensions drive the navigation project width requirements as affected by environmental conditions during transit and proximity to moored vessels along Canaveral Harbor's main channel. Cruise ship speed and turn widener geometry can ensure the safety of navigation outside the harbor and jetties. Safe navigation inside the harbor, with minimal surge effects to moored vessels, requires a balance between vessel speed and good ship handling capability to manage the yaw of the vessel or "crab angle" or "leeway" as it moves through the waterway under the influence of moderate to high wind conditions.

Crab angle or leeway carried by a cruise ship is a measure of the effective width of a ship and the space it consumes within a channel. Cruise ship "effective beam" was discussed in a letter from the Canaveral Pilot's Association to CPA in December 2002. This letter was written in anticipation of the arrival of Mariner of the Seas in 2003 and the need for dredging of certain locations within the harbor, but outside and adjacent to the existing 400 ft channel boundaries. The pilots requested these key areas of dredging to improve the safety of navigation for this new large cruise ship. The pilot's define the ship effective beam (SEB) as follows:

SEB (ft) = LOA (ft) X (1.75 / 100) X Crab Angle (deg) + Beam (1)

Crab angle or leeway refers to the difference between the ship's heading and the course made good. The crab angle carried by a ship increases as wind speed increases and vessel speed decreases. This parameter is most important for the cruise ship traffic having large wind sail areas and post-panamax beams.

Cruise ships now transit Port Canaveral channels twice daily—inbound from early to mid-a.m. hours and outbound approximately late afternoon to mid-p.m. hours. The largest cruise ships home-ported at Port Canaveral, as well as various regularly scheduled Port of Call vessels, sail to and from the West Basin in winds of up to 35 knots unassisted. These large vessels with significant sail area generally travel at speeds on the order of 6 to 7 knots to minimize surge at critical locations in the West Access and Inner Reach channels but are greatly affected by channel cross-winds on occasions where sustained wind speeds exceed 20 knots. In the absence of the project and until such time as the navigation improvements are constructed, the pilots will recommend and/or require tug-assisted cruise ship maneuvering and transit and tug support to berthed tanker and cargo vessels at north and south cargo piers or berthed surface ships and submarines at military berths as wind conditions dictate. Roughly 15 occurrences of tug assistance for inbound or outbound cruise vessels and berthed vessels during 2011 resulted from wind conditions of 25 knots and above from primarily the North and East directions. The tug assist on berthed vessels ensures their safety by minimizing surge effects at commercial or military berths. On four occasions in 2011, the Carnival Dream has required tug assist to maneuver away from the Cruise Terminal 10 berth in winds of 20 to 25 knots. This is an example of the very large cruise vessel with some degree of lesser power and handling capability than say, the Freedom of the Seas. However, during the weekend of October 8, 2011, sustained high winds of 25 knots and greater, not associated with a tropical storm system, necessitated the use of one or two tugs for all cruise ship transits.

In the 2009 simulations, two project channel width alternatives of 500 ft (Plan A) and 450 feet (Plan B) have been considered for a portion of the middle reach, the inner reach, and a very short section of the Middle Basin Channel, east end. In the West Access Channel, the project formalizes the inclusion of an 87.5 ft width along the south side of the existing channel in the barge canal. Approximately 70 percent of this area was previously dredged to the 35 ft project depth in 2003 in preparation to receive the Voyager Class vessel home ported in West Basin from 2003-2009 as discussed below. CPA has historically held a regulatory permit authorizing maintenance dredging of this area along the southern boundary of the West Access Channel to support the safe navigation of the existing cruise vessel traffic. In following sections, the results of the various simulations are discussed with respect to the project width alternatives beginning first with the 2003 simulations as the outcome resulted in dredging the barge canal along the southern boundary of the existing 400 ft West Access Channel and Cut A for a width of 87.5 ft by approximately 2,550 ft long in 2003 to receive the Voyager Class homeport ship.

1.6.1 STAR Center Simulations for Voyager Class and Pilots Dredging

A Port Canaveral Berth Access Simulation Study was conducted in May 2003 to evaluate Mariner of the Seas navigation through Port Canaveral in various configurations including: 1) the existing channel; 2) the existing channel along with areas requested to be dredged by the pilots adjacent to but outside the channel; and 3) a 500 ft channel width. The Canaveral Pilots and RCCL ship captains participated in the simulations at the STAR Center.

Through the existing channel, Voyager Class vessel speeds were on the order of 6 to 10 knots between the Port entrance and the Navy's Poseidon Wharf in the MTB. Between the Poseidon Wharf and the entrance to the WTB, ship speeds were generally 6 knots or less. The study reported that for Voyager Class vessel speed of 6 knots, crab angles of 2.5 to 3 degrees were observed for 15-knot cross winds. The crab angle increased to approximately 4.5 degrees for 25-knot cross winds. Also noted were minimal clearances to berthed vessels that likely would have resulted in undesirable surge effects on those moored ships and associated operations. For the configuration that included the pilot dredge areas and for 30-knot cross winds, crab angles of 7 to 8 degrees were observed for transit speeds of 6 knots or less. For 30-knot winds, a more comfortable vessel speed of 6.2 knots limited the crab angle to about 6 degrees.

The STAR Center characterized the test wind conditions of 15- and 25-knot winds at Port Canaveral as average to moderately high. The 2003 report details five simulation exercises, runs 19-23, with the Voyager Class vessel in a 500 ft channel, the widening of the entrance to the West Basin, and the outbound range. Inbound and outbound runs were conducted with 20- and 25-knot winds from the south with one inbound run using 15 knot winds from the north. The pilots considered the southerly wind of most importance, as the cruise vessel tracked along the south side of the channel allowing for leeway, positioning the passing vessel in close proximity to the south side cruise and cargo berths along the Inner Reach. In the presence of high southerly crosswinds, the pilots preferred track is to favor the windward (south) side of the channel such that the stern tracks on or near the channel centerline. This is a key point for navigating these large vessels as the distance to the moored vessels is reduced in the case of southerly winds. Similarly, favoring the windward (north) side of the channel in northerly winds results in a reduced distance to the bank along the inner reach.

A key result of the 2003 navigation simulations for Voyager in the 500 ft channel was that the uniform width of 500 feet allows greater clearance to moored vessels, having a significant reduction of surge effects associated with these transits in the existing 400 ft channel. The additional width would allow the Voyager Class vessel to carry a higher crab angle while maintaining transit speeds of 6 knots or less, optimizing safety and control of the vessel under the widest range of environmental conditions.

Prior to the arrival of the Voyager Class vessel, Mariner of the Seas, in 2003, and at the request of the Canaveral Harbor Pilots (also with confirmation by simulations at the STAR Center), CPA executed dredging at five locations adjacent to but outside the channel that were considered to be key navigation areas and/or restricted channel areas critical to the safe navigation of this cruise vessel (see Figures 11 and 12). Those dredge areas effectively provided 50 ft of additional room north of the channel at either end of the Inner Reach and 87.5 ft of additional room south of the channel along the West Access Channel. Since 2003, the areas dredged have been permitted and authorized for maintenance dredging by the CPA to effectively provide 450 and 487 feet of navigable channel width at key areas where surge effects are of prime concern. This suggests that the pilots are most comfortable navigating the Voyager Class vessel where the channel is 450 ft wide having ideal bank clearances of at least 100 ft.

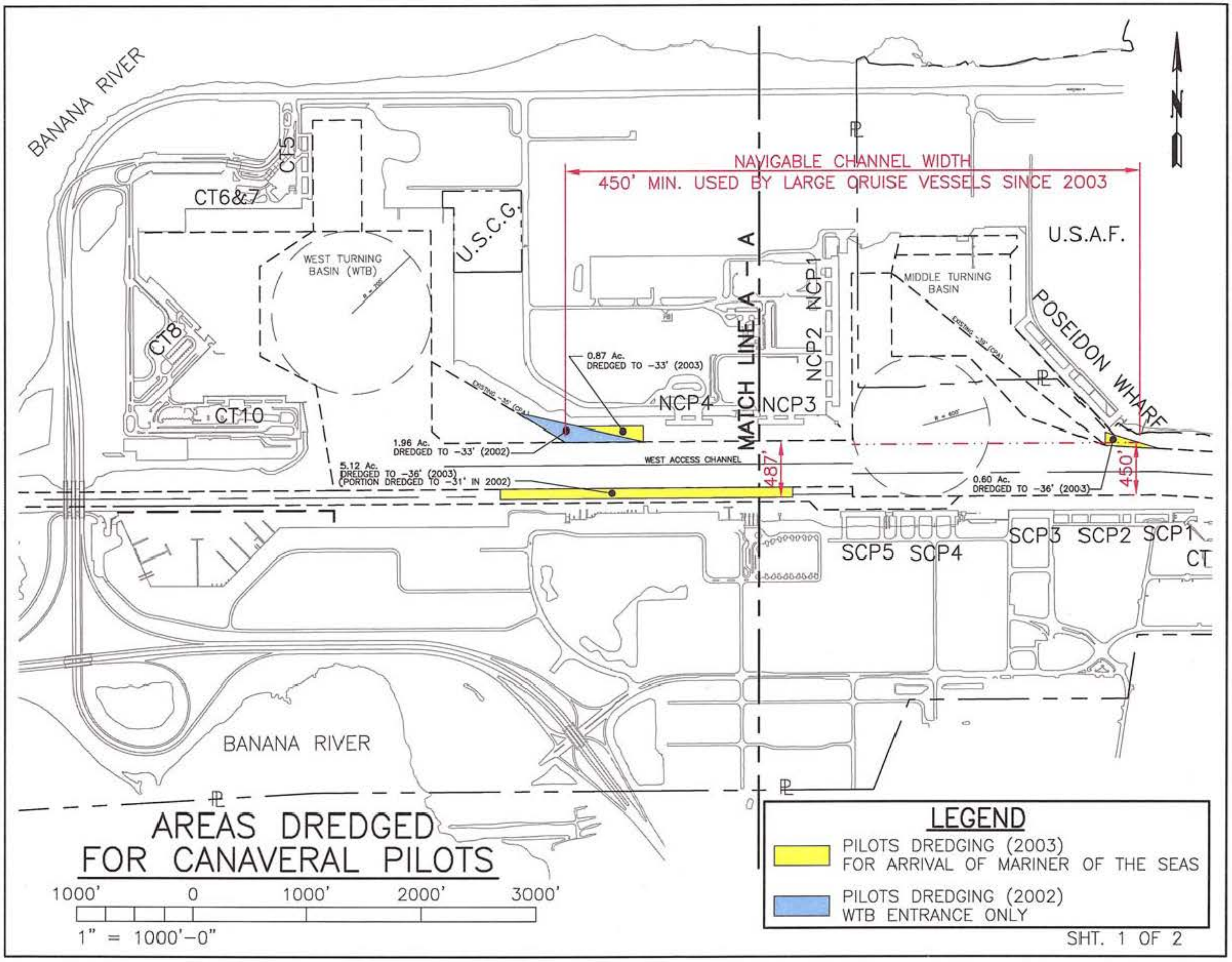

Figure 11. Areas Dredged for Canaveral Pilots, Sht 1 of 2

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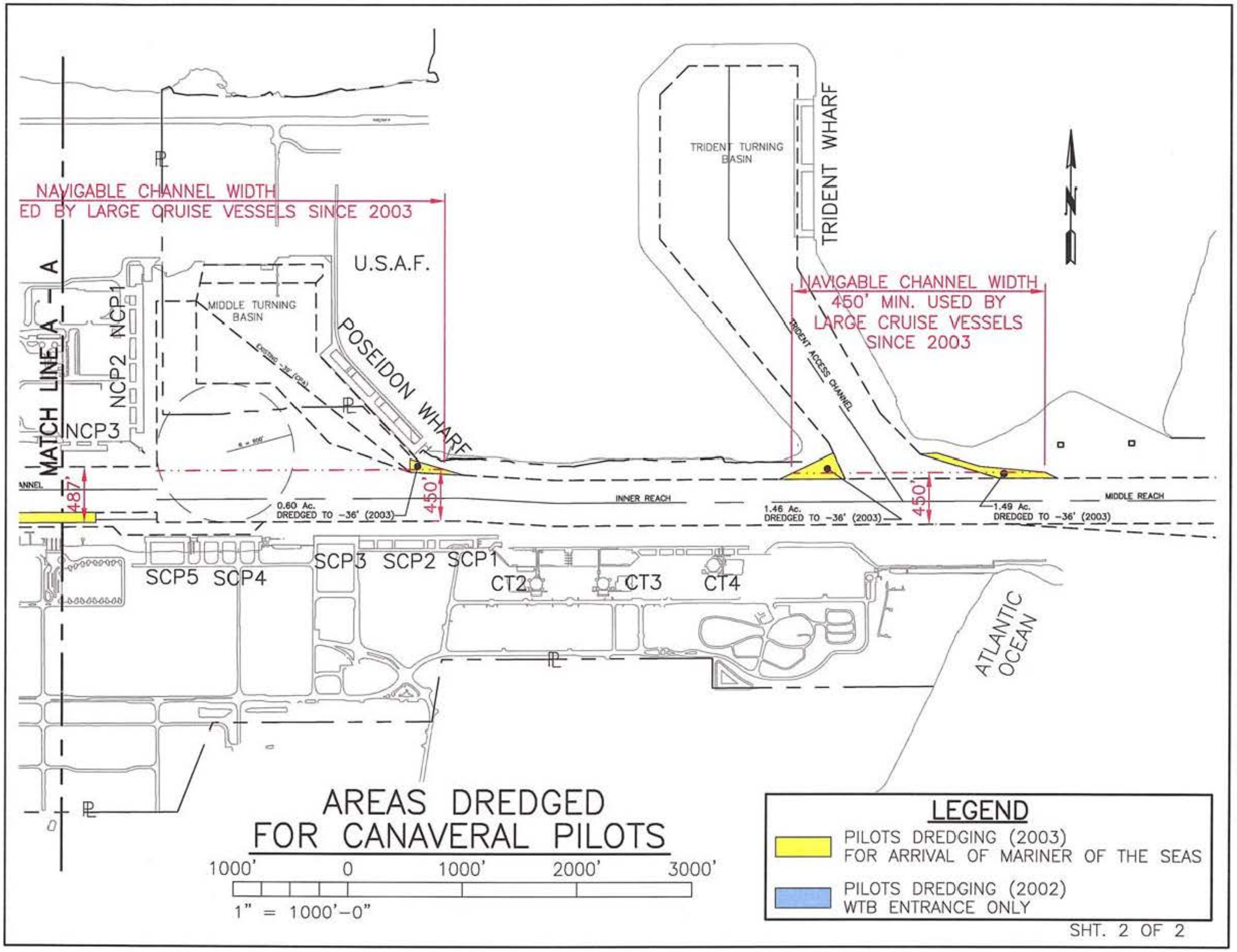
Figure 12. Areas Dredged for Canaveral Pilots, Sht 2 of 2



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1.6.2 STAR Center Simulation Findings and Recommendations for Cruise Ship Freedom and Tanker Jupiter

The following findings are noted for the Freedom and 30- to 35-knot winds relative to the project channel width alternatives from the 2009 simulations.

- Inside the jetties, the pilots consistently transited the middle and inner reaches at lower speeds in Plan A (4-8.8 knots) than Plan B (5.8-10.1 knots);
- Assessment of leeway for the middle and inner reaches, based on course and heading empirical data that was available for some of the exercises, indicates a mean of 3.7 degrees with a maximum of 13 degrees for Plan A and a mean of 5.1 degrees with a maximum of 12 degrees for Plan B; and
- Assessment of leeway for the west access channel indicates a mean of 3.4 degrees with a maximum of 9 degrees.

Pilot evaluations reflect a strong preference for the Plan A channel width of 500 ft. At the time of the simulations, the pilots expressed that the new Carnival and Disney cruise ships would not have podded propulsion as the Freedom does, and therefore, were expected to have a somewhat lesser degree of controllability and handling responsiveness in the channel.

The following findings are noted for the tanker Jupiter relative to the project channel width alternatives for the inner reach from the 2009 simulations.

- Transit speed inside the jetties, through the middle and inner reaches was noted as similar for both plans in three run sets and the same conditions; inbound speeds were 4.5 to 4.7 knots and outbound speeds were 6.7 to 8.6 knots;
- No significant difference between the plans with regard to the potential for surging cruise ships along the inner reach and clearance to the north channel boundary was demonstrated on the simulator; however,
- The wider inner reach of Plan A does provide increased tug maneuvering room.

The pilots rated the Plan A channel width as providing a better margin of safety than Plan B for partially laden and ballasted ship models.

