SAN JUAN HARBOR, PUERTO RICO NAVIGATION IMPROVEMENTS STUDY

Final Integrated Feasibility Report & Environmental Assessment

APPENDIX C

Economics

June 2018

US Army Corps of Engineers
Jacksonville District

EXECUTIVE SUMMARY

San Juan Harbor is located on the northeastern coast of Puerto Rico and is the island's busiest port, accounting for over half of the total cargo tonnage passing through Puerto Rican ports in 2015. San Juan is also an important cruise port. In 2015 San Juan Harbor ranked 8th among North American and Caribbean cruise ports in terms of total number of passengers. Among Caribbean ports it ranked 4th in total passengers.

Currently there are navigational constraints, which cause loading inefficiencies, in-port delays, and increased maneuvering times. The existing and future fleets of petroleum tankers and the future fleet of LNG tankers transiting the Army Terminal Channel and the current fleet of cruise vessels utilizing the cruise docks north of the San Antonio Approach Channel are the main sources of project benefits. Measures considered in the analysis would allow larger petroleum tankers and LNG vessels to call San Juan Harbor, allow these larger vessels to use San Juan Harbor more efficiently through increased vessel loading, allow existing medium range (MR) tanker vessels to use San Juan Harbor more efficiently through increased vessel loading, reduce cruise vessel maneuvering times within the port, and allow use of waterway transportation of LPG direct to San Juan rather than trucking of the product from the island's southern coast.

This economic analysis examined widening and deepening. The HarborSym model was used to determine total transportation costs attributable to the study port. Transportation cost savings were determined based on the difference in total transportation costs between the with- and without-project conditions. Power generation cost reduction benefits were calculated using power generation cost information provided by the Puerto Rico Electric Power Authority (PREPA). Due to uncertainty associated with PREPA's future conversion from the use of diesel fuel to LNG for power generation, the economic analysis and plan formulation were completed using two distinct sets of future with-project (FWP) condition assumptions resulting in a range of possible project benefits. The two scenarios considered are the following:

1.) Assume San Juan area power plants will convert from the use of diesel fuel for power generation in the future without-project condition to the use of LNG for power generation if a Federal navigation project is constructed. Include power generation cost reduction benefits as a project benefit.
2.) Assume San Juan area power plants will maintain use of diesel fuel in the future both with and without a Federal navigation project. Do not include power generation cost reduction benefits as a project benefit.

Both analyses outlined above resulted in the same National Economic Development (NED) plan, which includes the following measures:

- Widen Army Terminal Channel from 350' to 450'
- Deepen Cut 6 to 46'
- Deepen Anegado Channel to 44'
- Deepen Army Terminal Channel to 44'
- Deepen Army Terminal Turning Basin to 44'
- Construct eastern and western flares at the southern end of the Army Terminal Turning Basin
- Deepen Cruise Ship Basin East to 36'

- Deepen San Antonio Approach Channel, San Antonio Channel, and San Antonio Channel Extension to 36’
- Expand the Federal limits of San Antonio Channel Extension to the east by 1,050 feet to incorporate into the Federal project that area which was previously constructed to a 36 foot depth by the Port

The combination of measures listed above reasonably maximizes net benefits and makes up the recommended plan. Considering each of the aforementioned scenarios, the recommended plan provides average annual net benefits ranging from $2,041,000 to $60,097,000 and has a benefit-cost ratio ranging from 1.9:1 to 5.0:1 at the FY18 Federal Water Resources Discount Rate of 2.75 percent and FY18 price levels.

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1 Introduction

The U.S. Army Corps of Engineers (USACE) Jacksonville District has conducted an economic analysis to determine the feasibility of improvements to the Federal navigation project at San Juan Harbor. San Juan Harbor is located on the north coast of the island of Puerto Rico, about one-third of the distance west along the coast from the northeast corner, and provides the only natural harbor offering all-weather protection to shipping along the entire north coast. San Juan Harbor is Puerto Rico's principal cargo port, accounting for approximately 78 percent of all non-petroleum and non-coal products handled on the island[1] and is in the island's population center with nearly two-thirds of the island's inhabitants residing in the San Juan-Carolina-Caguas Metropolitan Statistical Area (MSA)[2]. Because Puerto Rico is an island, waterborne commerce is crucial to meeting inhabitants' and visitors' needs, with everything from food and household supplies for daily use to petroleum products used to power vehicles and to generate electricity moving through San Juan Harbor. In addition to the port's importance in supplying goods to the island, San Juan is a popular stop on Caribbean cruise itineraries and brought over 1.4 million cruise passengers to the city in 2015[3]. In 2015 San Juan Harbor ranked 8th among North American and Caribbean cruise ports in terms of total number of passengers. Among Caribbean ports it ranked 4th in total passengers[4].

1.1 Background, Problems, and Objectives

Federal interest in navigation in San Juan Harbor began in 1917 with the inner harbor area and establishment of the San Antonio Channel with a depth of 30 feet.[5] Most recently, in 1999-2001, another Federal construction event deepened the Bar and Entrance Channels to between 56 and 42 feet, the Anegado Channel to 40 feet, the Army Terminal Channel to 40 feet, the Puerto Nuevo Channel to 39 feet, and the Graving Dock Channel to 36 feet, establishing the existing Federal project.

The current study analyzes measures designed to improve the existing channel to better meet the needs of port users today. The economic analysis considers alternatives that will do the following:

- allow larger vessels to call San Juan Harbor,
- allow larger vessels to use San Juan Harbor more efficiently through increased vessel loading,
- allow existing vessels to use San Juan Harbor more efficiently through increased vessel loading,
- reduce vessel transit times within the port, and
- allow use of waterway transportation of LPG direct to San Juan rather than trucking of the product from the island's southern coast

1.2 Economic Appendix Overview

The Economics Appendix tells the story of the economic analysis for the San Juan Harbor Navigation Improvements Study from start to selection of a recommended plan. The appendix describes the

[1] Source: Waterborne Commerce Statistics Center, *State to State and Region to Region Commodity Tonnages Public Domain Database* (2015) and *Waterborne Commerce of the United States Calendar Year 2015 Part 2–Waterways and Harbors Gulf Coast, Mississippi River System and Antilles.*

[2] See Section 2 Socioeconomics for details.

[3] Passenger data from Puerto Rico Tourism Company, *Cruise Passenger Movement in Old San Juan (Calendar Year).*

[4] Source: AAPA Port Industry Statistics - Tables used: *NAFTA Region Port Cruise Traffic 2014-2016*, *NAFTA Region Port Cruise Traffic 2013-2015,* and *Caribbean Port Cruise Traffic 2013-2015* tables

[5] See Main Report for additional information about previous studies, authorizations, and construction events.

socioeconomic conditions in the study area, discusses the existing conditions and constraints at the port, lays out the commodity forecast, summarizes the future without-project condition, and presents study alternatives and alternative screenings conducted over the course of the study. Finally, economic analysis methodology and the future with-project condition will be discussed and net benefits of alternative plans will be presented to arrive at the recommended plan.

2 Socioeconomics

This section summarizes the socioeconomics of the San Juan-Carolina-Caguas Metropolitan Statistical Area (MSA), which includes San Juan, Puerto Rico. The parameters used to describe the demographic and socioeconomic environment include recent trends in population, employment, and income distribution for the Commonwealth of Puerto Rico and the forty municipalities that make up the immediate economic study area of San Juan Harbor. Environmental justice (EJ) issues are examined within a one-mile radius of the immediate study area, where surrounding communities may be directly impacted by the widening and deepening of San Juan Harbor. Figure 1 is a map of the municipalities that make up the San Juan-Carolina-Caguas MSA.

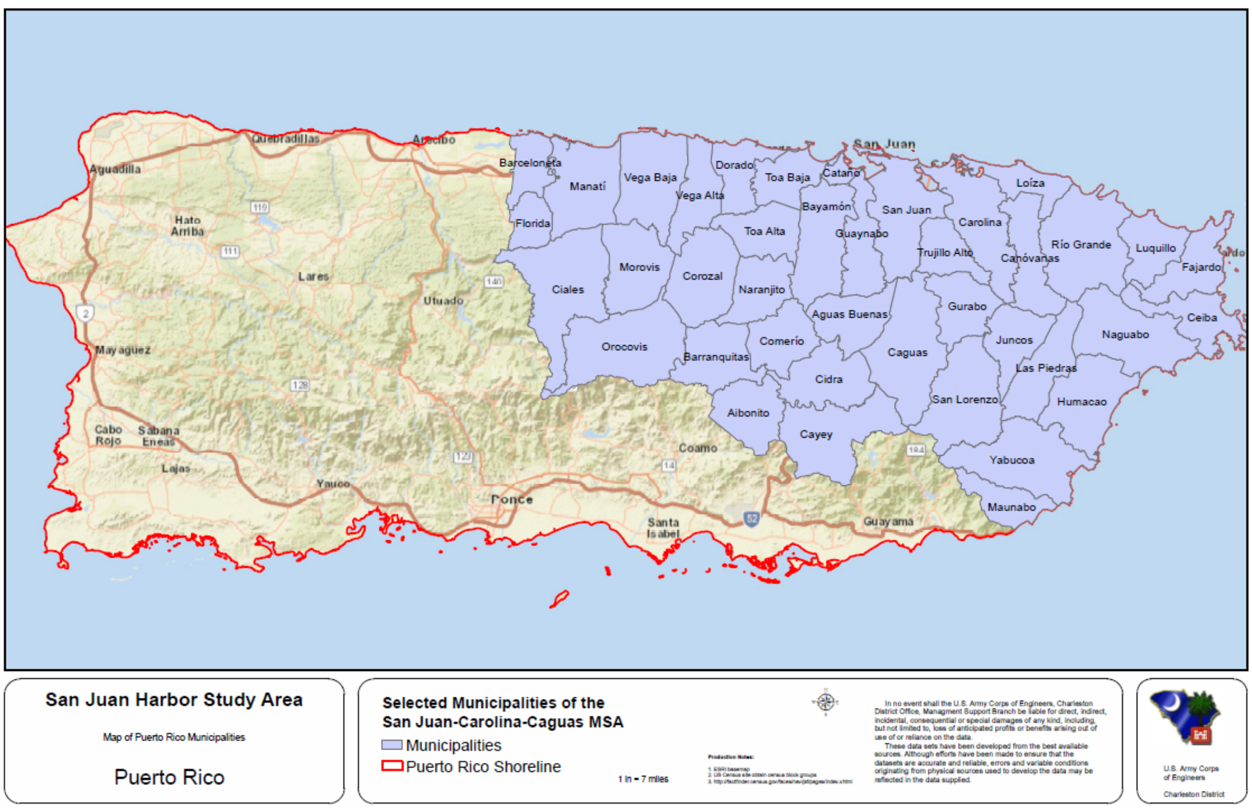


Figure 1. San Juan-Carolina-Caguas, PR Metropolitan Statistical Area (MSA)

Source: Graphic created by U.S. Army Corps of Engineers, Charleston District using data from OMB BULLETIN NO. 15-01 dated 15 July 2015.

2.1 Population

The following subsections outline historical and projected trends in population in Puerto Rico as a whole and in the island's most populous municipalities, the majority of which are part of the San Juan-Carolina-Caguas MSA.

2.1.1 Historical Population of Puerto Rico

The U.S. Census data reveals that the population of Puerto Rico experienced a net increase of 1,597,907 from 1950 to 2000. This constitutes an average annual increase of 1.5 percent, or 31,958 per year during that period. Figure 2 presents the 1950 – 2010 Decennial Census of Puerto Rico. The 2010 census shows a population of 3,725,789, a net loss of 82,821 or a 2.2 percent decline from the 2000 census.

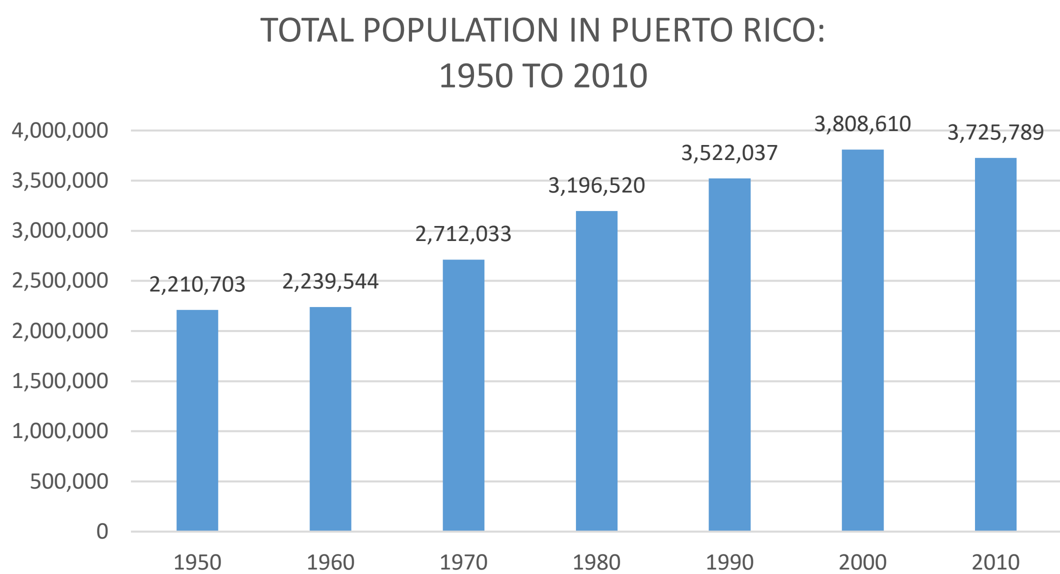


Figure 2. Puerto Rico Population Trends 1950-2010

Source: U.S. Census Bureau, 1910 to 2010 Decennial Census

2.1.2 Puerto Rico Population Projections

According to the statistics presented by the Puerto Rico Statistics Institute regarding U.S. Community Survey estimates, the population of Puerto Rico is expected to continue its downward trend in the period from 2010 to 2050. The decline in population is projected to reach 737,000 or 19.8 percent over the 40 year period. This constitutes an average annual decline of 0.5 percent, or 18,423 people per year. Compared to the 50 states of the U.S., Puerto Rico ranked as the area with the largest population loss. A surge in the out-migration of its citizens explains much of the decline. Nearly one-third of those born in Puerto Rico lived on the U.S. mainland in 2013[6]. Figure 3 presents population projections for Puerto Rico from 2010 to 2050.

[6] Based on 2013 data from the United Nations and U.S. Census Bureau as reported by the Pew Research Center in the August 11, 2014 article entitled “Puerto Rican Population Declines on Island, Grows on U.S. Mainland” by D’Vera Cohn, Eileen Patten and Mark Hugo Lopez.

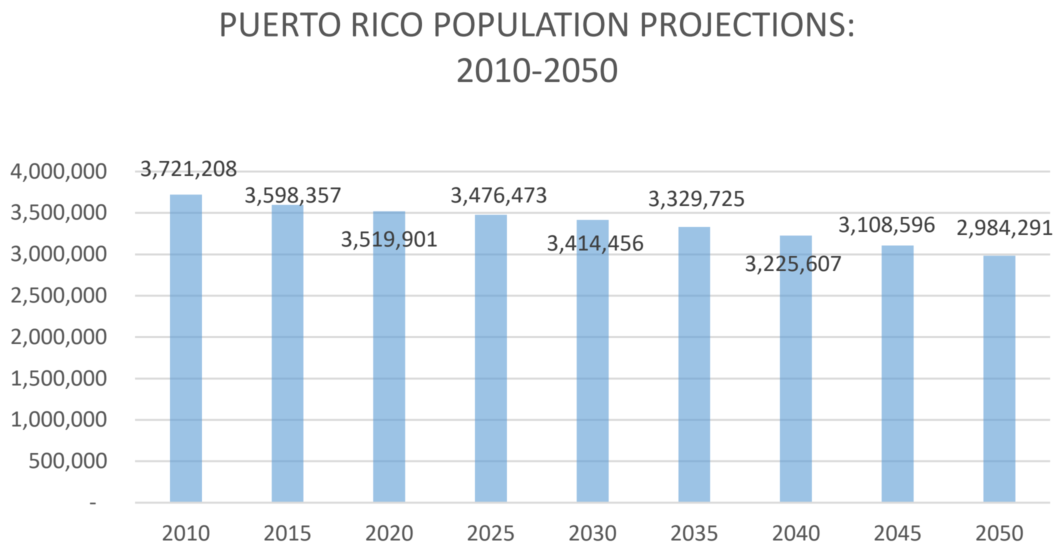


Figure 3. Population Projections for Puerto Rico
Source: United States Census Bureau, International database

2.1.3 Population Density

Based on the 2015 population estimate, population density in Puerto Rico is 988 people per square mile or 362 people per square kilometer. This makes Puerto Rico the fourth most densely populated state or territory in the USA. It is behind only Washington, DC (10,589 people per square mile); New Jersey (1,210 people per square mile); and Rhode Island (1,006 people per square mile). Puerto Rico is 10 times more densely populated than the United States as a whole.

Figure 4 presents, at a glance, the 2010 Census Profile for the U.S. Territory of Puerto Rico including population distribution by race, population distribution by sex and age, population density, and the decennial population from 1970 to 2010.

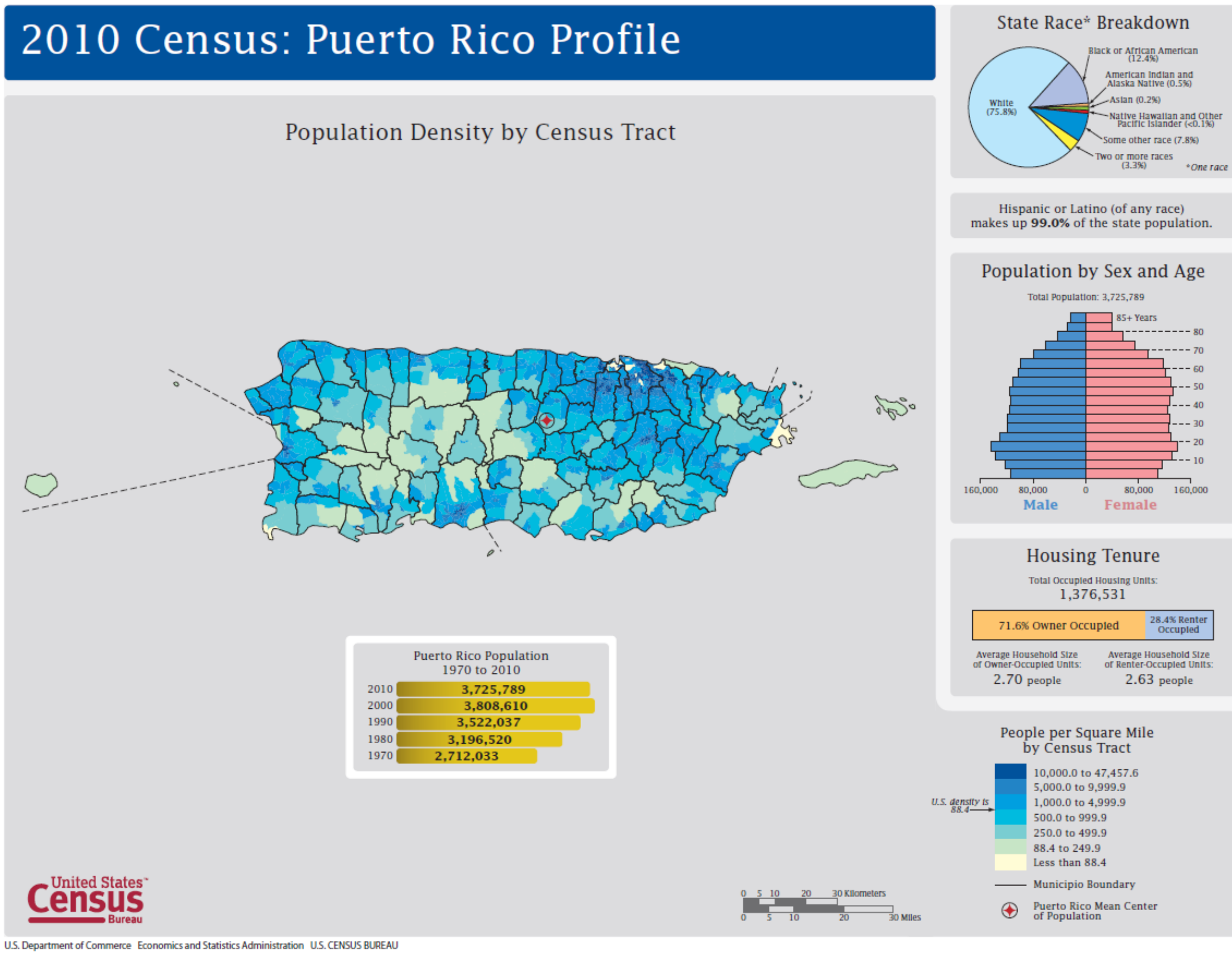


Figure 4. Commonwealth of Puerto Rico 2010 Demographic Profile

Source: United States Census Bureau, 2010 Decennial Census

2.1.4 San Juan Puerto Rico and Top Ten Municipalities by Population

In all, there are 16 statistical areas and 78 municipalities of the Commonwealth of Puerto Rico. The largest MSA is the San Juan-Carolina-Caguas MSA with a total population of 2,350,126 in 2010, approximately 63.0 percent of the total population of Puerto Rico. Figure 5 presents the 2010 census for the top ten municipalities by population. Of the ten most populous municipalities, all but three (Ponce, Arecibo, and Mayaguez) are located in the San Juan-Carolina-Caguas MSA.

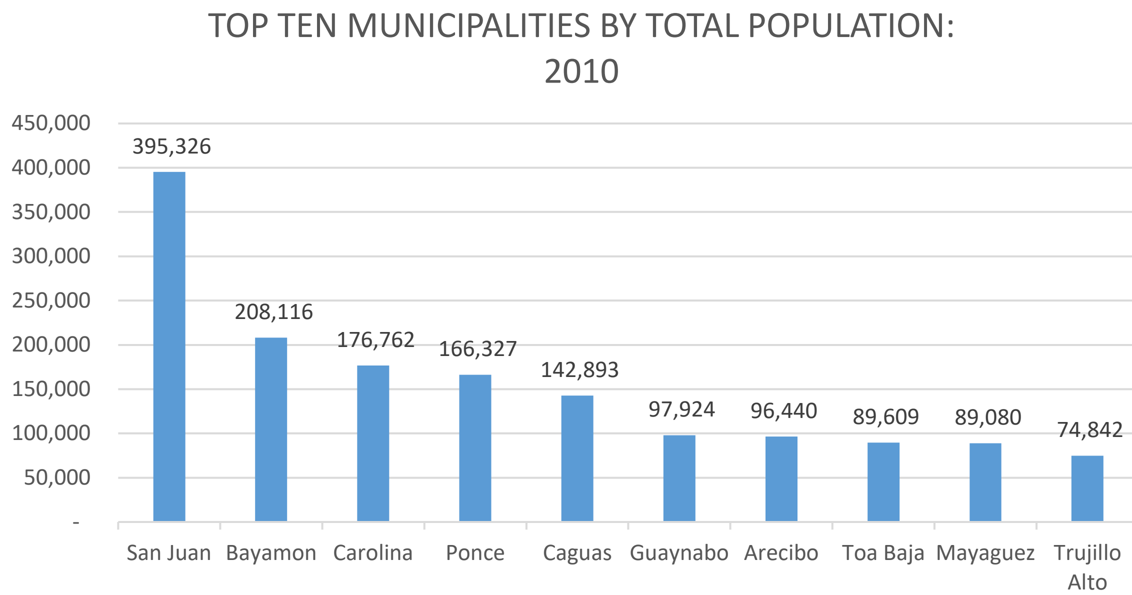


Figure 5. Largest Municipalities of Puerto Rico by Total Population
Source: United States Census Bureau, 2010 Decennial Census

2.2 Employment and Income

According to the U.S. Census Bureau's 2011-2015 American Community Survey, Puerto Rico employment totaled 1,063,350 with a median household income of $19,686 as shown in Table 1 and Table 2, respectively. The following subsections provide details on employment and income within the San Juan-Carolina-Caguas MSA and compare the MSA and its municipalities to Puerto Rico as a whole.

2.2.1 Employment by Sector

The economy of Puerto Rico is relatively concentrated in (1) educational services, and health care and social assistance and (2) retail trade with over 37 percent of jobs in 2011-2015 attributable to these two sectors combined. Of the major industry sectors within the Commonwealth of Puerto Rico, the educational services, and health care and social assistance sector employs the most persons, with 251,139 employees; and the retail trade sector follows with annual employment of 143,674. The San Juan-Carolina-Caguas MSA industry sectors yield employment distributions similar to those in Puerto Rico overall, which is expected given that over 68 percent of all jobs on the island are found within the San Juan-Carolina-Caguas MSA. Also of note, the arts, entertainment, and recreation, and accommodation and food services sector ranks fourth in terms of the percentage of people employed in the San Juan-Carolina-Caguas MSA, which is consistent with San Juan Harbor's prominence as a Caribbean cruise port and with the importance of tourism on the island (Table 1).

Table 1: Employment by Sector for San Juan-Carolina-Caguas MSA and Puerto Rico

Sector	San Juan-Carolina-Caguas MSA		Puerto Rico	
	Count	Percentage	Count	Percentage
Agriculture, forestry, fishing and hunting, and mining	4,493	0.62%	14,489	1.36%
Construction	40,302	5.53%	59,003	5.55%
Manufacturing	58,032	7.96%	96,303	9.06%
Wholesale trade	24,266	3.33%	29,562	2.78%
Retail trade	97,306	13.35%	143,674	13.51%
Transportation and warehousing, and utilities	28,769	3.95%	39,313	3.70%
Information	16,351	2.24%	21,251	2.00%
Finance and insurance, and real estate and rental and leasing	46,739	6.41%	58,154	5.47%
Professional, scientific, and management, and administrative and waste management services	77,548	10.64%	102,630	9.65%
Educational services, and health care and social assistance	165,680	22.73%	251,139	23.62%
Arts, entertainment, and recreation, and accommodation and food services	65,965	9.05%	93,899	8.83%
Other services, except public administration	41,540	5.70%	58,579	5.51%
Public administration	61,932	8.50%	95,354	8.97%
Total	728,923	100%	1,063,350	100%

Source: U.S. Census Bureau, 2011-2015 American Community Survey (ACS) 5-Year Estimates

2.2.2 Income and Poverty

The U.S. Census Bureau's 2010-2014 American Community Survey income and poverty data for selected municipalities of the San Juan MSA and for Puerto Rico are summarized in Table 2. Compared to national poverty levels (15.6 percent), the selected municipalities and the territory of Puerto Rico all had a higher percentage of people living below the poverty line than the U.S as a whole. Similarly, the median household income for all selected municipalities and Puerto Rico is much lower than the median household income in the U.S. As shown in Table 2, the median household income for Puerto Rico ($19,686) is 2.7 times lower than that of the U.S. ($53,482).

Table 2: Regional Income and Poverty

Geography	Median Household Income (in 2014 dollars)	Per Capita Income	Individuals Below Poverty Level
Bayamón	$24,597	$12,975	35.4%
Caguas	$24,083	$13,149	37.5%
Canóvanas	$20,494	$10,304	44.1%
Carolina	$28,660	$14,937	30.1%
Cataño	$18,625	$10,592	49.6%
Dorado	$27,924	$14,753	36.1%
Guaynabo	$34,450	$21,992	27.7%
Gurabo	$27,909	$14,523	34.7%
Manatí	$18,796	$10,390	45.3%
Naranjito	$17,478	$9,481	49.7%
San Juan	$22,266	$16,931	40.9%
Toa Alta	$29,183	$13,197	32.9%
Toa Baja	$23,642	$11,736	37.8%
Trujillo Alto	$30,687	$15,182	30.8%
Vega Baja	$16,625	$9,145	50.4%
Puerto Rico	$19,686	$11,331	45.2%
USA	$53,482	$28,555	15.6%

Source: U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, Selected Economic Characteristics

2.3 Environmental Justice (EJ)

Executive Order 12898, “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,” directs Federal agencies to address environmental and human health conditions in minority and low-income communities. The evaluation of environmental justice is dependent on determining if high adverse impacts from a proposed project would disproportionately affect minority or low-income populations in the affected communities.[7] Figure 6 presents the Environmental Justice communities by census blocks.

[7] See IFR/EA for discussion of potential adverse impacts from the recommended plan.

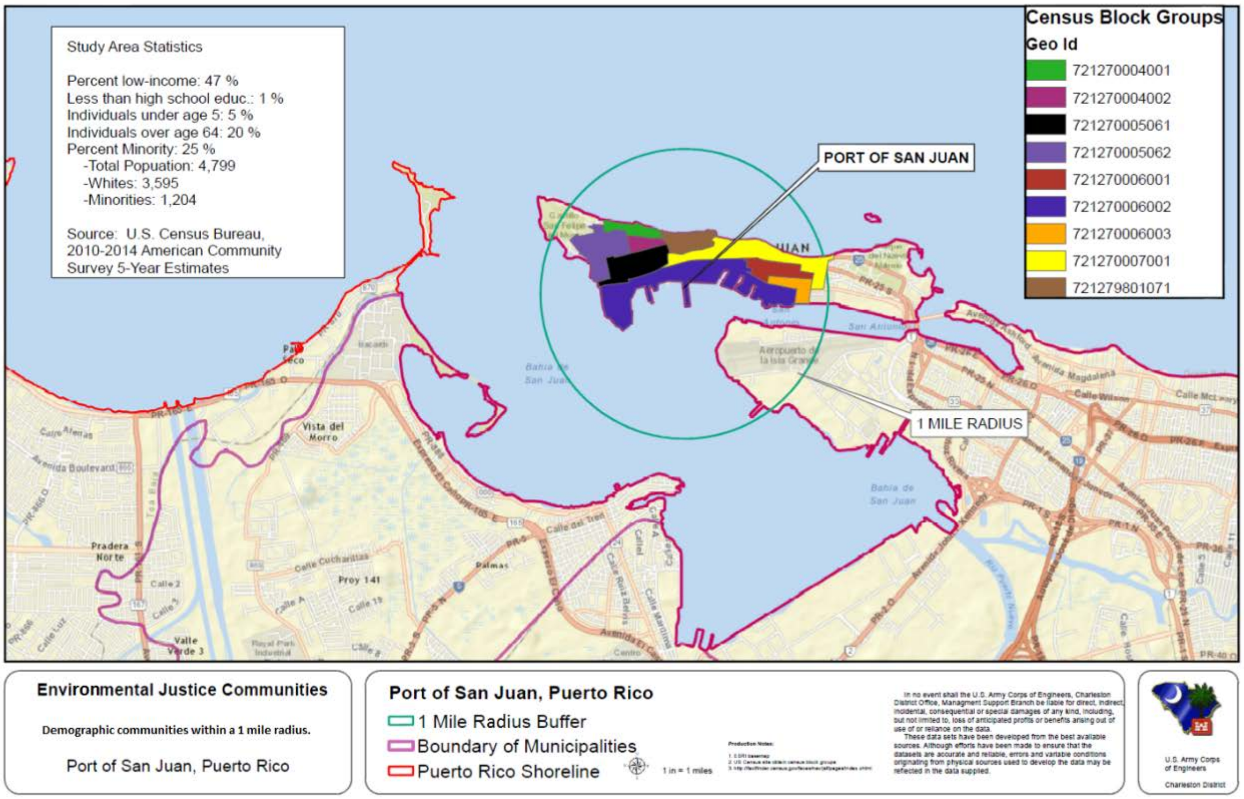


Figure 6. Environmental Justice Communities of San Juan Harbor

Based on the size of the proposed project, the region of interest for environmental justice analysis was determined to be the area within a one-mile radius of the project. The demographic characteristics of persons living within the buffer were identified and summarized using the digital Census block group layers for the San Juan Municipality. A geospatial analysis tool was used to create a one-mile buffer from the centerline of the San Juan Municipality. A summary of the population demographics (racial and socioeconomic data) for persons living within the one-mile buffer is presented in Table 3.