STAR Center recommends that the 2009 simulations for the Freedom Class and tanker Jupiter vessels support improving the middle and inner reaches inside the jetties per Plan A (500 ft), and improving the west access channel per Plan B (450 ft). Note: the west access channel agreed to modeling should have only considered Plan A widening based on the accomplishment of the 2003 dredge project and subsequent use of the Plan A widener in this area by the cruise ships since that time.

1.6.3 Canaveral Pilot Experience with Freedom Class and Disney Dream Navigation

Over the few years that Freedom of the Seas and now the Disney Dream have been home-ported at Port Canaveral, the local pilots have gained much experience and knowledge in the vessel control and handling in a wide range of conditions. The pilots collectively offered their real world experience in handling these vessels with regard to the leeway or yaw angle necessary to maintain the desired course in the channel for beam or beam quartering winds.

Transiting the Middle Reach between the approach turn and the jetties, vessels are affected by surface current as well as wind. At times the forces are opposing rather than from the same direction. The surface current often crosses the jetties which has an effect on the leeway needed. Applied leeway for vessel speeds of 8 to 12 knots outside the jetties and through the turn area, slowing on inbound transit and accelerating on outbound transit, is given as:

Wind Conditions (knots)	Freedom Class Applied Leeway (deg)	Disney Dream Applied Leeway (deg)
15-20	1-4	2-5
20-25	3-5	4-6
25-30	4-6	5-8
30-35	4-7	6-9

Additional leeway may be necessary when surface current and wind come from similar directions. Based on this data, 6 degrees was selected to represent the applied leeway or crab angle carried in this part of the channel for wind speeds of 25 knots and higher for the purpose of project width investigation.

The remainder of the Middle Reach, the Inner Reach, and the West Access Channel, all inside the jetties, are considered together because the transit speed through these channel areas, in most cases, is about 6 knots. In the Middle Reach between the jetties and Trident Basin cruise vessels are slowing or accelerating between 6 and 8 knots. The pilots make every effort to be slowed to approximately 6 knots when passing any vessel at the south side cruise terminals along the Inner Reach. For these areas, the applied leeway commonly occurs within the following ranges:

Wind Conditions (knots)	Freedom Class Applied Leeway (deg)	Disney Dream Applied Leeway (deg)
15-20	2-5	3-6
20-25	3-6	4-7
25-30	4-8	5-9
30-35	5-9	6-10

General Note: Under the without-project conditions and at the location in the Inner Reach adjacent to the eastern end of the South Cargo Piers, transiting vessels make an adjustment of an additional 2 to 4 degrees between the centerline of the channel for Middle and Inner Reaches to or from the centerline of the West Access Channel. This course change adjustment may add to the leeway needed for wind such that on an inbound transit, the pilot might steer 10 to 12 degrees from the base course when passing buoy 14A, just east of Poseidon Wharf.

If required in wind conditions of 20 knots and higher, the pilot may order between 6 and 7.5 knots while transiting these areas in order to keep leeway within the above ranges. In light to moderate winds, 20 knots or less, the vessels may be slowed to between 5 and 5.5 knots in the West Access Channel when approaching the entrance to West Basin on inbound transit.

The pilots conclude by saying that the ranges for applied leeway occur depending on the angle of the wind relative to the beam and whether the ship can be positioned aggressively on the windward side of the channel or whether the situation dictates that the ship be steered near the channel centerline. The pilots generally prefer to work well to windward, within reason, to avoid hydrodynamic effects of being too close to the bank. However, sudden wind shifts associated with frontal passages or summer thunderstorms would not permit this technique. So, the upper end of the applied leeway ranges are more uncommon than the lower to mid-range angles and it may only be necessary to apply the higher leeway for a short period of time, but those are in fact, the very times when a widened channel is imperative.

1.6.4 Project Width Analysis Based on Design Guidance

USACE navigation guidance has been considered in assessing project width alternative requirements. It is understood that the results of real-time navigation simulations for the design vessels are the basis for the recommended plan project navigation features. Primary factors influencing channel width analysis at Port Canaveral include the design cruise and displacement vessel dimensions, one-way vessel traffic, local pilot practices for ship handling at Port Canaveral, the channel cross-section geometry, currents, wind, and wave effects outside and inside the harbor, visibility, and potential for surge effects within the basins and along the channel during consecutive outbound cruise vessel movements. Outside of the jetties, vessels can transit at higher speeds to offset the effects of quartering currents and winds and waves on horizontal ship motions. Channel cross-sections outside the jetties are either shallow water or trench type while inside the jetties, the cross-sections are considered to be asymmetric about the centerline and generally trench type. Some of the interior channel cuts are bounded by commercial vessel operations on one side with sloped banks or shallow-draft recreational concerns along the other side. Figure 13 provides beam multipliers for the desktop assessment of one-way traffic channel width for the type of channel cross-section, current conditions assumed to be aligned with the channel, and for the variation in the cross-section geometry over the length of the channel.

EM 1110-2-1613
31 May 06

Table 8-2
One-Way Ship Traffic Channel Width Design Criteria

Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, Knots		
	0.0 to 0.5	0.5 to 1.5	1.5 to 3.0
Constant Cross Section, Best Aids to Navigation			
Shallow	3.0	4.0	5.0
Canal	2.5	3.0	3.5
Trench	2.75	3.25	4.0
Variable Cross Section, Average Aids to Navigation			
Shallow	3.5	4.5	5.5
Canal	3.0	3.5	4.0
Trench	3.5	4.0	5.0

Figure 13. USACE Channel Width Design Guidance

USACE navigation guidance suggests that interior channel widths range from 3.0 to 3.5 times beam width for canal, trench, or shallow type channel cross sections with average to the best aids to navigation and no more than 0.5 knots of current, assumed to be aligned with the channel. Sections in the outer reach are closest to the shallow type, largely unrestricted. Sections near the jetties in the middle reach are either canal or trench type. The inner reach has primarily canal type sections, and the west access channel is a combination with canal type on the north bank and trench type on the south bank owing to the presence of the barge canal. In the case of cruise ships passing occupied berths and carrying a crab angle, the maximum beam of the vessel is of importance to ensure reasonable clearance. Using this simplified empirical approach, recommended project widths of 450 and 500 ft were considered in the simulations and modeling.

Table 20. USACE Guidance on Interior Channel Width

Channel Width	Freedom Class	Tug-Assisted Displacement Vessel
Vessel Beam at waterline (ft)	127	138
Vessel Beam, maximum (ft)	156	NA
All Reaches at 3.0 X Beam (ft)	381 to 468	414
All Reaches at 3.5 X Beam (ft)	445 to 546	483

First, to roughly compare the adequacy of alternate channel widths ranging from the existing 400 ft to 500 ft, cruise ship effective widths were assessed for the home ported Freedom Class and Disney Dream for the maximum credible cross-wind conditions of 35 knots. Then, clearances to the edges of the channel were computed assuming transit with the conning point offset from the channel centerline to account for the windward bias applied by the pilots for interior channel cross winds. Pilot experience aboard the Freedom of the Seas and the Disney Dream for the channel reaches inside the jetties suggest crab angles of 5-10 degrees occur for this range of wind conditions. The simulations for Freedom showed maximum crab angles of 9 to 12 degrees carried inside the jetties for the same wind conditions. Table 21 and Figure 14 summarize and illustrate the ship crab angle and bank clearance geometry for either 6 or 8 degrees of leeway and 75 to 100 ft of windward bias about the channel centerline as representative of the range of the majority of the worst transit conditions experienced.

Table 21. Cruise Vessel Clearance to Edge of Channel for Various Channel Widths

Cruise Vessel Class	Length Overall (ft)	Beam at Waterline (ft)	Ship Crab Angle (degrees)	Minimum Bank Clearance (ft)		
				400-ft Channel	450-ft Channel	500-ft Channel
Freedom	1,112	127	6°	63	88	113
Disney Dream	1,113	121	8°	32	57	82

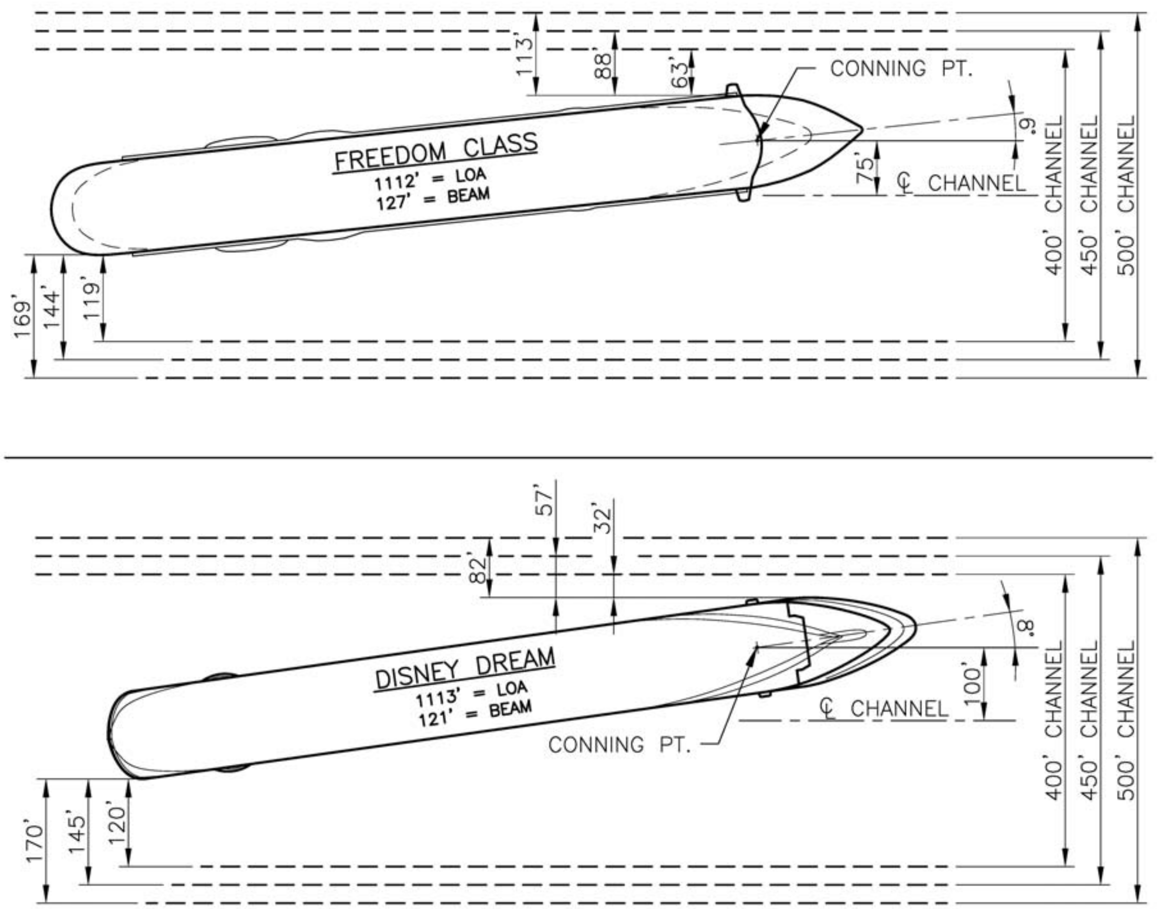

Figure 14. Design Cruise Vessel Position Relative to Channel Width Plan

The above minimum clearances to channel edge and the navigation simulations demonstrate that only the Plan A (500 ft) channel will offer a consistent margin of safety and operational capability for these very large cruise vessels. The presence of several of the largest cruise vessels operating from Port Canaveral increases the level of difficulty in safely executing consecutively scheduled ship transits on specific days of every week.

The desktop review suggests that the Freedom Class vessel requires more channel width than afforded by the present channel, at least 450 ft inside the jetties in the middle and inner reaches and the full width of 500 ft through the West Access Channel. At the approach turn and in adverse winds, the rate of turn for Freedom will be higher than desired to remain in navigable waters. In addition to berth improvements, at the entrance to the West Basin, the Plan A corner cut-off has been completed and allows good access for the largest cruise vessels arriving and departing the West Basin.

The 500 ft channel modeled in the recent simulations with the Freedom Class vessel confirms that a 500 ft wide channel promotes safe navigation within the Harbor and a level of comfort among the pilots for this size vessel. It is also apparent from discussions with the pilots and in the simulations that the cruise vessels tend to track on the windward side of the channel centerline to maintain good position in the channel. This serves to reduce bank clearance on the favored side of the channel, making the 500 ft wide channel significant for the safety of navigation for the very large cruise vessels that will frequent the port on the same days and with consecutively scheduled arrivals and departures. The 500 ft wide channel further assists the pilots in minimizing bank effects in the Inner Reach and West Access Channel and surge effects within Trident Basin, at south side cruise and cargo piers along the Inner Reach, particularly opposite the U.S. Navy Poseidon Wharf, and at north side cargo piers along the West Access Channel. The widening on the north side of the middle and inner reaches and south side of the west access channel in accordance with Plan A provides a straighter channel alignment than the present 400 ft or alternative 450 ft channel (Plan B) allows.

Historically, no problems with the width of the outer reach of the entrance channel have been identified. The pilots have indicated that the existing 400 ft width of the Outer Reach will be suitable for the design vessel traffic.

In recent simulations, the cruise and cargo vessels began inbound transits from the center of the outer reach in the vicinity of Buoys 7 and 8, just seaward of the start of the proposed turn widener where the existing channel is 400 ft wide. The results of the simulations do not suggest any further widening of the outer reach is required.

The project design ship drafts for navigation without tidal advantage result in new project recommended depths assuming economic viability. Therefore, the existing outer reach will support vessel transit speeds that allow good control of vessels within the bounds of the 400 ft wide channel in the design environmental conditions.

The existing approach channel width of 400 ft will be adequate for navigation considering that vessel speeds can be increased as needed on approach to or departure from the jetties. Design vessel transit speeds in each part of the channel are discussed in subsequent sections regarding project depth alternatives.

1.6.5 West and Middle Basin Turning Area Alternatives

A new turning area is proposed at the location of the corner cut-off at the entrance to the West Basin to accommodate the design cruise vessel traffic utilizing the West Basin. The existing federal 1400 ft diameter circle leaves no margin of safety in turning the Freedom Class and Disney Dream vessels in moderate to high wind conditions. The existing turning area is not considered adequate for routine use by the new larger vessels now calling Port Canaveral home.

The pilots requested a turning circle of 1,725 ft minimum diameter (Plan A) or 1.55 times the length of the Freedom and the new larger Disney ships. USACE guidelines suggest turning circle diameters of 1.2 to 1.5 times ship length depending on the use of tugs and environmental wind and current conditions. While some of the cruise ships are well powered and highly maneuverable for their size, the wind sail area on a large cruise ship is still significant and results in large applied forces in moderate to high winds often experienced at Port Canaveral. The location of the proposed turning circle is economically driven by the fact that the corner cut-off is the only unimproved shoreline to accommodate the basin expansion without expensive removal and replacement of the cruise terminal piers. The 2009 simulations considered an alternate turning area of 1,675 ft in diameter (Plan B). Both circles were located tangentially to the future berth line of the new cargo piers along the corner cut-off. As a result, the Plan B turn area would result in a slightly smaller dredge quantity. The size and location of the two circles considered and clearance to surrounding existing and future bulkheads is further justified in the interest of minimizing surge effects at NCPs 3 & 4, at future cargo berths along the corner cut-off, and at the small marina docks located along the shallow draft bulkhead wall on the south side of the channel. The 1,725 ft diameter turning area affords the greatest level of safety for the surrounding berthed vessels while providing adequate maneuvering area for the large cruise vessels frequently moving to and from the West Basin. The STAR Center observed no significant difference between maneuvering of the Freedom Class vessel in the Plan A or Plan B turn areas and as such, recommended that Plan B was acceptable. However, the project team with strong endorsement by the pilots has adopted the slightly larger 1,725-ft basin as necessary to provide a comfortable margin of safety for frequent maneuvering by very large cruise vessels in close proximity of berthed bulk and cargo vessels conducting operations along the corner cutoff and adjacent small craft marinas at this very busy vessel movement location within Canaveral Harbor.