Table 3: Demographic and Socioeconomic Data of 15 Census Block Groups

	San Juan							
Census Block Groups	0005062	0004002	0006003	0006001	0005061	0006002	0004001	0007001
Total Population	963	756	245	714	500	595	332	694
White	805	489	144	519	409	501	200	528
% White	84%	65%	59%	73%	82%	84%	60%	76%
Minority	158	267	101	195	91	94	132	166
% Minority	16%	35%	41%	27%	18%	16%	40%	24%
% of individuals under age 5	7%	5%	0%	14%	5%	2%	0%	2.0%
% of individuals over age 64	9%	3%	11%	6%	7%	9%	12%	36%
% of households living under poverty level	31%	37%	86%	77%	31%	7%	71%	71%

Source: U.S. Census Bureau, 2010-2014 American Community Survey 5-Year Estimates

The U.S. Census Bureau's 2010-2014 American Community Survey estimates indicate that a total of 4,799 individuals live within one-mile radius of the project site. A total of 25 percent of this population (1,204 individuals) is minorities. Approximately 32 percent of San Juan Municipality's population is identified as belonging to minority a group. The population density of minorities living in the one-mile buffer area is lower than the rest of San Juan. The highest concentration of minority population is located in Census Block Group 0006003 (41 percent) and the lowest is in Census Block Groups 0005062 and 0006002 (16 percent).

Approximately 46.5 percent of households in the one-mile radius live below the poverty level compared to 42.3 percent in San Juan and 45.5 percent in the Commonwealth of Puerto Rico. Census Block Group 0006001 has the highest number of people living below poverty level (77 percent) compared to 7 percent for 0006002, which is the lowest. In all, households living under the poverty level for the one-mile radius are about the same compared to households in the immediate surroundings or municipalities.

As shown in Figure 6 above, the racial minority population within the one-mile radius (25 percent) is lower than that of San Juan Municipality (32 percent) and about the same compared to the Commonwealth-wide average (24.2 percent) for the same groups. Thus, the San Juan Harbor Improvements Project would not be expected to cause disproportionately high and adverse effects on any minority or low income populations in accordance with Executive Order 12898.

3 Existing Conditions at Port

The purpose of this section is to define how the port currently functions in serving its hinterland[8]. This includes discussions of San Juan Harbor's configuration, infrastructure, commodity throughput, vessel traffic, operations and navigational constraints, and trade routes.

3.1 Port Configuration, Infrastructure, and Overall Operations

Figure 7 below shows the existing port configuration, including channel names, federally authorized and federally constructed depths, user and dock names, and commodity types. Existing federally constructed channel widths and depths are displayed in Table 4, and approximate channel lengths are displayed in Table 5.

Figure 7: Overview of San Juan Harbor Existing Port Configuration and Commodities

[8] The San Juan Harbor hinterland is considered a captive hinterland and includes the entire island of Puerto Rico.

Table 4: Existing Federally Constructed Dimensions of San Juan Harbor

Channel Segment	Project Depth (feet)*	Width (feet)
Bar Channel (Cuts 1-3)	56 – 51	800
Entrance Channel (Cuts 4-6)	48 - 42	Range Varies
Anegado Channel	40	800
Army Terminal Channel	40	350
Sabana Approach Channel	32	Range Varies
Army Terminal Turning Basin	40	1450-foot Turning Diameter
Puerto Nuevo Channel	39	350
Puerto Nuevo Turning Basin	39	1015-foot Turning Diameter
Graving Dock Channel	36	350
Graving Dock Turning Basin	30	Range Varies
San Antonio Approach Channel	35	Range Varies
Cruise Ship Basin North	36	Range Varies
Cruise Ship Basin East	30	Range Varies
San Antonio Approach Channel	35	Range Varies
San Antonio Channel	35	Range Varies
San Antonio Channel Extension	30	Range Varies
Anchorage - E	36	Range Varies
Anchorage - F	30	Range Varies
*This represents the federally constructed depths. In the San Antonio and cruise ship areas of the harbor, surveys indicate that actual channel depths exceed federally constructed depths.		

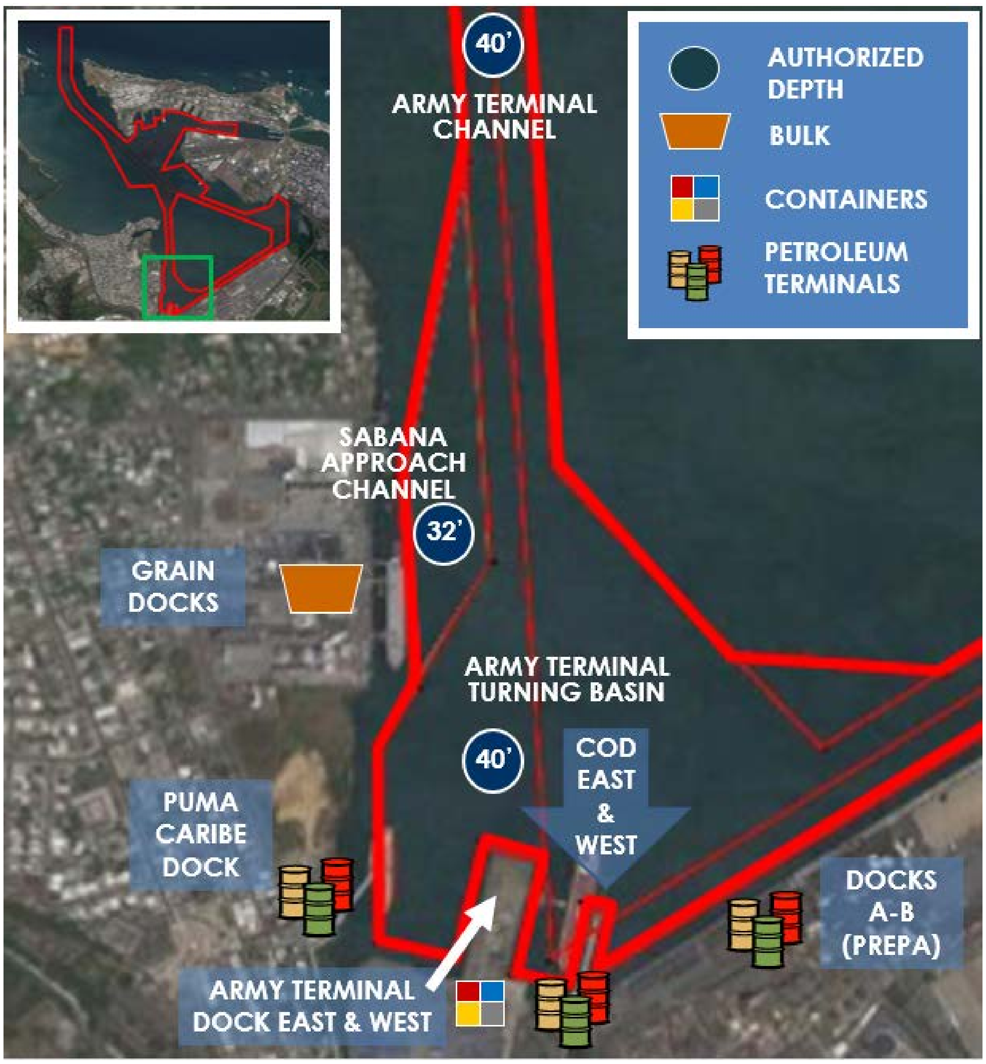
Table 5: San Juan Harbor Channel Lengths

Channel Name	Approximate Length (nautical miles)
Bar Channel & Entrance Channel	**1.1**
Anegado Channel	**1.2**
Army Terminal Channel	**1.3**
Puerto Nuevo Channel	**1.5**
Graving Dock Channel	**1.3**
San Antonio Approach Channel, San Antonio Channel, and San Antonio Channel Extension	**1.2**

The entrance to the harbor is composed of Cuts 1-6, which decrease in depth from 56 feet down to 42 feet as vessels pass into the protected waters of the inner channel and vertical motion concerns decline. Anegado Channel is the harbor's central inner channel and must be transited by all vessels bound for all terminals. Inside of the Anegado Channel, the harbor can be divided into five distinct areas identified by the letters A thru E in Figure 7 and described in more detail below.

A. The Army Terminal Turning Basin (ATTB) area is home to docks receiving petroleum products (liquid bulk), containerized cargo, and bulk grains. The Cataño Oil Dock (COD) East and COD West (collectively referred to as "COD" going forward) are leased from the Puerto Rico Land Authority for shared use by Tropigas, BTB Placco, Puma Energy Caribe (Puma), and Total Petroleum Puerto Rico (Total). Tropigas and BTB Placco bring propane and bitumen, while Puma and Total handle primarily gasoline, jet fuel, and diesel. Puma also operates its own private use dock at the ATTB's western edge. Landside storage facilities with significant capacity for storage of a variety of petroleum products are located nearby COD and the Puma Caribe dock. Product can also be supplied from these terminals to the Luis Muñoz Marín International Airport located approximately 10 miles east of San Juan Harbor. The Puerto Rico Electric Power Authority (PREPA) dock located on the southeastern side of the turning basin receives fuel oil #6 and diesel (fuel oil #2) for use in power generation at the San Juan and Palo Seco Power Plants. In addition to the petroleum docks, Trailer Bridge[9] brings containerized cargo to the Army Terminal dock located between the Puma dock and COD, and bulk grain cargos are received by various companies including Pan American Grain, ADM (Archer Daniels Midland), and Molinos de Puerto Rico at docks just north of the ATTB and adjacent to the Sabana Approach Channel. Figure 8 shows a more detailed view of the ATTB area docks and the vessels and cargos received in this part of the channel.

Figure 8: Army Terminal Channel and Army Terminal Turning Basin



B. The Puerto Nuevo Channel (PNC) area receives primarily containerized cargo with smaller amounts of liquid bulk (e.g., molasses, alcohol, etc.), general cargo, and ro-ro cargo. The liquid bulk arrives

[9] Trailer Bridge transports containers and vehicles on ro-ro and lo-lo barges on routes that include Jacksonville, FL-San Juan, PR; Jacksonville, FL-San Juan, PR-Virgin Islands; Jacksonville, FL-San Juan, PR-Santo Domingo, DR; and Puerto Plata, DR-San Juan, PR.

primarily at the eastern-most Puerto Nuevo docks (Piers L-O) on tankers and services a rum production facility in San Juan. Terminal operators along the channel include Luis A. Ayala Colón Sucrs., Inc.; Island Stevedoring; and Puerto Rico Terminals (formerly Tote Maritime Puerto Rico and Intership). Puerto Rico Terminals (PRT) has eight newly renovated cranes, can handle ro-ro and lo-lo cargos, and covers 122 acres of land, including warehousing and container storage space.[10] Figure 9 shows a more detailed view of the PNC area docks and the vessels and cargos received in this part of the channel.

Figure 9: Puerto Nuevo Channel and Puerto Nuevo Turning Basin

C. The Graving Dock Turning Basin (GDTB) area is located north of the Puerto Nuevo Channel and currently receives general cargo, containerized cargo, and ro-ro cargo (vehicles) on general cargo and ro-ro vessels. Figure 10 shows a more detailed view of the GDTB area docks and the vessels and cargos received in this part of the channel.

[10] Sources: (1) *Facilities.* Intership, http://www.intership.ws/facilities.html. Accessed 27 July 2017.
(2) Johnston, Grant. "TOTE Maritime, INTERSHIP Team to Create Puerto Rico's Leading Terminal Operator." Tote Maritime, 2 August 2016, https://www.totemaritime.com/home-news/tote-maritime-intership-team-create-puerto-ricos-leading-terminal-operator/. Accessed 27 July 2017.
(3) *Services*. Luis A. Ayala Colón Sucrs., Inc. http://www.ayacol.com/services.html. Accessed 27 July 2017.
(4) *Puertos Marítimos*. Puerto Rico Ports Authority, http://www.prpa.gobierno.pr/maritimo, Accessed 27 July 2017.

Figure 10: Graving Dock Channel, Graving Dock Turning Basin, and Puerto Nuevo Turning Basin

D. The Crowley terminal handles containerized cargo. The terminal is currently (2017) undergoing improvements, including construction of a 900 ft. by 114 ft. pier, dredging to accommodate new con-ro vessels (34 ft. design draft), paving 15 acres to be used for container stacking, and receipt of three new-build ship-to-shore gantry cranes.[11] See Figure 11 for detailed depiction of Crowley terminal location and cargo. Existing vessels calling this terminal are mainly tugs and barges, although the composition of the fleet calling this terminal is expected to change by the project base year (estimated at 2026) as part of the terminal improvements underway and described above.[12]

E. The San Antonio Channel (SAC) area is made up of the San Antonio Approach Channel (SAAC), San Antonio Channel (SAC), and San Antonio Channel Extension (SACE) and includes all of the port's cruise facilities. Home-ported cruise facilities are located south of the SACE at the Pan American Cruise Docks East and West (PAD-E and PAD-W) and in-transit cruise vessels utilize the berths north of the SAAC on the channel's western end. Ro-ro and bulk cargos are received at Piers 11-14 and the Navy Frontier Pier. Supply ships, known locally as "goletas", operate mainly out of Piers 8-10 and transship a variety of goods, equipment, and materials to smaller Caribbean islands. See Figure 11 for detailed depiction of SAC area docks, vessels, and cargo.

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[11] Source: Crowley News and Media. "Three New Gantry Cranes Manufactured for Crowley's Puerto Rico Terminal". Crowley Maritime Corporation, 01 March 2017, http://www.crowley.com/News-and-Media/Press-Releases/Three-New-Gantry-Cranes-Manufactured-for-Crowley-s-Puerto-Rico-Terminal. Accessed 27 July 2017.

[12] Expected fleet changes between the existing condition and base year will be discussed in Section 5.

Figure 11: San Antonio Channel and Crowley Docks

3.2 Commodities and Cargo

Puerto Rico relies heavily on waterborne commerce to supply the island with food, manufactured goods, fuels, and nearly all other items needed to power the economy and sustain the island's inhabitants and visitors. Waterborne commerce also facilitates the movement of goods off of the island, including goods produced in Puerto Rico and goods transshipped through Puerto Rico. Based on data from the Waterborne Commerce Statistics Center, in 2015, over 50 percent of all waterborne commerce taking place on the island passed through San Juan Harbor. In the same year, approximately 78 percent of all non-petroleum and non-coal cargo passing through Puerto Rico was shipped to/from San Juan Harbor, while about 35 percent of all petroleum and coal handled on the island passed through the port (Figure 12 and Table 6).

Figure 12: Ports of Puerto Rico

Table 6: Total Waterborne Commerce in Puerto Rico - 2015 (metric tons)

Year	Commodity Type	San Juan Harbor	Puerto Rico*	Percentage of Total to San Juan
2015	Petroleum and coal products	3,780,000	10,667,000	35%
	All other products	6,258,000	8,022,000	78%
	Total	10,038,000	18,688,000	54%

***** Puerto Rico includes San Juan Harbor throughput and throughput for Guanica, Guayanilla, Humacao, Jobos, Mayaguez, Ponce, Tallaboa, and Yabucoa. Las Mareas (Guayama) and Arecibo throughput quantities are unknown. Per information provided on the Puerto Rico Ports Authority's website, cargos at Las Mareas and Arecibo are mainly petroleum products and other fuels for use by the AES Corporation and Puerto Rico Electric Power Authority (PREPA) in power generation.
Source: Waterborne Commerce Statistics Center resources entitled *State to State and Region to Region Commodity Tonnages Public Domain Database* (2015) and *Waterborne Commerce of the United States Calendar Year 2015 Part 2– Waterways and Harbors Gulf Coast, Mississippi River System and Antilles*

In addition to cargo throughput, a significant number of cruise passengers pass through San Juan Harbor each year. This includes passengers participating in cruises that begin and end in San Juan (homeport passengers) and passengers participating in cruises for which San Juan is a stop on the cruise itinerary (transit passengers). Table 7 below shows that over the period from 2009-2015 the highest and second highest number of passenger movements occurred in the two most recent years for which data is available, 2015 and 2014, respectively, suggesting the industry is currently strong and growing in San Juan Harbor.

Table 7: Cruise Passenger Movement in San Juan Harbor 2009-2015 (by Calendar Year)

Calendar Year	Homeport Passengers	Transit Passengers	Total Passengers
2009	449,670	729,352	1,179,022
2010	545,395	645,660	1,191,055
2011	529,884	602,255	1,132,139
2012	409,337	642,382	1,051,719
2013	428,541	744,190	1,172,731
2014	436,117	928,180	1,364,297
2015	488,813	971,176	1,459,989

Source: Puerto Rico Tourism Company – Cruise Passenger Movement in Old San Juan (by Calendar Year)

3.3 Vessel Traffic

As an island, Puerto Rico relies on waterborne commerce to meet the needs of residents and visitors to the island. Thus, San Juan Harbor receives calls by vessels of all types and sizes carrying all types of cargo. The island's Caribbean location paired with the tourist attractions found in Old San Juan have led to many annual cruise calls to San Juan Harbor as well. Table 8 provides summary data on the estimated frequency of vessel calls by vessel type in 2014 based on Waterborne Commerce Statistics Center data.

Table 9 summarizes historical call counts for cruise vessels and cargo vessels by arrival draft based on information provided by the San Juan Bay Pilots. Because the channel depths throughout the harbor vary widely with only 30 feet of depth in the Graving Dock Turning Basin up to 40 feet in the Army Terminal Turning Basin, identification of potentially constrained calls requires additional information about the terminal for which these vessels are bound. Discussion of which vessels and terminals were determined to be depth-constrained and potentially benefitting is provided in the Existing Condition Operations and Navigational Constraints section that follows.

Note that based on anecdotal evidence and historical call data, it was determined that inbound cargo (i.e., the inbound leg of the call) was most relevant for identifying depth-constrained calls. Outbound calls tend to not use all existing channel depth and the vessels used for transshipment of consumer goods to smaller islands have maximum drafts (design drafts) well below the current channel depths.

Table 8: Estimated Number of Vessel Calls by Vessel Class 2014

Vessel Type	Call Count
Bulker	29
Container (Cont)	650
General Cargo (GC)	430
LPG-LNG	17
Miscellaneous (Misc)	238
RoRo	338
Tankers	180
Cruise	516

Notes: Number of calls here is likely understated as it may not include all calls that carried exclusively imports or exclusively exports (i.e., not both imports and exports).
General Cargo vessels include dry barges.
Tanker vessels include liquid barges.
Miscellaneous vessels are made up primarily of supply ships ("goletas").
Sources: Waterborne Commerce Statistics Center

Table 9: San Juan Harbor Historical Cargo and Cruise Traffic Arrival Drafts by Calendar Year

Year	Arrival Draft			Annual Count of Cargo or Passenger Calls
	<30 feet	30-34.99 feet	35+ feet	
2010	80%	19%	1%	2,301
2011	85%	14%	1%	2,785
2012	85%	13%	2%	2,838
2013	86%	11%	2%	2,777
2014	87%	11%	2%	2,663
2015*	91%	7%	2%	2,722

*Available 2015 data runs through 25 October 2015 only, so 2015 data was prorated to include an estimated 2 additional months of calls.
Source: San Juan Bay Pilots' Log

3.4 Existing Condition Operations and Navigational Constraints

The purpose of this section is to describe existing operations at San Juan Harbor with a focus on the navigational constraints and problems currently faced by specific vessel types in specific areas of the harbor. In cases where changes in port-specific variables or in the world fleet between now and the estimated project base year of 2026 are expected to alter operations or navigational constraints, then such future changes and their expected impacts will be included.

The identification of problems is part of the first step in the six-step planning process described in the Principles and Guidelines[13]. Channel dimension-related problems at San Juan Harbor occur under existing conditions and are projected to continue to occur under the future without-project conditions.

[13] The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies, Water Resources Council (February 3, 1983).

Problem statements important in framing the economic analysis as outlined in this appendix are the following:

1. Existing cargo shippers experience increased operation costs due to light loading, vessel size limitations, and congestion delays.
2. Puerto Rico Electric Power Authority (PREPA) experiences increased power generation costs in northern power plants due to inability to reliably bring LNG by ship to its proposed San Juan Harbor LNG terminal given the world fleet of available LNG tankers.
3. Existing cruise vessel operators experience increased in-port maneuvering costs due to channel and turning basin width and depth constraints.
4. Existing LPG importers on the island of Puerto Rico experience increased operating costs due to transporting LPG to San Juan from the southern coast by truck rather than by ship direct to San Juan Harbor.

Problem statement (1) above applies mainly to petroleum tankers transiting the Army Terminal Channel bound for terminals in the Army Terminal Turning Basin (ATTB) area of the harbor. The Puma Caribe Dock currently has terminal facilities capable of accommodating larger tanker vessels with capacities beyond those of petroleum tankers presently calling San Juan. However, due to the current Army Terminal Channel width of 350 feet and the 131-foot maximum beam limitations associated with this channel, these larger tankers with greater cargo capacities and lesser costs per metric ton even at the channel's current depth are unable to call San Juan because of channel width limitations, leading to transportation inefficiencies. Furthermore, the existing petroleum fleet must currently light load due to the existing Army Terminal Channel depth of 40 feet again demonstrating the transportation inefficiencies present in San Juan today and expected to continue into the future. Additionally, cruise vessels have priority over all cargo vessels, which can sometimes lead to cargo vessel delays on arrival.

Problem statement (2) above applies to PREPA's future plans to convert from use of fuel oil #6 and diesel (fuel oil #2) to use of LNG in order to meet the utility's goals to comply with Commonwealth and Federal environmental regulations governing power plant emissions (namely EPA Mercury and Air Toxics Standards, or MATS) and to lower the cost of power generation to help stimulate economic growth in Puerto Rico. The Army Terminal Channel width is the limiting factor here as the current width can only accommodate the smallest LNG and combination gas tankers in world fleet, of which there are a limited number and by which a relatively frequent call would be required to meet PREPA's demand. Currently, inefficiencies exist in power generation in Puerto Rico. See Section 3.5 for additional details.

Problem statement (3) above applies primarily to cruise vessels calling the northern cruise docks (Piers 1-4). Due to limited usable width in the shallow Cruise Ship Turning Basin East, these vessels must take extra time to complete the outbound turn to avoid shallow portions of the turning basin.

Problem statement (4) above applies to LPG tanker vessels that are currently unable to enter the Graving Dock Turning Basin to call the future LPG terminal at Piers 15 and 16. LPG is currently imported to Puerto Rico via Peñuelas, a port on the Puerto Rico's southern coast, and then trucked north the San Juan metro area, increasing the transportation costs of getting the LPG from the origin to the demand center in San Juan and thus creating transportation inefficiencies.

Further details related to operations and constraints are included in the subsections that follow.

3.4.1 General Operational Considerations

The following items affect the operations of all vessels using San Juan Harbor:

- Cruise ship priority – Cruise (passenger) vessels are given priority over all other vessel types on both arrival and departure from San Juan Harbor. The San Juan Bay Pilots shift the arrival and departure times of non-cruise vessels to accommodate cruise vessels if needed.[14]
- Safety and security zones – A safety zone of 100 yards when in transit (300 feet) and 50 yards when at dock (150 feet) is required for tanker vessels carrying LPG and LNG commodities. Similarly, a security zone of 100 yards when in transit (300 feet) and 50 yards when at dock (150 feet) is required around cruise vessels. A safety zone is created when the cargo onboard a ship is potentially hazardous and is designed to protect those not on the ship from any harm that the cargo could cause. A security zone is designed to protect what is on the ship, in this case the passengers on board of the cruise vessel.[15]
- Meeting and overtaking – From Buoy 11 to Buoy 13 (straight stretch in Anegado Channel between Coast Guard station and Crowley dock), two vessels may meet while transiting the channel simultaneously (one inbound & one outbound vessel). See Figure 7. No meeting is permitted from the harbor entrance to Buoy 11, beyond Buoy 13, or anywhere else outside of Anegado Channel. Additionally, there is no overtaking permitted ever in any part of the harbor.
- Small tidal range – Tidal datums computed from NOAA Tide Station 9755371 and referenced to Mean Sea Level (MSL) and Puerto Rico Vertical Datum 2002 (PRVD02) indicate the mean tide range is 1.11 feet and the spring tide range is 1.57 feet. This is a relatively small tidal range and there is no indication from stakeholders that tide is typically used to allow vessels to load deeper than is possible at mean tide or that vessels routinely wait on tide at the harbor entrance. Furthermore, because the difference between the mean tide level at 0 feet and mean high water at 0.55 feet is less than a foot and because sailing draft data is often rounded to the nearest foot, any use of some small tide would be very difficult to capture in the economic analysis. Thus tide is not considered a factor in the economic analysis and will not be discussed further in the appendix. See Engineering Appendix for additional details regarding tidal range.
- Port rules dictate minimum under keel clearance (UKC) requirements as follows[16]:
  - One foot of under keel clearance for double-hulled vessels
  - Two feet of under keel clearance for single-hulled vessels

  Actual observed under keel practices will be discussed in greater detail in each vessel type-specific section below.
- Strong wind, wave, and current conditions – The effects of these conditions are particularly notable in the Bar Channel, where prevailing winds from the East at 25-30 knots can increase the effective beam of the ship and the combination of wind, waves, and currents causes ships to roll and heel increasing the draft of the ship. Additional discussion and details related to wind, wave, and current conditions is provided in the Main Report and the Engineering Appendix.

[14] Source: Rules provided by San Juan Bay Pilots - Reglamento 6763 11 de diciembre 2004, Regla 31.
[15] LNG safety zones are covered by 33 CFR 165.
[16] Source: Rules provided by San Juan Bay Pilots - Reglamento 6763 11 de diciembre 2004, Regla 20

3.4.2 Petroleum Tanker Operations and Navigational Constraints

According to the U.S. Energy Information Administration (EIA), approximately 80 percent of the energy used in Puerto Rico comes from petroleum with the transportation and electric power sectors being the island's top consumers of petroleum products as of 2014[17]. Because Puerto Rico neither produces nor refines crude oil, all petroleum consumed on the island must be imported[18]. The main ports through which these products are generally imported include San Juan Harbor in the north and Ponce and Guayanilla in the south[19].

Petroleum tankers calling San Juan typically call docks in the Army Terminal Turning Basin (ATTB) area of the channel where the federally constructed channel depth is 40 feet. (See Section 3.1 Port Configuration, Infrastructure, and Overall Operations above for overview of the ATTB area.) Vessels reach these docks by entering the harbor at the Bar Channel and then transiting Anegado Channel to Army Terminal Channel to arrive at the ATTB docks. On departure the petroleum tankers utilize the ATTB to turn such that the vessels can exit by the same path through which they entered, following the Army Terminal Channel to the Anegado Channel and proceeding to the harbor entry/exit point.

The main docks used by petroleum tankers are COD, the Puma Caribe dock, and the PREPA dock. The current berthing area dimensions and expected base year berthing area dimensions for these docks are displayed in Table 10. As shown in the table, the only docks that appear to have the potential to benefit from deepening are COD and the Puma Caribe dock. At an existing depth of 28 feet, the PREPA dock is currently approximately 12 feet shallower than the existing channel depth and there is no indication that between now and 2026 or in the future without project condition (FWOP) that these berths would be deepened to beyond their current depths.

[17] Source: *Puerto Rico Territory Energy Profile.* U.S. Energy Information Administration (EIA). July 2017, https://www.eia.gov/state/print.php?sid=RQ. Accessed 27 July 2017.
(1) U.S. EIA, International Energy Statistics, Petroleum, Consumption, Puerto Rico, Total Petroleum Consumption, Quadrillion Btu, 2009-13.
(2) U.S. EIA, International Energy Statistics, Total Energy, Total Primary Energy Consumption, Puerto Rico, 2008-12.
(3) U.S. EIA, International Energy Statistics, Puerto Rico, Petroleum, Consumption, Total Petroleum Consumption and individual products, quadrillion Btu, 2010-14.

[18] Source: *Puerto Rico Territory Energy Profile.* U.S. EIA. July 2017, https://www.eia.gov/state/print.php?sid=RQ. Accessed 27 July 2017.
(1) U.S. EIA, Puerto Rico Territory Energy Profile, Data, Reserves & Supply, and Imports & Exports, accessed March 8, 2016.
(2) U.S. EIA, International Energy Statistics, Petroleum, Total Imports of Refined Products, Puerto Rico, 2008-13.

[19] Source: U.S. EIA, Petroleum & Other Liquids, Company Level Imports Archives, 2013-15.

Table 10: Approximate Berthing Area Dimensions at Petroleum Docks (all dimensions in feet)

Dock Name	HarborSym Dock Name	Dock Capacity – Maximum Number of Vessels	Estimated Existing Depth (2016)	Expected Depth - Base Year (2026)	Estimated Length (Existing 2016 & Base Year 2026)
COD	Puma_COD	2	38*	40	1200
Puma Caribe Dock	Puma_COD	1	40	40	800
PREPA Dock	DocksA-B	2	28	28	1200

Sources: Puerto Rico Ports Authority; Total Petroleum Puerto Rico Corp letter received 16 November 2015; conversations with Puma Energy Caribe representatives

Note: COD and the Puma Caribe dock will have a depth at least equal to the current channel depth of 40 feet. It is possible that this will be achieved by terminal operators piggybacking on a future USACE O&M contract to dredge berthing areas.

* In December 2017, COD berths were dredged to a depth of at least –40 feet mllw.

Based on information received from port users and historical vessel call data, the two principal constraints existing in San Juan Harbor and impacting the operations of petroleum tankers are:

1.) the current 350-foot width of the Army Terminal Channel and
2.) the current 40-foot depth in the Anegado and Army Terminal Channels.

The width constraint prevents a partial transition of fleet from the existing Medium Range (MR) and Long Range 1 (LR1) tankers to include some calls by Long Range 2 (LR2) tankers. The depth constraint impacts the existing fleet of MR tankers and LR1 tankers, many of which light load to be able to use the channel at its current 40-foot depth. The depth constraint would also impact LR2 tankers which, assuming the channel width issue were addressed and these vessels were able to call San Juan, would be required to light load significantly.

Table 11 outlines the MR, LR1, and LR2 tanker classes and existing channel constraints faced by each. The next three subsections provide details of the two aforementioned constraints as they pertain to the MR, LR1, and LR2 tanker classes.

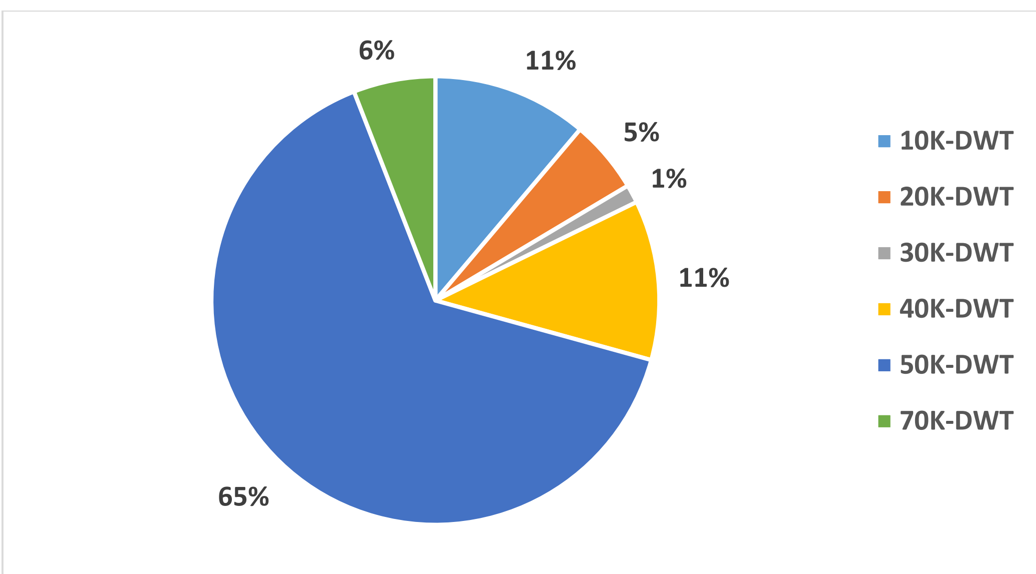
Table 11: Existing Channel Constraints Experienced by Petroleum Tankers (all dimensions in feet)

Existing Channel Constraints Experienced by Petroleum Tankers (all dimensions in feet)									
Tanker Description	DWT range	LOA		Beam		Design Draft		Can call San Juan under existing conditions?	Constrained by channel:
		Min	Max	Min	Max	Min	Max		
MR[1]	35-55K	570.7	654.7	88.6	105.9	34.45	44.29	Yes	Depth[2]
LR1[3]	55-85K	700	796.6	105.7	131.2	38.55	48.23	Yes	Depth
LR2[4]	85-130K	748	869	134.8	150.9	37.99	55.02	No - limiting factor is channel width	Width and Depth

1) MR dimensions come from fleet of 40K and 50K DWT tankers that called San Juan from 2010-2015 (WBC Statistics Center and San Juan Bay Pilots' Log).
2) Note that for MR tankers, only 50K DWT tankers (45-55K DWT) were considered to be constrained. For analysis purposes, 40K DWT tankers were not considered to be constrained by the current channel dimensions.
3) LR1 dimensions come from fleet of 60K, 70K, and 80K DWT tankers that called San Juan's Puma_COD dock from 2010-2014 (WBC Statistics Center).
4) LR2 dimensions come from world fleet of 85K to 130K DWT tankers with beams >131 feet. Out of over 1000 vessels in the world fleet, only 4 have beams <131 feet. Beam of > 131 feet was used as the criteria of identifying LR2 vessels of relevance to this study because it defines the constraining factor.

Figure 13 summarizes calls by tankers to Puma_COD by displaying the percentage of import calls attributable to each vessel class over to the period from 2013 through October of 2015. As the graph shows, over 75 percent of the import calls to Puma_COD in this period were by 40K-DWT and 50K-DWT class tankers, or MRs. These vessels carry primarily gasoline, jet fuel, and diesel fuel.

Figure 13: 2013-2015 Import Calls by Tankers to Puma_COD by Vessel Class



Notes: Includes all commodities bound for Puma_COD on tanker vessels. Tank barges are included. Liquid gas tankers are excluded. Data from 1 January 2013 through 25 October 2015.
Source: San Juan Bay Pilots' Log

Based on historical Pilots' Log data and anecdotal evidence from port users, the under keel clearance for petroleum tankers is typically 2 feet, meaning the maximum sailing draft of tankers at the existing Army Terminal Channel depth of 40 feet is 38 feet. A letter provided by the San Juan Bay Pilots to Puma Energy Caribe in November of 2015 indicated that the pilots would increase the maximum allowable draft of vessels bound for the Puma Caribe dock to 39 feet dependent upon the winds, tides, and any other factors at the discretion of the pilots. However, Pilots' log data from 25 October 2015 thru 30 September 2016 (11 months) shows only two petroleum tanker calls (both in 2016) with recorded drafts of 39 feet and all other calls with drafts of 38 feet or less. Thus, as a general rule, a minimum of 2 feet of under keel clearance is still needed in practice for petroleum tankers calling San Juan's ATTB berths. This assumption of 2 feet of under keel is carried throughout the economic analysis of petroleum tankers.

3.4.2.1 Medium Range (MR)

Users of COD provided a letter to the USACE-SAJ on 16 November 2015 stating that the existing fleet of MR petroleum tankers calling COD could use up to 44 feet of channel depth assuming a maximum sailing draft of 42 feet plus 2 feet of under keel. For the purposes of this analysis, tankers with deadweights (DWT) from 35,000 metric tons up to 55,000 metric tons will be considered MR tankers. Additionally, the analysis assumes that of the MR tankers, only those with a DWT in the 45,000-55,000 metric tons range (called "50K-DWT" going forward) are depth-constrained and have the potential to benefit from deepening. This assumption is based on the fact that when loaded with the most common petroleum products arriving at these docks (i.e., gas, diesel, jet fuel, or a mixture of these), only about 2 percent (or 1 vessel) of 40K-DWT tankers that called San Juan from 2010-2015 would have the capacity to load beyond 38 feet of depth.

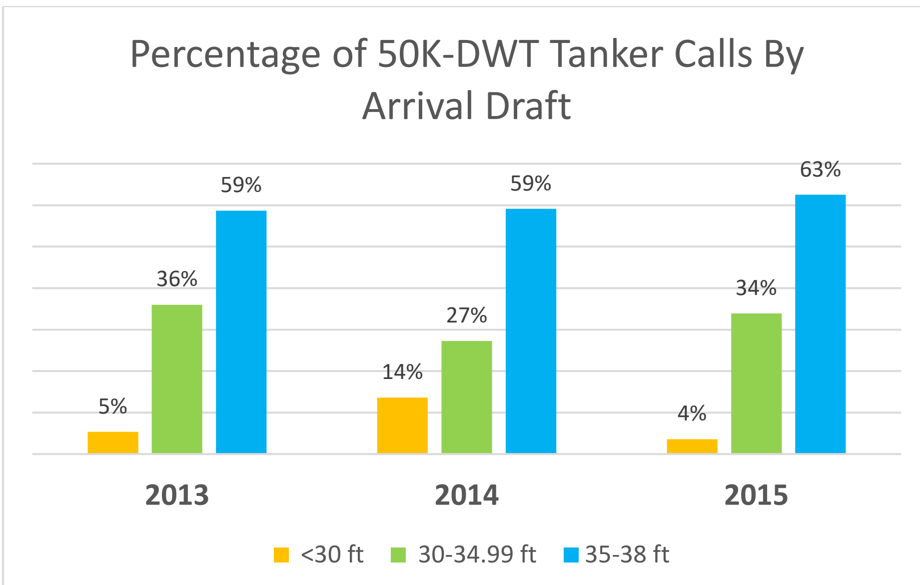
The COD berths were last dredged in 2012 (prior to 2017 dredging discussed below) by "piggybacking" on the USACE port maintenance dredging project, at which time the berths were dredged to 38 feet. Since that time, trade routes and "supply mode" associated with petroleum shipments to San Juan have changed. According to information received from port users, the previous supply mode consisted of loading ships at the Hovensa Refinery in Saint Croix and then using combined cargo ships (with all grades of product) to deliver shipments to San Juan terminals on an almost weekly basis. With such a frequent shipment and a short distance (only 120 nautical miles from Limetree Bay, St. Croix to San Juan) MR ships could be partially loaded and/or smaller ships could be used. Thus, the full 40-foot channel depth was not needed. Because the Hovesna Refinery in St. Croix closed in 2012, operators have had to alter their practices to adjust to ships now coming from Europe (gasoline, jet fuel), Canada (ULSD), Venezuela (jet fuel), and the Middle East (jet fuel) with larger cargo loads and at deeper sailing drafts.

Consistent with this shift in supply, dredging of the COD berths was completed in December of 2017 after the USACE O&M event. The COD berths were dredged to a depth of at least –40 feet mllw and now match the federally authorized Army Terminal Channel depth of 40 feet. In addition to the increased berthing area depth, users are currently constructing additional petroleum storage tanks to be able to accommodate offloading more product per call. Thus, it is appropriate to include the 40-foot berthing area depth in the FWOP and to assume that a portion of future tanker calls to COD will use all currently available Federal channel depth and could potentially utilize and benefit from Federal channel depths beyond 40 feet.

The economic analysis assumes that by the project base year of 2026 petroleum vessel calls to COD over the period from 2010-2014 (data from the Waterborne Commerce Statistics Center) that reported inbound sailing drafts of 35+ feet become the pool of calls that will be utilizing all available channel depth and/or loading to the maximum allowed based on that particular vessel's volumetric capacity constraints and DWT capacity constraints as determined by the vessel's physical dimensions and density of cargo onboard. This assumption is based on the fact that the berthing area depths at COD now match the existing Army Terminal Channel depth of 40 feet. In order to account for loading pattern changes between the 2010-2014 data used to establish the existing condition and the base year, adjustments were made to the tonnage per call (parcel size) and the annual number of calls since vessels will be bringing the same total amount of cargo but loading slightly deeper by the project base year than they were able to prior to the 2017 berthing area dredging. Thus, the channel depth is the benchmark for the depth constraint driving the future with- and without-project conditions used in the economic analysis.

Figure 14 below outlines historical arrival drafts of 50K-DWT tankers to Puma_COD.

Figure 14: Historical 50K-DWT Tanker Calls to Puma_COD by Arrival Drafts



Source: San Juan Bay Pilots' Log for 2013-October 25 2015

3.4.2.2 Long Range 1 (LR1)

For the purposes of this study, LR1 tankers include 60K-DWT, 70K-DWT, and 80K-DWT vessels. The historical record shows that LR1s have typically called the PREPA and Puma_COD terminals.

In the period from 2013-2015, these vessels frequently called the PREPA terminal at a sailing draft of 26 feet, which is much shallower than the current Army Terminal Channel depth of 40 feet but is consistent with the 28-foot berthing area depth displayed in Table 10 (above). In the existing condition, these vessels bring fuel oil #6 and fuel oil #2 (diesel) to the PREPA dock for use by PREPA (Puerto Rico Electric Power Authority) in power generation. By the project base year of 2026, it is expected that fuel oil #6 will be phased out in order for PREPA to comply with the EPA's Mercury Air Toxins Standards (MATS). Further discussion of PREPA's plans and power generation in San Juan and Puerto Rico will be provided later in the appendix.

As Figure 13 (above) demonstrates, 70K tankers made up a relatively modest 6 percent of all import calls to Puma_COD over the 2013-2015 period. Data from the San Juan Bay Pilot's Log indicates that approximately 72 percent of the 70K-DWT tanker calls bound for Puma_COD in that timeframe had arrival drafts between 30 and 36.99 feet, while 22 percent arrived drafting 37-38 feet. For LR1 tankers, the analysis assumes that 70K tankers drafting less than 37 feet are not depth-constrained, while vessels drafting 37 feet or greater would potentially load deeper with more depth.

The limited use of these LR1 vessels calling Puma_COD compared to the MR tankers in the existing condition may be, at least in part, due to the following:

- Availability in the world fleet – As of 2017, over 2,000 35K-55K tankers are available/being built in the world fleet, while less than 500 LR1 vessels were available/being built.
- Only one berth in the Puma_COD terminal equipped to handle LR1s versus three available to handle MRs.
- Lack of depth in San Juan – LR1s often have deeper design drafts than MRs. However, at San Juan's current 40 foot depth, the additional draft capacity of LR1s over MRs can not necessarily be used which diminishes the advantages associated with using LR1s over MRs.

3.4.2.3 Long Range (LR2) Tankers

Currently, Long Range 2 (LR2) tanker vessels are not able to call San Juan's Army Terminal Turning Basin berths because the current Army Terminal Channel width of 350 feet will not allow for vessels with beams greater than 131 feet to safely transit per the judgment of the San Juan Bay Pilots. Early in 2016, Puma Energy Caribe requested that the San Juan Bay Pilots bring these vessels into the harbor at the current 350 foot width and current 40 foot depth of the Army Terminal Channel. The San Juan Bay Pilots declined this request and stated in a letter that a channel width of at least 380 feet would be needed to make transit of these vessels possible. Puma Energy Caribe has stated clearly that if permitted the company would bring these vessels into San Juan today at the current channel depth of 40 feet (i.e., with no deepening). A rough calculation performed by USACE economists early in the study process indicated that based on Economic Guidance Memorandum 15-04: Deep Draft Vessel Operating Cost FY 2013, the per ton operating cost spread over the most common petroleum tanker route (Baltic region/Europe to San Juan) of loading an LR2 to 38 feet was less than that of loading a MR to 38 feet even though the LR2 would be significantly light loaded. Thus, the limiting factor for a partial transition away from MRs and to LR2s is the channel width constraint. If the transition were to occur, then these LR2 vessels would also benefit from any channel deepening beyond the current 40-foot depth. A similar simplified preliminary calculation indicated that the vessel operating cost per ton of using an LR2 on the most common tanker route would be less than that of using an LR1 at sailing drafts of 38 feet (current channel depth of 40 feet) up to 43 feet (deepest alternative depth of 45 feet). Furthermore, over 1,000 LR2s with beams greater than 131 feet exist or were under construction in the world fleet as of 2017, which is more than double the number of LR1s available in the world fleet, making LR2s a more efficient and available option than LR1s.

While it is assumed that the current operating parameter of 2 feet of UKC as set by the San Juan Bay Pilots will be applicable to the new LR2, it may be possible that more UKC will be needed once the vessel is operated through real-world conditions. If this were to occur then either the Pilots would institute an operational restriction to limit the LR2 vessel draft or additional depth would need to be built into the project.

3.4.2.4 Tanker Trade Routes - Imports

Petroleum products imported to San Juan come from a variety of locations. The Baltic Seas region, including Estonia, Lithuania, and Latvia, has historically been an important source of petroleum products arriving in San Juan, especially gasoline as well as some diesel fuel. Jet fuel and diesel fuel often come from Canada and Venezuela. Historically, some other Caribbean islands have also served as sources of petroleum products for San Juan, including Curacao (Bullen Bay) and St. Eustatius. The various geographic sources of petroleum products shown in the historical record are factored into the weighted average route distances used for this analysis and discussed in further detail in Section 8.1.6.

3.4.2.5 Transshipment

In addition to the petroleum imports that have been the focus of this section so far, petroleum companies in the ATTB area also transship a small amount of petroleum products on a combination of barges and small tankers (DWT of 10,000 metric tons) to other cities on the Puerto Rican coast to service PREPA plants at those locations and to other Caribbean islands such as St. Thomas, USVI[20]. Given that the vessels used for these operations are small and thus have relatively shallow design drafts, the existing channel easily accommodates these vessels.

3.4.3 Cruise Ship Operations and Navigational Constraints

San Juan Harbor is a popular cruise port and serves as a homeport location for Royal Caribbean as well as a transit stop for many of the cruise industry's major companies, including Royal Caribbean, Disney, Celebrity, Norwegian, Carnival, and Crystal. In 2002, the 1023-foot long Voyager class of cruise vessels with a maximum draft of approximately 29 feet were the largest cruise vessels in the world. Since that time the cruise industry has continued to evolve to include the larger Freedom of the Seas class of vessels introduced in 2006, the Quantum of the Seas class of vessels introduced in 2014, and the Oasis of the Seas class which was launched in 2009 and is currently the world's largest cruise ship in terms of passenger capacity and gross tonnage (GT).[21] Figure 15 shows the evolution in cruise ship sizes pictorially. In 2017, San Juan Harbor received calls by Freedom class, Quantum class, and Oasis class vessels. For the purposes of this analysis, cruise vessels calling San Juan were divided into eight classes based on passenger capacity. Summary statistics associated with each of those eight classes are displayed in Table 12. These summary statistics reflect the physical characteristics of the cruise fleet calling San Juan in the existing condition (including incorporation of data from 2017 cruise ship schedule) as well as that expected to call in the project base year of 2026.

[20] Resupply of PREPA plants at different port cities across Puerto Rico is done using barges on approximately a weekly basis. Calls to St. Thomas typically have a frequency of approximately every 6 weeks.

[21] Vessel Tracking. "Biggest cruise ships (industry overview)". Vesseltracking.net, http://www.vesseltracking.net/article/biggest-cruise-ships. Accessed 27 July 2017.

Figure 15: Evolution of Cruise Vessel Sizes

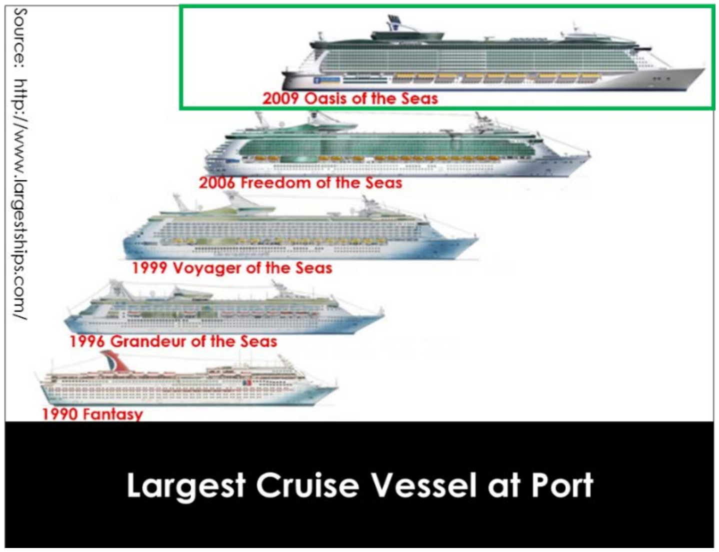


Table 12: Cruise Ship Summary Statistics for San Juan Harbor by Vessel Class

Vessel Class Name	Minimum Passenger Capacity	Average Passenger Capacity	Maximum Passenger Capacity	Average LOA (feet)	Average Beam (feet)	Average Design Draft (feet)	Average Gross Tonnage (metric tons)
Cruise1	28	174	296	380	55.1	14.93	8,019
Cruise2	388	649	960	646	86.0	21.76	34,406
Cruise3	1,140	1,584	2,014	798	102.8	25.23	63,947
Cruise4	2,106	2,358	2,450	922	105.7	26.16	82,566
Cruise5	2,496	2,772	3,013	970	109.4	26.82	95,281
Cruise6[1]	3,129	3,544	3,840	965	117.7	27.52	114,137
Cruise7[2]	4,000	4,423	5,300	1,091	127.8	28.40	146,930
CruiseOasis[3]	6,320	6,347	6,360	1,183	154.2	30.51	225,842

[1] The Adventure of the Seas cruise ship homeports at the Pan American Cruise Dock located in San Juan Harbor's San Antonio Channel and falls into the Cruise6 classification above.
[2] Cruise7 includes the Freedom and Quantum classes of ships.
[3] CruiseOasis includes Oasis class of ships.
Note: Data includes all vessels anticipated to be calling San Juan by 2026. Based on 2010-2014 cruise fleet plus 2017 cruise schedule provided by the Puerto Rico Ports Authority and Continental Shipping (cruise ship agents in San Juan).

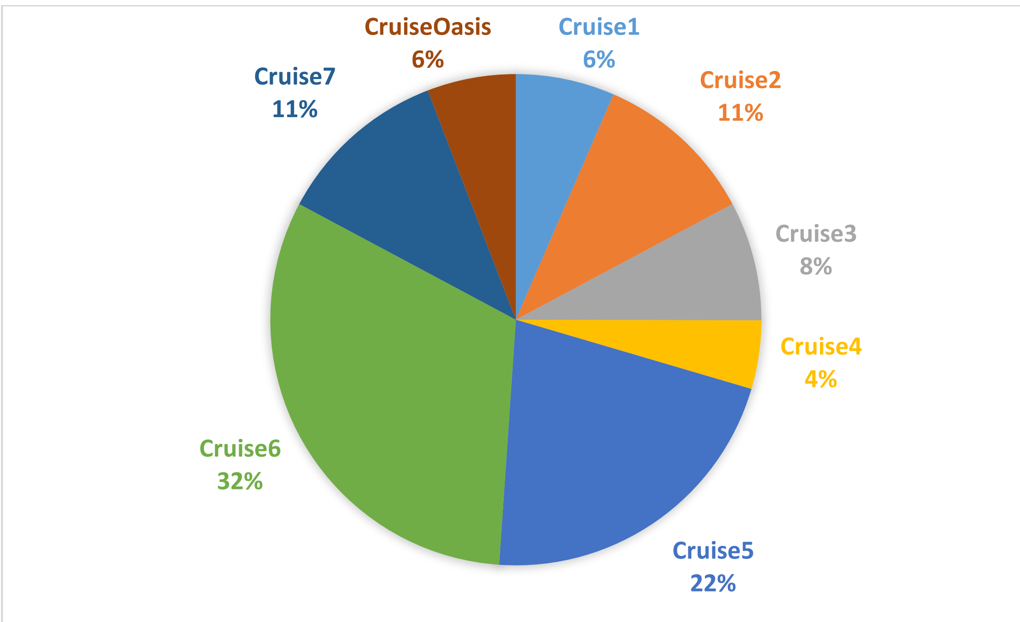
Historical cruise ship call counts are displayed in Table 13. Homeported cruise vessels typically use the Pan American docks on the southern edge of San Antonio Channel (Figure 11). Transit calls typically utilize Piers 1-4 on the northern edge of the San Antonio Channel (Figure 11). Figure 16 shows the distribution of cruise ship calls to San Juan Harbor by vessel class based on the 2017 cruise schedule. The data indicates that calls by vessels in the size range of the Cruise6 class are the most prevalent today in San Juan.

Table 13: Cruise Ship Calls to San Juan Harbor 2009-2015 (by Calendar Year)

Calendar Year	Homeport Calls	Transit Calls	Total Calls
2009	183	280	463
2010	228	247	475
2011	226	247	473
2012	169	242	411
2013	177	279	456
2014	176	340	516
2015	188	344	532

Source: Puerto Rico Tourism Company

Figure 16: Distribution of 2017 Cruise Calls by Vessel Class



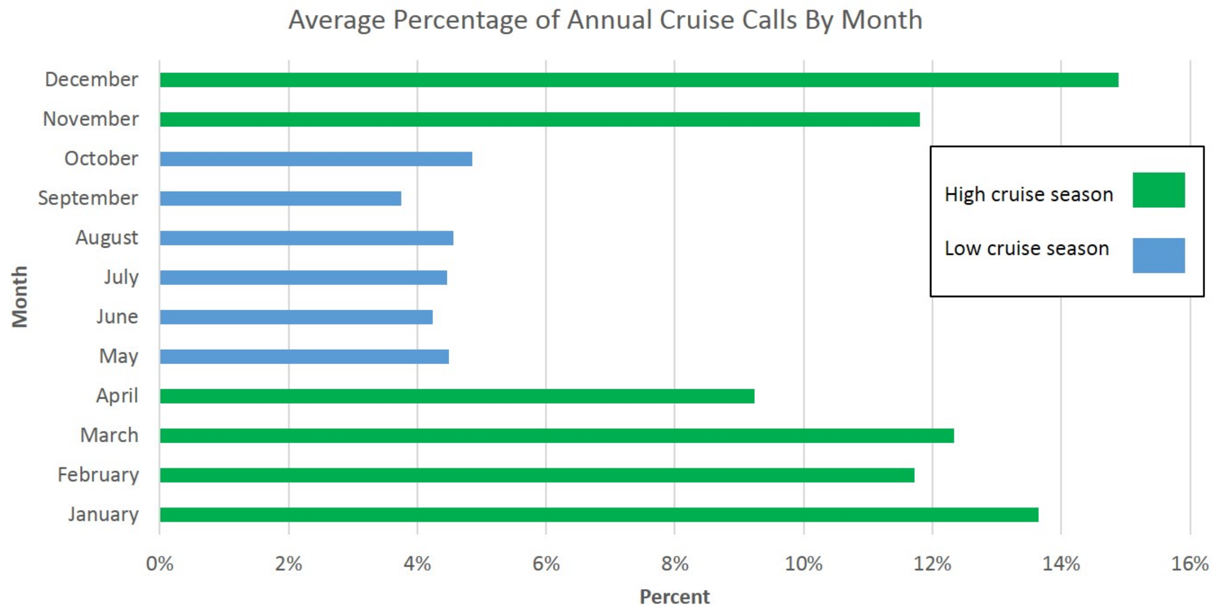
Source: 2017 schedule of cruise ship calls provided by Puerto Rico Ports Authority and Continental Shipping (cruise ship agents)

As mentioned in the General Operational Considerations subsection above, cruise ships are given priority over all other vessel types on both arrival and departure. Arrival times of transit calls can vary from 0400 to 1600 (4:00am to 4:00pm) according to the San Juan Bay Pilots. Based on conversations with the San Juan Bay Pilots and representatives from Continental Shipping (San Juan agents to major cruise companies), smaller cruise vessels (Cruise1 through Cruise3) typically stay at dock for around 12 hours, while larger cruise vessels (Cruise4 through CruiseOasis) typically spend around 8 hours in San Juan.

In San Juan, the difference in the number of cruise calls taking place during the "high season" and the "low season" is very pronounced. The high cruise season runs November through April corresponding with the holidays, spring vacations, and the winter season with little rainfall in the Caribbean. This 6-month period generally accounts for over 70 percent of the annual cruise traffic passing through San

Juan Harbor, while the period from May through October accounts for the remainder of annual cruise traffic (Figure 17).

Figure 17: Monthly Cruise Ship Calls in San Juan Harbor



Sources: Waterborne Commerce Statistics Center 2010-2014 call data and San Juan Bay Pilots Log Data for 1/1/16-9/30/16, cruise vessel call schedule for 10/1/16-12/31/16, cruise vessel call schedule for 1/1/17-12/31/17, and 2017 cruise vessel call schedule + new Oasis class vessel home ported at Pan Am docks in 2018.

As mentioned previously, the Cruise Ship Basin East is located south of the San Antonio Approach Channel and is designed for use by cruise ships exiting Piers 1-4. See Figure 11 for map. Note that Piers 1-4 will be referred to as “CruiseDockNorth” in the text going forward. The federally constructed depth of 30 feet in the Cruise Ship Turning Basin East currently affects maneuvering of cruise vessels utilizing the CruiseDockNorth. Cruise vessel pilots are hesitant to venture into this area as it is markedly shallower than the rest of San Antonio Channel, which is federally constructed to 35 feet[22]. On arrival to the San Antonio Channel, cruise vessels must make a relatively tight left-hand turn into the San Antonio Channel, taking care not to drift into the Cruise Ship Basin East on the inbound turn to CruiseDockNorth. Instead of confidently backing directly out of the northern cruise docks into the Cruise Ship Basin East, cruise vessels must work to avoid the Cruise Ship Basin East by backing into the San Antonio Channel and continuing this backing maneuver into the Anegado Channel. This maneuver has the following consequences:

- Outbound turning times of cruise vessels are increased over what they would be if cruise vessels could utilize the full width of the Cruise Ship Basin East.
- The Anegado Channel, which serves as the main and only path in or out of the harbor for all vessels, is temporarily blocked during the outbound turning maneuver.

[22] The San Antonio Channel has been federally constructed to 35 feet. However, 2017 USACE hydrographic surveys indicate the area is in fact at or deeper than the federally authorized depth of 36 feet in most places.

3.4.4 Container Ship Operations and Navigational Constraints

Container ship terminals are located primarily along the Puerto Nuevo Channel (Area B in Figure 7). As of 2018, the Crowley terminal is set to become a second area receiving regular calls by Panamax size container vessels.[23] This will be a twice weekly call by Crowley's two new LNG-powered dual-fuel Con-Ro (container-ro-ro) vessels which will replace the current tugs and barges servicing Crowley's Jacksonville-San Juan route and calling the Crowley terminal (Area D in Figure 7). Crowley is currently (as of 2017) completing all dredging needed to accommodate these new Panamax container ships.

Puerto Nuevo Channel, where the majority of the container ship calls in San Juan take place, has a current federally authorized depth of 39 feet. Historical call data indicates a lack of depth-constrained container ship calls to docks along the Puerto Nuevo Channel in recent history. San Juan Bay Pilots' Log data for container ship calls to Docks A through O (all located along the Puerto Nuevo Channel) from 2010 through October of 2015 shows the spread of sailing arrival drafts of 30 feet or greater presented in Table 14.

Table 14: Historical Counts of Container Ship Calls to Puerto Nuevo Docks by Arrival Draft

Year	30 feet	31 feet	32 feet	33 feet	34 feet	35 feet	36 feet	37 feet
2010	162	8	226	0	0	2	3	0
2011	118	4	217	0	0	3	2	0
2012	70	7	202	0	0	0	0	0
2013	79	3	136	0	0	0	0	0
2014	70	0	139	4	3	1	0	0
2015	1	18	37	5	0	1	0	0

Source: San Juan Bay Pilots' Log data
Note: Only includes inbound transit drafts.

Assuming that 2 feet of under keel clearance is needed, the Pilot's Log data does not demonstrate constraint on arrival by container ships calling docks situated along the Puerto Nuevo Channel between 2010 and October 2015.

San Juan Bay Pilots' Log data for vessels characterized as "Container Ship (fully cellular)" that called any dock in San Juan Harbor from October 26, 2015 through September 30, 2016 indicates the following spread of arrival and departure sailing drafts of 30 feet or greater. As shown in the table below, no container ship sailing drafts greater than 35 feet were recorded in the specified time period, indicating that container ships calling San Juan and the Puerto Nuevo Channel were not constrained by channel depth (Table 15).

Table 15: 2015/2016 Counts of Container Ship Transits of San Juan Harbor by Sailing Drafts

Year	Transit Count at Each Specified Depth						
	30 feet	31 feet	32 feet	33 feet	34 feet	35 feet	>35 feet
Oct 2015 thru Sept 2016	40	21	21	27	35	7	0

Source: San Juan Bay Pilots' Log data for calls taking place between October 26, 2015 and September 30, 2016.
Note: A transit represents one leg, either inbound or outbound, of a call. Two transits make up one call.

[23] Vessels will have DWT of 26,500 metric tons; dimensions of 720 ft. LOA X 105.97 ft. beam X 32.8 ft. draft; and capacity of 2400 TEUs and 400 vehicles.