Historically, no navigation issues have been reported with the existing turning area provided within the Middle Turning Basin. The existing turning circle diameter provided by the federal 39 ft project depth boundary is 1,200 ft. Including the CPA central portion of the basin, also currently maintained to -39 ft, an expanded turning circle of approximately 1,422 ft in diameter can be accommodated. The assumption of maintenance of the central portion of the basin currently maintained by CPA to -39 ft is recommended as the present cargo traffic fully utilizes this area in accessing NCP 1 and particularly when there is traffic at NCP2. The simulations show that the Jupiter had no difficulty turning within the turning area provided in Middle Basin. The near term tanker traffic that begins arriving at the Middle Basin berths in early 2010 will utilize the portion of the basin now maintained by CPA; thus, it is imperative that this area be authorized under the federal project as there is no means of maneuvering these AFRAMAX tankers to and from NCP1 without passing through this area.

1.6.6 Project Widener Alternative Dimensions

The USACE has constructed two wideners at the interior of the entrance channel turn. The triangular-shaped Navy widener at 44 ft project depth was constructed adjacent to the existing inside southerly channel boundaries at the intersection of the outer and middle reaches to accommodate USN Trident submarine traffic to and from Trident Basin. The civil works widener at 41 ft project depth was constructed to further expand or widen the turn to the south, largely for cruise ship traffic that began to dramatically increase in size in the late 1980's.

In previous interviews and prior to the recent simulations, the pilots provided the following rationale in support of the approach turn widening:

- For large cruise liners departing the port in moderate to severe winds from southerly through westerly directions, it is difficult to execute the turn without using a high rate of turn through the existing widener. The increased speed necessary to make the turn results in the ship experiencing up to a 20 degree/minute rate of turn and listing of the vessel with a directly negative effect on the comfort of passengers and crew carrying out shipboard functions. Some of this negative effect has been lessened as the pilots have allowed the stern of these vessels to swing outside the channel limit, where sufficient under keel clearance exists, and enables a slower speed and thus lower rate of turn. This occurs sometimes in the Outer Reach from Buoys 7/8 to the turn, where the pilots currently use, as environmental conditions dictate, the sufficiently deep water to the north side of the existing 400 ft channel width to navigate the 950 ft to 1,113 ft long cruise vessels using the Port today. This is not considered to be good practice and the current widener geometry currently does not suitably meet the needs of navigation for the long term.

- Similarly, with the inbound larger cruise vessels, it has been necessary to set-up and be strategically positioned relative to the navigational buoys to allow a reduced rate of turn while transiting through the existing turn.
- An expanded widener as the pilots envision (Plan A) will allow the future vessel traffic to be operated completely within the project limits with consistently reduced rates of turn estimated at 10 to 15 degrees per minute, even in adverse conditions, having a positive effect on vessel stability and passenger and crew comfort and safety.

Considering the Freedom Class and Disney Dream vessels, a segmented circle turn, providing symmetrical geometry on the inside of the 40-degree turn deflection angle, is recommended to eliminate the need for the unofficial use of area outside of the present 400 ft channel as described. This turn area also eliminates the need for channel widening on the north side of the middle reach and east of USACE North Jetty Sta 11+00 (roughly the west end of the new north jetty extension).

It has been determined that any channel widening/deepening to the north side of the existing channel from USACE North Jetty Sta 11+00 eastward will endanger the stability of the recently constructed north jetty extension. The proposed project does not encroach upon this envelope. Subsequent sections discuss the consideration of the north and south jetties, and the south jetty sediment trap, and their stability in relation to the proposed project. A Jetty Impacts Report was performed by hydrodynamic experts at Olsen & Associates, Jacksonville, Florida, and is included as Attachment G.

In accordance with USACE design guidance, Table 8-4, for channel deflection angles of 35 to 50 degrees, the turn radius ranges from 7 to 10 times ship length. For the Port Canaveral turn deflection angle of 40 degrees, a radius of 9 times design cruise ship length (R = 10,638 ft) has been determined to encompass the pilot requested widener area in the vicinity of the outer and middle reaches (Plan A). The Plan A widener covers roughly 22 acres. This will enable the pilots to begin the turn sooner while maintaining a safe rate of turn for inbound and outbound transits. The Plan B widener is a narrower widener that still maintains the symmetry of the westerly and southeasterly dog legs of the Plan A widener and encompasses roughly 11 acres.

The design guidance indicates that the design of tankers and bulk carriers may degrade their turn ability. Displacement vessels at Port Canaveral are tug-assisted, so their maneuvering is largely dependent on the tugs and the environmental conditions encountered. Port Canaveral's approach turn is subject to cross currents, winds and waves and has a large deflection angle of 40 degrees. The width of the proposed widener area as measured at the apex of the turn from the centerline of the channel to the inside edge of the Plan A improved turn geometry is 1,008 ft or 1.33 times the waterline length of the vessel. Consideration of a stepped depth widener as exists now, has been dismissed at the request of the pilots and their desire to maximize the safety of displacement vessel maneuvering in this area.

The STAR Center 2009 simulations report concludes that both Freedom Class and Jupiter simulations support expanding the ocean turn widener per Plan A. The cruise ship simulations for Freedom suggested inbound and outbound rates of turn and use of the Plan A and B wideners varied with the direction of applied wind and with transit speed. Transit speed generally decreased through the turn on inbound runs and increased on outbound runs. Runs with southerly winds utilized the ocean turn wideners. On Freedom inbound runs to west basin, observed rates of turn were 10 to 13 degrees per minute for Plan A and as much as 16 degrees per minute for Plan B. On outbound runs from west basin in southerly winds, observed rates of turn were roughly 12 to 15 degrees per minute with use of portions of both widener plans. In the inbound runs with southerly winds that were designed to primarily evaluate the ocean turn widener, observed rates of turn for Plan A and B were similar at 10 to 12 degrees per minute. However, the transits in the Plan A widener showed a more consistently gradual swept path of the vessel as noted by the STAR Center. The tanker Jupiter track plots also show a more controlled and slower transit through 203 civil turn widener (Plan A). Pilot comments and safety ratings during the simulations were highly favorable regarding the geometry and increased safety of the Plan A 203 civil turn widener.

1.7 Project Depth Analysis

The deep-draft displacement vessels (non-cruise) drive the project depth requirements. Present maximum panamax tanker and bulk carrier traffic visiting Port Canaveral is limited to a draft of 39.5 ft and existing federal project depths require the pilots to rely on tidal advantage when drafts exceed 36 ft.

Future displacement vessel traffic will be of similar to slightly larger size, having increased draft as channels, turning basins, and berths will permit. The new project features should permit all vessels with draft of up to 39.5 ft to transit without tidal restriction. Maintenance of cruise ship schedules to and from multiple berths along the channel and within the West Basin on twice daily channel transits severely restricts the opportunities for non-cruise displacement vessel traffic to use tide advantage without incurring significant delay upon arrival and departure.

1.7.1 Analysis Assumptions and Considerations

- Uniform density across the Port equal to that of seawater and therefore, no depth correction for salinity effects is used. This is considered reasonable as the Canaveral Lock design and operation essentially prevents flow between the river and the WTB, so salinity differences in the Port may only randomly occur and would likely be the result of stormwater runoff and circulation patterns in the Port.
- To avoid any limitations on navigation for the deep-draft displacement vessels, all ships should be able to transit the channel at Mean Lower Low Water (MLLW) datum. This will always be the case for cruise ships with static drafts of no more than about 30 ft. However, transiting on rising or high tide may still allow displacement vessels with draft of more than 39.5 ft to access the port where berth water depth permits.
- Vessel loading effects are negligible and vessels transit with even trim and without list.
- Wave effects inside the Port are negligible.

- Vessel vertical motion response due to heave and pitch due to wind-driven waves outside of the jetties has been conservatively estimated at 0.5 times the 3-hr duration wave height. The vessel lengths are an order of magnitude larger than the wave length for each wind condition and the wave periods are quite short, so the vertical response estimated is reasonably conservative. No consideration is given to roll as the planned turn widener permits a low rate of turn for the displacement vessels such that roll effects on vertical motion are anticipated to be insignificant.

Table 22. Vessel Wave Motion Response

Design Displacement Vessel	Design Cruise Vessel
20-knot Wind-driven Wave	30-knot Wind-driven Wave
Vertical Wave Response = 1.4’	Vertical Wave Response = 2.75’

- General parameters for design vessel squat have been estimated based on existing channel cross-sections and vessel transit speed through each portion of the channel as defined by pilots and/or documented in STAR Center simulations. Speeds are necessarily faster in the outer reach and slowest at either Middle or West Basin. These vessel sinkage depths are based on Barass Squat empirical formulas for unconfined and confined channels as applicable to the various portions of Canaveral Harbor channel reaches and compare reasonably well with STAR Center estimates of squat for the simulation test vessel, Jupiter.

  Briefly, from the outer reach to the inner reach (inbound), design displacement vessel transit speeds decrease from 10 to 5 knots with corresponding squat ranging from 2.7 to 1.3 ft. Similarly, design cruise vessel transit speeds decrease from 12.5 to 5 knots with predicted squat ranging from 3.1 to 0.9 ft.

- The channel bottom inside the port generally consists of softer silt and clay soils. No unusual hard material or rock was encountered in subsurface investigations, so no additional depth allowance for soils is required as may be required in ports with hard, rock or calcified bottoms.

- For more than ten years, the Canaveral Pilots have conducted vessel movements observing the established minimum under keel clearance requirement of 2.5 ft for all ships underway, in all channel reaches and basins, and for all stages of the tide (MLLW to MHHW). This is similar to the USACE design guidance that suggests a safety clearance of at least 2 ft between the bottom of the ship and the design channel bottom. The pilots require at least 6 inches of clearance under the keel at berth for all tides and stages of unloading or loading operations.

1.7.2 Project Depth Analysis Results

The following table presents the required project depths for the design displacement vessel considering only deepening of the existing channel cross sections. Attachment D contains project depth calculations for the design displacement vessel providing the total required water depth by channel reach or cut as summarized below. The project depth calculations consider design vessel draft, wave motion, squat, and safety clearance. Proposed project depths for the displacement vessel are more than adequate for the design cruise vessel. The depth calculations for the design displacement vessel inbound at 39.5 ft draft and without the use of tidal advantage, indicate deepening is required from the outer reach through the West Access Channel to NCPs 3 and 4. The STAR Center report confirms these findings, but does not address wave motions outside the jetties.

Table 23. Project Depths—Displacement Vessel

Parameter	WAC	MTB	INNER CHANNEL		ENTRANCE CHANNEL		APPROACH CHANNEL		
			INNER REACH		MIDDLE REACH		OUTER REACH		
	NCP 4	NOTU/SCP2	Cut 2 (CT3)	Cut 2 (TTB)	Cut 2 (S. Jetty)	Cut 2 (N. Jetty)	Cut 1	Cut 1 (B7/8)	
	Sta 255+00	Sta 215+00	Sta 200+00	Sta 185+00	Sta 165+00	Sta 150+00	Sta 85+00	Sta 55+00	Cut 1A/1B
Vessel Speed (knots)	4.5	5	6	7	7	8	8.5	9	10
Draft (ft)	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5	39.5
Salinity & Temp Corr (ft)	--	--	--	--	--	--	--	--	--
Wave Motions (ft)	--	--	--	--	1.4	1.4	1.4	1.4	1.4
Squat (ft)	0.9	1.1	1.6	2.0	1.8	2.3	2.0	2.2	2.8
Safety Clearance (ft)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Total Required Water Depth (ft)	42.9	43.1	43.6	44.0	45.2	45.7	45.4	45.6	46.2
Existing Authorized Depth (ft)	39	39	40	40	44	44	44	44	44
Proposed Project Depth (ft, MLLW)	43	43	44	44	46	46	46	46	46

1.8 Canaveral Harbor Recommended Plan Project Features

1.8.1 Table Summary of Recommended Plan Project Features

The following table summarizes the Canaveral Harbor proposed federal authorized dimensions of the recommended plan with widening per the cruise design vessel requirements and deepening to maximum required project depths based on the design displacement ship selection. The recommended plan considers an overdepth allowance of 1 ft below the project depths for the inner reach and westward navigation areas inside the harbor and 2 ft below the project depths for the middle and outer reaches and turn widener areas.

Table 24. Port Canaveral Recommended Plan Project Features (Plan A)

Project Feature	Cut and Centerline Station Start / End (ft)	Proposed Federal Dimensions Depth X Width X Length (ft)
Outer Reach	Cut 1A, 0+00 to 110+00 Cut 1B 0+00 to 55+00 Cut 1, 0+00 to 125+00	46 X 400 X 29,000 (CW) 44 X 400 X 29,000 (USN)
44-ft Turn Widener		46 X 400 X 29,000 (CW) 44 X Irregular Shape (USN)
41-ft Turn Widener		46 X Irregular Shape (CW)
203 Turn Widener		46 X Irregular Shape (CW)
Middle Reach	Cut 2, 125+00 to 181+70	46 X 400 X 5,670 (CW) 44 X 400 X 5,670 (USN)
Trident Access Channel	T.A.C., 5+00 to 32+33.60	44 X Width Varies X 2,733.6 (USN)
Trident Turning Basin	T.T.B., 0+00 to 15+00	41 X 1,200 X 1,500 (USN)
Inner Reach	Cut2, 181+70 to 207+00 Cut 3, 207+00 to 215+00	44 X 400 X 3,330
Middle Turning Basin	M.T.B., 215+00 to 241+70	43 X 2,670 X Irregular Shape w/ 1,422-ft DIA
West Access Channel (East of Sta 260+00)	W.A.C., 241+60 to 260+00 Cut A, 0+00 to 18+40	43 X 400 X 1,840
West Access Channel (West of Sta 260+00)	W.A.C., 260+00 to 277+30 Cut A, 18+40 to 36+70	31 X 400 X 1,730, CPA to 35’
West Turning Basin		31 X Irregular Shape w/ 1,725-ft DIA, CPA to 35’
Canaveral Barge Canal	Cut 1 to Canaveral Lock 241+60 to 260+00 260+00 to 272+43 272+43 to 300+25 300+25 to 327+70	43/12 X 87.5/37.5 X 1,840 35/12 X 87.5/37.5 X 1,243 35 X 125 X 2,782 12 X 125 X 2,745

1.8.2 Recommended Project Features Narrative Description

The recommended plan changes the Canaveral Harbor existing federal project features through widening, deepening, realignment of the centerline of the interior channels and Middle Reach, relocation of the inbound range structures, and construction of new outbound range structures. The outer reach portion of the entrance channel is oriented on a roughly northwest-southeast alignment. Except for the Trident Access Channel, all other harbor channels are oriented on a generally east-west alignment.

The following narrative describes the Canaveral Harbor recommended plan project features (Plan A) relative to existing conditions and progressing from the Atlantic Ocean entrance channel to the West Basin. Attachment E contains a set of drawings and color pictorial that describes the Recommended Plan project. The drawings identify the project features and show dimensions, stationing, typical feature sections, dredge areas, and dredge volumes.

- Outer Reach, Cut 1A: Existing civil works dimensions are 41 ft project depth by 400 ft wide by 11,000 ft long. New dimensions would increase the project depth to 46 ft. Recent USACE quarterly condition surveys indicate that the existing water depth at the seaward end of the project and up to 200 ft beyond the end of the project is at least 47 ft.
- Outer Reach, Cut1B: Existing civil works dimensions are 41 ft project depth by 400 ft wide by 5,500 ft long. New dimensions would increase the project depth to 46 ft.
- Outer Reach, Cut 1: Existing civil works dimensions are 41 ft project depth by 400 ft wide by 12,500 ft long. New dimensions would increase the project depth to 46 ft.
- US NAVY Turn Widener: Existing civil works dimensions are 41 ft project depth by 7.7 acres (triangular shaped area) bounded by outer and middle reaches to the north and northeast and the civil turn widener to the southwest. New dimensions would increase the project depth to 46 ft.
- Civil Turn Widener: Existing dimensions are 41 ft project depth by 15.6 acres (irregular shaped area) bounded to the north and northeast by the middle reach and the US Navy turn widener. New dimensions would increase the project depth to 46 ft.
- 203 Civil Turn Widener: New dimensions are 46 ft project depth by 22.2 acres (irregular shaped area) bounded to the north and northeast by the existing civil turn widener and Cut 1 of the outer reach.

The proposed interior channel widening at key locations has been defined relative to a new channel centerline. The new channel centerline consists of three segments and two alignments as defined for the Middle Reach, Inner Reach, Middle Turning Basin, West Access Channel, and Cut A. The new alignment through the middle and inner reaches into the middle basin removes the navigation awkwardness of the short alignment transition of the inner reach, Cut 2. The new alignment also provides direct transit between Middle Basin and the West Access Channel, eliminating the discontinuous centerline transition that now exists at the beginning of the West Access Channel. The first alignment has two segments and extends from Middle Reach, Cut 2, Station 124+77 / Range +215 to Station 180+00 / Range +150 to Middle Turning Basin, Station 224+65 / Range +100 (azimuth 89° 39’ 46.5224”). The second alignment with one segment extends from Middle Turning Basin, Station 224+65 / Range +100 to West Access Channel, Cut A, Station 266+96 / Range +100 (azimuth 90° 18’ 16.9613”).