Furthermore, of the 42 transits with drafts of 34-35 feet, 40 of these were by US-flagged vessels with recorded design drafts (maximum sailing drafts) of 34.45 feet and 34 feet respectively which indicates that these ships can fully load within Puerto Nuevo Channel's current 39-foot depth. These Tote Maritime LNG-powered container vessels are new (2015/2016) and serve the Jacksonville-San Juan route.

In 2016, a large Panamax containership (dimensions of 965 ft. LOA X 105.6 ft. beam X 44.3 ft. design draft) arrived at San Juan Harbor drafting 32 feet and departed drafting 35 feet. The vessel called San Juan with the purpose of picking up empty containers to return to China. While this vessel did have a design draft of 44.3 feet, neither the cargo on board nor the sailing draft of the vessel in San Juan indicates that it was constrained by the channel depth in San Juan, specifically by the 39 foot depth of the Puerto Nuevo Channel. This call is not a regular call/is not associated with a specific container service calling at a regular interval.

It is important to note that most of the container ship traffic through San Juan Harbor is domestic with Tote Maritime and Crowley both launching new LNG-powered Panamax container vessels in the period from 2015-2018 on their Jacksonville, FL - San Juan, PR routes. Other containerized commodities arrive to San Juan on tug and barges from Jacksonville, FL (Trailer Bridge) and from Pennsauken, NJ (Crowley). No shift in these vessel sizes or routes is expected from the existing condition to the project base year. Table 16 below shows the breakdown between domestic/foreign and inbound/outbound containers in terms of TEUs for San Juan Harbor. On average, over the period from 2010 through 2015 over 75 percent of inbound containers were from domestic sources and over 79 percent of outbound containers were bound for domestic locations. While some direct international traffic does exist, San Juan Harbor is mainly a regional Panamax and SubPanamax container port.

Table 16: San Juan Harbor Total Loaded TEUs 2010-2015

Direction and Origin/Destination		2010	2011	2012	2013	2014	2015	Average
Inbound	Domestic	498,605	480,197	437,239	463,490	481,083	432,559	472,123
	Foreign	151,188	144,541	157,196	157,357	147,198	158,137	151,496
	Total	649,793	624,738	594,435	620,847	628,281	590,696	623,619
Outbound	Domestic	110,542	148,473	112,138	110,108	124,954	106,861	121,243
	Foreign	64,629	32,891	13,734	21,299	20,665	17,893	30,644
	Total	175,171	181,364	125,872	131,407	145,619	124,754	151,887

Source: Waterborne Commerce Statistics Center

Port users have indicated a trend exists towards establishing container vessel sharing agreements, especially among major international containership companies that ship containers to/pick up containers in San Juan. The idea is that these companies, some of which currently run Europe-Central/South America routes that stop in San Juan, would partner to ship all containers on a single vessel rather than each bringing their own vessels to San Juan and that this could potentially lead to a regular call by a large Panamax vessel (965 ft. LOA X 106 ft. beam X 44 ft. design draft) with the need for use of depth beyond 39 feet in Puerto Nuevo Channel to allow for deeper loading. Such agreement would require participation by a significant number of container carriers and the PDT has received no evidence that the aforementioned scenario is actually taking place at the present time. Thus, no consideration of a large-scale vessel sharing agreement that would alter utilization of the container ship fleet in San Juan is incorporated into the study.

3.4.5 LPG Operations

In the existing condition, LPG tankers servicing a Puerto Rican propane company import LPG to Peñuelas on the southern coast of Puerto Rico. A high percentage of the total LPG volume received in Peñuelas is then trucked to the center of demand in San Juan, a road trip of over 80 miles. The current LPG tanker berthing area depth in Peñuelas is reported by users to be 36 feet. In San Juan Harbor, the current depths in the Graving Dock Turning Basin and Graving Dock Channel through which LPG tankers would have to pass to reach a proposed LPG terminal are 30 feet and 36 feet, respectively. Due to high costs associated with trucking compared to shipping, transportation inefficiencies likely exist. Per conversations between and PDT and port users, depth in the Graving Dock Turning Basin and Graving Dock Channel greater than or equal to the 36 feet currently available in Peñuelas is needed to trigger a transfer of LPG tanker calls from Peñuelas direct to San Juan Harbor.

Note that the best available record of historical LPG calls to the southern ports of Tallaboa and Guayanilla (used as a proxy for Peñuelas) from 2013-2015 indicates that over 40 percent of inbound LPG tanker calls arrived at sailing drafts of 27 feet or less and over 65 percent arrived at sailing drafts of 28 feet or less. Such information suggests that somewhere between 40 percent and 65 percent of the vessel calls taking place in the south in recent years could have conceivably transited the existing Graving Dock Channel and Turning Basin in San Juan with at least 2 feet of under keel clearance. Additional data (from 2016/2017) was requested from port users to determine if a trend toward deeper sailing drafts at the southern ports was evident. As of completion of this appendix, this specific piece of information had yet to be received.

3.5 Puerto Rico Electric Power Authority (PREPA) San Juan Harbor Existing Condition and Future Plans

PREPA is a public utility of the Government of Puerto Rico that produces, transmits, distributes, and sells electricity[24]. Two of PREPA's power plants, the San Juan Plant and the Palo Seco Plant, are located in the San Juan metro area and are currently serviced using fuel oil #6 and diesel fuel (i.e., fuel oil #2 or light distillate) imported through San Juan Harbor. From conversations with PREPA, their main goals are to (1) comply with environmental regulations and (2) lower electric costs to help stimulate economic growth in Puerto Rico.

In order to meet their first goal and to comply with Commonwealth and EPA regulations, specifically Mercury and Air Toxins Standards (MATS)[25] with which PREPA is currently non-compliant, PREPA must phase out use of fuel oil # 6 completely. This will happen prior to the project base year of 2026. PREPA had to be in compliance with MATS by April 16, 2015. A time extension was obtained for Aguirre units 1 and 2 (on Puerto Rico's southern coast), and for those the compliance date was April 16, 2016. Therefore, PREPA's existing generating units that use fuel oil No. 6, including units at the San Juan area plants, are not complying with MATS. The use of diesel fuel will allow PREPA to comply with MATS but is a more costly commodity than LNG. Also, the HHV (high heat value in terms of BTU/lb.) of diesel is lower

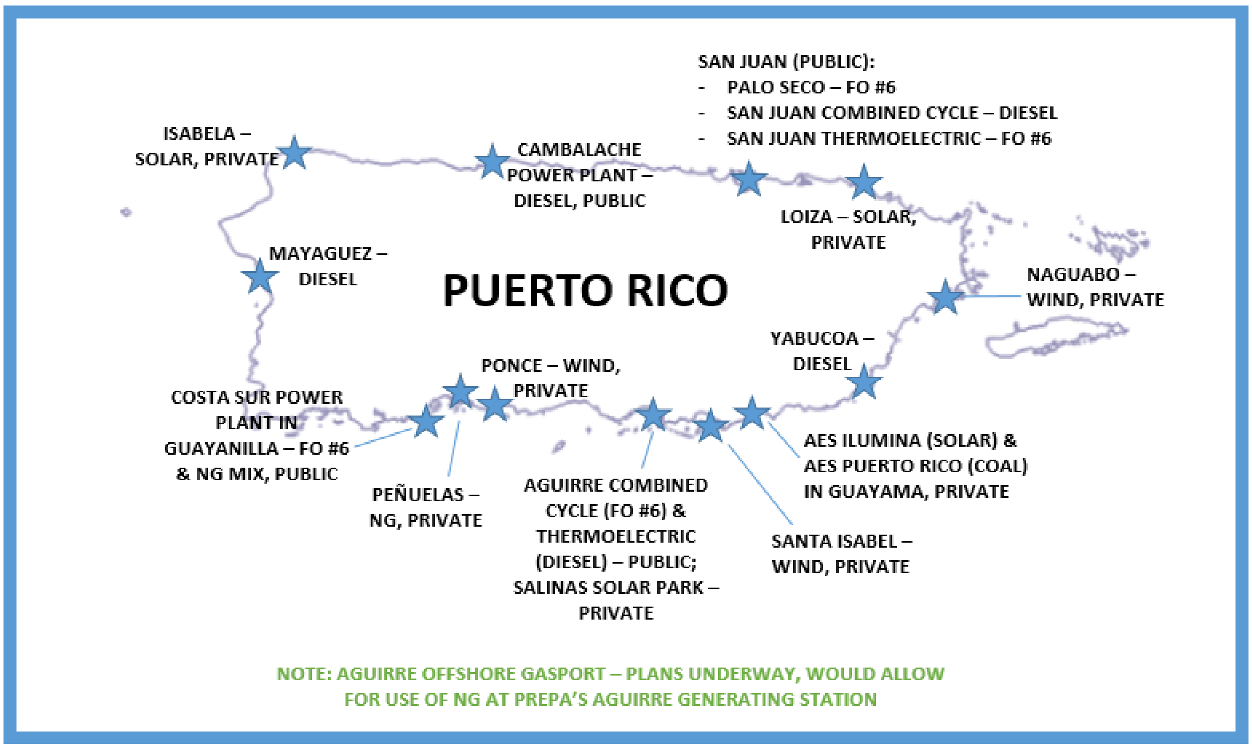
[24] Source: PREPA Company Profile from https://www2.aeepr.com/INVESTORS/companyprofile.aspx.

[25] MATS aims "to reduce air pollution from coal and oil-fired power plants under sections 111 (new source performance standards) and 112 (toxics program) of the 1990 Clean Air Act amendments". (https://www.epa.gov/mats/basic-information-about-mercury-and-air-toxics-standards).

than that of LNG, meaning that slightly more metric tons of diesel than LNG are needed to generate the same number of megawatt hours of electricity. Consequently, in order to meet PREPA's second goal to lower the cost of generating electricity, conversion to LNG at the San Juan area plants is needed. As of December 2015, electricity rates in Puerto Rico were higher than all U.S. states except Hawaii.[26]

Other power plants across the island, some of which are operated by PREPA and others which are private[27], currently use a variety a fuels to generate power. In 2015, petroleum supplied about half of the island's electricity, with natural gas supplying about one-third, coal supplying one-sixth, and renewables supplying about 2 percent.[28] Figure 18 below shows the location, fuel type, and ownership (public/private) of power generation facilities in Puerto Rico as of 2017. In addition to the facilities pictured, there are 21 hydroelectric generating unit in PR[29].

Figure 18: Puerto Rico Power Generation - Plants and Fuel Types



Notes: May not include all power plants in PR or most updated information. Information taken from various sources, including the U.S. Energy Information Administration (EIA), PREPA website, and websites of private generation companies operating in PR. This map is based on the best widely available information and was not officially coordinated through or provided by PREPA.

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[26] Source: EIA – *Puerto Rico Profile Analysis*, https://www.eia.gov/state/analysis.php?sid=RQ.

[27] According to *Volume I: Supply Portfolios and Futures Analysis* of PREPA's 7 July 2015 draft IRP, PREPA "owns and operates approximately 4,638 megawatts (MW) of fossil fuel fired generation and 60 MW of hydroelectric generation. To supplement its own capacity, PREPA purchases power from two cogenerators under Power Purchase Operating Agreements (PPOAs) for a total capacity of 961 MW. In addition, PREPA contracts 173 MW from six existing renewable projects…" (page xii).

[28] Source: U.S. Energy Information Administration (EIA), *Puerto Rico Territory Energy Profile* (https://www.eia.gov/state/print.php?sid=RQ)

[29] Source: EIA – *Puerto Rico Territory Energy Profile*, https://www.eia.gov/state/print.php?sid=RQ.

Due to the concentration of the population and of industry in the San Juan area and the nature of power grid, power can be transmitted from plants outside of the San Juan area to service customers in the San Juan area. According to PREPA, the current operating scheme requires electric power be transmitted from the south to the north because the capacity in both the Palo Seco and San Juan plants is insufficient to cover demand in the north where the greatest concentration of population and industry is found. While transmission of the power from the south does occur, it does not relieve need for power generation in the northern plants. Thus, per current electric grid operations criteria, a minimum amount of power generation must still take place in the San Juan area power plants in order to maintain electric grid stability.

Actions have been and continue to be underway by PREPA to rethink their power generation strategy over the next 20 years, which includes the San Juan area plants. These actions include the following:

- Completion of an Integrated Resource Plan (IRP) – An IRP is “a long term planning assessment, typically covering a 20 year period, by which an electrical service company finds the optimal plan to supply the current and forecasted electrical demand, meeting regulatory requirements, reliability criteria, and the least cost possible”[30]. PREPA’s plan covers 2016 to 2035 and discusses three supply portfolios and four “futures” which represent different possible paths forward for the public utility. Options include future retirement of several steam units in both the Palo Seco and San Juan Power Plants and conversion to dual fuel combined cycle units with capability of burning either LNG or diesel at each of these power plants.
- Completion of the Galway Energy Advisors report – The report entitled *LNG and Natural Gas Import and Delivery Options Evaluation for PREPA’s Northern Power Plants – Feasibility Study & Fatal Flaw Evaluation* assesses the feasibility of different methods by which PREPA could bring LNG to the northern coast of the island. The report recommended Option 14, which relies on a standard scale LNG carrier delivering directly to on-land tanks located adjacent to the PREPA dock and Army Terminal Turning Basin to supply LNG to the San Juan area power plants, as the most feasible of the options considered. As will be discussed in subsequent sections of the current appendix, assumptions in the future with project condition as they relate to PREPA’s operations correspond most closely with recommended Option 14.

Additionally, PREPA continues its work with the Puerto Rico Energy Commission to finalize future plans for power generation in Puerto Rico. The construction of the LNG infrastructure is still several years away, given that it is expected to be online in 2025 and the construction period is estimated to be around 3 years.

While PREPA would prefer to convert to LNG over diesel in the San Juan area plants in the long run, the current width of the Army Terminal Channel limits PREPA’s ability to do so. As mentioned in reference to petroleum tankers in a previous section of this appendix, the largest vessel beam currently permitted by the San Juan Bay Pilots to transit the Army Terminal Channel is the approximately 131 feet. In the world fleet today there 11 LNG or Combination Gas (LNG/LPG) tankers that have serviced the Caribbean or South American region in the past year (2016/2017) that meet the aforementioned beam requirement[31]. Of these 11 tankers, four have volumetric capacities of 10,000 cubic meters or less, which would require more than 30 calls per year to meet PREPA’s minimum LNG demand in the San

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[30] Source: *Puerto Rico Electric Power Authority Integrated Resource Plan 2016 – 2035*; presentation by Siemens on 21 August 2015; pages 3, 20, 31, 37; https://www2.aeepr.com/Documentos/Ley57/Presentación%20IRP%20-%20AEE%2020151106.pdf
[31] From IHS Sea-Web fleet database.

Juan area. Due to this high call frequency, PREPA has determined that use of these vessels to supply LNG is not viable going forward. That leaves a possible fleet of 9 vessels, 7 currently serving the Caribbean/South America and 2 new builds just launched in 2017, for servicing PREPA's annual LNG demand in the future. PREPA does not believe that this 9-vessel fleet is sufficient to reliably meet PREPA's minimum annual LNG demand and is still concerned that the annual call frequency of approximately every 3 weeks may encounter opposition from regulatory bodies and other port users as safety zone requirements of 300 feet in transit and 150 feet at dock would be imposed for each LNG call.[32] Thus, in the future without-project condition (FWOP) PREPA is expected to use diesel in the San Juan area plants and is not expected to convert to LNG at the San Juan areas plants.

4 Commodity Forecast

The commodity forecast was completed by USACE economists based on the following assumptions:

a. Zero growth in cargo throughput established in existing condition (both imports and exports)
b. Divergence in commodity types/throughput at PREPA dock from (a) existing condition to (b) future without project condition (FWOP) condition to (c) future with project (FWP) based on actions PREPA is taking to comply with EPA standards and reduce costs of power generation[33]
c. Increase in cruise passengers from existing condition through 2018 and then held constant to 2026 base year and throughout 50-year analysis period

The zero growth in imports assumption (assumption "a." above) is based on current trends in population in Puerto Rico. As discussed in the Socioeconomics section of the appendix, population has been on the decline in Puerto Rico since 2006[34] and projections estimate that this decline will continue into the future. Because import volumes are in large part driven by aggregate consumer demand which is a function of many factors including the number of consumers (i.e., the population) in a given market, one would expect population and import throughput to be closely connected. While the population steadily declined over the period from 2010 through 2015, total cargo throughput on the island, specifically in San Juan Harbor, does not appear to be declining at the same rate. Rather, the throughput is relatively steady, supporting the no growth scenario used in this analysis. As shown in Table 17, total throughput (both inbound and outbound) actually increased slightly from 2013 to 2014 and then again from 2014 to 2015 even though there were population declines estimated by the U.S. Census Bureau over these same periods. Outbound tonnages were also kept constant in the analysis (i.e., held to a no growth scenario) as there is no indication in the historical record from 2010-2015 of a clear and sustained trend toward increased export or transshipment quantities.

[32] See Correspondence appendix for 11 January 2018 letter from PREPA to SAJ Planning.
[33] Further discussion of PREPA's plans, which are expected to trigger the commodity transitions referenced here is provided later in this appendix.
[34] From Pew Research Center (http://www.pewresearch.org/fact-tank/2015/07/01/puerto-ricos-losses-are-not-just-economic-but-in-people-too/).

Table 17: Puerto Rico Estimated Population and Commodity Throughput 2010-2015

Year	Population Estimate	Inbound (metric tons)	Outbound (metric tons)	Total (metric tons)
2010	3,722,000	8,777,000	1,561,000	10,338,000
2011	3,679,000	9,028,000	976,000	10,004,000
2012	3,634,000	9,268,000	801,000	10,069,000
2013	3,593,000	8,282,000	1,198,000	9,482,000
2014	3,535,000	8,458,000	1,334,000	9,793,000
2015	3,473,000	8,643,000	1,395,000	10,038,000

Notes: All tonnages rounded to the thousands. Any discrepancies in sums and values shown in the "Total" column are due to rounding.
Sources: Waterborne Commerce Statistics Center
U.S. Census Bureau, Population Division – Table 1. Annual Estimates of Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2010 to July 1, 2016 (NST-EST2016-01)

Existing condition import and export tonnages held constant throughout the analysis period were established using Waterborne Commerce Statistic Center (WBSC) call and tonnage data from 2010-2014 and using San Juan Bay Pilots' Log data for 2010-2015. An average shipment size of a given commodity being either imported or exported through a given dock on a given vessel class operating on a given trade route was estimated based on available data[35]. Then an expected annual number of calls for each combination of commodity, dock, vessel class, and trade route was also determined. This number of calls combined with the expected tonnage per call resulted in the future import and export tonnages used for the analysis. See Table 18 below for existing and estimated future tonnages by generalized commodity type. Also note that changes between the existing, FWOP, and FWP tonnages for the "Bulk Petroleum Products" and "LNG" commodity categories are due to the assumed shift in commodity types/throughput at the PREPA dock, which is discussed in greater detail below.

Table 18: Commodity Throughput - San Juan Harbor (all in metric tons)

Commodity Category	Existing Condition[1]	2026 FWOP	2026 FWP
Containers	5,047,000	5,114,000	5,114,000
Dry Bulk	771,000	780,000	780,000
Bulk Petroleum Products[2]	3,383,000	3,053,000	2,692,000
General Cargo	244,000	241,000	241,000
Liquid Bulk[3]	289,000	312,000	312,000
LPG	46,000	42,000	42,000
LNG	0	0	307,000
Total	9,780,000	9,542,000	9,488,000

[1] Based on Historical Waterborne Commerce Statistic Center annual tonnage data (2010-2014)
[2] Includes bulk petroleum products bound for petroleum docks in ATTB area
[3] Includes non-petroleum liquid bulk cargo bound for petroleum docks in ATTB area and all liquid bulk cargo bound for other docks throughout the harbor

[35] Tonnage data for calls was based solely on the Waterborne Commerce Statistics Center data. Pilots' Log data included no information of the tonnage associated with a given call.

Divergence in commodity types/throughput at the PREPA dock is assumed when moving from the existing condition to the future conditions (assumption "b." above). In order to transition from the existing condition to the future conditions for analysis purposes, all tonnage currently going to the PREPA dock was eliminated. This tonnage came out of the "Bulk Petroleum Products" category in Table 18 above. FWOP "Bulk Petroleum Products" tonnage was then adjusted to include the number of metric tons of diesel fuel that will be needed by PREPA to maintain electric grid stability based on current electric grid operations criteria. Similarly, FWP "LNG" tonnage was adjusted to include the number of metric tons of LNG needed to maintain electric grid stability at the San Juan area plants. PREPA's plans regarding power generation in its San Juan area power plants are discussed in the section of the appendix entitled Puerto Rico Electric Power Authority (PREPA) San Juan Harbor Existing Condition and Future Plans (Section 3.5).

The number of cruise passengers visiting San Juan annually and the corresponding number of cruise calls is assumed to increase from the existing condition through 2018 and is then held constant to the 2026 base year and throughout the 50-year analysis period (assumption "c." above). A cruise ship call schedule for 2017 provided by the Puerto Rico Ports Authority was used to establish the number of cruise calls expected in 2017. The 2017 cruise calls were then increased by 52 calls in 2018 to account for plans by Royal Caribbean to add an additional weekly call by a homeported vessel at the Pan American Dock in the San Antonio Channel in 2018. Note that these increases in the number of calls correspond with an increased number of cruise passengers expected to visit San Juan.

5 Future Without-Project (FWOP) Overview

As mentioned above, no growth is assumed for all commodities (cargo). Growth in cruise calls and passengers from 2015 thru 2018 is applied, but no cruise growth is assumed beyond 2018. As such, the FWOP fleet looks very similar to the existing condition fleet with the following exceptions:

- Crowley replaces tugs and barges on the Jacksonville-San Juan route with LNG-powered combination container and ro-ro (con-ro) ships.
- Tote Maritime replaces ro-ro vessels on Jacksonville-San Juan route with LNG-powered container ships.[36]
- Less tanker calls to the PREPA dock as PREPA transitions away from use of fuel oil #6 to use of diesel to comply with environmental regulations. Diesel replaces fuel oil #6 completely and PREPA imports to San Juan only enough diesel to generate the amount of power needed to maintain electric grid stability per current electric grid operations criteria.

Table 19 summarizes the projected future without-project fleet in the project base year of 2026, which is held constant throughout the period of analysis (2026-2075). Further information on FWOP fleet and FWOP analysis assumptions is provided in Section 7 of this appendix.

[36] The transition occurred in 2015-2016. However, the existing condition fleet used for economic model calibration only incorporated data through October of 2015, which did not include these calls.

Table 19: Without-Project Fleet Summary

Vessel Class	FWOP 2026 Fleet
SubPanamax Container Vessels	537
Panamax Container Vessels	273
5K-35K DWT tankers and tank barges	102
MR	79
LR1	9
LR2	0
RoRo and Vehicle Carriers	231
Cruise	651
LPG	13
LNG	0
Bulkers and General Cargo	259
Other	514
Total	**2668**

6 Management Measures and Economic Modeling Phases

In order to address the navigational constraints in San Juan Harbor (see Section 3.4 above), various management measures were developed by the PDT based on information received from the local sponsor, port users, the San Juan Bay Pilots, the U.S. Coast Guard, and other study stakeholders. See the Main Report for details on all management measures initially developed. Due to the diversity of vessel and cargo types that pass through San Juan Harbor and the complexity of the harbor's configuration, the economic analysis focused on the measures that had the potential to best meet the study objectives corresponding with the problems identified in Section 3.4. The measures that were carried forward for more detailed consideration and that are the focus of the economic analysis were grouped into economic modeling phases based on the area of the harbor, types of vessels, and commodities potentially impacted by the measures. The following outlines the economic modeling phases and the measures evaluated within each phase, along with the objective(s) that each set of measures aims to meet:

- **Economic Modeling Phase 1**

Objective (a) – Reduce transportation costs by allowing larger vessels to transit Army Terminal Channel over the 50 year period of analysis (2026-2075)

Objective (b) – Reduce power generation costs at the San Juan area power plants by allowing larger vessels to transit Army Terminal Channel over the 50 year period of analysis (2026-2075)

Measures evaluated – Widen Army Terminal Channel 100 feet (from an existing width of 350 feet to a maximum width of 450 feet) at an existing depth of 40 feet

a. Widen Army Terminal Channel 50' to the east
b. Widen Army Terminal Channel 50' to the west

➢ Economic Modeling Phase 2

Objective – Reduce transportation costs by allowing vessels that transit the Anegado Channel and Army Terminal Channel to load deeper over the 50 year period of analysis (2026-2075)

Measures evaluated – Deepen at 1-foot increments a 100-foot widened Army Terminal Channel (ATC) from 41 - 45 feet including reaches from Cut-6 to Army Terminal Turning Basin (ATTB)

a. Cut-6 @ 43' + Anegado @ 41' + ATC @ 450 feet and Deepen to ATTB @ 41'
b. Cut-6 @ 44' + Anegado @ 42' + ATC @ 450 feet and Deepen to ATTB @ 42'
c. Cut-6 @ 45' + Anegado @ 43' + ATC @ 450 feet and Deepen to ATTB @ 43'
d. Cut-6 @ 46' + Anegado @ 44' + ATC @ 450 feet and Deepen to ATTB @ 44'
e. Cut-6 @ 47' + Anegado @ 45' + ATC @ 450 feet and Deepen to ATTB @ 45'

➢ Economic Modeling Phase 3

Objective – Reduce transportation costs by allowing LPG tankers to supply LPG direct to San Juan Harbor's Graving Dock Turning Basin docks area over the 50 year period of analysis (2026-2075)

Measures evaluated

a. Deepen Graving Dock Turning Basin up to 45' (current depth is 30')
b. Deepen Graving Dock Channel with 50-foot widening measure up to 45' (current depth is 36')

➢ Economic Modeling Phase 4

Objective – Reduce transportation costs by allowing vessels that transit the Puerto Nuevo Channel and Puerto Nuevo Turning Basin to load deeper over the 50 year period of analysis (2026-2075)

Measures evaluated – Deepen Puerto Nuevo Channel with 50-foot widening and Turning Basin

a. Deepen Puerto Nuevo Channel with widening and Turning Basin to 40' with widening
b. Deepen Puerto Nuevo Channel with widening and Turning Basin to 41' with widening
c. Deepen Puerto Nuevo Channel with widening and Turning Basin to 42' with widening
d. Deepen Puerto Nuevo Channel with widening and Turning Basin to 43' with widening
e. Deepen Puerto Nuevo Channel with widening and Turning Basin to 44' with widening
f. Deepen Puerto Nuevo Channel with widening and Turning Basin to 45' with widening

➢ Economic Modeling Phase 5

Objective – Reduce maneuvering time of vessels using the Cruise Ship Turning Basin south of the San Antonio Approach Channel over the 50 year period of analysis (2026-2075)

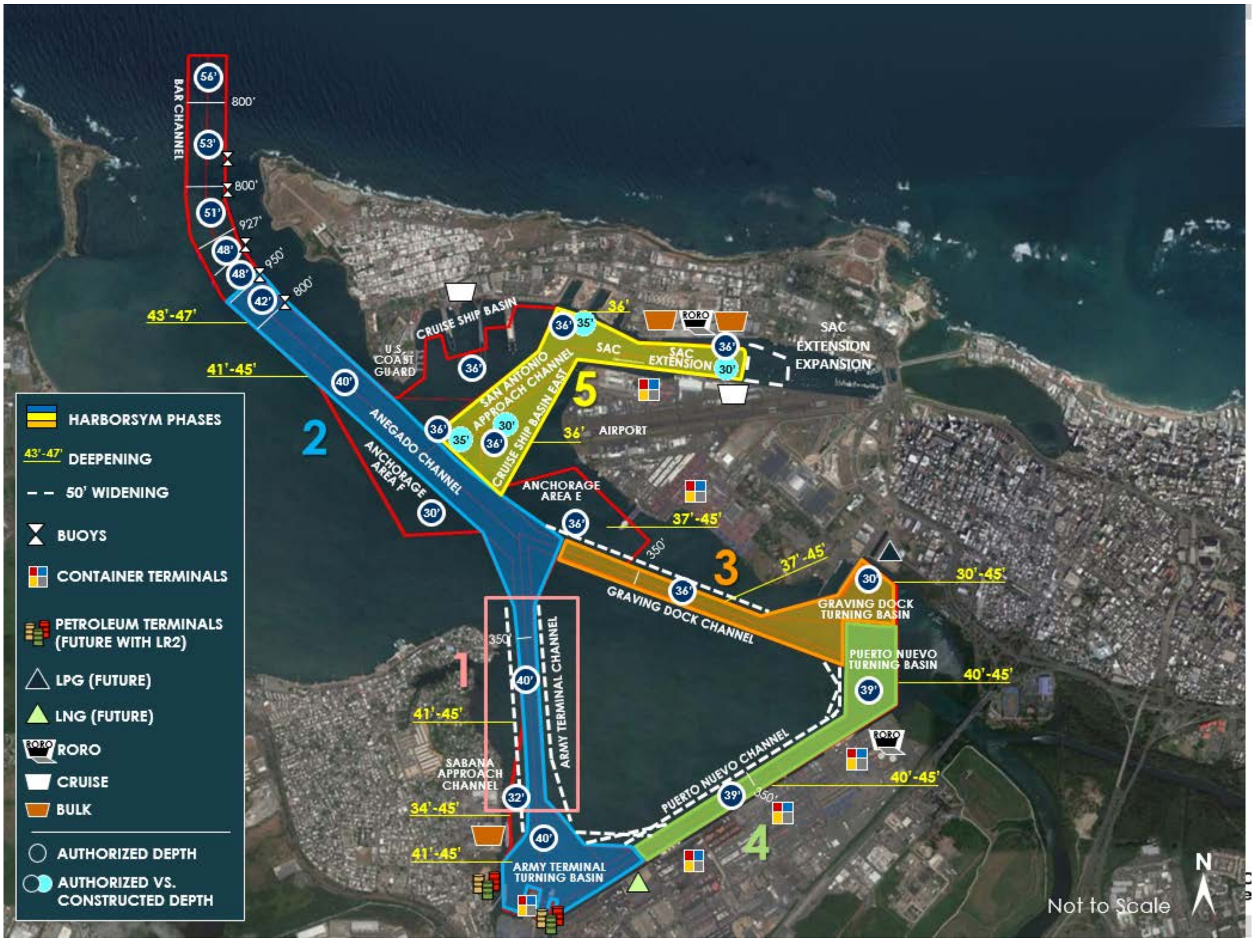
Measures evaluated – Deepen San Antonio Channel and Cruise Ship Basin East

a. Deepen San Antonio Approach Channel, San Antonio Channel, and San Antonio Channel Extension to 36'
b. Deepen Cruise Ship Basin East to 36'

In addition to the measures and economic modeling phases outlined above, results of ships simulation indicated the need for eastern and western flares at the southern end of the Army Terminal Turning Basin. This additional cost was added to the costs used in analysis of Economic Modeling Phase 2 and of the full plan when comparing the final array of alternatives and was also included in the recommended plan costs.

Figure 19 below shows the relative locations within the harbor of the economic modeling phases described above by phase number. Note that no deepening or widening measures are considered in Cuts 1-5 of the Bar and Entrance Channels. Due to depths of 48 feet or greater in these cuts, none of the measures being considered in the inner harbor require additional depth in the outer cuts. No depths beyond 45 feet were considered in this study in part to avoid deepening of these outer cuts where there are known hard bottoms and natural resources (e.g., reefs, etc.), which could lead to higher dredging and mitigations costs.

Figure 19: San Juan Harbor Measures by Economic Analysis Phase



6.1 Economic Screening of Study Measures

Prior to economic modeling, a second screening level assessment of groups of measures represented in Phases 1 through 5 shown above was conducted based on the best available economic information. Measures associated with Phase 3 (Graving Dock Channel and Turning Basin) and Phase 4 (Puerto Nuevo Channel) were screened out of further consideration as potential components of the recommended plan.

6.1.1 Screening of Graving Dock Channel and Turning Basin Improvements

In order to establish that deepening measures designed to accommodate LPG tankers projected to call the Graving Dock Channel and Graving Dock Turning Basin area (Economic Modeling Phase 3) in the future will produce economic benefit, additional information was requested from port users. As of the completion of this appendix, the PDT is still awaiting receipt of certain pieces of information necessary to complete a sound analysis of deepening and widening alternatives in this area of the harbor. See Section 3.4.5 for additional information. Thus, the set of study measures associated with the Graving

Dock Channel and Turning Basin was screened out of further economic analysis and was not included in economic modeling completed for the recommended plan.

6.1.2 Screening of Puerto Nuevo Channel Improvements

Deepening measures in Puerto Nuevo Channel were designed primarily to serve the container vessels that use this channel. In order to justify deepening measures, evidence showing that traffic is constrained by depth now and/or will be constrained by depth in the future is needed. Based on the best available information, deepening measures were considered and screened out without the need for economic modeling due to the following:

1. Historical sailing draft data indicates a lack of constrained calls by container ships to docks along the Puerto Nuevo Channel.
2. Historical sailing draft data indicates a lack of constrained calls by any ship (container vessel or otherwise) to docks along the Puerto Nuevo Channel.
3. There is a lack of evidence indicating that concrete actions/plans requiring greater channel depth in the future are currently underway.

Section 3.4.4 of this appendix describes existing container ship operations in San Juan Harbor, including information specific to container vessel calls to docks along the Puerto Nuevo Channel. Based on the data from the San Juan Bay Pilot's Log for 2010 through September of 2016, which is displayed in Table 14 and

Table 15 of Section 3.4.4, no preference for depth by containerships calling the Puerto Nuevo Channel docks is shown. Assuming that a minimum of 2 feet of under keel clearance is needed and considering that only five container ship sailing drafts recorded in the San Juan Pilots' Log for 2010 through September 2016 equaled 36 feet or greater[37], containerships are not generally constrained by the current Puerto Nuevo Channel depth of 39 feet.

In addition to a lack of depth-constrained containership calls, there has been a lack of depth-constrained calls by all vessel types to docks along the Puerto Nuevo Channel in recent history. Data from the Waterborne Commerce Statistics Center from 2010 through 2014 indicates that out of over 7,000 transits by vessels bound for or leaving the Puerto Nuevo Channel (Docks A-O), only 3 vessels transited with a sailing draft of 36 feet or greater (see Table 20). Again, this suggests that vessels are generally not constrained by the current 39 foot depth of the Puerto Nuevo Channel.

[37] Data from 2010 through September of 2015 includes only arrival drafts. Data from October of 2015 through September of 2016 includes arrival and departure drafts.

Table 20: Count of Transits by All Vessel Types Calling Puerto Nuevo Docks with Sailing Drafts >= 30 Feet

Year	30-31 feet	31-32 feet	32-33 feet	33-34 feet	34-35 feet	35-36 feet	36-37 feet	37-38 feet
2010	101	18	35	11	13	2		1[A]
2011	204	12	8	8	14	3		
2012	162	44	67	34	13	1	1[B]	
2013	177	17	73	120	8		1[B]	
2014	105	85	77	57	4			

[A] Call by large Panamax container vessel (LOA 965 feet, design draft 44.5 feet)

[B] Calls by 50K-DWT tankers importing molasses (LOAs 600 feet & 597 feet, design drafts 40 feet & 41.6 feet)

Source: Waterborne Commerce Statistics Center call-level data, 2010-2014

While mention has been made of the potential for large-scale vessel sharing agreements between multiple international container ship carriers serving San Juan, no evidence has been provided demonstrating that contracts exist and that action is being taken currently that will result in calls by larger Panamax container ships (965 ft. LOA and 41-44.5 ft. drafts) that will load to sailing drafts beyond 37 ft. in the future.

In conclusion, vessel call data does not currently support further analysis of deepening measures in the Puerto Nuevo Channel. Furthermore, the need for widening measures is contingent upon large Panamax vessels calling the Puerto Nuevo Channel at sailing drafts beyond those that the current channel dimensions will allow. Consequently, widening measures in Puerto Nuevo Channel can also be screened out of further economic analysis. The current fleet drafting/loading in a manner similar to what is done today is expected to continue to call the Puerto Nuevo Channel in the future and should be able to do so with no changes to the Puerto Nuevo Channel width. Speculation about future expansion of vessel sharing agreements between international container ship carriers and the cascading of larger Panamax container ships (design drafts of up to 44+ feet) to serve the San Juan route seems reasonable. However, concrete support (e.g., vessel sharing contracts between companies, actual sailing draft data, etc.) is lacking and thus uncertainty is high about whether these vessels will (a) come to San Juan and (b) be constrained by the depth of the Puerto Nuevo Channel.

6.2 Study Measures Carried Forward for Economic Modeling

The San Juan Harbor economic analysis of potential project benefits has two major components, (a) transportation costs savings measured using USACE's HarborSym model and (b) reduction in power generation costs to the Puerto Rico Electric Power Authority (PREPA) measured using dispatch run data provided by PREPA for its northern power plants. The remainder of the Economics Appendix will focus only on the study measures associated with Phases 1, 2, and 5. These are the phases for which components (a) and (b) were used to quantify potential project benefits.

7 Estimated Costs

Estimated project costs by economic modeling phase including General Navigation Features (GNF) and non-Federal Local Service Facilities are summarized in Table 21 below. In addition to the costs outlined in Table 21, Interest During Construction (IDC) was calculated[38] and included as part of the economic cost of the project. IDC is included for construction of the Federal project.[39] Also, the increase in O&M

[38] IDC is calculated at the FY18 Federal Natural Resources Discount rate of 2.75 percent.

[39] Duration of PED is assumed to be 24 months, and duration of construction is assumed to be 16 months (490 days).

costs attributable to proposed project measures was included as part of the analysis of the final array of alternatives (Table 31) and presented as part of the recommended plan costs. Further details on project costs including information on cost sharing can be found in the Main Report.

Table 21: Estimated Project Costs (GNF and Non-Federal Local Service Facilities)

October 01, 2017 Price Levels (FY 2018) Deepen Cut-6 to 46' + Widen & Deepen ATC to 44' + Deepen Anegado Channel & ATTB to 44' + Deepen SAC, SAAC, SAC Extension & CSBE to 36'		
	Cost	
GENERAL NAVIGATION FEATURES (GNF)		
Mobilization & Demobilization (Clamshell)	$	3,349,605
Standby Time (Mechanical Clamshell)	$	233,953
Mobilization & Demobilization (Hydraulic Hopper)	$	2,744,485
Standby Time (Hydraulic Hopper)	$	348,672
~Economic Modeling Phase 1~		
Widen ATC 100' @ Existing 40' (Cut 8)	$	7,388,739
~Economic Modeling Phase 2~		
Deepen Cut 6 @ 46'	$	741,698
Deepen Anegado (Cut 7) @ 44'	$	6,761,984
Deepen and Widen ATC 100' @ 44' (Costs only for deepening/widening improvements > 40')	$	8,474,605
Deepen ATTB @ 44' (Cut 8)	$	7,351,686
ATTB East & West Flares @ 44'	$	1,354,418
~Economic Modeling Phase 5~		
Deepen SAAC @ 36' (Cut 18)	$	493,660
Deepen SAC @ 36' (Cut 18)	$	2,848,594
Deepen SAC Extension @ 36' (Cut 20)	$	596,387
Deepen CSBE @ 36' (Cut 22)	$	2,346,283
Sea Turtle Non-Capture Trawl Sweeping	$	39,388
Real Estate Administrative Costs	$	66,000
Preconstruction, Engineering, & Design (PED)	$	4,619,060
Construction Management (S&A)	$	4,282,077
TOTAL GNF	$	54,041,295
SUBTOTAL PROJECT FIRST COSTS	$	54,041,295
NON-FEDERAL CONSTRUCTION COSTS (LOCAL SERVICE FACILITIES)		
Berthing Area Dredging (COD / Total Terminals) @ 44'*	$	611,499
Berthing Area Dredging (PUMA Terminal) @ 44'*	$	446,461
Berthing Area Dredging (PREPA Terminal) @ 44'*	$	746,948
PREPA LNG Facility Modifications	$	348,023,875
TOTAL NON-FEDERAL LOCAL SERVICE FACILITIES	$	349,828,783
USCG AIDS TO NAVIGATION (100% USCG FEDERAL COST)	$	104,939
PROJECT COSTS	$	403,975,016
PROJECT COSTS (ROUNDED)	$	403,975,000
*Berthing area costs assume dredging from 40 feet (which equals the depth of the current Federal channel) to the recommended plan's channel depth of 44 feet (see note C on Table 11 of the EN Appendix).		

PREPA's LNG infrastructure investment costs are estimated to be approximately $348 million in 2018 dollars and include the components listed below:

1.) 160,000 m^3 full containment tank EPC (EPC = "engineer, procure & construct" contract);
2.) tank pile foundation including architecture and engineering (A&E);
3.) LNG facility "balance of plant", or BOP, which comprises the LNG processing facilities and installations other than the tank (i.e., pipelines, valves, gasifiers, skids, controls, etc.) and includes A&E;
4.) 7 percent of the above costs (#1-3) for insurance, bonds, and taxes;
5.) New docks A, B, C & D including A&E, demolition, new construction, LNG unloading arms, cranes, and related infrastructure; and
6.) EPC pipeline from PREPA's San Juan Harbor docks to the Palo Seco Power Plant (4 mile route).

8 HarborSym Analysis

The first and most traditional component of the San Juan Harbor economic analysis is the calculation of transportation costs savings expected to result from implementation of proposed study measures. Transportation costs savings are project benefits and may result from use of larger vessels, more efficient use of larger vessels, more efficient use of existing vessels, reduction in transit time, lower cargo handling and tug assist costs, or use of waterway transportation rather than alternative land mode. HarborSym is an economic analysis tool that simulates vessel movements within the study harbor and calculates origin to destination voyage costs outside of the study harbor. HarborSym is used to model the without- and with-project conditions at the study port. The modeler is then able to compare without- and with-project transportation costs to estimate the transportation costs savings (i.e., benefits) of specific measures or of the entire project that is being assessed.

8.1.1 Model Overview

Economic modeling of widening and deepening measures proposed as part of the San Juan Harbor Improvements Study was completed using HarborSym, USACE's certified model for economic analysis of deep draft navigation projects[40]. HarborSym uses data-driven Monte Carlo simulations based on user-inputted parameters to calculate transportation costs for entire routes and time in port for all vessel calls projected throughout the period of analysis. The model is used to estimate transportation cost changes due to harbor improvements by comparing with and without-project conditions. For this study HarborSym version 1.5.5.2 was used for production modeling to reach a recommended plan and for total transportation cost calculations.

The simulations are based upon vessels moving through reaches from the harbor entrance to their destination dock. At each time increment (step) the model determines if each vessel can move from one node to the next, without violating transit rules. If a transit rule would be violated by a vessel entering a reach, such as passing another vessel when the channel width is too narrow, then the vessel waits until the next time step. This waiting continues until the rule is no longer violated and the vessel resumes its journey.

[40] The HarborSym Model has been certified for use on all deep draft navigation studies in accordance with Engineering Circular 1105-2-412, Assuring Quality of Planning Models.

HarborSym records and accumulates the total time and cost of vessel transits through the harbor and at sea. Since many variations of events can occur over a total voyage, 50 iterations of the simulation were run to obtain the average values for time in the harbor, time waiting, and total operating costs of vessels in the harbor and at sea.

8.1.2 Model Setup

HarborSym depends on user-defined parameters and inputs to reasonably represent the harbor of study. In development of the San Juan Harbor model, USACE economists collaborated with the San Juan Bay Pilots, the Puerto Rico Ports Authority, and various port users to learn the port's configuration, the typical paths through the port used by different vessel types, transit rules, and more. Historical data available through the Waterborne Commerce Statistics Center (2010-2014) was used to define the annual number of calls, tonnage per vessel call, vessel types and classes, vessel trade routes, and commodities moved. The San Juan Bay Pilots' Log (2010-October 2015) and conversations with member of the SJBP provided additional data on the annual number of calls, vessel types and classes, trade routes of vessels calling San Juan, transit times, maneuvering/turning times, anchorage area usage, and more. The Puerto Rico Ports Authority provided data on berthing area dimensions, dock locations, and cruise ship calls. Both the San Juan Bay Pilots and the U.S. Coast Guard provided transit rules within the harbor. Other stakeholders provided additional dock-specific information.

8.1.3 Harbor Configuration

In order to guide vessels through the study harbor, a link-node network must be constructed in HarborSym. A link-node network is a series of connected channel segments, anchorage areas, docks, and turning basins that dictate the path a given vessel takes to get from the harbor entrance to its destination dock and back to the harbor exit within a given HarborSym simulation. Figure 20 shows a screenshot from HarborSym of the link-node network constructed for San Juan Harbor. The colored dots represent different port structures and mark the beginning/end of channel segments ("reaches") and are color coded as follows:

- Purple – Entry/Exit
- Blue – Marks beginning/end of a channel segment
- Green – Dock
- Yellow – Turning basin
- Red – Anchorage area

Figure 20: HarborSym Link-Node Network

Note: The current figure is designed to provide context for the description of the port configuration as built within HarborSym. See Figure 7 through Figure 11 for more detailed depiction of harbor with channel and dock names.

San Juan Harbor has a triangular configuration made up of the Army Terminal Channel, the Puerto Nuevo Channel, and the Graving Dock Channel. The Anegado Channel, which must be transited by all vessels entering the harbor, forks to form the Army Terminal Channel to the west and the Graving Dock Channel to the east creating the first “point” in the triangle. The Army Terminal and Puerto Nuevo Channels meet at the Army Terminal Turning Basin forming a second “point” of the triangle, and the Puerto Nuevo and Graving Dock Channels meet at the Puerto Nuevo and Graving Dock Turning Basins forming the triangle’s third “point”. In addition to the triangular portion of the harbor, there is also the San Antonio Channel, which stretches east of the Anegado Channel prior to vessels reaching the triangle described above.

In everyday operations of the harbor, vessels may reach docks along the Puerto Nuevo Channel by entering through either the Army Terminal or Graving Dock Channels and may also exit by either channel, in some cases traveling the entire triangle (i.e., entering through one channel and exiting through the other). The San Juan Bay Pilots' decide which route a given vessel will take based on a variety of factors including the arrival and departure drafts of the vessel and movements of other vessels entering or exiting the port. Because HarborSym does not have the capability to adjust the route of a vessel based on variables such as vessel arrival draft or conflicting movements of other vessels, the configuration of the port in the model was set up such that vessels calling the most northeastern docks along the Puerto Nuevo Channel (Docks L-O or "ContDock2" in HarborSym) would enter and exit through the Graving Dock Channel and vessels calling the most southwestern dock along the channel (Docks C-K or "ContDock1" in HarborSym) would enter and exit through the Army Terminal Channel. Docks were grouped in a manner most consistent with actual practice within the harbor as conversations with the SJBP indicated that vessels bound for docks L-O often enter through Graving Dock Channel. Modeling showed minimal wait times for vessels calling the docks along Puerto Nuevo Channel, which is consistent what is actually happening in San Juan Harbor. Thus, this modeling method was determined to be a reasonable approach to representing harbor traffic.

Actual docks within a harbor can be grouped into a smaller number of synthetic docks within HarborSym. This technique is used for the San Juan Harbor modeling when docks are located in similar areas of the Harbor and receive similar types of vessels. Table 22 shows which actual docks are represented by each synthetic HarborSym dock using the naming conventions established in Section 3.1 of this appendix. HarborSym dock names will be used when referring to docks from here forward.

Table 22: HarborSym Dock Names

Label	Area	Docks	HarborSym Dock Name
A	ATTB	Puma Caribe Dock	Puma_COD
	ATTB	Cataño Oil Dock (COD) East and West	Puma_COD
	ATTB	Army Terminal Dock East and West	AT Dock
	ATTB	PREPA docks (docks A and B)	DocksA-B
	Grain Docks	Molino (Costado Zorra)	GrainDock
	Grain Docks	Nutrimix	GrainDock
	Grain Docks	Pan American Grain	GrainDock
	Grain Docks	Edelcar	GrainDock
B	PNC	Docks C-K	ContDock1
	PNC	Docks L-O	ContDock2
C	GDTB	Municipal Piers 15-16	Pier15-16
D	Crowley	Crowley	Crowley Dock
E	SAAC	Municipal Piers 1-4	CruiseDockNorth
	SAC	Municipal Piers 8-10	Pier8-10
	SAC	Municipal Piers 11-14	Pier11-14
	SAC	Navy Frontier Pier	Pier11-14
	SAC	Pan American Dock East and West (PAD-E and PAD-W)	PanAmCruiseDock
	SAAC	Isla Grande C	PanAmCruiseDock

8.1.4 Vessel Classes

Vessels in HarborSym are grouped into types and classes. Vessel dimensions are specified at the class level. Table 23 summarizes the San Juan vessel types and classes and provides a range of dimensions associated with each class.

Table 23: Vessel Dimensions by HarborSym Vessel Class

Vessel Type		Vessel Class	Cargo Capacity*		Design Draft (feet)		Beam (feet)		LOA (feet)	
			Min	Max	Min	Max	Min	Max	Min	Max
Cont	Container Vessels	SPX (Sub-Panamax)	4,802	31,630	21	38	59	97	327	814
		PX1 (Panamax 1)	24,041	40,949	31	40.99	97	107	614	845
		PX2 (Panamax 2)	33,936	61,439	41	44.50	105	107	662	965
		PPX (Post Panamax)	67,640	67,640	45.41	45.41	126	126	943	944
Tankers	Tankers, including tanker barges	10K-DWT	3,868	13,499.99	10	30	49	71	327	445
		20K-DWT	13,500	22,999.99	21	34	71	96	454	558
		30K-DWT	23,000	32,199.99	28	37	85	90	520	561
		40K-DWT (MR)	32,200	41,399.99	32	41	88	110	577	655
		50K-DWT (MR)	41,400	50,599.99	38	45	104	110	589	641
		60K-DWT (LR1)	50,600	59,799.99	40	42	105	110	700	750
		70K-DWT (LR1)	59,800	71,249.99	38	48	105	132	600	797
		80K-DWT (LR1)	71,250	80,749.99	47	49	105	110	750	751
		90K-DWT (LR2)	83,650	94,700	37	48	134	150	748	832
		110K-DWT (LR2)	100,000	121,380	39	56	135	151	749	870
Bulker	Bulk Carriers	Bulk-20K	6,500	22,999.99	22	32	56	90	370	558
		Bulk-30K	23,000	32,199.99	31	36	75	100	535	660
		Bulk-40K	32,200	41,399.99	32	39	77	101	580	660
		Bulk-50K	41,400	50,599.99	35	42	99	106	600	625
		Bulk-60K	50,600	64,399.99	41	43	105	107	620	640
		Bulk-80K	64,400	85,499	43	48	105	107	730	750
		Bulk-100K+	95,000	95,001	46	47	127	128	781	782
RoRo	Roll-on/Roll-off Vessels	RoRo1	1,955.7	7,888.5	11	23	51	89	267	614
		RoRo2	9,540	15,305.4	25	33	82	106	509	791
		RoRo3	15,414.3	21,207.84	29	37	76	106	491	791
Cruise	Cruise and Passenger Ships	Cruise1	-	320	8	18	34	70	218	512
		Cruise2	321	1,115	16	28	66	102	531	791
		Cruise3	1,116	2,025	20	27	92	106	665	937
		Cruise4	2,026	2,475	23	28	106	106	808	989
		Cruise5	2,476	3,075	25	29	103	121	865	1,041
		Cruise6	3,076	3,865	26	29	106	127	893	1,041
		Cruise7	3,866	5,300	26	29	121	136	1,002	1,139
		CruiseOasis	6,300	6,400	29	31	154	154	1,185	1,190
LPG-LNG	LPG Tankers and LNG Tankers	LPG-LNG1	3,249	12,107	18	29	54	65	314	414
		LPG-LNG2	12,108	22,586	28	36	70	84	479	525
		LPG-LNG3	22,587	24,500	31	36	92	92	577	578
		LPG-LNG4	40,000	48,000	31	40	106	106	672	673
		LPG-LNG5	49,863	49,865	38	39	120	120	744	745
		LPG-LNG6	63,057	80,743	36	42	137	151	880	962
GC	General Cargo Vessels and Dry	GC-Sm	1,443	19,690	9	36	31	105	201	737
		GC-Lg	20,551	40,495	28	40	76	102	508	662
Misc	Other Vessels	Misc1	-	9,000	6	30	30	86	150	541
Cont-LNG	LNG-powered Container Vessels	PX1-LNG	24,380	30,477	32	35	105	106	720	765

* All capacities are in metric tons except those of Cruise vessels for which capacities are shown as the number of passengers. Cargo capacities in metric tons were calculated as a percentage of DWT.

8.1.5 Commodity Grouping

Table 24 summarizes the grouping of all commodities within HarborSym and associates these commodities with the vessel classes that transport these commodities and the docks through which these commodities pass.

Table 24: HarborSym Commodities by Dock and Vessel Class

HarborSym Dock Name	Commodity Categories - HarborSym	Specific Commodity Notes	Vessels Types	Vessel Classes
Puma_COD	Petroleum products, LPG, LiqBulk	Diesel, jet fuel, gas, LPG, bitumen	Petroleum tankers, LPG tankers	10K-DWT, 20K-DWT, 30K-DWT, 40K-DWT, 50K-DWT, 70K-DWT, LPG-LNG1, LPG-LNG1, LPG-LNG2, 110K-DWT (FWP)
AT Dock	GeneralCargo	Vehicles, containers, general cargo	Tug and barge	GC-Sm
DocksA-B	Petroleum products (FWOP), LNG (FWP)	Diesel (FWOP), LNG (FWP)	Petroleum tankers (FWOP), LNG tankers (FWP)	10K-DWT, 40K-DWT, 50K-DWT, 60K-DWT, 70K-DWT (FWOP); LPG-LNG6 (FWP)
GrainDock	Bulk-GrDock	Bulk cargo, general cargo	Bulker, GC --> + tug and barge	GC-Lg, GC-Sm, Bulk-20K, Bulk-30K, Bulk-40K,Bulk-50K, Bulk-60K, Bulk-80K
ContDock1	Containers, GeneralCargo	Containers, general cargo	Cont, RoRo, GC, Cont-LNG	SPX, PX1, PX2, PX1-LNG, RoRo3, GC-Sm
ContDock2	Containers, GeneralCargo, LiqBulk	Containers, general cargo, molasses, alcohol, vehicles	Cont, RoRo, Tankers, GC --> Mixture of barge tankers and actual tanker vessels	SPX, PX1, PX2, RoRo1, RoRo2, RoRo3, GC-Sm, 10K-DWT, 20K-DWT, 50K-DWT
CruiseDockNorth	Passengers	Passengers	Cruise	Cruise1, Cruise2, Cruise3, Cruise4, Cruise5, Cruise6, Cruise7, CruiseOasis
Pier8-10	GeneralCargo, LiqBulk	Goods, equipment, materials transshipped to smaller islands	Misc, Tankers --> Goletas	20K-DWT, Misc1
Pier11-14	DryBulk, LiqBulk, GeneralCargo, Containers	Bulk cargo (construction materials) --> including rods, structural steel, wood; petroleum products, vehicles; general cargo; liquid bulk cargo	Bulker, GC, RoRo, Tankers	10K-DWT, 20K-DWT, Bulk-20K, Bulk-30K, Bulk-40K, Bulk-50K,GC-Lg, GC-Sm, RoRo2, RoRo3
PanAmCruiseDock	Containers, Passengers, DryBulk	Containers, general cargo, passengers, bulk cargo	Cruise, Ro-Ro, Bulker	Cruise4, Cruise5, Cruise6, RoRo1 (DR ferry), Bulk-30K
Crowley Dock	Containers, GeneralCargo	Containers, general cargo	GC, Misc, Cont-LNG	GC-Sm, Misc1, PX1-LNG
Pier15-16	Containers, GeneralCargo	Vehicles, containers, general cargo	GC, Misc, RoRo	GC-Sm, Misc1, RoRo2, RoRo3

Petroleum product imports on tankers are the main benefitting commodities in terms of reduced origin to destination transportation costs in the San Juan Harbor Study and are the source of a portion of benefits associated with Army Terminal Channel widening measures (Phase 1) and all benefits associated with deepening measures from Cut 6 (the most inner cut of the entrance channel) through the Army Terminal Channel and Turning Basin (Phase 2). The densities of petroleum products vary significantly depending on the type of petroleum product. When loading commodities onto vessels, product density dictates whether the ship's volumetric capacity or deadweight (DWT) capacity becomes the limiting factor in how much can be loaded onto the ship. Thus, density plays an important role in the tonnage that can be loaded onto a given ship at a given channel depth and also in the maximum sailing draft that a given vessel carrying a given commodity can achieve.

Several different categories of petroleum products are included in the San Juan model to be able to load petroleum tankers appropriately based on the density of the cargos they are carrying. The categories are the following:

- Gas/LightPetro – This category includes primarily gasoline, which has a density of 0.737 metric tons/$m^{3.}$
- Jet/MedPetro – This category includes primarily jet fuel and diesel fuel, as well as kerosene. These products have densities of approximately 0.82 metric tons/m^3.
- FuelOil – This category includes the highest density petroleum commodities of relevance in San Juan and was assigned a composite density of 0.89 metric tons/m^3. Commodity categories that were grouped here include Gas Oils; Fuel Oils; Petroleum Oils/Oils from Bituminous Minerals, Crude; and Fuel Oils, NEC.
- MixedPetro – This category includes cargos in the historical WCSC record for which the vessel was carrying multiple commodities and at least one of the commodities was a petroleum product. This commodity category was assigned a weighted density of 0.76 metric tons/m^3.

8.1.6 Trade Routes

Trade routes are important in determination of origin-to-destination transportation costs. For the purpose of the economic analysis done to date, origin-to-destination transportation costs are only relevant for petroleum tankers and LNG tankers since these are the vessel types for which the vessel loading and number of calls change with different study measures.

For petroleum tankers, a weighted average distance from origin to San Juan by vessel class, commodity, dock, and direction (inbound only) combination was estimated based on call and trade route information for 2010 thru 2014. Petroleum ("Petro") route groups were then set up in HarborSym to represent distance ranges. If the average route distance from origin to San Juan for a given vessel class, commodity, dock, and direction combination fell into a given route group then those calls were used in determining the average route distance for that route group. The route group average distance from origin to San Juan was applied as the minimum, most likely, and maximum values in the HarborSym "Additional Sea Distance" fields.

In order to account for the round-trip distance, the "Next Port" field was also utilized. This distance was calculated using Pilots' Log data (2009-2015) that included the name of the destination port after San Juan. Distances were assigned to each of the destinations appearing in the Pilots' Log. Three distance bins were established, <= 200 nautical miles (Bin #1 - shortest distance bin), 201-1000 nautical miles (Bin #2 - medium distance bin), and >1000 nautical miles (Bin #3 - longest distance bin) to help come up with the following minimum, most likely, and maximum next port distances:

- Minimum next port distance = mode of Bin #1 = 122 NM
- Most Likely next port distance = mode of Bin #2, which was also the overall mode across all bins = 518.5 NM
- Maximum next port distance = mode of Bin #3 = 1,763 NM

Table 25 outlines the distances as entered in HarborSym for petroleum tanker route groups. Table 26 shows the vessel class, commodity, and dock combination; the associated route group; and the percentage of the total inbound petroleum product tonnage received at petroleum docks associated with that row of the table in the future without-project condition.

Table 25: Petroleum Tanker Route Distances

Route Group	Additional Sea Distance (nautical miles)			Next Port (nautical miles)		
	MIN distance	ML distance	MAX distance	MIN distance	ML distance	MAX distance
Petro <200 NM	185.16			122	185.16	518.5
Petro 200-800 NM	574.32			122	518.5	1,763
Petro 800-1800 NM	1,425.41			122	518.5	1,763
Petro 1800-2800 NM	2,334.17			122	518.5	1,763
Petro 2800-3800 NM	3,111.88			122	518.5	1,763
Petro 3800+ NM	4,084.04			122	518.5	1,763

Table 26: FWOP Inbound Calls by Petroleum Tankers

Vessel Class	Commodity Name	Dock Name	Route Group Name	Percentage of Inbound Petroleum Product Tonnage to Petroleum Docks
10K-DWT	Jet/MedPetro	Puma_COD	Petro <200 NM	0%
10K-DWT	Gas/LightPetro	Puma_COD	Petro <200 NM	1%
10K-DWT	Jet/MedPetro	DocksA-B	Petro <200 NM	0%
30K-DWT	FuelOil	Puma_COD	Petro 800-1800 NM	1%
40K-DWT	Gas/LightPetro	Puma_COD	Petro 2800-3800 NM	5%
40K-DWT	Jet/MedPetro	Puma_COD	Petro 800-1800 NM	5%
50K-DWT	FuelOil	Puma_COD	Petro 1800-2800 NM	3%
50K-DWT	Gas/LightPetro	Puma_COD	Petro 3800+ NM	44%
50K-DWT	Jet/MedPetro	Puma_COD	Petro 800-1800 NM	18%
50K-DWT	MixedPetro	Puma_COD	Petro 800-1800 NM	8%
70K-DWT	Jet/MedPetro	Puma_COD	Petro 200-800 NM	3%
70K-DWT	Jet/MedPetro	DocksA-B	Petro 200-800 NM	12%

For the LNG tankers, which will only call in the with-project condition, no historical data on calls to San Juan was available to help in establishing trade routes. Thus, LNG trade route distances are based on the minimum, most likely, and maximum origin to San Juan and next port distances associated with historical LNG calls to the ports along the southern coast of Puerto Rico. The most likely LNG trade route origin and next port is from Trinidad (585 nautical miles) and the trade route with the maximum origin and next port distance is Nigeria to San Juan at 4,435 nautical miles (Table 27).