The widening along the north side of the channel in the area from Middle Basin eastward to Trident Basin and along the south side of the West Access Channel and Cut A varies slightly in width between key stations. The southern channel boundary of the Middle Reach, the Inner Reach, and the Middle Turning Basin and the northern boundary of the Middle Reach outside the jetties remains unchanged from the existing authorized project.

- Middle Reach: The middle reach extends from the apex of the channel turn westward to the western boundary of the Trident access channel. Existing civil works dimensions are 41 ft project depth by 400 ft wide by 5,670 ft long. New dimensions would increase the project depth to 46 ft and the project width from 400 ft to 500 ft, providing a 100 ft widener of 2,123 ft in length, parallel to and along the north side of the existing channel for the portion of the middle reach that is inside of the north jetty to Station 180+00. The eastern terminus of the 100 ft widener transitions from the existing to the new northern channel boundary over a plan distance of 500 ft. This portion of the project requires that the western "Surge Warning" notification sign structure be relocated 100 ft north of its present location. For the remainder of the Middle Reach, west of Station 180+00, the new northern channel boundary is parallel to the new channel centerline and the width of widening is 100 ft.
- Trident Access Channel and Trident Basin: With exclusive use by US Navy, the Trident Access Channel connects the middle reach to the trident basin. Existing dimensions are 44 and 41 ft project depth for the access channel and the basin, respectively. The new 100 ft north side channel widening at 46-ft project depth incorporates a portion of the entrance to the Trident Access Channel.
- Inner Reach, Cut 2 and Cut 3: Existing dimensions are 40 ft project depth by 400 ft wide by 3,330 ft long. New dimensions increase the project depth to 44 ft and the project width from 400 to 500 to 525 ft. The width of the north side widening ranges from 100 ft to 125 ft to 87 ft at the east and west ends of Cut 2 and the west end of Cut 3, respectively. The new northern channel boundary provides a constant 250 ft width north of the new Inner Reach channel centerline. The rip-rap protected shoreline and berm between the Middle and Trident Basins will be relocated northward to accommodate the widening.
- Middle Turning Basin: The Middle Turning Basin has shared use by commercial and military activities. The federal project area encompasses 92.4 acres with project depths of 35 ft in the north and east portions of the basin used exclusively by the military and 39 ft in the remainder of the basin supporting commercial vessel traffic. Because of the somewhat limited room afforded by the present 39 ft federal project boundaries toward the northwest portion of the basin, CPA maintains an irregular shaped central portion of the basin to 39 ft. This provides additional area for maneuvering cargo vessels to and from the North Cargo Pier 1 and ro-ro ramp and enlarges the available area for turning displacement vessels on arrival or departure. The existing 39 ft federal project provides a turning circle diameter of 1,200 ft. The new project dimensions for commercial purposes encompass 68.9 acres with a project depth of 43 ft yielding a turning circle diameter of 1,422 ft. Approximately 1.9 acres of the new 43 ft project area completes the western end of the north side channel widening in the area between the inner reach and the US Navy's Poseidon Wharf. The north side widening through this area ranges from 64 ft to 87 ft. As in the inner reach, the rip-rap protected north side shoreline will be relocated northward to accommodate the north side channel widening. The US Navy's mooring dolphin, located east of Poseidon Wharf, sits within 25 ft of the new channel boundary and will be removed to eliminate a potential hazard to navigation and a new monopile mooring dolphin will be constructed adjacent to the

existing boat ramp. The widening also impacts the AF property such that a new bulkhead retaining wall is required to provide the minimum 86 foot shoreline setback required by USAF regulations to the existing Bldg 1064. This bulkhead wall will also be configured to stabilize the existing boat ramp used by military security patrol boats. The USN submarine sail on display will also be relocated north. Work performed near under-channel communications lines, and related communications manholes will require careful coordination with the 45th Space Wing and AT&T to avoid service interruptions. This channel widening project will bear the cost to mitigate, replace, or relocate any impacted federal structure, utilities, or communications infrastructure.

- West Access Channel (east of Station 260+00): Existing dimensions are 39 ft project depth by 400 ft wide by 1,840 ft long. New dimensions would increase the project depth to 43 ft and increase the project width from 400 to 500 ft, providing 100 ft of widening along the entire length of the channel by redefining the northern channel boundary 12.5 ft north of the existing northern boundary, and widening the channel by 87.5 ft along the south side, incorporating a portion of the barge canal.
- West Turning Basin and West Access Channel, Cut A (west of Station 260+00): The West Turning Basin has exclusive use by commercial activities and the Coast Guard. The existing federal basin and Cut A of the West Access Channel make up 78.6 acres with a project depth of 31 ft as federally maintained and 35 ft as maintained by the CPA.

The existing federal project basin provides a turning circle diameter of 1,400 ft. The recommended plan, comprising 103 acres, expands the federal project limits to support cruise ship access to existing terminals and enlarges the entrance to the west basin providing a new turning circle diameter of 1,725 ft. The turning circle and entrance widening will be created by dredging beyond the present federal and CPA project boundaries to the northeast and to the south for the full width of the barge canal. Approximately 18.5 acres of existing bank, shoreline, and uplands adjacent to the CPA 35 ft project boundary, known as the corner cutoff, has been dredged to 35 ft as of September 2011. Roughly 6.9 acres within the existing barge canal will be dredged to the new project depth of 35 ft.

1.9 Canaveral Harbor Vessel-Induced Surge Modeling

1.9.1 Background

An analysis of vessel-induced surge was commissioned in 2011 in support of the Port Canaveral Harbor, Florida Integrated Section 203 Report sponsored by the Canaveral Port Authority (CPA). The Naval Ordnance Test Unit (NOTU), a United States Air Force 45th Space Wing (USAF 45 SW) tenant on the Cape Canaveral Air Force Station (CCAFS) and the USAF 45 SW requested the study to demonstrate that the recommended project and the present and foreseeable future ship traffic will not adversely impact current or future NOTU and CCAFS port operations within the Trident and Middle Basins. NOTU accommodates various classes of US and UK Navy submarines at Trident wharf located on the eastern side of the Trident Basin. NOTU and the Military Sealift Command (MSC) accommodate various military ships at Poseidon wharf located on the southeastern side of Middle Basin. The Mariner pier and the AF wharf are located at the north end of Middle Basin. The Mariner Pier supports the United Launch Alliance Evolved Expendable Launch Vehicle (EELV) Atlas and Delta launch programs at CCAFS and the occasional accommodation of MSC vessels and Kennedy Space Center program support vessels. The AF wharf is used for a variety of small scale ship and barge operations.

NOTU has experienced surge effects on vessels moored at both the Poseidon and Trident wharves when outbound cruise ships, departing from West Basin, are required to increase transit speed under the occasional occurrence of high quartering or cross-wind conditions. Under the existing navigation project conditions, operational mitigation measures have been employed for several years to manage the surge effects. Those measures include increased coordination and notification of conditions between the Canaveral Harbor Pilots and NOTU Port Operations, diligent tending of moored vessel lines in preparation for transit, and use of tugs to restrain vessel movements at the wharves. USAF 45 SW and NOTU expressed the need for a surge study to demonstrate that the recommended navigation channel widening and deepening plan will result in no additional impact on current and future port operations. This request was documented in a 4-13-11 email by Executive Officer CDR Michael LaPrade and a 4-14-11 email by USAF 45 SW Plans and Program Director Patrick Blucker, following a 4-13-11 briefing at Canaveral Port Authority. This request was reiterated at the 4-15-11 Alternate Formulations Briefing (AFB) at Canaveral Port Authority by both organizations, as well as the United States Coast Guard. Associated with the channel widening and deepening project, the CCAFS and NOTU have collectively identified the following facilities and operations of concern with regard to adverse impacts:

- Trident Basin, Trident Wharf
- Middle Basin, Poseidon Wharf
- Middle Basin, Delta Mariner Berth
- Middle Basin, AF Wharf
- Adjacent to Inner Reach, Poseidon Wharf Mooring Dolphin
- Adjacent to Inner Reach, Boat Ramp
- Adjacent to Inner Reach, Submarine Sail Monument
- Adjacent to Inner Reach, Bldg. 1064

1.9.2 Surge Effects and Modeling

Large cruise ships transiting the Canaveral Harbor main channel cause motions and forces on moored vessels at berths along the main channel or at berths within the east and middle basins. Transiting vessels pass moored vessels in the main channel in a parallel configuration and in the basins in perpendicular or oblique orientation. These motions and forces are typically referred to as surge or passing effects. Over the last decade and on a very limited number of occasions, passing effects have caused mooring lines to part or failed facility fixtures, damaged shoreside connections and personnel gangways, and injured shipboard personnel.

Passing effects are more problematic in complex or confined waterway configurations such as Canaveral Harbor and its east-west main channel, which is constrained by the Canaveral Locks system and three dead-end basins oriented in the north-south direction and positioned north of the main channel. Recent modeling and research suggests that in addition to the passing ship-moored ship interaction due to the flow effects surrounding a transiting vessel, the free surface effects associated with long period (low-frequency) waves that may be generated even by slow moving ships in channels and harbors with restricted water depths, sloping banks, and bulkheads, can significantly contribute to moored vessel motions and forces.

Physical and numerical modeling on this subject for both open water and more confined boundary conditions has been advanced in this decade. In 2005 and 2007, the Ocean Engineering Program within the U.S. Naval Academy and under the direction of David Kreibel has accomplished a series of parallel and perpendicular passing model test cases in open water conditions, where the free surface effects would not be present. Since 2004, J. A. Pinkster of the Department of Marine and Transport Technology, Delft University of Technology in the Netherlands has developed and enhanced numerical modeling of both the primary flow potential method for ships moored in open water conditions and most recently a model based on potential flow but to also include the free surface effects where harbor boundary conditions create discontinuities in the flow field. Most recently, Coast & Harbor Engineering developed numerical modeling tools for vessel hydrodynamics and loading on berthed vessels that address the complete range of vessel-generated hydrodynamic (surge) effects. These proprietary numerical models with various levels of validation represent the state of the art for passing ship-moored ship analysis. The Navy's model test data and empirical force formulations that are in the public domain provide a means of estimating the passing ship effects on moored ships as limited to open water conditions, which does not represent the situation at Port Canaveral.

The free surface effects, which are long period water level fluctuations, arise from the excitation and interaction of the water motions associated with the flow field moving with the passing ship by the surrounding harbor geometry. Port Canaveral's constrained geometry, the size of the largest cruise ships operating within Port Canaveral's constrained geometry, and the speed cruise ships need to maintain during channel transits all work to increase the magnitude and severity of dynamic motions and forces that may be experienced by moored ships in basins adjacent to channels.

With the start of Seaport Canaveral's tanker operations in Port Canaveral's Middle Basin at north cargo piers 1 & 2, there is a growing awareness of and intolerance to injury, disruption of operations, and environmental impacts that accidental disconnections could generate as a result of certain passing ship conditions. It is anticipated that the increase in large cruise ship passing traffic events will increase the incidence of passing effects on moored tankers with potentially detrimental consequences. In fact, a moored vessel at NCP 2 recently experienced surge effects that parted lines as a result of consecutive outbound cruise ship traffic. The surge effects were experienced some 13 minutes following the passing departure of the Freedom of the Seas.

Coast & Harbor Engineering performed the numerical modeling using their proprietary Vessel Hydrodynamics Longwave Unsteady (VH-LU) tool in accordance with a rigorous modeling plan coordinated and endorsed by the Mission Partners to evaluate passing ship effects for several combinations of berthed vessel scenarios at commercial and military berths. Modeling of the passing ship effects was conducted for port existing conditions and for the recommended plan navigation improvement features that include channel widening and deepening. The berthed vessels included detailed three-dimensional hull definitions for commercial and military surface ships and submarines. The passing vessel scenarios included the consecutive outbound transit of the Carnival Fantasy, the Freedom of the Seas, and the Disney Dream in a timed sequence, from the West Basin, a typical Saturday late afternoon departure scenario. The passing vessel conditions considered prescribed track, speed, and leeway carried relative to the existing conditions and recommended plan channel centerlines as fully coordinated with the Canaveral Pilots.

1.9.3 Hydrodynamic Surge Modeling Presentation and Results

The dynamic surge effects within the harbor, at key locations and berths, and passing ship forces for select berthed vessel scenarios were demonstrated in a presentation at the CPA on September 20, 2011, and delivered to the CPA, the Mission Partners, the Canaveral Pilots, the U.S. Coast

Guard, and the Canaveral Harbor Section 203 Project Team. The presentation compared the modeled impacts under “without-project” and “with-project” channel dimensions.

Key findings shared during the presentation include:

- The numerical modeling reproduced the primary surge effects as observed by the Canaveral Pilots and associated with the present channel (existing conditions) as follows:
    - Significant and consistent surge effects at SCP4 due to the limited separation between the passing and berthed vessel (parallel passing case);
    - Surge effects at Trident Wharf for passing speeds of 7.5 knots or greater—very large distance between the passing and berthed vessel (perpendicular passing case);
    - Delayed surge effects at NCP2 occurring some 10 to 15 minutes following the departure of one or more cruise ships; and
    - Water level retreat and wave breaking at the north jetty area just east of the Trident Access Channel.
- General effects of harbor widening and deepening as compared to the existing conditions show:
    - an overall reduction in peak water surface elevations throughout the harbor;
    - an overall improvement in moored vessel conditions throughout the harbor;
    - the passing vessel loading on berthed vessels at most terminals are reduced anywhere from a negligible amount to roughly 35 percent;
    - the passing vessel loading on berthed vessels at some terminals do not change significantly owing to the passing vessel route through the harbor as defined relative to the existing or recommended project channel centerlines;
    - except for the large, deep-draft USS America and the USNS Bob Hope, the peak passing surge and sway loads on the surface ships and submarines at Mission Partner berths are 20,000 lbf or less;
    - reductions in the peak passing vessel loads are generally predicted for ships at commercial berths; however, the predicted loads in some cases will contribute substantially to overall mooring loads and should be considered for the present and future operations at those terminals
    - reduction in maximum peak to trough surge height; and
    - a slight modification in the timing of surge waves and forces; and
    - a general reduction in the forces and moments on the berthed vessels ranging from slight to fairly significant.

Attachment F contains the vessel-induced surge modeling report.

1.10 Aids to Navigation

Port Canaveral currently has U.S. Coast Guard navigational range structures for inbound traffic centered on the present 400 ft wide entrance channel middle and inner reaches. Of the two structures, the entrance channel range front light is located in the water just east of the SR401 bridge and the entrance channel range rear light is positioned in the uplands on USACE property west of the bridge. For approximately 10 years the Canaveral Pilots Association has requested that the Coast Guard provide an outbound range for the existing channel.

The local pilots consider the inbound and outbound range structures as key navigation aids. The inbound aids will be relocated or replaced north and east of their existing locations to align with the new middle and inner reach centerline. Similarly, with expansion of the channel and handling of the largest cruise vessels afloat—the pilots and the STAR Center strongly urge that outbound range structures be installed to align with the new channel centerline in the Atlantic Ocean waters east of the turn widener area. The pilots conducted the recent simulations with inbound and outbound range structures featured in the visual geographical database. The outbound range structures were found to be extremely useful and enhanced safety as confirmed by the 2007 and 2009 simulations.

The authorization, funding, design and construction of aids to navigation such as the channel ranges and buoys are under the jurisdiction of the US Coast Guard. This navigation improvement project has been identified to the US Coast Guard, 7th District Aids to Navigation Office in Miami, Florida, to prepare a formal cost estimate of construction for new outbound ranges and relocation of the existing inbound ranges as dictated by the channel realignment due to widening. Documentation of coordination of the range navigation aids between the USCG and the Canaveral Port Authority and its consultants is included as Attachment N. The Canaveral Pilots confirm that the Recommended Plan project may be appropriately marked by relocating the existing floating aids to navigation such that no new floating aids will be required.

2.0 Hydrology and Hydraulics

Canaveral Harbor hydraulic modeling calibration data were collected based on two tide gages and a current meter deployed from August to September 2005 at strategic locations within the port. The data collection program, numerical modeling methods, discussion and results of the calibration and verification of the hydrodynamic model for the existing conditions, and discussion and results of the recommended plan hydrodynamic modeling are presented in Attachment F.