Table 27: LNG Tanker Route Distances

Route Grp	Additional Sea Distance (nautical miles)			Next Port (nautical miles)		
	MIN distance	ML distance	MAX distance	MIN distance	ML distance	MAX distance
LNGRoute	581	585	4435	195	585	4435

8.1.7 Rules

HarborSym allows the user to specify rules dictating how vessels will behave within the simulation. Rules are designed to reflect actual harbor rules regarding vessel passing, safety zones, and more. The following rules are built into the San Juan Harbor model:

- No overtaking is permitting anywhere in San Juan Bay.
- Passing is permitting only in the stretch of Anegado Channel located between Buoy 11 and Anchorage Area E/the Crowley Dock.
- A security zone of 300 ft. is maintained around cruise vessels. A safety zone of 300 ft. is maintained around LNG and LPG vessels. Note that in reality the safety/security zones enforced in the harbor is 300 feet around vessels in transit and 150 feet around vessels at dock. However, in the HarborSym model no distinction is made between the security/safety zone when the vessel is moving versus when the vessel is at dock. During model calibration a model test was done to determine if changing the modeled security/safety zone from 300 ft. to 150 ft. impacted the total time in system or the total transportation cost in a notable manner. The conclusion was that this change did not make a notable difference so the modeled security zone is 300 feet at all times.
- Vessels carrying passengers (i.e., cruise vessels) are given priority over all other vessels.

Also, note that the maximum beam for vessels transiting Army Terminal Channel is approximately 131 ft. in the without-project condition. Although this limit is not setup within a HarborSym rule, the limit is accounted for in the setup of the call lists.

8.1.8 Vessel Operating Costs (VOCs)

The HarborSym analysis utilized USACE DDN-PCX (U.S. Army Corps of Engineers Deep Draft Navigation Planning Center of Expertise) vessel operating costs (VOCs) at FY 2016 price levels as instructed in *Economic Guidance Memorandum, 17-04, Deep Draft Vessel Operating Costs FY2016 Price Levels, Supplemental Guidance* in calculating transportation costs associated with the study port over the 50-year period of study.

8.1.9 Estimate Total Trip Cargo (ETTC)

ETTC (estimate total trip cargo) values are used within the HarborSym model to allocate all or a portion of voyage costs to the study port. For the San Juan Harbor Study, these values were calculated differently for different vessel classes carrying different commodities depending on the loading behavior and routes associated with each.

1.) For all LPG-LNG vessels carrying LNG, which only appear in the with-project condition, ETTC is equal to the Commodity Units unloaded in San Juan. The assumption is that these vessels will unload all cargo in San Juan.

2.) For tanker vessels, if the Commodity Units unloaded/loaded in San Juan accounted for > 65% of the vessels' cargo capacity and historical trade route information did not indicate that there were generally multiple stops, then ETTC was assumed to equal the number of Commodity Units and the entire voyage cost was allocated to San Juan.

3.) The ETTC for 40K-DWT tanker calls and non-depth-constrained 50K-DWT tanker calls is based on a sample of historical 40K-DWT and 50K-DWT tanker calls to San Juan. For each call in the sample, the proportion of the total voyage cost that would have been allocated to San Juan was calculated based on the distance from the origin port to each port of call and the tonnage unloaded/loaded at each port of call. The average of these proportions and the commodity units associated with each HarborSym call were then used to calculate the ETTC. For example, if a 50K-DWT tanker were importing 20,000 metric tons to the study port and the average proportion of the voyage costs allocated to the study port for 50K-DWT tankers is 0.80, then the ETTC would be 20,000 ÷ 0.80 = 25,000.

4.) For all LPG-LNG vessels carrying LPG and all RoRo vessels, the ETTC was calculated using the following formula: ETTC = 2 * cargo on board at arrival - imports + exports, where cargo on board at arrival is based on sailing draft at arrival, estimated minimum draft of the vessel, TPI, and cargo capacity.

5.) For vessels for which it was determined early in the modeling process that only in-port costs were relevant (i.e., vessels that did not stand to benefit in terms of increased lading and fewer vessels calls), no ETTC was assigned. This includes all vessels that do not fit into the four categories above.

8.1.10 Tons per Inch Immersion (TPI)

Tons per inch immersion (TPI) or immersion rate is defined by the *Deep Draft Navigation* manual (IWR Report 10-R-4, April 2010) as “the amount of tons of cargo related to how much deeper a vessel will draft”. Each vessel class is assigned an immersion rate. This immersion rate is used to load vessels falling into a given vessel class subject to the channel constraints, cargoes carried, and physical characteristics of the vessel. The TPI is of direct importance to the analysis in the following cases:

- Transition of fleet: When a transition of fleet to larger or different vessels is expected to occur as a result of the proposed Federal project, the immersion rate is one of the pieces of information used to calculate how much cargo can be allocated to these vessels given a specific channel depth. In the case of San Juan Harbor, LR2 petroleum tankers have never called San Juan Harbor’s Army Terminal channel docks. The TPI, cargo density, channel depth, minimum vessel draft, sailing draft, and vessel physical characteristics (including DWT and volumetric capacity) are all used to figure out how much cargo per call can be transported on these vessels. The amount of cargo that can be transported on the LR2s at a given channel depth no longer needs to be transported on smaller petroleum tankers, resulting in reduced calls by these smaller vessels. For the LNG tanker (LPG-LNG6 vessel class), which would only call in the with-project condition, TPI was one of the pieces of information used to calculate the estimated number of calls per year needed to meet demand for LNG.
- Existing vessel classes that will benefit from project measures: Certain vessel classes have the ability to load deeper and thus increase efficiency as the channel is deepened. For these vessels, TPI is important because it dictates how much additional tonnage can be loaded onto the vessels per additional foot of channel depth. For the purposes of the San Juan Harbor study,

it was assumed that one foot of channel depth equals one foot of additional loading. In terms of TPI, this can be shown as the following:

$$(TPI \times 12\ inches) = additional\ tonnage\ loaded\ per\ foot\ of\ additional\ channel\ depth$$

The approximate immersion rates used in the San Juan analysis for each benefitting vessel class are shown in Table 28 below.

Table 28: TPI by Benefitting Vessel Class

Vessel Class	Immersion Rate (TPI)
50K-DWT Petroleum Tanker (MR)	135
60K-DWT Petroleum Tanker (LR1)	163
70K-DWT Petroleum Tanker (LR1)	172
80K-DWT Petroleum Tanker (LR1)	174
90K-DWT Petroleum Tanker (LR2)	219
110K-DWT Petroleum Tanker (LR2)	236
LPG-LNG6	239

8.1.11 Modeling Strategy

A phased approach to the economic modeling was developed in order to “build” a recommended plan. Each economic modeling phase looked at a specific measure or group of measures identified in Section 6 of this appendix. The future with- and without-project conditions for Phase 1 were modeled first. Once a plan was selected for Phase 1, the Phase 1 future with-project condition became the future without-project condition for Phase 2. In this way, each phase marks a decision point in building the recommended plan. This process continued until all modeling phases were complete and the sum the alternative plans became the overall National Economic Development (NED) Plan and recommended plan.

Measures were grouped into modeling phases based on several factors, including location in the harbor and benefitting docks associated with those phases. The phase(s) that would trigger a transition of fleet were modeled first so that the transitioned fleet could be carried forwarded into the modeling of subsequent phases. Phase(s) that would further change the number of vessel calls in the harbor by allowing for more efficient loading were modeled second. Phases that affected only traffic within the harbor itself (i.e., no origin to destination benefits and no change in the total number of calls) were modeled last. Section 6 has a detailed discussions of the alternative plans and also discusses the screening of alternative plans and their corresponding phases, which left Phases 1, 2, and 5 to be modeled. The phases 1, 2, and 5 are summarized below and are shown spatially in Figure 21. The next sections of the appendix discuss each section in more detail.

Economic Modeling Phase 1: Army Terminal Channel widening (50 feet on each side) → Transition of fleet to LR2 petroleum tankers & LNG design vessels

Economic Modeling Phase 1 selected plan becomes FWOP for Phase 2

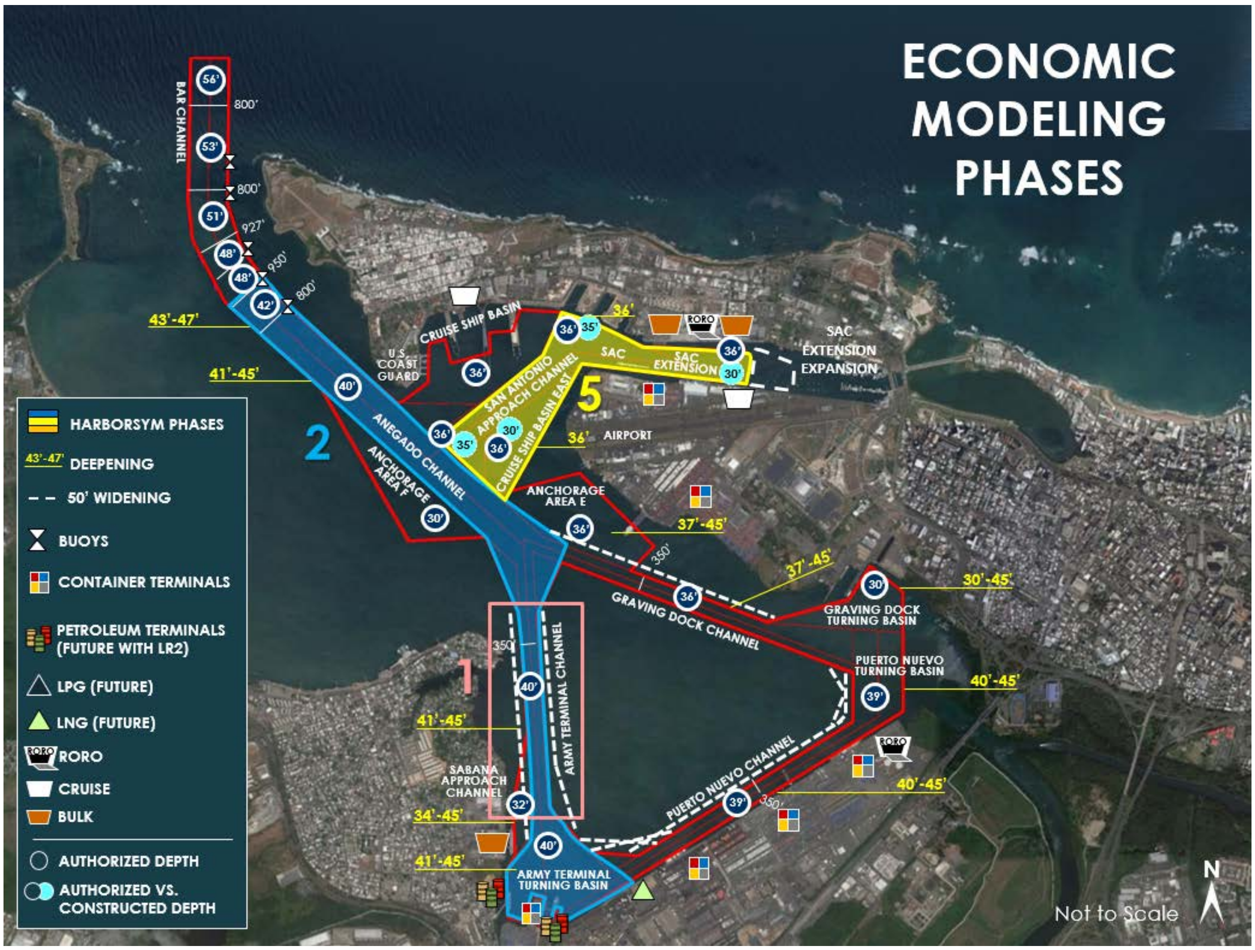
Economic Modeling Phase 2: Deepening in 1-foot increments

- Cut 6 (43-47 feet)
- Anegado Channel (41-45 feet)
- Army Terminal Channel (41-45 feet)
- Army Terminal Turning Basin (41-45 feet)

Economic Modeling Phase 2 selected plan becomes FWOP for Phase 5

Economic Modeling Phase 5: Deepening San Antonio Approach Channel, San Antonio Channel, San Antonio Channel Extension, and Cruise Ship Turning Basin East to 36 feet

Figure 21: San Juan Harbor Economic Modeling Phases Remaining After Initial Screening



8.1.12 Period of Analysis

The project base year, or the year in which the Federal project is expected to begin accruing benefits, is 2026. The period of analysis covers 50 years from 2026 through 2075. The model was run for 2026 only and results for 2026 were assumed to hold for the 50-year period of analysis. Because commodity volumes do not change after the base year and no gradual transition of fleet is assumed over the 2026-2075 period, there was no need to run multiple different years in HarborSym.

8.2 Economic Modeling Phases

This section explains the measures and assumptions associated with each economic modeling phase. Due to risks and uncertainties associated with PREPA's conversion to LNG at the San Juan and Palo Seco power plants[41], two alternative future with-project conditions are presented and used for plan formulation:

- FWP Sc1 (scenario one, with LNG conversion): Conversion from use of diesel fuel to LNG in power generation at the San Juan area power plants takes place. Power generation cost reduction benefits are included in project benefits.
- FWP Sc2 (scenario two, without LNG conversion): Diesel fuel continues to be used in power generation at the San Juan area power plants. Power generation cost reduction benefits are NOT included in project benefits.

Table 29 and Table 30 summarize the screening level results of each economic modeling phase assuming that a conversion to LNG does take place (FWP Sc1) and does not take place (FWP Sc2) and uses rough order of magnitude (ROM) costs provided by SAJ Cost EN. Costs are presented at FY17 price levels, and the FY18 Federal Water Resources Discount rate of 2.75 percent is assumed. Table 31 summarizes the final array results. The final array analysis utilized refined costs at FY18 price levels and the FY18 Federal Water Resources Discount rate of 2.75 percent. Details of each phase are discussed in Sections 8.2.1 through 8.2.3.

Table 29: Screening Level Economic Analysis Results by Phase – FWP Sc1

ECONOMIC ANALYSIS SUMMARY			EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS			
Phase	**Description**	**Alternative**	**AAEQ BENEFITS**	**AAEQ COSTS**	**AAEQ NET BENEFITS**	**BCR**
Phase-1	Alt 1: Army Terminal Channel 100-foot Widening @ Existing 40-foot Depth*	100-foot Army Terminal Channel Widener	$ 72,391,000	$ 13,347,000	$ 59,045,000	5.4
Phase-2	Alt 2: Deepen Cut-6 to 2' > Projet Depth; Deepen Anegado, Army Terminal Channel and Turning Basin	41 feet	$ 306,000	$ 381,000	$ (76,000)	0.8
		42 feet	$ 747,000	$ 514,000	$ 233,000	1.5
		43 feet	$ 1,191,000	$ 631,000	$ 560,000	1.9
		44 feet	$ 1,447,000	$ 824,000	$ 623,000	1.8
		45 feet	$ 1,447,000	$ 1,006,000	$ 441,000	1.4
Phase-5	Alt 7: Cruise Ship Basin East & San Antonio Channels and Deepening	36 feet (assumes 43 feet AT)	$ 1,418,000	$ 302,000	$ 1,117,000	4.7
		36 feet (assumes 44 feet AT)	$ 1,438,000	$ 302,000	$ 1,136,000	4.8
Full Plan	Cut-6 @ 45 feet, Anegado @ 43 feet; 100-foot Army Terminal Channel Widener, 43-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening*		$ 74,934,000	$ 14,279,000	$ 60,650,000	5.2
	Cut-6 @ 46 feet, Anegado @ 44 feet; 100-foot Army Terminal Channel Widener, 44-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening*		$ 75,269,000	$ 14,472,000	$ 60,790,000	5.2

*Power generation benefits included

NOTES: All costs are preliminary.

- Costs at are FY17 price levels. All $ values rounded to the $1,000's.
- Costs above do NOT include PED or construction management. A subsequent calculation to include these costs led to the same plans (43-foot and 44-foot depths) being carried forward to the final array.
- Only Phase-1 and Full Plan costs include mob/demob. It is assumed that Phase-2 and Phase-5 will piggyback on Phase-1 by taking advantage of that mob/demob.
- IDC NOT included for ~$346 million LNG infrastructure investment.

[41] See Section 11 for further discussion of risks and uncertainties.

Table 30: Screening Level Economic Analysis Results by Phase – FWP Sc2

ECONOMIC ANALYSIS SUMMARY			EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS			
Phase	**Description**	**Alternative**	**AAEQ BENEFITS**	**AAEQ COSTS**	**AAEQ NET BENEFITS**	**BCR**
Phase-1	Alt 1: Army Terminal Channel 100-foot Widening @ Existing 40-foot Depth	100-foot Army Terminal Channel Widener	$ 1,438,000	$ 519,000	$ 919,000	2.8
Phase-2	Alt 2: Deepen Cut-6 to 2' > Projet Depth; Deepen Anegado, Army Terminal Channel and Turning Basin	41 feet	$ 305,000	$ 381,000	$ (76,000)	0.8
		42 feet	$ 747,000	$ 514,000	$ 233,000	1.5
		43 feet	$ 1,191,000	$ 631,000	$ 560,000	1.9
		44 feet	$ 1,447,000	$ 824,000	$ 623,000	1.8
		45 feet	$ 1,447,000	$ 1,006,000	$ 441,000	1.4
Phase-5	Alt 7: Cruise Ship Basin East & San Antonio Channels and Deepening	36 feet (assumes 43 feet AT)	$ 1,418,000	$ 302,000	$ 1,117,000	4.7
		36 feet (assumes 44 feet AT)	$ 1,438,000	$ 302,000	$ 1,136,000	4.8
Full Plan	Cut-6 @ 45 feet, Anegado @ 43 feet; 100-foot Army Terminal Channel Widener, 43-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening		$ 3,986,000	$ 1,452,000	$ 2,530,000	2.7
	Cut-6 @ 46 feet, Anegado @ 44 feet; 100-foot Army Terminal Channel Widener, 44-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening		$ 4,321,000	$ 1,645,000	$ 2,670,000	2.6

NOTES: All PREPA calls were removed from the benefit analysis by post-processing HarborSym outputs to take out transportation costs associated with calls to the PREPA dock in both the FWOP and FWP conditions.

- Costs at are FY17 price levels. All $ values rounded to $1,000's.
- All costs are preliminary.
- Costs above do NOT include PED or construction management. A subsequent calculation to include these costs led to the same plans (43-foot and 44-foot depths) being carried forward to the final array.
- Only Phase-1 and Full Plan costs include mobilization (mob)/demobilization (demob). It is assumed that Phase-2 and Phase-5 will piggyback on Phase-1 by taking advantage of that mob/demob.

Table 31: Final Array Economic Analysis Results

<table>
<tr><th colspan="3">ECONOMIC ANALYSIS SUMMARY</th><th colspan="4">EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS</th></tr>
<tr><th></th><th></th><th></th><th colspan="2">WITH LNG CONVERSION FWP (FWP Sc1)</th><th colspan="2">WITHOUT LNG CONVERSION (FWP Sc2)</th></tr>
<tr><th>Phase</th><th>Description</th><th>Measure</th><th>AAEQ NET BENEFITS</th><th>BCR</th><th>AAEQ NET BENEFITS</th><th>BCR</th></tr>
<tr><td>Phase-1</td><td>Army Terminal Channel 100-foot Widening @ Existing 40-foot Depth</td><td>100-foot Army Terminal Channel Widener</td><td>$ 58,907,000*</td><td>5.4</td><td>$ 781,000</td><td>2.2</td></tr>
<tr><td rowspan="2">Phase-2</td><td rowspan="2">Deepen Cut-6 to 2' > Project Depth; Deepen Anegado, Army Terminal Channel and Turning Basin</td><td>43 feet</td><td>$ 447,000</td><td>1.6</td><td>$ 447,000</td><td>1.6</td></tr>
<tr><td>44 feet</td><td>$ 481,000</td><td>1.5</td><td>$ 480,000</td><td>1.5</td></tr>
<tr><td rowspan="2">Phase-5</td><td rowspan="2">Cruise Ship Basin East & San Antonio Channels and Deepening</td><td>36 feet (assumes 43 feet AT)</td><td>$ 1,183,000</td><td>6.0</td><td>$ 1,183,000</td><td>6.0</td></tr>
<tr><td>36 feet (assumes 44 feet AT)</td><td>$ 1,202,000</td><td>6.1</td><td>$ 1,202,000</td><td>6.1</td></tr>
<tr><td rowspan="2">Comprehensive Plan: Phase-1 + Phase-2 + Phase-5</td><td colspan="2">Cut-6 @ 45 feet, Anegado @ 43 feet; 100-foot Army Terminal Channel Widener, 43-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening</td><td>$ 60,147,000*</td><td>5.1</td><td>$ 2,027,000</td><td>2.0</td></tr>
<tr><td colspan="2">RECOMMENDED PLAN: Cut-6 @ 46 feet, Anegado @ 44 feet; 100-foot Army Terminal Channel Widener, 44-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening</td><td>$ 60,195,000*</td><td>5.0</td><td>$ 2,075,000</td><td>1.9</td></tr>
<tr><td colspan="7">* Power generation cost reduction benefits and PREPA LNG infrastructure investment costs of ~$350 million included. Recommended plan includes unemployment benefits. All $ values rounded to $1,000's. Costs are at FY18 price levels. FY18 discount rate of 2.75 percent assumed.
Comprehensive plan costs include the following: GNF construction cost (including mobilization/demobilization), PED, construction management, lands and damages, USCG construction features, LSF (berthing area deepening), IDC on everything except LSF, and annual increase in O&M due to construction of project.</td></tr>
</table>

8.2.1 Phase 1: Army Terminal Channel Widening

Phase 1 of the economic analysis looks at the widening of the Army Terminal Channel by 100 feet (from an existing width of 350 feet to a maximum width of 450 feet) at an existing channel depth of 40 feet. Widening measures of 50 feet to each side of the existing channel were considered. Ship simulation determined that the full 100 foot widener was needed in order for both the petroleum tanker design vessel and the LNG tanker design vessel to be able to transit the channel safely. Thus, the economic analysis for Phase 1 compares one alternative (a channel widener of 100 feet) to the future without project condition in which the channel width remains at 350 feet.

8.2.1.1 Fleet Transition

The petroleum tanker design vessel is the Long Range 2 (LR2) tanker, which has a beam greater than the 131-foot limit of the existing Army Terminal Channel. Based on the world fleet and data provided by port stakeholders, beams of LR2 vessels typically range from 134.8 ft. to 150.9 ft. The existing Puma Caribe dock can accommodate these vessels. Thus widening of the Army Terminal Channel will immediately allow a partial transition of fleet by Puma Energy Caribe away from MR tankers and towards LR2 tankers. See Table 11 for comparison of MR and LR2 tanker dimensions. Transition from MRs to the larger LR2s allows the same quantity of commodities to be transported in fewer voyages producing transportation costs savings even given the fact that the LR2 hourly vessel operating costs (90K-DWT and 110K-DWT tanker classes) are higher than the MR hourly vessel operating costs (40K-DWT and 50K-DWT tanker classes). LR2 vessels are prevalent in the world fleet, so it seems reasonable to think that San Juan would be able to receive the seven 110K-DWT calls per year forecasted in this analysis. Additionally, information from terminal operators on landside storage capacity (infrastructure) for petroleum products indicates that existing (2016) and future (in construction as of 8/1/17) storage capacity accessible from the petroleum docks will support the increase in cargo volume offloaded per call in the FWP condition.

The design vessel selected for the LNG service has a design draft of 38.8 feet. It is assumed that this vessel will be able to operate without any draft restrictions as the new channel depth will be -44' MLLW, providing more than 5 feet of UKC which is 3 feet more than required for current operating vessels.

The LNG design vessel for the economics has a capacity between 130,000 m^3 and 145,000 m^3. Maximum dimensions of 951 ft. LOA X 150.9 ft. beam X 38.80 ft. design draft were selected to encompass 68 percent of the world fleet[42]. Widening of the Army Terminal Channel allows for this size vessel to call PREPA's San Juan Harbor dock (DocksA-B) located in the ATTB area of the harbor. Based on the minimum amount of power generation that needs to take place in San Juan in order to maintain electric grid stability given current electric grid operations criteria, 5 calls per year will be needed by these vessels in the with-project condition to meet PREPA's annual demand for LNG.

8.2.1.2 Underlying Assumptions

The underlying assumptions associated with Economic Modeling Phase 1 are outlined below.

Future Without-Project Condition Assumptions:

1) PREPA brings diesel (Jet/MedPetro) through San Juan Harbor to service San Juan area power plants (San Juan Plant and Palo Seco Plant).
2) The power generation costs provided by PREPA associated with using diesel fuel to generate 1,860,000 MWhrs of power are used. This is the minimum annual amount of power generation that must take place in the San Juan area power plants both with and without a Federal navigation improvements project in order to maintain electric grid stability given current electric grid operations criteria.
3) The existing condition fleet of petroleum tankers is used to transport commodities to Puma_COD.

Future With-Project Condition Assumptions, LNG Conversion Assumed (FWP Sc1):

1) PREPA brings LNG through San Juan Harbor to service San Juan area power plants (San Juan Plant and Palo Seco Plant).
2) The power generation costs provided by PREPA associated with using LNG to generate 1,860,000 MWhrs of power are used. This is the minimum annual amount of power generation that must take place in the San Juan area power plants both with and without a Federal navigation improvements project in order to maintain electric grid stability given current electric grid operations criteria.
3) Approximately 18 percent of the petroleum commodity tonnage imported to the Puma_COD synthetic dock in HarborSym is transitioned from MR tankers to LR2 tankers.

[42] World fleet data pulled from IHS Sea-Web database in 2016.

Future With-Project Condition Assumptions, Continued Use of Diesel Fuel in Power Generation Assumed (FWP Sc2):

1) PREPA brings diesel (Jet/MedPetro) through San Juan Harbor to service San Juan area power plants (San Juan Plant and Palo Seco Plant).

2) The power generation costs provided by PREPA associated with using diesel fuel to generate 1,860,000 MWhrs of power are used. This is the minimum annual amount of power generation that must take place in the San Juan area power plants both with and without a Federal navigation improvements project in order to maintain electric grid stability given current electric grid operations criteria.

3) Approximately 18 percent of the petroleum commodity tonnage imported to the Puma_COD synthetic dock in HarborSym is transitioned from MR tankers to LR2 tankers.

8.2.1.3 *Power Generation Cost Reduction Component (FWP Sc1 Only)*

Because the Phase 1 Army Terminal Channel widening measures trigger the fleet transition that allows 130-145K m^3 LNG tankers to call San Juan Harbor, power generation cost reduction benefits are incorporated into the Economic Modeling Phase 1, FWP Sc1 analysis. An explanation of the methodology used in calculating these benefits is found in Section 9 of this appendix.

An investment in LNG terminal infrastructure is needed in order to receive LNG vessels at PREPA's San Juan dock and in order to be able to transport, store, and use the LNG in the San Juan area power plants. Because a Federal widening project is needed to facilitate PREPA's transition to LNG, costs associated with this infrastructure investment become project costs and are included in calculation of the BCR. This investment is estimated by PREPA to be approximately $346.3 million (in 2017 dollars), and the construction of PREPA's terminal is estimated to take 36 months to complete[43]. Per information provided by PREPA, the infrastructure and terminal are expected to be complete by 2024 and will be constructed through the formation of a public-private partnership (P3) between PREPA and a private entity[44]. Thus, the San Juan area power plants would be able to use LNG in power generation at completion of the Federal project construction and to begin accruing benefits of the use of LNG beginning in the project base year of 2026.

Inclusion of power generation cost reduction benefits is important to this economic analysis because transportation costs do not capture the true benefit of being able to bring LNG on LNG tankers to San Juan over bringing diesel on petroleum tankers for two main reasons:

1. The hourly vessel operating costs associated with LNG tankers are higher than the hourly vessel operation costs associated with petroleum tankers.
2. The routes associated with LNG tankers are longer than those associated with the petroleum tankers that have historically serviced the PREPA dock in San Juan.

Consequently, due to higher hourly VOCs and longer routes for LNG than for diesel, the conclusion would be that "negative" benefits result from PREPA's transition from diesel to LNG if only transportation costs are considered. The true and very real value to the nation of Federal widening of the Army Terminal Channel that allows PREPA to transition from diesel to LNG for use in power

[43] Information provided by PREPA representatives to SAJ Planning.

[44] See Main Report for further discussion of P3, how infrastructure investment will be financed, and timeline for formation of P3 and subsequent LNG infrastructure construction.

generation at its northern power plants would not be captured. Reduction in power generation costs contribute to national economic development by increasing the net national value of goods and services and therefore should be captured.

8.2.1.4 Benefit Sources

The Puma_COD HarborSym dock benefits from widening of Army Terminal Channel. Benefitting commodities for Phase 1 at the Puma_COD HarborSym dock are Gas/LightPetro, Jet/MedPetro, and MixedPetro. As discussed in the previous section, DocksA-B (i.e., the PREPA dock) also benefits (FWP Sc1) with a transfer from Jet/MedPetro in the without-project condition to LNG in the with-project condition, but this benefit is not directly captured through transportation costs savings in HarborSym but rather through reduction in the costs of power generation to PREPA.

Table 32: Phase 1 FWOP and FWP Number of Calls

FWOP Calls	FWP Calls	Call Reduction/Fleet Changes by Vessel Class
174	162	FWP Sc1 only: (-) Reduced 2 calls by 10K tankers and 7 calls by 70K tankers to PREPA docks (+) Added 5 calls for 130-145K m^3 capacity LNG tankers to PREPA docks FWP Sc1 and FWP Sc2: (-) Reduced 3 calls by 40K tankers and 12 calls by 50K tankers to Puma_COD (+) Added 7 calls by LR2 tankers to Puma_COD

Note: Number of calls only includes calls to docks that benefit from Phase 1 widening measures. These are Puma_COD and DocksA-B (PREPA dock) in HarborSym.

8.2.1.5 Phase 1 Summary

Table 31 shows AAEQ net benefits for Economic Modeling Phase 1 ranging from approximately $781,000 without the LNG conversion to $58.1 million with the LNG conversion and BCRs of 2.2 and 5.4, respectively. Thus, Economic Modeling Phase 1 widening of the Army Terminal Channel to 450 feet is economically justified and becomes the first component of the National Economic Development (NED) plan and of the recommended plan. This is true using both the FWP Sc1 and FWP Sc2 assumptions outlined above, meaning that the LNG conversion does not impact the justification of measures included in Economic Modeling Phase 1. The Phase 1 with-project fleet becomes the Phase 2 without-project fleet going forward. Construction of measures included in Economic Modeling Phase 1 is estimated to take 70 days.

8.2.2 Phase 2: Cut 6 through Army Terminal Channel Deepening

Phase 2 of the economic analysis looks at deepening Cut 6 to 43-48 feet, deepening the Anegado Channel to 41-45 feet, deepening the widened Army Terminal Channel to 41-45 feet, and deepening the Army Terminal Turning Basin to 41-45 feet in 1-foot increments. MR, LR1, and LR2 tankers have the capacity to use depth beyond that available in San Juan in the existing condition. See Table 11.

8.2.2.1 Underlying Assumptions

The underlying assumptions associated with Economic Modeling Phase 2 are outlined below.

Future Without-Project Condition Assumptions:

- Economic Modeling Phase 1 future with-project fleet and assumptions held constant.

Future With-Project Condition Assumptions:

1) One foot of loading capacity is gained with each additional foot of channel depth.
2) Vessels are loaded based on density of commodities carried.
3) No additional transition of fleet occurs in Phase 2. Rather, the Phase 1 future with-project fleet can now load deeper.

Note that for Economic Modeling Phase 2, FWP assumptions are the same whether or not the LNG conversion is considered. This is because calls to the PREPA dock, whether by LNG vessels or by petroleum tankers carrying diesel, are not assumed to benefit from Army Terminal Channel deepening. Any difference in Economic Modeling Phase 2 benefits between FWP Sc1 and FWP Sc2 is very slight and is due only to the impacts of slight differences in in-port vessel interactions that result when the LNG conversion and the resulting LNG vessels are/are not included in the call list. Thus, for simplifications, the remainder of the discussion in this section on the analysis of Phase 2 measures focuses on the specifics of the FWP Sc1 analysis and results. See Table 30 and Table 31 for results specific to FWP Sc2 assumptions.

8.2.2.2 Benefit Sources

Deepening of the Army Terminal Channel allows MR, LR1, and LR2 tankers calling the Puma_COD petroleum dock in the ATTB area to load deeper. Table 33 summarizes the FWOP and FWP number of calls and the call reductions resulting at each alternative Army Terminal Channel depth.

Table 33: Phase 2 FWOP and FWP Number of Calls (FWP Sc1)

Alternative	FWOP Calls	FWP Calls	Call Reduction/Fleet Changes by vessel class
41 feet	162	160	(-) Reduced 1 call by 10K tankers and 1 call by unconstrained 50K tankers to ATTB petroleum docks
42 feet	162	158	(-) Reduced 1 call by 10K tankers, 1 call by unconstrained 50K tankers, and 2 calls by 40K tankers to ATTB petroleum docks
43 feet	162	156	(-) Reduced 2 call by 10K tankers, 2 call by unconstrained 50K tankers, and 2 calls by 40K tankers to ATTB petroleum docks
44 feet	162	154	(-) Reduced 2 call by 10K tankers, 4 call by unconstrained 50K tankers, and 2 calls by 40K tankers to ATTB petroleum docks.
45 feet	162	154	(-) Reduced 2 call by 10K tankers, 4 call by unconstrained 50K tankers, and 2 calls by 40K tankers to ATTB petroleum docks.

Notes: Number of calls only includes calls to docks that benefit from Phase 2 deepening measures. While total number of calls vary between FWP Sc1 and FWP Sc2 assumptions, call reductions at each depth do not change.

8.2.2.3 Phase 2 Summary

Table 29 and Table 34 show the net benefits for each incremental Phase 2 depth. The 44-foot alternative maximizes net benefits and becomes the selected alternative plan for Economic Modeling Phase 2. Table 35 and Figure 22 show the marginal benefits of each incremental increase in depth for Phase 2. Marginal benefits increase from 41 feet to 43 feet and then decrease from 43 feet to 45 feet. When the depth increases from 44 feet to 45 feet, no additional calls are reduced so no marginal benefit is shown. This result seems reasonable given that the load factor analysis done for this study shows that MR tankers benefit up to a sailing draft of 41.25 feet, which equates with a channel depth of 43.25 feet. Once this channel depth is reached, only LR1 and LR2 tankers calling San Juan will benefit from additional channel depth. Note that the Economic Modeling Phase 2 with-project fleet becomes the Economic Modeling Phase 5 without-project fleet going forward. Construction of measures included in Economic Modeling Phase 2 is estimated to take 225 days.

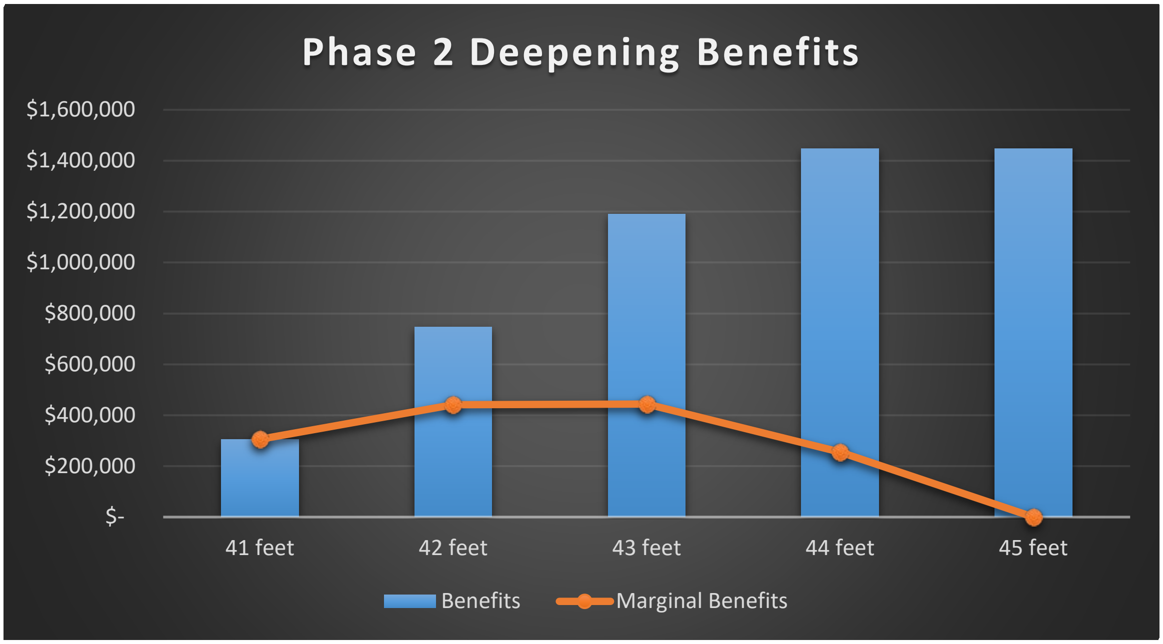
Table 34: Incremental Analysis of Phase 2 Alternative Depths (FWP Sc1)

ECONOMIC ANALYSIS SUMMARY			EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS			
Phase	Description	Alternative	AAEQ BENEFITS	AAEQ COSTS	AAEQ NET BENEFITS	BCR
Phase-2	Alt 2: Deepen Cut-6 to 2' > Projet Depth; Deepen Anegado, Army Terminal Channel and Turning Basin	41 feet	$ 306,000	$ 381,000	$(76,000)	0.8
		42 feet	$ 747,000	$ 514,000	$233,000	1.5
		43 feet	$ 1,191,000	$ 631,000	$560,000	1.9
		44 feet	$ 1,447,000	$ 824,000	$623,000	1.8
		45 feet	$ 1,447,000	$ 1,006,000	$441,000	1.4

Table 35: Marginal Benefits by Incremental Depths (FWP Sc1)

Depth	Benefits	Marginal Benefits
41 feet	$ 306,000	$ 306,000
42 feet	$ 747,000	$ 441,000
43 feet	$ 1,191,000	$ 444,000
44 feet	$ 1,447,000	$ 256,000
45 feet	$ 1,447,000	$ -

Figure 22: Phase 2 Deepening Benefits (FWP Sc1)



8.2.3 Phase 5: San Antonio Channel and Cruise Ship Turning Basin East Deepening Measures

Economic Modeling Phase 5 of looks at deepening of the San Antonio Channel and the Cruise Ship Turning Basin East to depths of 36 feet. From a practical perspective, the deepening of the Cruise Ship Basin East serves as a widening measure because the additional depth creates more usable turning basin width for cruise ships when turning to exit the harbor.

8.2.3.1 Underlying Assumptions

The underlying assumptions associated with Economic Modeling Phase 5 are outlined below and do not vary between FWP Sc1 and FWP Sc2. For simplification, the results presented here reflect the FWP Sc1 fleet. Phase 5 measures do no directly impact calls servicing PREPA and the difference in time in-port and associated transportation costs are only slightly different between FWP Sc1 assumptions and FWP Sc2 assumptions as can be seen by comparing Economic Modeling Phase 5 results in Table 29, Table 30, and Table 31 above.

Future Without-Project Condition Assumptions:

1) Cruise vessels using the northern cruise docks (Piers 1-4/CruiseDockNorth) make a non-continuous turn when exiting the northern cruise docks to avoid use of the shallow (30 ft.) Cruise Ship Basin East. Those who do attempt to use this Basin are slow/inefficient in turning due to concern about the area’s shallow depth. HarborSym turning time of .55 hours (33 mins) on average based on input from San Juan Bay Pilots and from ERDC ship simulation is assumed based on preliminary ship simulation results.

2) Cruise ships exiting CruiseDockNorth block the Anegado Channel on their outbound turn.

Future With-Project Condition Assumptions:

1) With 36 feet of depth in the San Antonio Channel and the Cruise Ship Basin East, cruise vessels exiting the northern cruise docks can now make the optimum/efficient turn by confidently using the Cruise Ship Basin East to complete their turning maneuver. HarborSym turning time of .40 hours (24 mins) on average is assumed based on preliminary ship simulation results.
2) Cruise ships exiting CruiseDockNorth no longer block the Anegado Channel on their outbound turn.

The Oasis of the Seas class of cruise ships have design drafts of 30.5 feet. These are the world's largest cruise vessels and this class of vessel does call San Juan. San Juan Bay Pilots' Log sailing draft data for the period for 1 January 2016 through 30 September 2016 shows that out of 26 transits recorded over this time period, 10 transits were made at 30 feet and 16 were made at 31 feet, so these vessels are using their full draft when calling San Juan.

Current depths in the San Antonio Channel segment from the Anegado Channel to the bend in the San Antonio Channel are already to 36 feet of depth in most places, suggesting that for the most part cruise vessels already utilize this depth. Note that the Cruise Ship Basin East is currently shallower than the channel, which is why deepening that area gives you benefits in terms of decreased maneuvering times.

The depth of 36 feet was determined to be needed based on input from a cruise captain provided during his participation in the 28 October 2016 ERDC ship simulation, the use of azipods (a specific type of propulsion unit) in the cruise industry, and similar depth requirements at other ports receiving calls by the Oasis of Seas vessel class.

Many cruise ships use a type of propulsion unit called an azipod. Azipods are popular in the cruise industry because of the efficient electric motor and enhanced maneuverability offered by this propulsion unit design. The increased maneuverability and vessel control provided by azipod propulsion allows for the cruise industry to conduct operation without tug assist. However, due to the design of these units, they are vulnerable to damage if they touch the bottom. There is historical record of many vessels being disabled for extended periods of time for repairs to azipod units that accidentally touched the bottom.

Based on research by SAJ economists, other ports that receive calls by the Oasis of the Seas cruise vessel class appear to have depths ranging 34.4 to 41 feet, including St. Thomas, VI with a depth of 37 feet. Pilots at another port that receives calls from the Oasis of the Seas recently shared with SAJ Engineering that "the minimum UKC for the Oasis is at least 5' at MLLW." Thus, a depth of 36 feet in San Juan with 5 feet of under keel for cruise vessels is reasonable and consistent with standards across the industry.

Assumed without-project and with-project depths are shown in Table *36.* The economic analysis assumes that Segments 2 and 3 are non-separable because vessels using the Cruise Ship Turning Basin East (Segment 3) must pass through the San Antonio Approach Channel (Segment 2) when exiting the CruiseDockNorth. In order to achieve optimal maneuvering in the cruise ship area, Segments 2 and 3 must be deepened to 36 feet to match the current federally constructed depth of 36 feet in the cruise ship turning basin north of the San Antonio Channel. No benefit is achieved at shallower incremental depths and no additional benefit is achieved at a depth beyond 36 feet.

Table 36: Phase 5 With- and Without-Project Depths

Segment	Segment Description	FWOP Depth (feet)	FWP Depth (feet)
1	Cruise ship turning basin north of San Antonio Approach Channel and San Antonio Channel	36	36
2*	San Antonio Approach Channel and San Antonio Channel	35	36
3*	Cruise Ship Turning Basin East (located south of the of San Antonio Channel)	30	36

*Segments 2 and 3 are non-separable.
Notes: The cruise ship turning basin north of the San Antonio Channel and the Cruise Ship Turning Basin East are combined into a single turning basin for HarborSym modeling purposes. FWOP depth shown above reflects the federally constructed depth. Because cruise ships calling the San Antonio Approach Channel in the existing condition require 5 feet of underkeel clearance (31-foot draft + 5 feet of UKC = 36-foot channel depth needed) and because the actual depth (per hydrographic survey) in this part of the harbor is generally 36 feet or greater, the depth of Segment 2 in the HarborSym model is set up as 36 feet in both the with- and without-project conditions to avoid modeling issues (vessels getting stuck in the system, etc.).

The HarborSym analysis of Phase 5 also incorporates the high/low cruise ship season into both the FWOP and FWP call lists when assigning arrival dates. Based on conversations with the San Juan Bay Pilots, arrival times of cruise ships are expected to be between 4:00 am and 4:00 pm. Time spent at dock generally varies between larger and smaller cruise ships. Larger cruise vessels (Cruise4 through CruiseOasis classes) typically stay at dock in San Juan for 6-12 hours, with most staying for around 8 hours. Smaller cruise vessels (Cruise1 through Cruise3 classes) typically stay at dock in San Juan for 8-24 hours, with most staying for around 12 hours.[45]

8.2.3.2 *Benefit Sources*

The majority of Phase 5 benefits come from a savings in turning time for all cruise vessels using the northern cruise berths (CruiseDockNorth). An average savings of 9 minutes was used based on preliminary ship simulation results. The analysis includes 488 uses of the Cruise Ship Basin East by cruise ships annually, and, based on input from the San Juan Bay Pilots, the analysis assumes all cruise vessels utilizing this turning basin experience this time savings. Eighty-eight percent of Phase 5 benefits are a result of the decreased turning time by cruise ships, while the remaining twelve percent are attributable to reductions in other in-port cruise ship costs. Results indicate that other vessels calling other areas of the harbor are not impacted by these study measures (i.e., no reduced in-port congestion or transportation costs for non-cruise vessels).

8.2.3.3 *Other Considerations*

The quantitative analysis as described above measures benefits to cruise ships associated with the San Antonio Channel west of the channel "bend" (i.e., the San Antonio Approach Channel). Other benefits that may accrue to docks east of the "bend" through the San Antonio Channel Extension and 1050 feet expansion are considered only qualitatively here. Based on SAJ FY2016 hydrographic surveys, the existing depths east of the "bend" are generally deeper than the federally constructed depths of 35 feet (for the most westerly portion) and 30 feet (for the eastern side). The estimated quantity of material needed to get this specific segment from its current depths to 36 feet is ~90,000 cubic yards with construction costs of approximately $2.9 million or $130,000 AAEQ at the FY18 discount rate of 2.75 percent and assuming a 50-year period of analysis.

[45] Sources: San Juan Bay Pilots, San Juan Bay Pilots' Log data 2010-2015, and Continental Shipping (cruise ships agents)

The potential need for depth in this area is driven by plans to homeport either a Freedom or Oasis class vessel at the Pan American docks south of the channel. Assuming 5 feet of under keel, these vessels would need up to 34 and 36 feet of channel depth, respectively. This would add a weekly homeported call to the Pan American docks, the possible benefit of which has not been quantified. Bulk vessels, general cargo ships, and car carriers call docks along the channel segment's northern edge. According to data in the San Juan Bay Pilots' log, approximately 10 percent of these vessels calling Piers 11-14 and the Frontier Pier arrived at sailing drafts of 30 feet or greater between 2010 and October 2015. Thus, vessels currently calling and expected to call this channel segment in the future could have potential to benefit from channel depths beyond the existing federally constructed depths of 35 feet and 30 feet. The costs associated with the dredging of this area but no quantified benefits are included in the Phase 5 BCR.

8.2.3.4 *Phase 5 Summary*

Table 31 shows the average annual net benefits and BCR associated with Economic Modeling Phase 5, which are approximately $1.2 million and 6.1, respectively (mob/demob not included). Therefore, the NED plan and recommended plan will include deepening of the San Antonio Channel and the Cruise Ship Basin East to depths of 36 feet. Construction of Phase 5 measures is estimated to take 85 days.

9 Power Generation Cost Reduction Analysis

The second component of project benefits is the calculation of the reduction in the costs of generating power in Puerto Rico's northern power plants, the Palo Seco and San Juan Plants.[46] As outlined previously, this component of project benefits was included as part of with LNG conversion future with-project scenario (FWP Sc1) benefits and was not included as part without LNG conversion future with-project scenario (FWP Sc2) benefits. The underlying assumptions of this portion of the analysis are the following:

1. Widening of the Army Terminal Channel will allow LNG vessels to reliably supply PREPA with LNG in San Juan, enabling PREPA to transition from the use of diesel fuel for power generation in the without-project condition to the use of LNG for power generation in the with-project condition.[47] LNG is a cheaper commodity than diesel[48], cleaner burning than diesel, and marginally more efficient than diesel[49].
2. A constant number of megawatt hours of power generation is assumed to be produced in the without- and with-project conditions. As per current electric grid operations criteria, the minimum annual amount of power generation that must take place in the San Juan area power plants both with and without a Federal navigation improvements project in order to maintain electric grid stability is 1,860,000 MWhrs.[50]

The 1,860,000 MWhrs figure is based on the results of grid stability studies for PREPA's operating scheme for the upcoming years. At least this amount of power will need to be generated in the

[46] Note that certain details of the calculation currently included in this section may be removed in future versions of this appendix to be released to the public.
[47] See Section 3.5 for additional discussion of PREPA's current operations and future plans.
[48] See Section 11 for risk and uncertainty surrounding the price spread between diesel and LNG.
[49] LNG produces a greater amount of BTUs per metric ton than does diesel. This means fewer metric tons of LNG are needed than of diesel to produce the same number of megawatt hours of power generation.
[50] Information provided by PREPA.

northern power plants in order to achieve grid stability and prevent loss of load hours[51], which is related to blackouts or other issues that can result from power demand exceeding power supply. That operation scheme is not expected to change, so PREPA feels confident that a minimum of 1,860,000 MWh per year will represent the reality of operation of the Palo Seco and San Juan power plants during the period over which the Federal navigation project is being analyzed (2026-2075). Note that 1,860,000 MWh annually does take into account the projected future population decline in Puerto Rico and any resulting decline in power demand. From an operations perspective, population in Puerto Rico would have to drop more drastically than projected to have any impact on this minimum annual number of MWh expected to be generated in San Juan.[52]

The terminology "balancing the grid" or "stabilizing the grid" is used to describe the actions needed to ensure that given the power generation capacity available across the entire power grid (i.e., all power plants operated by PREPA and all private plants that generate power and sell that power to PREPA), power is supplied where and when it is demanded. For example, the population of Puerto Rico is heavily concentrated in the San Juan metro area, but generation at the northern plants alone cannot meet the high demand in this area, especially at peak load times. Therefore power generated at other plants must be transmitted to the San Juan area to "balance the grid" and ensure demand is met. Factors that impact grid stability include but are not limited to electricity demand/peak load, generation capacity at each of Puerto Rico's power generation facilitates, availability of units because of maintenance or forced outages, availability of transmission lines, fluctuations in power generation due to both distributed generation and large renewable projects, as well as economic dispatch.[53]

9.1 Benefit Calculation

Due to the highly technical nature of power generation operations schemes, the economic analysis of power generation cost reduction benefits relies heavily upon the expertise of PREPA and PREPA's consultants. The prices per KWh for power generation using diesel fuel versus using LNG was calculated by PREPA and PREPA's consultants based on their knowledge of PREPA's power generation equipment and capabilities. These prices per KWh for power generation provided by PREPA were then applied by SAJ economists using the basic formula below. This formula was developed by SAJ Economics:

$$((D * 0.5) * 1{,}860{,}000{,}000) - ((L * 0.5) * 1{,}860{,}000{,}000) - (\text{Annual value of infrastructure investment annuity}) + (\text{Phase 1 HarborSym FWOP sea transportation cost} - \text{Phase 1 HarborSym FWP sea transportation costs}) = \text{Phase 1 benefits}$$

Where:

- **D** = Price per KWh for power generation using diesel fuel
- **L** = Price per KWh for power generation using LNG
- **1,860,000,000** = Annual number of KWh of demand
- **0.5** = Adjustment made to ensure that the sea voyage transportation costs are not double counted. HarborSym is the Corps' tool for measuring sea voyage transportation costs. However, per KWhr power generation costs provided by PREPA included sea voyage transportation costs. No information is available on what percentage of the power generation cost is attributable to sea voyage transportation cost. SAJ assumed 50 percent

[51] Loss of Load Hours (LOLH) is used to measure the number of hours of power generation shortfall expected and is a concept employed in defining resource adequacy. From: https://www.ferc.gov/legal/staff-reports/2014/02-07-14-consultant-report.pdf; https://www.nrel.gov/docs/fy11osti/50355.pdf.

[52] Based on information provided by PREPA.

[53] From 8/9/17 email correspondence with PREPA representatives.

of the cost was attributable to this transportation with the idea that this was likely overstating the proportion of power generation costs coming specifically from the sea voyage transportation costs of fuel and thus understating benefits.

- **Annual value of infrastructure investment annuity** = Annual amount that PREPA will have to pay back for infrastructure investment, including interest. This investment is instead factored into the cost side of the BCR.

The annual costs of power generation were provided by PREPA for a constant annual number of megawatt hours produced with diesel and also produced with LNG per year over the period from 2026 to 2035[54]. Note that for incremental justification of alternative plans/phases, power generation benefits are only included in the Phase 1 analysis of widening measures.

See Sections 3.5 and 8.2.1.2 for additional discussion of power generation by PREPA and of the incorporation of power generation costs reduction benefits into the economic analysis.

9.2 Tonnage Calculation

In order to determine the number of metric tons of diesel and of LNG that are needed to generate this 1,860,000 MWh of electricity, two main pieces of information are needed. The first piece of information that is needed is the heat rate. According to the U.S. EIA (Energy Information Administration), "The heat rate is the amount of energy used by an electrical generator or power plant to generate one kilowatt hour (KWh) of electricity."[55] The power generation process produces losses in energy. In fact, the U.S. EIA reports that in 2016 the average tested heat rate for combined cycle with natural gas was 7,652 BTU/KWh or 45 percent efficiency. [56] The second piece of information needed is the conversion rate of BTU/lb. for each fuel type. Study calculations assume approximately 18,700 BTU/lb. in diesel fuel and approximately 22,000 BTU/lb. in LNG. This is consistent with U.S. Department of Energy reports that U.S. conventional diesel has a Lower Heating Value (LHV) of 18,397 BTU/lb. and a Higher Heating Value (HHV) of 19,676 BTU/lb. and that LNG has an LHV of 20,908 BTU/lb. and an HHV of 23,735 BTU/lb.[57]

9.3 Fuel Prices

Section 2 of PREPA's August 17, 2015 draft Integrated Resource Plan (IRP) Volume III – Demand and Fuel Forecast and Demand Side Management (Section 2.2.1.1 "Historical Figures") states that fuel prices used in the IRP were calculated based on price data for the period from January 1st, 2010 until March 26th, 2015. This is a period of more than 5 years. Specific sources of price information by product can be found in the IRP and are listed below:

"For No. 2 price calculation, the following information is relevant:

- Ultra Low Sulfur Diesel (ULSD) lowest and highest daily price as provided by Platt for New York/Boston cargo,
- ULSD lowest and highest daily price as provided by Platt for Gulf Coast,

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[54] Annual data provided by PREPA for 2026-2035 was applied for all years in the 50-year period of analysis as the best available estimate of power generation costs as of the completion of the draft economics appendix.

[55] *What is the efficiency of different types of power plants?* U.S. EIA. 10 May 2017, https://www.eia.gov/tools/faqs/faq.php?id=107&t=3. Accessed 11 August 2017.

[56] *Table 8.2. Average Tested Heat Rates by Prime Mover and Energy Source, 2007 – 2016*. U.S. EIA. https://www.eia.gov/electricity/annual/html/epa_08_02.html. Accessed 24 February 2018.

[57] *Lower and Higher Heating Values of Hydrogen and Other Fuels,* U.S. Department of Energy. January 2015, http://hydrogen.pnl.gov/hydrogen-data/lower-and-higher-heating-values-hydrogen-and-other-fuels. Accessed 11 August 2017.

- ULSD lowest and highest daily price as provided by Argus for New York,
- ULSD lowest and highest daily price as provided by Argus for Gulf Coast.

For Natural Gas price calculation, the following information is relevant:

- 0.3% sulfur content (Low Pour) No. 6, lowest and highest daily price as provided by Platt for New York/Boston cargo,
- 0.7% sulfur content No. 6, lowest and highest daily price as provided by Platt for New York/Boston cargo" (page 2-2).

Note that based on coordination by SAJ Economics with PREPA, the fuel forecast used in the information provided by PREPA for the current USACE study was updated in early 2016. Therefore the price information used in the draft IRP and outlined above likely varies slightly from what is reflected in the power generation cost reduction benefits calculated in the current report.

See Risk and Uncertainty Section 11 of this appendix for information of commodity price fluctuations.

10 Recommended Plan Summary

Combining the measures selected in each phase above results in the National Economic Development (NED) Plan, which is the plan that reasonably maximizes net benefits. The NED plan becomes the recommended plan. This recommended plan includes widening of the Army Terminal Channel by 100 feet to a width of 450 feet; deepening of Cut 6 to 46 feet; deepening of the Anegado Channel through the Army Terminal Channel Turning Basin to 44 feet; providing eastern and western flares at the southern end of the Army Terminal Turning Basin[58]; and deepening of the San Antonio Approach Channel, San Antonio Channel, San Antonio Channel Extension, and Cruise Ship Turning Basin East to 36 feet. Once all measures were selected, comprehensive future without-project and future with-project HarborSym runs were completed. Where the phased modeling just focused on the calls for areas of the harbor impacted by a specific phase and on the change brought in transportation costs attributable to that phase alone, these runs included all port traffic. As demonstrated previously in Table 29, Table 30, and Table 31, the aforementioned plan reasonably maximizes net benefits both with and without the LNG conversion and associated power generation cost reduction benefits being included. Table 37 summarizes the transportation costs and number of calls in the future without- and future with-project (FWP Sc1 – with LNG conversion) conditions for the recommended plan. The recommended plan reduces the net number of annual calls to San Juan by 20 and reduces the annual transportation costs associated with cruise vessels by approximately $1.2 million and with petroleum tankers by approximately $4.2 million.

[58] Measure added per ship simulation recommendation. Cost included in analysis. See Engineering Appendix for additional information.

Table 37: Summary of FWOP and FWP Number of Calls and Transportation Costs - 2026

Vessel Classes	Number of Calls			Transportation Costs		
	FWOP-2026	FWP-2026 (FWP Sc1)	Change	FWOP-2026	FWP-2026 (FWP Sc1)	Percent Decrease*
10K-DWT	86	82	4 calls reduced	$ 1,635,000	$ 1,437,000	12%
20K-DWT	15	15	0	$ 1,250,000	$ 1,250,000	0%
30K-DWT	1	1	0	$ 447,000	$ 322,000	28%
40K-DWT	13	8	5 calls reduced	$ 3,371,000	$ 2,042,000	39%
50K-DWT	66	50	16 calls reduced	$ 24,100,000	$ 18,622,000	23%
70K-DWT	9	2	7 calls reduced	$ 1,599,000	$ 399,000	75%
110K-DWT	0	7	7 calls added	$ -	$ 4,082,000	N/A
Bulk-20K	2	2	0	$ 16,000	$ 16,000	0%
Bulk-30K	19	19	0	$ 761,000	$ 762,000	0%
Bulk-40K	5	5	0	$ 171,000	$ 169,000	1%
Bulk-50K	3	3	0	$ 57,000	$ 57,000	0%
Bulk-60K	2	2	0	$ 24,000	$ 24,000	0%
Bulk-80K	1	1	0	$ 48,000	$ 47,000	2%
Cruise1	39	39	0	$ 870,000	$ 853,000	2%
Cruise2	64	64	0	$ 4,023,000	$ 3,927,000	2%
Cruise3	47	47	0	$ 4,866,000	$ 4,752,000	2%
Cruise4	27	27	0	$ 2,241,000	$ 2,207,000	2%
Cruise5	129	129	0	$ 9,841,000	$ 9,567,000	3%
Cruise6	190	190	0	$ 19,695,000	$ 19,327,000	2%
Cruise7	68	68	0	$ 8,765,000	$ 8,484,000	3%
CruiseOasis	87	87	0	$ 17,163,000	$ 17,059,000	1%
GC-Lg	14	14	0	$ 1,042,000	$ 1,034,000	1%
GC-Sm	213	213	0	$ 1,734,000	$ 1,692,000	2%
LPG-LNG1	5	5	0	$ 34,000	$ 34,000	0%
LPG-LNG2	8	8	0	$ 148,000	$ 140,000	5%
LPG-LNG6	0	5	5 calls added	$ -	$ 4,000,000	N/A
Misc1	514	514	0	$ 1,925,000	$ 1,923,000	0%
PX1	63	63	0	$ 423,000	$ 422,000	0%
PX1-LNG	208	208	0	$ 4,086,000	$ 4,069,000	0%
PX2	2	2	0	$ 11,000	$ 11,000	0%
RoRo1	138	138	0	$ 464,000	$ 464,000	0%
RoRo2	35	35	0	$ 195,000	$ 196,000	-1%
RoRo3	58	58	0	$ 373,000	$ 374,000	0%
SPX	537	537	0	$ 2,924,000	$ 2,923,000	0%

* The 1% decrease in the annual transportation costs associated with the RoRo2 class of vessels is due to (a.) the triangular distributions used for model parameters and (b.) randomization of arrival dates and times in the model and the resulting vessel interactions.
The FWP information reflects the scenario with the LNG conversion taking place. Without the LNG conversion, 10K-DWT, 70K-DWT, and LPG-LNG6 number of calls and transportation costs above would change.
Note: Results are based on aver transportation costs taken form 50-iteration HarbroSym runs.

Costs for the recommended plan were provided by SAJ Cost EN. IDC (Interest During Construction) was calculated for the 24-month PED period and for the 16-month Federal construction period. Costs are reported at FY18 price levels[59] and cost and benefit calculations use the FY18 Federal Water Resources discount rate of 2.75 percent. Costs used in Table 38, Table 39, and Table 40 are certified costs for the recommended plan.

Table 38: Recommended Plan Costs and Benefits Summary – With LNG Conversion (FWP Sc1)

ECONOMIC ANALYSIS SUMMARY			EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS			
Phase	**Description**	**Alternative**	**AAEQ BENEFITS**	**AAEQ COSTS**	**AAEQ NET BENEFITS**	**BCR**
Recommended Plan	Cut-6 @ 46 feet, Anegado @ 44 feet; 100-foot Army Terminal Channel Widener, 44-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening*		$ 75,269,000	$ 15,172,000	$ 60,096,000	5.0

Notes: Transportation costs savings and power generation cost reduction benefits included. All $ values rounded to $1,000's. General navigation features (GNF) costs, local service facility costs, cost to move ATONs, increase in O&M, and IDC included in AAEQ costs column.