3.0 Coastal Studies

Coastal studies have been limited to analysis of entrance jetty and south jetty sediment trap impacts. As this project is simply an expansion of existing channels and turn areas and as evidenced in the hydraulic modeling of the recommended plan as compared with the existing conditions, no discernible impact is anticipated to adjacent shorelines to the north and south of the inlet.

3.1 Entrance Jetty and South Jetty Sediment Trap Impacts

Proposed channel widening and turn expansion were investigated for impacts to the north and south jetties and the South Jetty Sediment Trap. A Jetty Impacts Report was performed by hydrodynamic experts at Olsen & Associates, Jacksonville, Florida, and is included as Attachment G.

The proposed South Channel Widener does not pose significant risk for increasing adverse impacts to the south jetty structure. This topic was re-visited by the hydrodynamics consultant for CPA in December 2007. The proposed widener and existing sediment trap were altered in area (the sediment trap proposed wider as well) to effect a greater buffer. The reduction in capacity due to the South Channel Widener to the South Jetty Sediment Trap can be recaptured by deepening and expanding the trap as advised by the consultant in their report.

The proposed North Channel Widener does not pose significant potential for adverse impacts to the north jetty following channel and side-bank equilibration. The eastern limit of the improvement was set at USACE North Jetty Station 11+00 to establish a minimal seabed buffer between the channel and the north jetty. Any widener that extends further east of this limit has some likelihood of undermining the north jetty.

Two surge warning signs for local mariners and fishermen are presently located just west of the north jetty. The eastern sign is not affected by the north side channel widening and will remain at its present location. The western sign will be removed and a new sign constructed 100 ft north of the existing western sign position as part of this project.

3.2 Sea Level Change Projections

The USACE requires that potential relative sea-level change be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence. Guidance for incorporating the direct and indirect physical effects of projected future sea-level change in USACE projects is provided in the Engineering Circular EC 1165-2-211 titled *Water Resource Policies and Authorities Incorporating Sea-Level Change Considerations in Civil Works Programs* (USACE 2009). EC 1165-2-211 has an expiration date of July 1, 2011 and is slated to be updated and replaced by a new guidance document, EC 1165-2-212. However, at this point, EC 1165-2-212 has not been formally issued and is still under review. Therefore, EC 1165-2-211 is considered to be the current guidance document for the Port Canaveral widening and deepening project.

The Corps guidance states that consideration should be given to how sensitive and adaptable proposed alternatives are to climate change and other related global changes. Because of the variability and uncertainty in projected future sea-levels, alternatives should be evaluated using low, intermediate, and high rates of future sea-level change for both “with” and “without” project conditions in order to bound the likely future conditions.

The estimated potential sea-level change at Port Canaveral over the period 2014 to 2064 based on guidelines presented in EC 1165-2-211 is presented below.

Low estimates of rate of sea-level change are based on extrapolation of historic rates of sea-level change. Intermediate and high rates include potential future acceleration of sea-level rise based on scenarios represented by modified NRC Curves I and III, respectively, from updates to NRC (1987).

Mean sea-level trends are available for a number of tidal stations along the Florida Atlantic coast from NOAA. The standard error for the calculated trends is related to the period of record for the individual stations. The uncertainty can become large compared to the calculated trend values for smaller periods of record and, therefore, EC 1165-2-211 indicates that the stations used for calculating sea-level trends should have a minimum duration of 40 years of data.

Table 25 presents sea-level trends for the three stations along the Florida Atlantic coast both north and south of Port Canaveral obtained from the NOAA website (http://tidesandcurrents.noaa.gov/sltrends/).

The nearest station, Daytona Beach Shores, contains a record that spans 48 years, but with significant gaps (on the order of 20 years of missing data) and therefore, has more uncertainty than the other two stations. For comparison, the next closest station, Mayport, located approximately 145 miles north of the Port has a continuous 78 year record. Miami Beach, located approximately 185 miles south of the Port has a 50 year record with a single gap in the record of about 5 years. EC 1165-2-211 directs to consider the next closest gauge if the period of record of the closest gauge is not greater than 40 years. The sea-level trend of +2.4 mm/year calculated for the Mayport station was used for this analysis to represent the regional sea-level change due to the period of record of the station and apparent relative uniformity of the trends between the three stations.

Table 25. Sea-Level Trends for Gauges along the Atlantic Coast of Florida

Station	Distance from Port	Period of Record	Trend	95% Confidence Limit
Mayport, FL	145 mi north	1928 to 2006	2.40 mm/yr	+/- 0.31 mm/yr
Daytona Beach Shores, FL	60 mi north	1925 to 1983	2.32 mm/yr	+/- 0.63 mm/yr
Miami Beach, FL	185 mi south	1931 to 1981	2.39 mm/yr	+/-0.43 mm/yr

Figure 15 shows results of low, intermediate, and high relative sea-level projections based on methods from EC 1165-2-211. Table 26 presents the results of calculations from the project completion in 2014 through 2064 in five year increments. These show sea-level change estimates over a 50-year life of the project ranging from 0.120 meters (0.39 ft) for the low rate of change scenario, to 0.245 m (0.80 ft) for the intermediate rate scenario, and 0.653 m (2.14 ft) for the high rate scenario.

3.2.1 Impacts

Sea-level rise at the rates presented in Table 26 below will have little or no impacts related to the proposed navigation improvements.

With respect to the channel deepening, an increase in sea-level can result in greater water depths within the Port. However the channel depth is set relative to Mean Lower Low Water (MLLW), so as sea-level rises and the MLLW datum is adjusted upward in response, the dredged water depth relative to the new datum will not change.

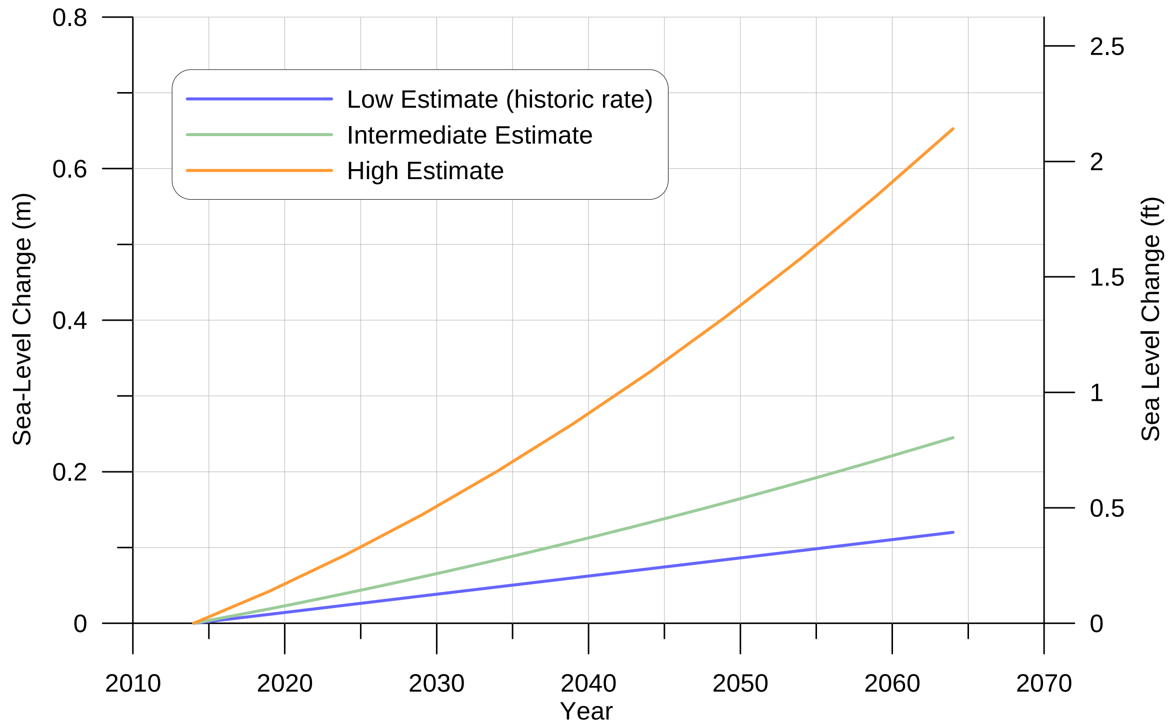

Figure 15. Regional Sea-Level Change Estimates

Table 26. Projected Regional Sea-Level Change from 2014 through 2064.

Year	Projected Sea-Level Change (m)		
	Low (Historic rate)	Intermediate (NRC Curve I)	High (Curve III)
2014	0	0	0
2019	0.012	0.019	0.043
2024	0.024	0.040	0.090
2029	0.036	0.061	0.143
2034	0.048	0.084	0.201
2039	0.060	0.108	0.264
2044	0.072	0.133	0.331
2049	0.084	0.159	0.404
2054	0.096	0.187	0.482
2059	0.108	0.215	0.565
2064	0.120	0.245	0.653

The same can be said about the navigation improvements outside the mouth of the Port. As part of the recommended plan, the new turn widener will be constructed, and cut through the footprint of the existing sediment trap. To maintain the sediment trap's design capacity, it is proposed that the trap be deepened, consistent with the new channel depth, and slightly expanded to the south as described in Attachment J of the Engineering Appendix. Sea level rise should have no impact related to these improvements. Depths of the sediment trap and the widener are both set relative to MLLW and though sea level may rise, maintenance dredging of these features will maintain similar depths relative to the future sea level. The duration between maintenance dredging cycles would be extended reducing long-term O&M costs.

Inside the Port, the project also includes a corner cut-off (CCO) at the entrance to the West Turning Basin (WTB). A portion of the cut bank will be protected by a bulkhead with concrete rubble extending from the top of the bulkhead at 0 ft Mean Low Water (MLW) to +8 feet MLW. These shore protection measures are temporary until the construction of deep sheetpile wall berths along the CCO. The new berths are not part of this project and the temporary measures will be replaced long before sea level rise is projected to become significant.

4.0 Surveying and Mapping

Existing USACE Jacksonville District hydrographic condition survey data along with other project area specific surveys commissioned by CPA or performed by Morgan & Eklund were compiled to create a three-dimensional model of Canaveral Harbor and the navigation areas outside of the jetties. Attachment H presents the project survey with sources of data, cross-sections, and volume cut/fill quantities for incremental depths that were used in the economic analysis and construction cost estimate for project feasibility.

At the seaward end of the outer reach, marking the seaward end of the project, USACE Quarterly Condition Survey 07-050 and most recent survey 11-088, Sheet 02, for Canaveral Harbor indicates bottom depths to be at least -47 ft MLLW. Therefore, present water depths, as shown in Figure 16 suggest that no extension of the length of the outer reach is required to achieve the project depth of 46 feet at this location.

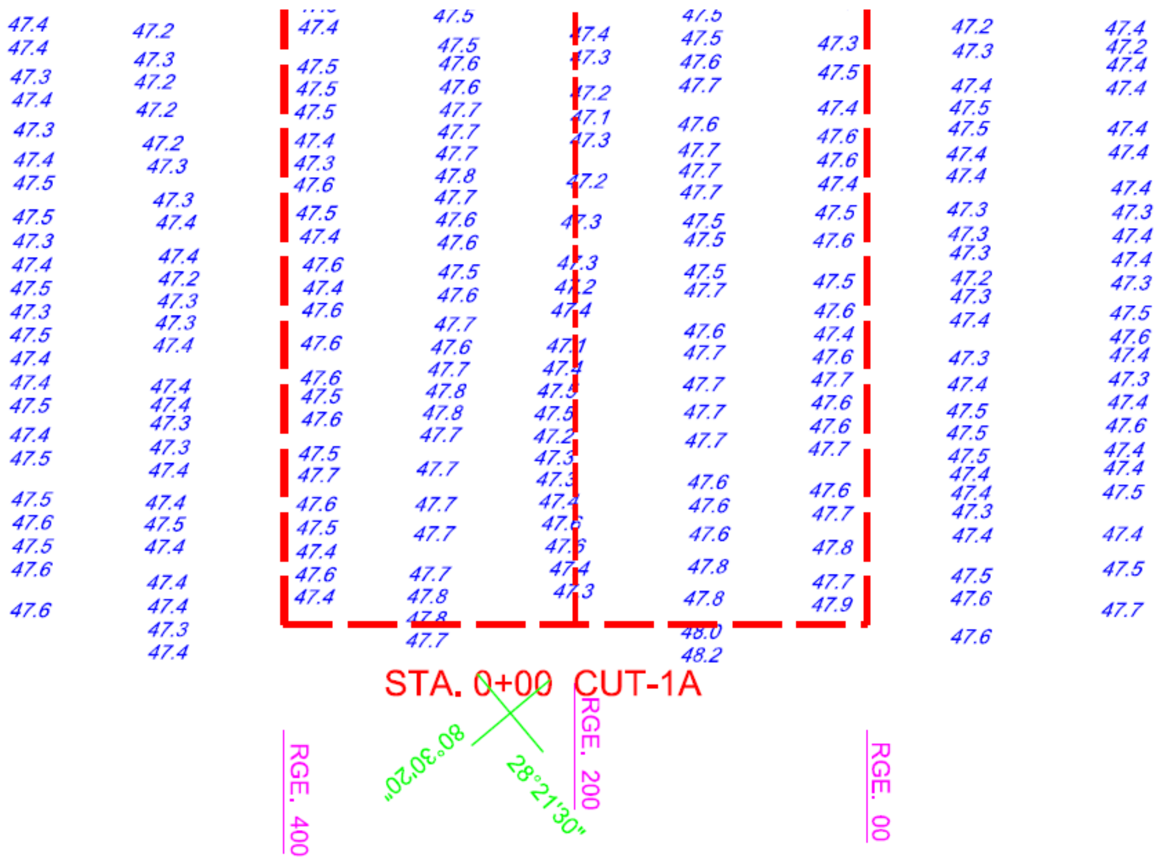

Figure 16. Seaward End of Canaveral Harbor Approach Channel

5.0 Geotechnical Evaluations

Geotechnical information has been collected, reviewed, and summarized from previous studies within the vicinity of the project area. A land side and marine side field exploration program has been conducted at eight locations where available geotechnical information was limited. The following geotechnical engineering tasks have been performed in support of the Section 203 feasibility study including characterization of site geology within the project area, soil classification and laboratory testing of samples from new borings, selection of design soil parameters, and limited engineering analyses to evaluate the stability of submerged slopes, the relocated north side berm along the inner reach, the West Basin corner cut-off, and existing structural bulkheads within the harbor. Existing submerged slopes vary slightly, but are approximately 1V:3H. Therefore, any proposed project slopes are at maximum steepness of 1V:3H.

Previous dredging projects in Port Canaveral have not had been documented to cause groundwater impacts. The Florida aquifer in this area is mineralized and it is subject to artesian pressure (vertical flow upward). In addition, the confining unit at Port Canaveral is approximately 40 feet thick and is located between elevation -85 feet (MSL) and -125 feet (MSL), well below the project dredging depths.

Attachment I contains the full geotechnical evaluation and analyses. Further structural assessment of existing bulkheads considering various project depth increments is found in the following section.

6.0 Civil/Structural Design

The engineering requirements relative to civil design of the navigation project include:

- impacts to vehicle traffic within the port;
- water quality in terms of storm water runoff and retention;
- impacts of the project with regard to existing utilities crossing the channel and those uplands utilities, roads, and structural features, and shoreline protection; and
- excavation and stabilization of uplands in expanding the entrance to the West Basin and construction of channel widening along the north side of the channel from middle basin to the north jetty at the harbor inlet.

6.1 Impacts to Traffic and Projections

Port Canaveral's predominant mainland access is State Road (SR) 528, the "Beachline Expressway". SR 528 is a limited access expressway extending from an interchange with Interstate 4 in Central Florida through interchanges with the Florida Turnpike and Interstate 95 to the Port. Currently, the Florida Department of Transportation (FDOT) is completing a Project Development and Environmental (PD&E) Study to evaluate alternative ways to widen SR 528 from four to six lanes from State Road 520 to the Port and to provide other improvements needed to serve the ever-increasing traffic demand. According to Brevard County, the average daily traffic along the road near the Port last year was 39,820 vehicles.

Access to the north side of the Port is provided by the SR528 interchange with SR401, a four-lane arterial. SR401 ends shortly after the Port's property line at the Cape Canaveral Air Force Station. The highway's current capacity is expected to meet both the needs of the AF and CPA through 2025. The roadway crosses over the Barge Canal from the Port Channel to the Banana River via a drawbridge.