Table 39: Recommended Plan Costs and Benefits Summary – Without LNG Conversion (FWP Sc2)

ECONOMIC ANALYSIS SUMMARY			EXPECTED VALUE BENEFITS, COSTS, & NET BENEFITS			
Phase	**Description**	**Alternative**	**AAEQ BENEFITS**	**AAEQ COSTS**	**AAEQ NET BENEFITS**	**BCR**
Recommended Plan	Cut-6 @ 46 feet, Anegado @ 44 feet; 100-foot Army Terminal Channel Widener, 44-foot Army Terminal Channel Deepening; 36-foot San Antonio & Cruise Ship Basin East Deepening		$ 4,321,000	$ 2,281,000	$ 2,040,000	1.9

Notes: All PREPA calls were removed from the benefit analysis by post-processing HarborSym outputs to take out transportation costs associated with calls to the PREPA dock in both the FWOP and FWP conditions. All $ values rounded to $1,000's.
General navigation features (GNF) costs, local service facility costs, cost to move ATONs, increase in O&M, and IDC included in AAEQ costs column.

[59] Transportation costs savings use FY16 transportation costs and thus reflect FY16 price levels. Power generation cost reduction benefits reflect FY17 price levels, which is the price level at which information was provided by PREPA. Approved escalation factors for adjusting these benefits to FY18 price levels were not available at the time of this analysis, so benefits were not adjusted to FY18 price levels.

Table 40: Equivalent Annual Costs and Benefits

Equivalent Annual Benefits and Costs		**28-Feb-18**
FY2018 Price Levels - Cost Estimate 2-28-18		
50-Year Period of Analysis / 2.75 % Discount Rate		
Capital Recovery Factor = PMT(0.0275,50,-1)	0.03704	
	WITH LNG CONVERSION[1]	**WITHOUT LNG CONVERSION**[2]
Project Costs	$403,975,000	$55,951,000
General Navigation Features [3]	$54,041,000	$54,041,000
Associated and Local Service Facility (LSF) Costs	$349,829,000	$1,805,000
USCG Aids to Navigation	$105,000	$105,000
Interest During Construction (GNF Construction Cost + PED + Construction Management + Lands & Damages)	$1,207,000	$1,207,000
Economic Investment	$405,182,000	$57,158,000
AAEQ Costs		
Economic Investment	$15,008,000	$2,117,000
Increased O&M for Dredging	$164,000	$164,000
O&M for Mitigation Site	$0	$0
Increased O&M for Navigation Aids	$0	$0
Total AAEQ Costs	$15,172,000	$2,281,000
AAEQ Benefits		
Transportation Costs Savings [4]	$1,612,000	$4,315,000
Unemployment Reduction Benefits	$7,000	$7,000
Power Generation Costs Reduction	$73,650,000	$0
Total AAEQ Benefits	$75,269,000	$4,322,000
Net Benefits	$60,097,000	$2,041,000
Benefit-Cost Ratio (at 2.75% FY18 Discount Rate)	5.0	1.9

All values rounded to the $1,000s. Any discrepencies in costs are due to rounding.

[1] Includes PREPA's LNG infrastructure investment costs and power generation cost reduction benefits.

[2] Does NOT include PREPA's LNG infrastructure investment costs or power generation cost reduction benefits. HarborSym modeling outputs were post-processed to remove all calls to the PREPA dock in both the FWP and FWOP conditions.

[3] Project Costs WITH PREPA include ~ $348 million in PREPA LNG Facility Modification

[4] Difference in transportation costs savings between the two scenarios is attributable to the fact that in the WITH PREPA scenario LNG transportation costs in the FWP exceed diesel transportation costs in the FWOP, which is included in the WITH PREPA transportation costs savings displayed here.

As shown in Table 40, costs of General Navigation Features (GNF) remain the same whether or not the conversion to LNG to assumed. In other words, **the cost to the Federal government remains the same under both FWP scenarios outlined in this appendix**. The following are the most notable differences in costs and benefits between the two scenarios:

- **Associated and LSF costs** in the "with LNG conversion" scenario exceed those same costs in the "without LNG conversion" scenario by an amount equal to the LNG infrastructure investment needed for the LNG conversion (~$348 million).
- **Transportation cost savings** with a conversion to LNG are less than those same savings without a conversion to LNG due to the fact that hourly vessel operating costs of LNG vessels exceed those of petroleum tanker vessels. This effectively means that the annual transportation costs of delivering fuel used by PREPA in power generation to San Juan is lower when the fuel is diesel carried on petroleum tankers than when the fuel is LNG carried on LNG vessels. This increase in annual transportation costs from the without-project condition to the with-project condition for vessels servicing PREPA offsets a portion of the transportation cost savings attributable to vessels that do not service PREPA. Thus, when the transportation cost of supplying fuel to PREPA stays constant rather than increasing, the average annual transportation cost savings appears greater.
- **Power generation cost reduction benefits** only accrue if the LNG conversion occurs.

11 Risk and Uncertainty

This section will cover select sources of risk and uncertainty associated with economic modeling assumptions and with assumptions used in calculating power generation cost reduction benefits. The section also outlines how these assumptions and information could potentially impact economic analysis results and consequently plan selection.

11.1 Modeling Assumptions

Risks related to the fleet forecast and modeling assumptions include the following:

- Uncertainty exists surrounding the diesel tonnage passing through San Juan Harbor in the FWP condition. Data sources available at the start of the economic analysis do not clearly show which entities receive what quantities diesel at which ATTB docks. Assumptions made in the economic analysis are based on the best available information and on best professional judgement. However, if the current analysis overstates diesel tonnage in the FWP condition this would have the greatest impact on transportation costs savings associated with Economic Modeling Phase 2 deepening. A sensitivity analysis was completed to remove all diesel tonnage passing through the ATTB docks from the economic model so that no benefits would accrue from the movement of diesel. The analysis used the refined Phase 2 costs from SAJ Cost Engineering and indicated that in the absence of diesel calls, the depth that maximizes net benefits in ATC would likely change from 44 feet to 43 feet. Net benefits for this economic modeling phase would also go down significantly.
- No fleet transition for use of more LR1 tankers in the Phase 2 FWP condition is currently considered. Such an assumption could potentially be appropriate as the channel depth increases and more of these vessels' capacity can be used. This transition would only be

appropriate if sufficient landside storage capacity exists to store the additional product[60] and there are sufficient LR1 vessels available in the world fleet. Addition of more LR1 tankers and reduction of MR tanker calls could impact transportation costs savings associated with Economic Modeling Phase 2 deepening.

- Based on historical data, modeling currently assumes that a percentage of MR tankers and LR1 tankers call San Juan not utilizing all existing available channel depth and will continue this practice in the future. Because these vessels are not currently taking advantage of all existing channel depth, the analysis assumes that such vessels cannot benefit from channel deepening even when the design drafts of the vessels and the densities of the products carried could theoretically allow for additional loading. Information received at May 2017 meetings with port users suggested that construction of additional landside petroleum storage capacity (to be completed before the 2026 project base year in both the with- and without-project conditions) in San Juan could potentially reduce the occurrence of partial loading seen in the historical record and assumed to continue in the existing, FWOP, and FWP conditions. Reduction in the number of partially loaded 50K and/or 70K tanker calls (i.e., increase in fully loaded 50K and/or 70K tanker calls) could result in an increased number of benefitting vessels in the Phase 2 deepening of the Army Terminal Channel.

11.2 Power Generation Cost Reduction Benefits

Uncertainty exists around several assumptions supporting the calculation of power generation cost reduction benefits. These risks include the following:

- Variation in the price spread over time between LNG and diesel fuel: Diesel fuel and LNG prices fluctuate and thus the spread between the prices of these two commodities varies over time. When LNG prices are lower and diesel prices are higher, then Economic Modeling Phase 1 power generation cost reduction benefits will appear larger. When the opposite is true and LNG and diesel prices converge, the Economic Modeling Phase 1 power generation cost reduction benefits will decrease. Assuming that the historical price data (2010 through March 2015) used in the 2015 draft IRP was also used in the power generation cost calculations for diesel and LNG, the current analysis uses a historical period over which the spread between natural gas and diesel prices is relatively wide and sustained, a risk that should be acknowledged as use of this time period leads to significant project benefits. However, it is also important to note that the prices used by PREPA in the 2015 draft IRP are based on a period of more than five years, which was the best available information at the time of that report. Furthermore, although the magnitude of the price differential has varied, natural gas prices have been consistently lower than diesel prices between 2000 and 2016 with only a few exceptions. Given the Phase 1 BCR of 5.0:1.0 at 2.75 percent, some decrease in the spread between diesel and LNG prices can occur and still result in Phase 1 justification with the LNG conversion.

  Also, while power generation cost reduction is the largest source of project benefits, it is also the largest source of project costs. As shown in FWP Sc2 (without PREPA conversion), the

[60] Landside storage capacity is assumed to be sufficient to accommodate the MR, LR1, and LR2 FWP fleet established in the primary analysis described throughout this appendix. However, if there were a shift to less MR calls and more LR1 calls and if the same number of LR2 calls was assumed, then presumably additional analysis would be needed to ensure that the landside storage capacity could accommodate this increased average tonnage/call.

project is economically justified if both the costs and benefits associated with LNG conversion are removed and it is assumed that diesel is used for power generation both with and without a Federal navigation project. Thus, from a planning perspective, the risk in price fluctuations between diesel and LNG is borne by PREPA and not by the Federal government since the cost to the Federal government remains the same both with and without the LNG conversion and the project remains justified in both scenarios.

- Changes in power generation technology and/or EPA policy between now and conversion to LNG: First, changes in technology that lead to changes in the efficiency rates between diesel and LNG could possibly lead to changes in which fuel is preferred from a profitability perspective. For example, if technology were developed that allowed the BTU content of diesel to be used more efficiently than the BTU content of LNG, then diesel may become cheaper option and the advantages of using LNG may diminish. As mentioned previously, the risk associated with changes in technology are borne by PREPA rather than by the Federal government since the Federal cost remains unchanged and the project remains justified both with and without a conversion to LNG in the San Juan area power plants.

  Second, a major driving force behind PREPA's conversion to LNG is environmental regulations that restrict emissions by power plants. If the EPA were to scale back requirements of the MATS or other environmental standards, then incentives to convert to LNG may diminish and other fuels for generating power such as fuel oil #6 may again become viable options. Changes in environmental standards are possible due to factors such as policy shifts and legal challenges, several of which have been brought against MATS since its 2013 adoption. *Volume I: Supply Portfolios and Futures Analysis* of PREPA's 2015 draft IRP acknowledges the legal uncertainty but states that "MATS is currently in force, until such time that is vacated by the courts, and it is likely that by the time the decisions recommended in this IRP are implemented, MATS in its current form or substantially in its current form will be in place" (page xiii). In the case that PREPA were to abandon the conversion to LNG, then both project benefits and costs would decrease. As stated above, even in the absence of a conversion to LNG, the measures included in Economic Modeling Phase 1 would be justified based on the partial transition from MR to LR2 tankers.

- Use of methods other than those proposed in the current study to supply LNG to the northern coast of Puerto Rico: Efforts to pipe LNG from the south to the north have been made in the past but the project was cancelled in large part due to concerns by opponents that the pipeline through the islands undeveloped central mountains may have negative environmental impacts.[61] In October of 2012 PREPA withdrew the permit application for this project known as the Via Verde Natural Gas Pipeline while the application was under review by USACE. At this time USACE was in the process of finalizing an Environmental Assessment for the project after receiving public comments.[62]

[61] Source: U.S. Energy Information Administration (EIA). July 2017, https://www.eia.gov/state/print.php?sid=RQ. Accessed 27 July 2017.

[62] Source: Sticht, Nancy J. "Busy year for nation's largest regulatory program." U.S. Army Corps of Engineers Jacksonville District, 10 January 2013, http://www.saj.usace.army.mil/Media/News-Stories/Article/479590/busy-year-for-nations-largest-regulatory-permitting-program/. Accessed 27 July 2017.

PREPA's 2015 draft IRP also mentions the possibility of a natural gas pipeline that would take a different route from the southern coast to the northern coast than that proposed by the previously failed pipeline. When referring to the prospect of a south to north pipeline, Section 4 of *Volume 1* (*Supply Portfolios and Futures Analysis*) of the draft IRP states, "Planning such a project must consider the pipelines' costs as well as permitting feasibility" (page 4-2). The IRP also states the following: "…Siemens recommends that PREPA continue to develop further information on each of the alternatives discussed below: … 3. Undertake new studies of pipeline options to deliver natural gas to San Juan and Palo Seco sites, along with development of natural gas supply options in the south to feed such a pipeline" (page 4-4). Thus, the pipeline option appears to be in the scoping phase.

If a pipeline were to be constructed from Puerto Rico's southern coast to its northern coast, then the benefits of bringing LNG to the San Juan area power plants would no longer be attributable to the proposed Federal navigation improvements project. Thus, costs and benefits of the LNG conversion would again be removed from Phase 1 of the current analysis, but, as indicated by the FWP Sc2 (without LNG conversion) analysis results discussed previously, the project would still be justified if the costs and benefits of LNG conversion are not included.

- <u>Use of alternative fuels</u>: The 2015 draft IRP also addresses renewable generation in Section 3: Renewable Generation of Volume 1 (Supply Portfolios and Futures Analysis) and considers how these sources of power generation might be used by PREPA as part of their overall energy mix in Puerto Rico in the future but does not specifically use renewables to replace other energy sources in the San Juan area plants. Currently, Puerto Rico does have a limited amount of wind and solar power generation capability.

  Smaller LNG storage tank and more frequent vessel call: As mentioned previously in this appendix, the size of the landside full containment tank assumed in the LNG infrastructure costs provided by PREPA is 160,000 m^3. With a tank of this size and with calls by LNG tankers in 130,000-145,000 m^3 capacity range, SAJ economists estimated than only 5 LNG vessel calls per year would be needed to meet PREPA's annual minimum demand for LNG. This would potentially lead to natural gas being stored for several months. Having such large amounts of idle inventory on hand ties up business resources that could otherwise be employed elsewhere and can be potentially costly in terms of the time value of money. There are also potential tax implications of holding inventory. In the U.S., inventory held in storage tanks is taxed each month. If such a tax structure exists in Puerto Rico, then incentives could exist to construct a smaller LNG storage tank and bring a more frequent LNG call, especially in the case that private companies get involved in generation in the north in the future. Assuming PREPA, a public utility, continues generation then inventory taxes may not apply.

  Based on PREPA's assessment of alternative methods of supplying LNG to the northern power plants (Palo Seco and San Juan Plants), the selected method (130-145K m^3 LNG tankers bringing LNG to PREPA's San Juan Harbor docks) was deemed by PREPA and PREPA's consultants as the most feasible alternative. Estimates by SAJ economists indicate approximately 18 calls per year by the smaller ships mentioned in the comment would be needed to meet PREPA's projected annual LNG demand of 306,952 metric tons. PREPA has expressed concern that a frequency of 18 calls per year would likely meet objections from other terminal operators in the Army

Terminal Turning Basin area and from the Coast Guard due to the safety zone requirements associated with calls by LNG vessels (300 ft. in transit, 150 ft. at dock). Furthermore, limited availability of smaller vessels in the world fleet (only 11 LNG or Combination Gas (LNG/LPG) tankers that have serviced the Caribbean or South American region in the past year (2016/2017)) raises concerns about whether PREPA could rely upon these vessels to call San Juan frequently enough to meet PREPA's LNG demand since these same vessels currently serve other ports in the Caribbean and across the world.

Additionally, the size of the smaller vessels is such that these vessels could call San Juan Harbor with or without a Federal project. Because these vessels have beams at or below Army Terminal Channel's existing 131-foot maximum beam limit, these vessels do not require widening of the Federal channel in order to be permitted to transit the Army Terminal Channel. Thus, PREPA's use of LNG would become a future with-project AND a future without-project condition. If we assume that PREPA (or a private company) would opt to bring smaller LNG vessels more frequently to avoid holding inventory for long periods and to avoid construction of such a large storage tank, then both project benefits associated with PREPA's conversion to LNG and costs associated with the conversion to LNG would no longer be included in the project benefits and costs.

- PREPA bankruptcy and possible privatization: In July 2017, PREPA filed for a form of bankruptcy (Title III), increasing uncertainty about PREPA's ability to fund the ~$348 million (FY18 price levels) non-Federal infrastructure investment needed in conjunction with the Recommended Plan to yield power generation cost reduction benefits. Based on a letter from PREPA sent to SAJ Planning and Policy Division and dated January 11, 2018[63], a public-private partnership (P3) will be formed to initially build the LNG infrastructure and to operate the regasification facility, thus providing the funds needed for the investment to take place. As stated above, the project is justified with or without the conversion to LNG, making this a relatively low consequence item to the Federal government from a plan selection perspective.
  Additionally, in January of 2018, the governor of Puerto Rico announced plans to privatize the Puerto Rico Electric Power Authority. Such an announcement demonstrates the high degree of uncertainty associated with PREPA's future and, consequently, with who will be making decisions about power generation and what those decisions will be both in the San Juan area and across the island in the future. If the commodity mix needed to supply power in the San Juan area in the future is something other than diesel or LNG delivered through San Juan Harbor, then this could impact the commodity mix expected to pass through San Juan Harbor and result in changes in project benefits, possibly leading to need for additional study. However, because this is a high uncertainty item and because the best available information today indicates that power generation with diesel or LNG are the most likely future with-project scenarios, the plan laid forth in the current study is a reasonable recommendation.

The information outlined above looks at the risks associated with a possible failure to convert the San Juan area power plants to LNG primarily from a Federal planning perspective. However, one should note that a high level of risk exists when considering future budgeting of Federal funds for design and construction since the higher average annual net benefits and BCR resulting from scenario #1 (with LNG

[63] See Correspondence appendix for copy of letter.

conversion) assumptions would likely increase the project's budgetary priority above what it would be if the scenario #2 (without LNG conversion) assumptions and BCR are used.

12 Sensitivity Analysis

In addition to the primary economic analysis and plan formulation, which considered project costs and benefits both with and without a conversion to LNG at the San Juan area power plants, sensitivity analyses were completed to estimate the benefits, net benefits, and BCRs of the recommended plan associated with the LNG conversion taking place in the San Juan area power plants one, two, three, four, and five years, respectively, after the Federal navigation project base year 2026. In all five scenarios, the project remains justified with a BCR of greater than 4.0 at a discount rate of 2.75 percent (FY18).

Table 41: Sensitivity Analysis Results – Timing of LNG Conversion

LNG facility online X year(s) after Federal navigation project construction is complete	AAEQ Net Benefits	BCR
1	$ 57,637,000	4.8
2	$ 55,148,000	4.7
3	$ 52,726,000	4.5
4	$ 50,367,000	4.3
5	$ 48,073,000	4.2

Notes: Net benefits rounded to the $1,000s. BCR rounded to the tenths. Refined costs for the 44-foot channel depth were used in the above calculations rather than the certified recommended plan costs.

The results shown in Table 41 above indicate that the consequences of a conversion to LNG not taking place by the project base year but rather between one and five years after the Federal navigation project is constructed are low in the sense that the project would still be justified with significant AAEQ net benefits.

13 NED Unemployment Benefits (San Juan Harbor)

The purpose of this section is to assess the applicability of section D-7 of Engineer Regulation (ER) 1105-2-100, for the incorporation of unemployed or underemployed labor resources National Economic Development (NED) benefits in USACE Civil Works construction projects, to the San Juan Harbor Navigation Improvements Project.

Direct construction activities for each alternative in consideration for the study take place within the limits of San Juan Municipality, the capital and most populous municipality in the Commonwealth of Puerto Rico. Like the majority of municipalities in Puerto Rico, San Juan has recorded unemployment rates consistently above the national average throughout the previous decade.

Per ER 1105-2-100, NED unemployment benefits are to be incorporated following project alternative formulation and NED plan determination, and cannot be used to justify a project where the Benefit-to-Cost Ratio (BCR) is less than unity.

13.1 Background

The economic effects of the direct use of otherwise unemployed or underemployed labor resources during project construction may be included as an NED benefit in circumstances where the study area has substantial and persistent unemployment at the time the plan is submitted for authorization and for appropriations to begin construction.

The opportunity cost of employing otherwise underemployed workers is equal to their earnings under the without project condition, which fall below market cost by virtue of their underemployment. The most straightforward way to reflect the effects of employing unemployed or underemployed labor resources would be to reduce by the appropriate amount the project construction costs in the NED account, but this method would cause accounting difficulties in appropriations, cost allocation, and cost sharing. Therefore, these effects are treated as a project benefit in the NED account.

Conceptually, any employment, anywhere in the Nation, of otherwise unemployed or underemployed resources that results from a project represents a valid NED benefit. However, primarily because of identification and measurement problems and because unemployment is regarded as a temporary phenomenon, only those labor resources employed onsite in the construction or installation of a project are counted.

13.2 Requirements

13.2.1 Unemployment Threshold

As defined in Engineer Regulation 1105-2-100, substantial and persistent unemployment exists in an area when the following circumstances are present:

1) The current rate of unemployment, as determined by appropriate annual statistics for the most recent 12 consecutive months, is 6 percent or more and has averaged at least 6 percent for the qualifying time periods specified in subparagraph 2.

2) The annual average rate of unemployment has been at least:
    a) 50 percent above the national average for three of the preceding four calendar years; or
    b) 75 percent above the national average for two of the preceding three calendar years; or
    c) 100 percent above the national average for one of the preceding two calendar years.

Table 42 presents the NED unemployment benefit qualification analysis pertaining to San Juan Municipality based on 2015 American Community Survey data, the most-current available for the immediate project area.

Table 42: San Juan NED Unemployment Benefit Qualification Evaluation

	Civilian Labor Force	Unemployed	Unemployment Rate	150% Threshold	175% Threshold	200% Threshold
	2012					
United States	156,533,205	14,536,657	9.29%	13.93%	16.25%	18.57%
San Juan Municipio	172,947	27,747	16.04%	**Met**	**X**	**X**
	2013					
United States	157,113,886	15,249,189	9.71%	14.56%	16.99%	19.41%
San Juan Municipio	167,666	26,951	16.07%	**Met**	**X**	**X**
	2014					
United States	157,940,014	14,504,781	9.18%	13.78%	16.07%	18.37%
San Juan Municipio	164,193	25,995	15.83%	**Met**	**X**	**X**
	2015					
United States	158,897,824	13,150,045	8.28%	12.41%	14.48%	16.55%
San Juan Municipio	158,109	24,923	15.76%	**Met**	**Met**	**X**

Both requirements set forth in ER 1105-2-100 are satisfied in San Juan for the years in consideration. Unemployment rates comfortably meet the minimum six percent requirement for each year from 2012 through 2015. Further, the US unemployment rate was exceeded by over fifty percent for each four of the previous years. In addition, 2015 saw the unemployment rate for San Juan exceed the one-hundred seventy-five percent threshold.

13.2.2 Labor Pool / Labor Demand Congruency

Due to data limitations, unemployment benefits cannot be estimated directly on the basis of a comparison of the size of the pools of unemployed and underemployed labor with and without the project. Instead the benefit evaluation procedure implicitly projects the percentage of project labor hires estimated to come from the local unemployed labor pool. In order to do so, it must first be established that unemployed labor pool availability in the project area is sufficient to meet project labor requirements for locally-filled project occupations.

13.2.2.1 Labor Pool Availability

In order to estimate the composition of the San Juan Municipality unemployed labor pool by industry specialization, it is assumed for the purposes of this analysis that industry employment rates are proportionally reflective of the unemployed labor pool.

Table 43: San Juan Employment Distribution by Industry

INDUSTRY	2012	2013	2014	2015	2012 - 2015 Average	Percent Total
Agriculture, Forestry, Fishing and Hunting, and Mining	410	339	282	327	340	0.24%
Construction	8,649	8,181	7,950	7,945	8,181	5.87%
Manufacturing	5,937	5,722	5,795	5,358	5,703	4.09%
Wholesale Trade	5,218	4,879	4,818	4,720	4,909	3.52%
Retail Trade	16,000	15,029	14,878	14,519	15,107	10.84%
Transportation and Warehousing, and Utilities	5,158	5,115	5,180	5,097	5,138	3.69%
Information	3,889	3,705	3,855	3,775	3,806	2.73%
Finance and Insurance, and Real Estate and Rental and Leasing	11,806	10,998	10,524	10,191	10,880	7.81%
Professional, Scientific, and Management, and Administrative and Waste management Services	19,340	19,428	19,043	17,978	18,947	13.60%
Educational Services, and Healthcare and Social Assistance	31,637	31,197	30,288	28,898	30,505	21.89%
Arts, Entertainment, and Recreation, and Accommodation and Food Services	15,005	14,580	14,185	14,000	14,443	10.37%
Other Services, Except Public Administration	10,679	10,222	10,591	10,123	10,404	7.47%
Public Administration	11,472	11,320	10,809	10,255	10,964	7.87%

Interpolating these percentages to the 2012-2015 San Juan Municipality unemployment average of 26,404 yields the distribution of unemployed industry workers in the labor pool displayed in Table 44.

Table 44: Estimated Unemployed Labor Pool by Industry

INDUSTRY	2012 - 2015 Estimated Average
Agriculture, Forestry, Fishing and Hunting, and Mining	64
Construction	1,550
Manufacturing	1,081
Wholesale Trade	930
Retail Trade	2,863
Transportation and Warehousing, and Utilities	974
Information	721
Finance and Insurance, and Real Estate and Rental and Leasing	2,062
Professional, Scientific, and Management, and Administrative and Waste management Services	3,591
Educational Services, and Healthcare and Social Assistance	5,781
Arts, Entertainment, and Recreation, and Accommodation and Food Services	2,737
Other Services, Except Public Administration	1,972
Public Administration	2,078

***13.2.2.2** Project Labor Requirements*

Current total project cost estimates (as of January 2018) lack the degree of precision needed to produce a defensible estimate of total project local direct job creation and labor requirements. As such, project local labor requirements are based on those associated with San Juan Harbor maintenance dredging contracts awarded in 2016. Information from that contract offers a baseline on which employment and wage trends for the SJHIP can estimated. Due to the expanded scope of the SJHIP in comparison to the 2016 maintenance dredging, it can be assumed that this calculation constitutes a minimum estimate.

Certified payroll information and contract information from the 2016 San Juan maintenance dredging as recorded in the USACE Resident Management System differentiates occupations filled locally from those filled non-locally as presented in Table 45.

Table 45: San Juan Harbor 2016 Dredging Occupations

Occupations Filled by Non-Locals	Occupations Filled by Locals
• Crane Operator • Mate • Dredge Engineer • Boat Operator	• Endangered Species Monitoring Personnel • Deckhand

The two locally-filled occupations directly employed under the 2016 maintenance dredging contract include Endangered Species Monitoring Personnel and Deckhands. A total of ten Endangered Species Monitoring Personnel positions and two Deckhand positions were directly created as a result of the project.

In the framework set forth by ER-1105-2-100, locally-filled occupations must be classified as either "Skilled," "Unskilled," or "Other." As Endangered Species Monitoring Personnel is not listed in the occupational classification tables that appear in that guidance, it is classified as "Other" for the purposes of this analysis. Deckhands are classified as "Unskilled."

Industry employment data suggests that the availability of unemployed workers in the study area far exceeds the minimum requirements of the project set by the 2016 San Juan Harbor maintenance dredging.

13.2.2.3 Project Local Wage Estimation

Total project wage information for locally-filled jobs in the 2016 maintenance dredging of San Juan Harbor is presented in Table 46. Since Deckhands were supplied by a contracted local company operating on an independent pay roll, the US minimum wage is applied for the purposes of this estimate.

Table 46: San Juan 2016 Maintenance Dredging Estimated Local Wage Project Cost

Deckhands	
Number Deckhands Per Scow	1
Number Scows	2
US Minimum Wage (Hourly)	$7.25
Project Deckhand Shift Length (Hours)	12
Deckhand Shifts Per Day	1
Daily Project Cost (Deckhands)	$174
O&M Contract Duration (Days)	135
Total Wage Unskilled	$23,490
Endangered Species Monitoring Personnel	
Total Wage Skilled	$93,000

In adherence with EM 110-2-1304, local wages from the 2016 San Juan Harbor maintenance dredging are brought forward to FY 2018 dollars through the use of the USACE Civil Works Construction Cost Index System (EM 110-2-1304, 31 March 2017, Amendment #1 Tables Revised as of 30 September 2017). Civil Works Breakdown Structure (CWBS) feature code twelve for costs related to navigation ports and harbors is applied.

Table 47: CWCCIS Escalation Factor

Navigation Ports & Harbors	
1Q FY 2016	744.87
1Q FY 2018	827.4
Escalation Factor	1.11

Note: From EM 110-2-1304 (31 March 2017 - Amendment #1 Tables Revised as of 30 September 2017)

RMS data pertaining to the 2016 San Juan Harbor Maintenance Dredging records that Endangered Species Monitoring Personnel and Deckhands were each employed for a duration of 135 days through the project. As the construction period is scheduled to take place over 16 months[64], a scale multiplier will be applied in order to provide a more accurate wage estimation for locally-filled occupations (Table 48).

Table 48: Scale Multiplier

	Local Employment Duration (Days)
San Juan Harbor 2016 Maintenance Dredging	135
San Juan Harbor Improvement Project	485
Scale Multiplier	3.59

Applying these factors to the maintenance dredging wages yields the following estimation of wages by construction year and worker category for the SJIP.

Table 49: Estimated Wages by Worker Category (FY 2018 Dollars, rounded to $1,000s)

Other	Unskilled	Total
$377,000	$95,000	$472,000

13.3 NED Benefit Calculation

In order to estimate project unemployment benefits, ER 1105-2-100 requires that estimated local wages for the occupation types identified above must be multiplied by the percentages listed in Table 50.

Table 50: Occupation Type Multipliers

	Applicable Percentage
Skilled	30%
Unskilled	47%
Other	35%

Applying the appropriate occupation type multipliers yields the total NED unemployment benefits listed in Table 51. Average annual equivalent NED unemployment benefits displayed in Table 52 are calculated over a fifty year period of analysis at the current FY2018 discount rate of 2.75 percent as established in Economic Guidance Memorandum 18-01. These benefits were incorporated into the recommended plan as outlined in Section 10 of this appendix.

Table 51: Total NED Unemployment Benefits by Worker Category (FY 2018 Dollars, rounded to $1,000s)

Other	Unskilled	Total
$132,000	$45,000	$177,000

[64] The 16-month timeline is based on construction of the following features: Widening of Army Terminal Channel to 450'; deepening of Cut 6 to 46'; deepening of Anegado Channel through Army Terminal Turning Basin to 44'; and deepening of San Antonio Approach Channel, San Antonio Channel, and Cruise Ship Basin East to 36'.

Table 52: Average Annual Unemployment Benefits (FY2018 Dollars, rounded to $1,000s)

Other	Unskilled	Total
$5,000	$2,000	$7,000