Access to the Southside of the Port is primarily provided by the SR528 interchange with George King Boulevard (GKB). The interchange constructed in 2002 provides two lanes on the off-ramps from eastbound SR528 traffic to accommodate future growth within the Port. Additional access to the south side of the Port is provided by North Atlantic Avenue, a two lane local street within the City of Cape Canaveral that has access from A1A, a state road which turns into SR528. Due to residential growth within the City, improvements to the roadway are likely warranted.

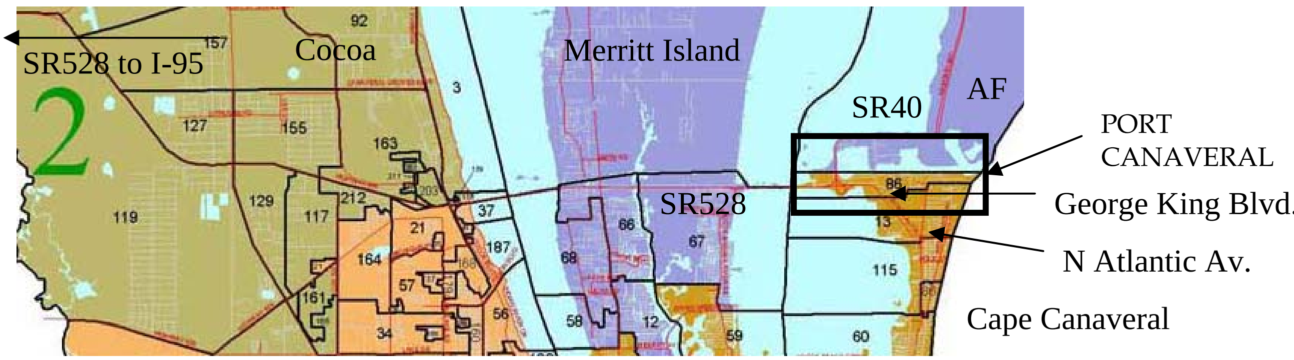

Figure 17. Vicinity Map (Source: Brevard Co. Precinct Map w/ CPA Boundary)

In May 2006, Ghyabi & Associates completed the "North side and Southside Traffic Study, Port Canaveral" which was commissioned by the Port Authority. The traffic Study is included in Attachment J. The internal roadway system of the Port is evaluated in the report. The existing traffic conditions were evaluated using the 24-hour volume counts, 72 hour classification counts and the turning moving counts at various roadway segments. The operating conditions at eleven critical intersections were analyzed. The level of service (LOS) for each of these intersections was an A or B, except for the GKB/Dave Nesbit Drive intersection which operates at a LOS of C during the Mid-day and PM peak hours. A weave analysis of the GKB segment between the A1A eastbound off-ramp to Dave Nesbit Drive determined an operational LOS of B during AM and Mid-day peak hours and a LOS of A during PM peak. In summary, the current operating conditions at these roadways are highly adequate for the existing roadway capacity.

Future traffic conditions were determined from trip generations for future development described by the Port Authority and a 3% annual growth rate for traffic not associated with the Port's development. Southside expansion projects include the aggregate conveyor/yard by, fully occupied Premier Office Building, Milrose Hotel, and a Hotel and Conference Center on the Banana River site. North side expansion projects include the Cruise Terminals 6 and 7 by 2008, Cargo Piers 5 and 6 supported by 18.5 acres of uplands by 2010 and then another 35 acres by 2015, and a 30-acre fuel tank farm by 2010. Future traffic analysis was performed for years 2010 and 2025. Further details of the developments can be read in the Ghyabi report.

Traffic volume forecasts were determined, a LOS analysis of the intersections was performed, and mitigation possibilities were investigated. By 2010, the proposed developments will generate approximately 15,330 new daily trips. By 2025, the proposed developments will generate approximately an additional 1,630 new daily trips. Other than the new roadways required by the developments, modifications to three existing critical intersections were recommended.

The GKB/Nesbit intersection would unsuccessfully operate at a LOS of F by 2010. A traffic signal would allow the intersection to improve to a LOS of C. By 2025, another left-turn lane would need to be added to GKB at this intersection to allow an operating LOS of D. Other improvements required by 2025 include lengthened signal cycles at the SR401/Charles Rowland Drive intersection to the Cruise Terminals and the SR401/Grouper Road intersection to the north side Cargo Area.

The proposed upland developments as outlined in the Ghyabi report align with the developments associated with the proposed channel improvements. Overall, the existing roadway system with a few modifications can accommodate the traffic growth associated with Port's expansion plans.

Additional supporting traffic information is provided in Attachment J including details from the "Brevard County Accident Analysis" from January 2000 through October 2005 for the following intersections: GKB/A1A, GKB/SR528, GKB/N Atlantic Av., and SR401/Grouper Rd. The following Table 27 summarizes the reported accidents. Attachment J also provides traffic counts from the County's database for roadway segments of SR528, George King Blvd. and N. Atlantic Avenue.

Table 27. Summary of Traffic Accidents, January 2000 – October 2005

Year	GKB/A1A	GKB/SR528	GKB/N Atlantic	SR401/Grouper
2000	0	0	4	1
2001	0	1	3	2
2002	3	0	4	2
2003	1	1	3	3
2004	0	2	1	0
2005	0	1	2	0
6-YR TOTAL	**4**	**5**	**17**	**8**

6.2 Impacts to Water Quality

Monthly water quality sampling has been performed continuously by the Canaveral Port Authority since September 1992. Based on the *Port Canaveral Harbor Water Quality Monitoring 2004 Annual Report* by Safety & Environmental Assessment Services, Inc., the Canaveral Harbor generally met requirements of its designation as a Class III predominantly marine water body per 62-302 Florida Administrative Code (FAC).

Seven sampling stations were utilized until 2004. One station was located in each of the three turning basins and the other four stations were along the access and barge channels. Field measurements were profiled at one foot below the water surface, mid-depth, and one foot above the mudline. Field measurements included temperature, pH, conductivity, dissolved oxygen and salinity. General chemistry samples such as turbidity, biochemical oxygen demand, total suspended solids, and total organic carbon content were collected at mid-depth. Chlorophyll samples were collected at mid-Secchi depth. Total coliform, fecal coliform, and oil and grease samples were taken at the surface.

This proactive water quality monitoring program assists the CPA in addressing concerns by the public as to the quality of the Port's water and identifies any potential issues that exist. Another program that the Port engages in to address water quality concerns is the monitoring of freshwater runoffs under the NPDES. CPA monitors discharge from nine of the 42 freshwater outfalls into the Harbor.

No adverse impacts to water quality are anticipated as a result of the construction or maintenance of the navigation project. Dredging would result in a temporary and localized water column impact from turbidity, but all dredging would be conducted in accordance with State Water Quality Standards dictated in the state (FDEP) environmental permit standard conditions. Turbidity monitoring would be required to insure that turbidity levels would not exceed 29 NTUs above background at the edge of the 150-meter mixing zone. If turbidity levels exceed 29 NTUs over baseline at any time, construction activities would cease immediately and not resume until modifications or corrective measures were taken and turbidity has returned to acceptable levels.

Excavation to the -13 MLLW elevation in the two upland removal areas for the project will require turbidity control on the uplands and in the adjacent waters. State/FDEP Best Management Practices shall be employed throughout the upland excavation and dredging portions of the project. For upland removal work, the form of turbidity control would be to completely surround the adjacent slope work area with double floating turbidity. If the upland site is left unattended or a significant rain event is anticipated where excavation work cannot proceed, then staked hay bales and/or silt curtains shall be employed at the top of the bank to guard against sediment runoff. Turbidity control for dredging operations may include installing temporary sheet pile walls or double turbidity barriers.

6.3 Impacts to Existing Utilities

There are no overhead utility crossings within the project study area. The Middle Basin and West Access channels have communications, gas, electrical, and the CPA CCTV utility crossings as described below and presented on each of four drawings contained in Attachment J.

Military Communications Duct:
Location: Station 214+72.5 on a north-south alignment.

- Owner: USAF
- Year Installed: 1993
- Approximate depth at center of existing channel: -83 feet (MLW)
- Remarks: The duct consists of a cluster of seven, 4-inch HDPE conduits encased in 24" of concrete. This duct was installed by horizontal directional drilling and replaced the original USAF communications duct as part of the previous channel widening project. The present duct is well clear of all proposed channel alternative plans, both at the bottom and at the side slopes. No remedial action is necessary.

Natural Gas Pipe Line:
Location: Center at approximately Station 214+72 on an east of north-south alignment.

- Owner: NUI/City Gas
- Year Installed: 1999
- Approximate depth at center of existing channel: -70 feet (MLW)
- Remarks: The pipe line consists of a single pipe installed by horizontal directional drilling. The present pipe line is well clear of all proposed channel alternative plans, both at the bottom and at the side slopes. No remedial action is necessary.

FPL Electrical Power Feeder Duct:
Location: Center at approximately Station 260+45 on a north-south alignment.

- Owner: Florida Power & Light
- Year Installed: 1999
- Approximate depth at center of existing channel: -67 feet (MLW)
- Remarks: The feeder duct consists of a single, 6-inch PVC conduit installed by horizontal directional drilling. The present feeder duct is well clear of all proposed channel alternative plans at the bottom. A future sheet pile wall along the corner cut off will cross the duct. The elevation of the duct at this point is -44 feet (MLW). The future wall will be engineered at that location with shorter sheets and king piles as necessary to avoid impacting the duct.

CPA CCTV Duct:
Location: Centered at approximately Station 285+45 on a west of north-south alignment.

- Owner: Canaveral Port Authority
- Year Installed: 2006
- Approximate depth at center of the existing Barge Canal channel: -26 feet (MLW)
- Remarks: The CCTV duct consists of three, 4-inch HDPE conduits installed by horizontal directional drilling. The present duct is west of the western limits of all alternative plans. No remedial action is necessary.

Grouper Road Utilities:
Location: West Turning Basin (WTB) Corner Cut Off (CCO)

The WTB CCO and Grouper Road relocation have been constructed in advance by the Canaveral Port Authority. This work preceded the Section 203 project out of necessity to accommodate the feasibility study design cruise vessels which are now homeported at Port Canaveral. Grouper Road in the vicinity of the relocation is a two-lane access accommodating large shipping trucks hauling/loading cargo into and out of North Cargo Piers 3 and 4. The relocation entailed approximately 1,600 LF of roadway, drainage swales, water main, wastewater force main, and communications lines.

6.4 Impacts on Embankments and Pier and Bulkhead Structures

The inner channel and turning basins are bounded by various bulkheads, wharfs, dikes, and embankments. The impact of the alternative plans was evaluated for typical sections from each structure.

6.4.1 North Dike Relocation

Dredge spoil containment dikes are located on the north side of the Inner Reach and the Middle Reach. The east-west dike adjacent to the harbor channel will be shifted 100 feet north to accommodate the channel widening. Stability analyses were conducted on a typical design cross section for the existing and proposed replication of the dike on the north side of the channel. The computer model SLOPE/W was used to analyze the various stability considerations.

SLOPE/W, developed by Geo-Slope International Ltd. of Calgary, Alberta, Canada, is a fully integrated slope stability analysis program. The computer program determines the critical failure surface for each failure mode by converging on the failure surface through an iterative procedure. Final stability analyses on the most critical failure surfaces identified in the search routine were completed using Spencer's method, which satisfies total force and moment equilibrium. The stability analyses were performed using an estimated pore pressure distribution assuming ponding of water to elevation 20 feet (MLLW) behind the dike.

The computed factor of safety for the slope stability analyses of the existing dike geometry is approximately 1.57 for failure in the foundation soils, 1.69 for the lower slope by the shoreline and 2.29 on the dike slopes, all of which exceed the minimum recommended safety factor of 1.5. Since the geometry of the relocated dike is proposed to be identical to the existing geometry, and the soil profile is generally similar to the profile of the existing dike, the factor of safety obtained from the slope stability analyses would also be similar to the factor of safety of the relocated dike.

The above analysis was a preliminary assessment utilizing SPT data and soil index testing. A detailed laboratory testing program and design analysis on undisturbed clay samples will be needed to further optimize the slope stability solution. During the detailed design process, all scenarios should be analyzed using Slope/W including circular and wedge failure.

Dike relocation will involve the movement of approximately 100,000 cubic yards of material. The existing rock rip-rap will be recovered for reuse on the new shoreline. The existing unimproved (earthen) perimeter road, security fence, and signage will be re-established at the new location and will be consistent with existing conditions. The abandoned boresight tower guy foundation (concrete pile tripod) and an existing mooring dolphin east of the U.S. Navy Poseidon Wharf will be removed and replaced with a monopile dolphin positioned near the new shoreline.

6.4.2 Jetty Park Embankment

The Jetty Park embankment is located at the south side of the Inner Reach. The stability of the existing embankment was analyzed for a worst case project depth of -46 ft. Using the computer model Geoslope, Version 4, it was determined that the embankment would have a factor of safety of 2.57. Therefore, the deepening options will have no impact on the existing embankment.

6.4.3 FPL Barge Berth Embankment

The FPL Barge Berth embankment is located on the south side of the West Access Channel. The computer model SLOPE/W was used to analyze the stability of the embankment for the worst case channel depth of -44 ft. The safety factor was found to be 1.91. Therefore, the deepening options will have no impact on the existing embankment.

6.4.4 Wharves and Piers

The open pile pier structures were not significantly affected by the various channel depth options. Increasing the berth depth, to take advantage of the deeper channel, did reduce the pile load capacities. Most pier piles in Port Canaveral are 18-inch and 24-inch square prestressed concrete piles with tip elevations ranging from -75 to -110 feet (MLW). The piles are designed as friction and bearing piles, using factors of safety of 2 and 3, respectively. The worst case reduction in pile capacity occurs at NCP 3 and 4, where the berth depth would be increased from -35 feet to -44 feet (MLW). This resulted in a pile capacity reduction of about 6% for the pile row near the berth face. This reduction decreased as the pile rows progressed towards the bulkhead. The new capacities were then compared to actual loads and it was determined that the reduced allowable loads were acceptable and that additional remedial action would not be necessary.

SCP3, however, is a deep wall wharf with a pile supported relieving platform that replaced an anchored SSP bulkhead wall in 1980. The wall was analyzed for a berth depth of -41 feet with a channel depth of -44 feet using USACE program CWALSHT. The wall safety factor was found to be 0.86 for the Free Earth Method. Previous studies of this wall have also resulted in safety factors less than one, in spite of the fact that the wall has shown no distress. This may be due to somewhat stronger soil conditions than those selected for the analyses, or it may be due to the relieving platform piles penetrating the wall’s active wedge and reducing the soil pressure on the wall. In any case, it is recommended that the berth depth be limited to the present -41 feet regardless of the final depth of the channel, and that the port continue to monitor the wall. As far as this feasibility study is concerned, no remedial action is necessary.

6.4.5 Bulkhead Walls

Existing bulkhead walls were analyzed for various alternative plan channel and berth depths using USACE program CWALSHT. It was found that the older walls, which have been in service for 30 plus years, had safety factors well below 1.0 for almost all of the channel depth options. Because these walls were already programmed for replacement during the next ten years, the recommendation will be to advance the replacement to coincide with the channel project. The replacement walls would then be designed for the needed depths and slopes for the selected plan.

The newer walls generally had safety factors that were acceptable and the future wall along the corner cut off at the entrance to West Basin would be designed for the recommended plan project depth for West Basin and West Access Channel, Cut A. Table 28 summarizes the results of the bulkhead wall analysis.

Table 28. Bulkhead Wall Analysis Summary

Bulkhead Wall Location	Adjacent Channel or Reach	Safety Factor Based on Channel Depth			Elevation of Wall Toe (ft)	Wall Section	Wall Surcharge (psf)	Recommended Action
		40 or 41 ft	43 ft	46 ft				
Cove	West Access Channel	2.94	2.8	2.68	-37	AZ13	200	None
Wall "L" (west of cove)	West Access Channel, Cut A	0.51	0.51	0.51	-15	MP115	200	Replace wall
Scallop Road Wall, "O"	West Basin	1.44	1.44	1.44	-20	MP116	200	None
George King Outfall	West Basin	1.64	1.45	1.29	-30.5	AZ13	600	None
NCP3&4 (Exist. Berth -35')	West Access Channel	0.86	0.86	0.86	-30.5	FROD3N	600	Replace wall
NCP3&4 (match channel depth)	West Access Channel	0.84	0.81	0.7	-30.5	FROD3N	600	Replace wall
CT2&3	Inner Reach	1.33	1.33	1.33	-16.5	Concrete	200	None
CT4 (Exist. Berth -35')	Inner Reach	N/A	1.38	1.38	-19	BZ7	200	Add fill to -5 ft
SCP1&2 -41' Berth	Inner Reach & Middle Basin Channel	1.43	1.43	1.43	-36	AZ26	600	None
SCP3 front face	Middle Basin Channel	0.86 (41')	--	--	-59	PZ32	500	Continue to monitor
SCP3 E/W faces	Middle Basin Channel	1.42 (41')	1.42	1.42	-70	AZ48w/36"pipe	500	None
TB1&2 Cantilever (between SCP	Middle Basin Channel	4.12 (41')	4.03	3.86	-85	CAZ18	200	None
TB1&2 Anchored	Middle Basin Channel	1.62 (41')	1.59	1.31	-71.5	BZ42	200	None
USN Bulkhead	Middle Basin	2.51	2.51	2.51	-16.4	Concrete	300	None
SCP1 at former A1A crossing	Inner Reach							Fill in gap in wall
West of George King Outfall	West Basin							Fill in gap in wall

6.4.6 West Basin Corner Cut-Off

Expanding the entrance to the West Basin to enable navigation access by the design cruise vessel and to accommodate a new turning basin requires the excavation of submerged lands and uplands along the southeast corner of the present entrance to the West Basin. This project feature is referred to as the Corner Cut-Off (CCO). The excavation area measures 18.5 acres at an estimated 861,575 cy. Excavated material above -13 feet MLW has been identified as material for reuse within the Port or for other beneficial uses as identified elsewhere in this feasibility study. Excavated material below -13 feet MLW will be tested, and assuming approval, permitted for disposal at the Canaveral ODMDS. Work at the corner cut off also requires removal of 822 linear feet of shallow bulkhead wall within the project feature areas and along the eastern boundary of the basin. A water line, sewer force main, and Grouper Road, all within the project area, will require relocation and realignment. The geometry of the constructed corner cut off bank slope is proposed to be 1V:3H, similar to or flatter than the existing profile. With similar soil profiles and slope conditions, the CCO is anticipated to be at least as stable as existing conditions.

It should be noted that the CCO dredging has been executed and completed by the Canaveral Port Authority as of September 2011. This work included 354,322 CY of upland excavated material (above -13 MLW), 507,253 CY of dredged material (below -13 MLW) with removal of 879 linear feet of shallow bulkhead wall and the Grouper Road and associated utilities relocation. This portion of the Section 203 project was completed in advance out of necessity to accommodate homeport ships, Freedom of the Seas and Carnival Dream which began in 2009. The costs of this work are included in the Section 203 Feasibility Study, and the Port Authority plans to obtain cost-shared funds through legislation.

6.5 Project Construction and Sequence of Work

The major cost magnitude and time duration element of the project is the harbor and channel dredging. The dredging accounts for approximately 68 percent of the total project cost. The dredging duration is estimated at 272 days or nine months. The total project duration including dredging and non-dredging elements is estimated to be 430 days. It is anticipated that some of the non-dredging project elements will be performed while dredging in other areas is taking place. Some necessary sequencing of work will be required in the area of the northside widening. Excavation and dredging work in that area must be performed well enough in advance to accommodate the berm and rock revetment replacements that must follow.

Construction methods shall conform to federal, state and local environmental permitting regulations. State standards for maintaining water quality, manatee protection and sea turtle protection would be adhered to throughout the project. Hopper dredging would not be employed and has been discouraged in past state and federal permits. Hydraulic and clamshell dredging are the methods of choice for economic and environmental concerns and are not known to “take” manatees or sea turtles when the state standards for operations and observance are employed. More detailed environmental project information can be found in the Environmental Appendix (a separate document from the Engineering Appendix).

Construction of the project involves both marine and uplands work and equipment. The following sequence of work is provided to generally describe the progression of the project:

- Remove all physical obstructions within the submerged project area and remove or relocate all physical obstructions within the uplands portions of the project area.
- Install temporary project security measures for protection of the uplands property and work.
- Perform the uplands earth work along the north side of the channel from the Middle Basin to the start of the north jetty. Install the SSP wall and monopile features adjacent to the Poseidon pier prior to dredging to allow continued use of the facilities. For the north dike relocation project feature, remove and stockpile rip-rap for reuse.
- At the same time, dredging of the project features would begin starting in the Outer Reach and working toward the Harbor and to the West Basin.
- Replacement of the rock revetment at the northside widener, installation of the security fencing for the USACE dredged material containment site, relocation/addition of the aids to navigation (range structures) and replacement of the west "Surge Warning" sign at the North Jetty complete the project.

The dredging operation will consist of clamshell bucket dredge(s) and bottom dumping scows used for transportation and disposal at the Canaveral Offshore Dredged Material Disposal Site (ODMDS). This method is preferred due to the 10 mile distance from the mouth of the harbor to the ODMDS. Piping of hydraulically dredged material would not prove to be logistically (from a navigation standpoint) or economically feasible. Dredged material suitable for nearshore disposal or other beneficial reuse would be disposed of in the USACE upland containment site on Air Force property. Work would be closely coordinated with local pilots to ensure the safety of navigation while working around ship transits with the least disruption to the dredge operations. The dredge contractor may take advantage of working inside the harbor when conditions do not allow work outside the jetties.

6.6 Dredged & Upland Excavated Material Disposal and Reuse

In Attachment J, drawings C1 and C2 show the uplands and offshore disposal sites that would receive the dredged or excavated material from the recommended plan. The upland site consists of one existing containment area utilized by the USACE on Air Force property between the Middle and Trident Basins. The offshore sites, Canaveral Ocean Dredged Material Disposal Site (ODMDS) and the Nearshore Disposal Area are located approximately 10 miles from the entrance jetties via the outer reach.

The recommended plan requires dredging of approximately 3.6 million CY and excavation of approximately 808,391 CY of sand, silts and clays. The completed CCO dredging has resulted in placement of 507,253 CY in the ODMDS leaving approximately 3.1 million CY for future ODMDS placement. The CCO excavation of 354,322 CY was placed in uplands on CPA property. An estimated 454,069 CY of excavation would occur at the northside widener. 100,000 CY of this volume is estimated as dike relocation of the existing upland containment area on Air Force property and the remaining 354,069 CY from existing grade down to elevation -13 MLLW is designated for disposal in the containment area after the dike relocation and improvements are completedThe geotechnical investigations show that sands suitable for reuse are generally located at and above elevation -13 feet (MLLW). Although these sands do not appear to be suitable for direct placement on the beach, they can be stockpiled on land for beneficial reuse as construction fill material. Excavated material below -13 feet MLLW is generally not suitable for reuse and would be disposed in the offshore disposal site. In the event that suitable material is found below -13 feet MLLW, it could be placed in the Nearshore Disposal Area.

6.6.1 ODMDS (Ocean Dredged Material Disposal Site)

The Canaveral ODMDS is located approximately 10 miles south of Canaveral Harbor and has historically been used from placement of dredged materials from new work and maintenance events that are predominately silts and clays and have been tested to meet Ocean Dumping Criteria of the Marine Protection Research and Sanctuaries Act (MPRSA). Dredge material below -13 feet (MLLW) generally consists of the silts and clays typically evaluated for ODMDS placement (see Attachment I) and are included as part of the Recommended Plan CPA upland disposal sites are currently at capacity will material removed from above -13 feet MLLW which is considered preferred material for future reuse.

The most recent management plan for the ODMDS is the Site Management and Monitoring Plan (SMMP) dated February 2012, which replaced the previous SMMP that expired October 2011. The SMMP is a ten-year plan, jointly implemented by the Corps' Jacksonville District and USEPA's Region 4. The new February 2012 SMMP does not identify an annual placement volume limit. Additionally, overall planning for the revised SMMP accounts for construction and maintenance dredging volumes associated with this project. The SMMP identifies a ten-year cap of 9.2 million cubic yards, which may be increased if an increase is supported by future modeling.

The following table (Table 29) provides the history of disposal within the Canaveral ODMDS. In addition, EPA coordination of the 10-year update to the SMMP is considering allowing project specific volumes greater than the current 3 million annual limit.

Table 29. Canaveral ODMDS Disposal History (1974-2011)

YEAR	TYPE OF ACTION	SOURCE	VOLUME (CY)	SPONSOR	COMPOSITION
1974	NW	Entrance Channel & Trident Basin	645,198	Navy	Sandy Silt
1974	MD	Entrance Channel & Trident Basin	223,986	Navy	Sandy Silt
1975	NW	Entrance Channel & Trident Basin	2,196,470	Navy	Sandy Silt
1975	MD	Entrance Channel & Trident Basin	187,212	Navy	Silty Sand
1975	MD	Trident Basin	63,077	Navy	Sandy Silt
1976	NW	Entrance Channel	1,343,121	Civil Works	Sandy Silt
1976	MD	Entrance Channel	341,888	Civil Works	Sandy Silt
1977	MD	Entrance Channel	48,017	Civil Works	Sandy Silt
1978	MD	Entrance Channel	282,517	Civil Works	Sandy Silt
1980	MD	Entrance Channel	1,402,547	Civil Works	Sandy Silt
1981	MD	Entrance Channel	257,326	Civil Works	Sandy Silt
1983	MD	Entrance Channel	929,555	Civil Works	Sandy Silt
1985	MD	Entrance Channel	2,958,827	Civil Works	Silty Sand
1986	NW	Entrance Channel	63,370	Civil Works	Silty Sand
1986	MD	Entrance Channel	351,535	Civil Works	Silty Sand
1988	MD	Entrance Channel	442,750	Civil Works	Silty Sand
1988	MD	Entrance Channel	1,200,188	Civil Works	Silt
1988	MD	General berth Areas	15,600	CPA	Silts & Clays
1989	MD	Entrance Channel	203,000	Civil Works	Silt
1990	MD	Entrance Channel	173,772	Civil Works	Silt
1991	MD	Middle Turning Basin	497,380	Civil Works	Silt
1991	MD	General berth Areas	178,800	CPA	Silts & Clays
1992	MD	Entrance Channel	342,000	Civil Works	Silt
1992	MD	Middle Turning Basin	208,000	Civil Works	Silt
1993	MD	Entrance Channel	1,878,460	Civil Works	Silt
1993	MD	Trident Access Channel	108,410	Navy	Silty Sand
1993	NW	WTB SE Corner	400,000	CPA	Clay
1994	NW	Entrance Channel	454,000	Civil Works	Silty Sand
1994	NW	Middle Turning Basin	1,039,000	Civil Works	Silty Sand
1994	MD	Entrance Channel	98,820	Civil Works	Silt
1994	MD	Trident Access Channel	17,510	Navy	Sandy Silt
1994	MD	WTB CT5	24,000	CPA	Sandy Clay
1994	NW	WTB CT10	86,000	CPA	Silty Sand
1995	MD	Entrance Channel	243,180	Civil Works	Silt
1995	MD	Trident Access Channel & Turning Basin	12,090	Navy	Silt
1996	MD	Entrance Channel	245,274	Civil Works	Sandy Silt
1996	MD	General berth Areas	33,000	CPA	Silts & Clays
1996	NW	WTB CT8	212,000	CPA	Silty Sand
1997	MD	Entrance Channel	773,999	Civil Works	Sandy Silt
1997	MD	Trident Turning Basin	36,965	Navy	Silts & Clays
1998	MD	Entrance Channel	688,839	Civil Works	Sandy Silt
1998	MD	Entrance Channel, TTB & Poseidon Wharf	160,044	Navy	Sandy Silt
1998	MD	WTB CT5	5,600	CPA	Sandy Clay
1999	MD	Entrance Channel	1,312,703	Navy	Sandy Silt
2000	MD	Entrance Channel	300,320	Civil Works	Silt
2002	MD	Entrance Channel	410,000	Civil Works	Silts & Clays
2002	MD	CT5, NCP4, SCP1-3, TB 1&2	41,000	CPA	Silts & Clays
2002	NW	WTB Entrance	89,000	CPA	Silts & Clays
2003	NW	Inner Reach & West Access Channel	132,000	CPA	Silts & Clays
2003	MD	Entrance Channel & Trident Entrance Channel	512,482	Navy	Silts & Clays
2004	MD	Entrance Channel	202,624	Civil Works	Silts & Clays *
2004	MD	Trident Access Channel & Turing Basin	28,195	Navy	Silts & Clays *
2004	MD	CT8, NCP3 & 4	11,000	CPA	Silts & Clays
2005	MD	Entrance Channel	417,997	Civil Works	Silts & Clays *
2006	MD	WTB Entrance, Federal WTB, CT5, 8, 10, NCP 1&2	104,500	CPA	Silts & Clays
2006	MD	Entrance Channel & Middle Turning Basin	952,705	Civil Works	Silts & Clays *
2007	NW	S. Jetty Sand Trap	368,160	CPA	Silty Sand
2007	MD	CT6/7,CT10,NCP3/4	124,756	CPA	Silts & Clays
2008	MD	EC,TAC,TTB,MTB	436,627	CW/Navy	Silts & Clays
2008	MD	Cuts1b&1&2,TAC,TTB,Poseidon Wharf	286,230	CW/Navy	Silts & Clays
2009	MD	WTB	92,160	CPA	Silts & Clays
2009	NW	ICCO	239,714	CPA	Silty Sand
2010	MD	Cuts1,&2,TAC,TTB	1,170,762	CW/Navy	Silts & Clays
2011	MD	S. Jetty Sand Trap	172,130	CPA	Silty Sand
2011	NW	CCO	267,539	CPA	Silty Sand

* Includes sands that were placed on the Near Shore Berm (estimated to be a small percentage of the total)

The suitability of the dredged material for ocean disposal will be verified as part of the permit process. Based on the past history of testing and evaluation of dredged material in Port Canaveral and the current Section 103 EPA authorizations, it is anticipated that all of the material proposed for ocean disposal will be approved.

6.6.2 Disposal and Reuse of Upland Excavated Material

The maximum amount of excavated material for reuse and/or upland disposal is estimated to be 354,069 cubic yards and will be disposed at the existing USACE upland containment site on the USAF property. Reuse of upland excavated material is considered to consist of the sands that are generally found at and above elevation -13 feet MLLW. The dredge material is expected to be of a quality suitable for construction fill material and would be stockpiled at an agreeable location on the containment site for later reuse pending formal Air Force approval for use of that area for material placement.

Air Force approval for use of the existing USACE upland containment site for material placement would be based on an evaluation of competing interests and on test results of the composition of the spoils to be placed. The Sponsor is well aware that Brevard County has a beach restoration project that intends to use the USAF disposal area to stockpile beach quality sand. The beach quality sand will be hydraulically dredged from just offshore of the USAF coastline and will require a competent dike system to contain the fluid spoil. The existing USAF containment dike, however, is in poor condition and will need to be restored, possibly raised in elevation, and a new intermediate dike constructed to subdivide the containment area. Based on the previous channel widening and the Sponsor's experience with recent dredging, the material above elevation -13 feet will be construction grade fill material recovered using excavation methods. This material will be suitable for the dike modifications and the new intermediate dike needed for the Brevard County project. CPA is currently coordinating with USAF and Brevard County to insure that the one-time placement of the recovered spoil will complement the Brevard County project. Use of the recovered stockpiled material to reconstruct and improve the containment dike system would not reduce the area available for spoil.

In the unlikely event that the USAF should not approve placing the excavated upland material on their existing spoil disposal site, other options for reuse of the upland excavated material can be further developed, including off-site placement or existing disposal area dike upgrades requiring suitable fill. If the USAF wishes to retain ownership of their material (since the upland material is being excavated from their property), then the Sponsor could truck the material to a different site on CCAFS as designated by the USAF. These alternatives would be slightly more expensive than the recommended upland disposal plan due to additional haul distances, but would be expected to remain within the contingency allowance for upland material disposal costs estimated in this report.

7.0 Hazardous and Toxic Materials

The Section 203 Feasibility Study, Hazardous, Toxic, and Radioactive Waste (HTRW) Assessment - Preliminary Assessment Report is comprised of the following five components: 1) Records and Database Review, 2) Historical Aerial Photography and Topographic Map

Study, 3) Site Reconnaissance, 4) Interviews, 5) Report. The goal of the site investigation was to identify Recognized Environmental Conditions (RECs) and indicate the presence or likely presence of hazardous substances or petroleum products in and around the target property areas. To the extent supported by the investigative approach typically used for this type of project, the assessment attempts to reveal conditions that indicate an existing release, a past release, or a material threat of a release of hazardous substances or petroleum products on the properties or into the ground, groundwater, or surface water of the properties. This report substantially satisfies the requirements of ER-1165-2-132 and ASTM Practice E 1527. Refer to Attachment K for the HTRW report.

As recommended in the HTRW report, a further detailed study was performed for the property formerly leased by Beyel Brothers, Inc. that is located within the West Basin entrance corner cutoff project area. The site, vacated in 2006, is the former location of Beyel Brothers, a crane and rigging company. On the site, a portable skid above-ground storage tank (AST) was maintained for fueling equipment with diesel fuel. A limited scope soil and groundwater assessment was completed in October 2006. The assessment identified the presence of petroleum impacted soil and groundwater and a discharge report form was submitted to Brevard County Natural Resources Management Office in December 2006. An environmental services company was then contracted to complete the source removal and assessment activity. In August 2007, approximately 779 tons of petroleum contaminated soil was excavated from the source area at the site and transported from the site for disposal at the Omni Waste Landfill in St. Cloud, Florida. Laboratory analysis of 24 confirmatory soil samples indicated the presence of petroleum fuel constituents, but at levels well below the most restrictive Residential Soil Cleanup Target Levels. Laboratory analysis of groundwater samples collected from seven monitor wells installed at the excavation sites did not indicate the presence of petroleum impacts to the groundwater in excess of the most restrictive Residential Groundwater Cleanup Target Levels.

The site now meets the FDEP criteria for a “No Further Action with Conditions” status. Attachment K includes the assessment and source removal report. No further review of activities associated with Coastal Fuels or Mid-Florida Freezer were performed as their lease properties are well outside the limits of the project area and will not impact or to be impacted by this navigation project.

8.0 Operations and Maintenance

Historical data available for federal and non-federal (Canaveral Port Authority) maintenance dredging disposal at offshore and nearshore locations provides a trend indicating where shoaling, and therefore, maintenance dredging is typically required along with volumes dredged. The greatest concentration of maintenance dredge material, roughly 200,000 cy or one-third of dredge/disposal quantity removed per dredge event, has occurred in the vicinity of the Canaveral Harbor inlet and attributable to littoral shoaling. The remaining roughly 400,000 cy or two-thirds of dredge/disposal quantity removed from the Federal Project originates as non-littoral background deposition. Waters outside the jetties and inside the harbor are relatively quiet and without tidal flow or sufficient bottom current that would otherwise tend to sweep away the finer silts and clays from the deep approach channel and turn wideners cut through overbanks on either side. The interior of the harbor is mostly lined with bulkheads, with some natural shorelines. Interior maintenance dredging consists of more fine, silty material with the source being slough from the natural shorelines or underwater grade transitions caused by ship thrusters and wakes.

The implementation of the Port Canaveral Inlet Management Plan, ca. 1995-1998 and on-going, has resulted in a decrease in maintenance dredging and offshore disposal at Canaveral Harbor particularly over the last decade. The transport of sand into the inlet channel from the adjacent shoals has been minimized to nearly negligible levels through the combined actions of (a) sand- tightening and extending the inlet jetties, completed in 2005; (b) dredging and bypassing of sand from the updrift beach immediately north of the inlet to the shoreline south of the inlet, performed four times from 1995 and most recently in 2010, and perpetual 6-year cycles thereafter; and (c) construction of the advance-maintenance south jetty sediment trap in 2007. Additionally, in recent years, the frequency of dredging has been potentially decreased from annual to bi-annual events. Before the plan and implementation of the improvements, the need for annual dredging was largely dictated by critical shoaling at the inlet jetties. Maintenance dredging of the south jetty sand trap may be performed without impeding navigation and as convenient with regard to budget and schedule.

The first regular placement of maintenance dredged material into the nearshore disposal area offshore of Cocoa Beach began in 1992. This allows dredged littoral material containing less than 20 percent fine sediment to be returned to and retained within the littoral system instead of being disposed of offshore at Canaveral ODMDS. Most of the sand placed nearshore in the last decade was due to severe shoaling of the channel in 2004 as a result of the passing of multiple hurricanes.

Maintenance dredging is performed using a clamshell bucket rig on a barge. Loaded scows transport dredged material to a state and federal permitted offshore disposal site. This is simply due to the fact that upland dredged material disposal is limited at Port Canaveral and it is not economical to hydraulically dredge and pump to the offshore disposal site approximately ten miles from the mouth of the harbor. The average yearly federal maintenance dredge volume, before Section 203 project construction, ranges from approximately 400,000 to 575,000 cubic yards. As detailed below, the increase in federal maintenance dredging is estimated to be 67,400 cubic yards at a cost of approximately $544,592 per year, in 2007 U.S. dollars. An escalation factor of 11% based on September 2010 CWCCIS cost index tables for ports and harbors increases the estimated federal maintenance dredging cost to $604,578 in 2011 U.S. dollars.

8.1 Federal Maintenance Dredging History

Based on the Canaveral Ocean Dredged Material Disposal System history, average annual federal project maintenance dredging volumes can be tabulated. From 1974 to 2000, a 27-year period, the Navy and Civil maintenance dredging projects averaged 585,266 cubic yards of dredging per year. Similarly, over the last 12-year period, 1998-2011, the average annual Navy and Civil dredge volume is approximately 565,000 cy, showing good agreement with the longer range historical average. This maintenance work has primarily been referenced to the entrance channel outer and middle reaches and navy and civil wideners. Review of federal maintenance dredging west of Trident Basin indicates that work has been negligible compared to the mass of longshore sandy material that deposits near the port inlet.

8.2 Areas of Maintenance Dredging

Port Canaveral's submerged federal areas subject to maintenance dredging, including basins, inner channels and the ocean access channel, is 674.6 acres. The proposed widening of the Section 203 includes areas such as West Turning Basin CCO, the channel widening to the south into the existing barge canal, the north channel widening from middle basin eastward to the north jetty area, and the 203 widener enlarging the turn area between the middle and outer reaches.

Based on the nature of sedimentation at the port, recent hydraulic modeling of the recommended plan as compared to the existing conditions, and the federal maintenance dredge history, it is anticipated that only the middle reach portion of the north side channel widening and the 203 widener at the entrance channel turn will appreciably contribute to future annual maintenance dredge volumes post-construction.

8.3 Hydraulic Model Results

Comparison of hydraulic models for the existing conditions and the recommended plan shows that the general pattern of currents throughout the port does not appreciably change and the magnitude of currents remains relatively low. The velocities ranged from a low of 0.048 ft/sec in the West Basin to a maximum predicted velocity of 0.576 ft/sec found at the inlet. No significant increase in scour potential or rate of sedimentation is indicated or predictable from the hydraulic model of the preferred alternative and recommended plan.

8.4 Future Maintenance Dredging Volume Increase

Discussion with the USACE site manager for federal dredging projects at Port Canaveral reveals that the material removed west of the Trident Basin is softer material, silt and may contain muck and is more likely the result of sloughing of perimeter bank slopes than transport from the inlet. The perimeter of the harbor and basins is not significantly increased by the widening areas, but is simply shifted due to the constructed Section 203 project, and any increase in maintenance dredging would therefore take place near the inlet as historically observed. The accumulation of material west of Trident Basin is negligible compared to areas just inside and mostly outside of the inlet as evidenced by the infrequency of federal maintenance dredging required west of the Trident Basin. The sedimentation in the middle and outer reaches near the inlet is sandy in nature.

In order to project the annual incremental maintenance dredge volume associated with the construction of the project, it is necessary to determine an average annual depth of maintenance material removed from the primary dredge areas just inside and mostly outside of the inlet. The annual federal dredge volume considered for these areas was 575,000 cy (15,525,000 cf). For the previous two multi-year maintenance dredging contracts, significant portions of the reaches and cuts are dredged every year, but not 100% of the area. So to account for that, it is reasonable and representative to assume that on average, dredging occurs on an annual basis in the following areas:

50% of the outer reach Cut 1A (11,000’ x 400’)	2,200,000 sf
100% of the outer reach Cut 1B (5,500’ x 400’)	2,200,000 sf

50% of the outer reach Cut 1	(12,500' x 400') 2,500,000 sf
100% of the navy and civil wideners	1,013,500 sf
100% of the middle reach (5,658' x 400')	2,263,200 sf
TOTAL AREA	10,176,700 sf

The total annual dredge volume divided by the total representative area dredged yields the average dredge depth for the middle and outer reaches and navy and civil wideners.

15,525,000 cf / 10,176,700 sf = 1.52 ft average dredge depth

Therefore, the estimated incremental maintenance volume for the 203 widener and the eastern portion of the north side channel widener adjacent to the middle reach is:

203 Widener (22.24 Acres):
968,774 sf X 1.52 ft / (27 cf/cy) = 54,538 cy

North side Channel Widener Adjacent to Middle Reach (2282' x 100'):
228,200 sf X 1.52 ft / (27 cf/cy) = 12,847 cy

Total incremental annual federal maintenance dredge volume = 54,538 cy + 12,847 cy = 67,385 cy, say 67,400 cy.

Projected sea level change discussed in Section 3.2 would increase the mean water levels by 0.8 feet over the next fifty years. Based on the estimated volume calculation above, this would potentially reduce the annual maintenance volume by approximately half.

8.5 Estimated Cost of Maintenance Dredging

The cost estimate for the new work dredging portion of the Section 203 construction project is $5.42/CY, excluding mobilization and demobilization of equipment. The CPA has bid recent non-federal maintenance dredging projects in 2006 and 2007 with the following most favorable bid sheet results for each contract for selected line items that may be considered for upward bounding the potential cost associated with federal O&M dredging. These values are significantly higher due to the scattered dredge locations, minimal depths of dredging and difficulty in scheduling work around cruise and cargo ship berthing.

Annual O&M dredging averaging 575,000 cy pre-Section 203 project construction and 642,400 cy post-Section 203 project construction still represent significant volumes of material that would be expected to command very competitive bid costs, particularly in the areas just inside and outside the inlet.

Table 30. Recent Historical Dredge Costs for CPA Projects

Year	Project Area	Estimated Dredge Volume	Low Bid Cost / cy	2nd Low Bid Cost / cy
2006	South Jetty Sediment Trap	365,000 cy	$5.27 * Weight 75%	$8.80 Weight 75%

	Construction			
2006	Federal West Basin Maintenance	65,400 cy	$7.30 Weight 15%	$7.70 Weight 15%
2007	Federal West Basin Entrance Maintenance	33,247 cy	$16.50 Weight 10%	$17.04 Weight 10%
Unit Cost (Weighted Average)			$6.70	$9.46

* Unit cost reflects that this contractor was already mobilized on-site in support of Canaveral Harbor federal maintenance multi-year dredge contract.

The South Jetty Sediment Trap construction costs come closest to representing the volume and potential costs for dredging for the incremental volume due to the project. The west basin maintenance dredge costs take into consideration the interruptions to operations with ship movements to and from west basin and a fairly small quantity of material. Owing to the 2006 and 2007 dredge locations and bid volumes, the sediment trap costs were assigned a weight of 75% and the west basin maintenance costs were assigned weights of 15% and 10%. This distribution of historical costs provides a weighted dredge cost ranging from $6.70 to $9.46 per cy. Using an average cost of $8.08 per cy, the incremental increase in maintenance dredging cost following construction of the Section 203 project is estimated at 67,400 cy X $8.08/cy, or approximately $544,592 per year, in 2007 dollars. Using the September 2010 CWCCIS cost indexing tables for ports and harbors provides an 11% escalation factor applied to the average unit rate. The revised cost for 2011 is $604,578 at $8.97 per cy.

9.0 Project Security

Multiple agencies have jurisdiction at Port Canaveral including Brevard County Sheriff, Florida Marine Patrol, Florida fish and Wildlife Conservation Commission, Florida Department of Law Enforcement, U.S. Homeland Security, U.S. Fish & Wildlife Service and Canaveral Port Authority Police Department and Security.

Areas of landside project work are located within the secure areas of the Cape Canaveral Air Force Station (CCAFS) and CPA that will require personnel to obtain port security badges and/or a Transportation Worker Identification Card (TWIC). Marine side project work will be executed under the security requirements of CPA.

10.0 Cost Estimates

10.1 Basic Cost Elements

The channel and harbor were analyzed for different dredge volumes in one-foot deep area increments beginning at existing or maintained elevations. Incremental volumes and the cost to dredge to those increments were compared with benefits at each increment by the project economist to determine the Preferred Alternative, or Section 203 Project. The Preferred

Alternative is graphically described in Attachment E of the Section 203 Feasibility Study Engineering Appendix.

The basic project cost elements consist of dredging the channels and basins, removing upland soil material in two locations, and costs of certain non-dredging items. Project costs, for the purposes of this discussion, do not include operating and maintenance cost (O&M), which is discussed in detail elsewhere in the Section 203 Feasibility Study. Upland port and tenant facility improvements are also not included in the direct harbor improvement costs, but are considered elsewhere in the Section 203 Feasibility Study.

A specific list of project elements includes:

- Dredging (material below -13 MLLW)
- Upland Excavation (WTB CCO and Northside Widener, material above -13 MLLW)
- Stockpiling and Replacing Existing Rock Revetment (associated with northside channel widening)
- Security Fence Around USACE Disposal Area (associated with northside channel widening)
- Mooring Dolphin Demolition and Replacement (associated with northside channel widening)
- Boresight Tower Guy Foundation Demolition (associated with northside channel widening, tower previously removed)
- New Bulkhead Wall Near USAF Building 1064 and Boat Ramp (associated with northside channel widening)
- Aids to Navigation (New outbound pair and relocate existing inbound pair)
- West Surge Warning Sign Replacement

10.2 Unit Cost Derivation

Dredging unit costs were prepared using CHECKRATE to calculate dredging equipment and production rates for the Recommended Plan volume. Other project element unit costs are based on industry standards of construction and demolition cost estimate data bases and supplemented when necessary with costs derived from bids for work completed in the port. All cost information has been assembled and reported in Micro-Computer Aided Cost Estimating System (MCACES) format provided in Attachment L. Also included is the Total Project Cost Summary Sheet for work completed and work remaining in the Recommended Plan.

10.3 Cost Estimates

The fully funded project cost estimate is $56,726,000.00 including Sponsor spent costs. A discussion regarding the disposition of Sponsor completed work and work remaining is provided in the Main Report. The costs presented in the Final Draft Section 203 Port Canaveral Navigation Feasibility Study are less than the costs presented in the Total Project

Cost Summary, which was certified by the Cost Center of Expertise at the Walla-Walla District in February, 2012. The total project cost has been reduced based on comments received from HQ Office of Water Policy Review and the South Atlantic Division. The reviewers required that the land value included in WBS Account 01 Lands and Damages be removed from the Total Project Cost Summary because the land is currently owned by the federal government and, therefore; there would be no cost to the project based on the value of the land. The administrative costs associated with the land in question remain as a project cost and is included in WBS Account 30. The difference between the Total Project Costs as certified in February, 2012 ($43,340,000) and the costs used in the final report ($41,349,000) is $1,990,600, which is the appraised value of the land in question (plus contingency).

In addition, the reviewers have determined that the costs included in WBS Account 02 Relocations ($2,429,000) were inappropriately labeled as relocations and should be switched to WBS Account 12 Navigation Ports and Harbors. This change has been made in the main report and does not affect the total cost of the project.

The fully funded estimate includes a contingency factor of 20.97% and escalation to the estimated project midpoint of February 2014. Escalation is based on the current Civil Works Construction Cost Index System (CWCCIS) as provided in EM 1110-2-1304. The contingency was determined using the USACE prescribed procedures in USACE Documents: ETL 1110-2-573, ER 1110-2-1302 and ECB 2007-17. The latter document requires use of the "Crystal Ball" program and preparation of a risk register by the Project Delivery Team (PDT), culminating in a Cost and Schedule Risk Analysis Report. The Cost and Schedule Risk Analysis Report is included as Attachment M. The MCACES format cost estimate in Attachment L provides a complete accounting of all the project cost elements.

11.0 Schedule for Design and Construction

The total project time from the date of approval of the Section 203 Feasibility Study to the end of construction is estimated to be from July 2013 to October 2014. This total project time includes authorization by Congress, negotiating and signing a project cooperation agreement, engineering design, environmental permitting, and acquisition of easements, bidding and construction. The construction phase is estimated at 430 days, or 14.15 months. A project schedule is included as Attachment O.

12.0 Special Studies

No special studies have been identified as being required for the PED phase.

13.0 Figures, Tables, Drawings and Attachments

Figures, tables, drawings and attachments are used throughout this Engineering Appendix and are referenced where applicable.

14.0 Use of Metric System Measurements

In keeping with historical navigation project records for Port Canaveral, this feasibility study has been prepared using the traditional British system of units rather than metric system measurements.